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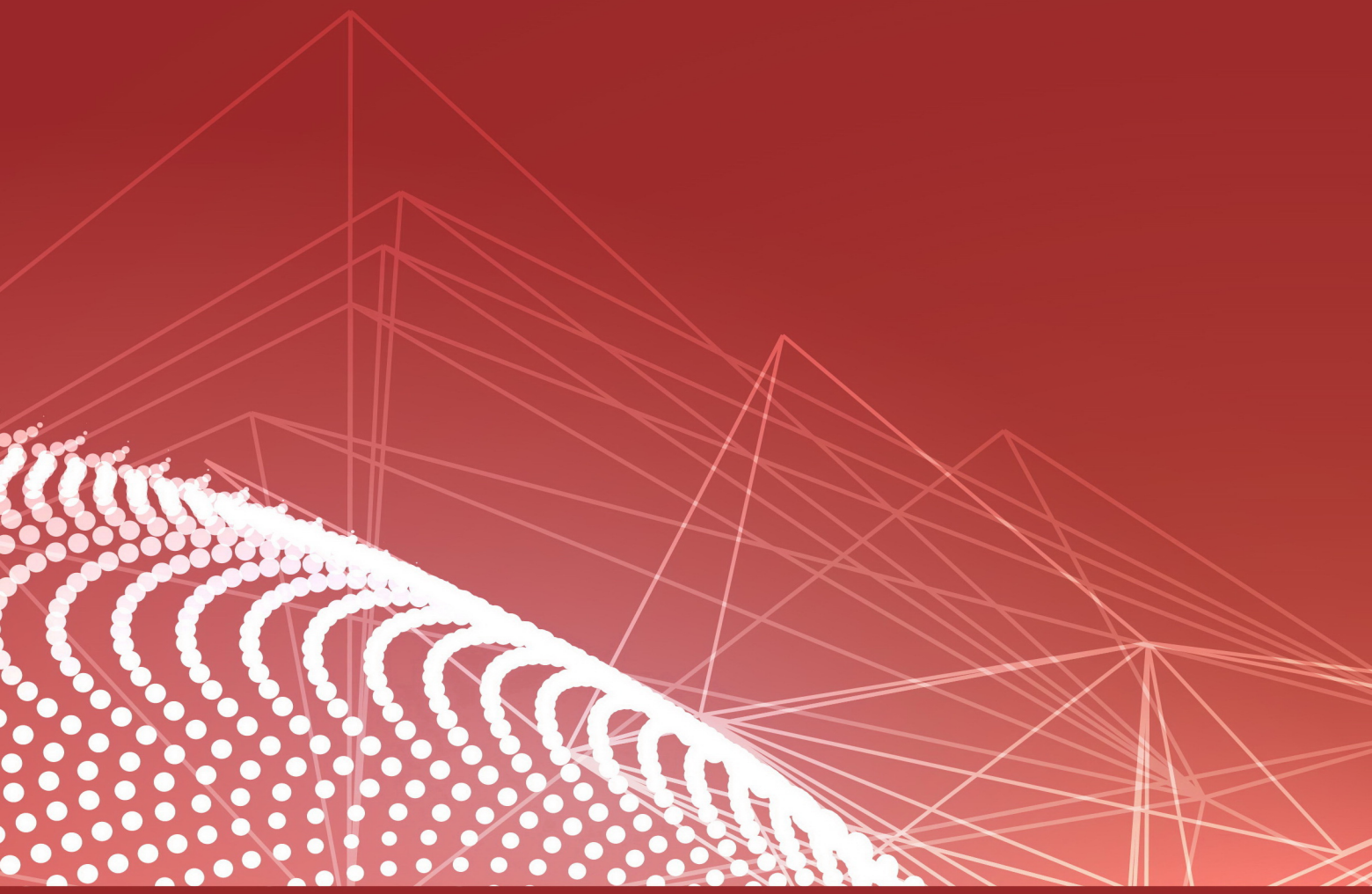

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INTERNATIONAL SCIENTIFIC JOURNAL OF ENGINEERING AND TECHNOLOGY (ISJET)

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Dear Contributors,

Once again, we cherish the new issue of the International Scientific Journal of Engineering and Technology (ISJET). At this time, the world is facing a great challenge posed by coronavirus (COVID-19) pandemic. Not only has it ravaged global health and the economy, but ignited instant leadership, contributions, and technological breakthrough. Thanks to the innovation in digital technologies, the economy could still operate under social distancing measures. The Republic of Korea has promptly developed the COVID-19 test kits with the help of AI. Singapore has launched an app called Trace Together using Bluetooth signals between smartphones. While in Thailand, the research team led by Vidyasirimedhi Institute of Science and Technology (VISTEC) has developed the rapid test kit based on CRISPR technology.

Rome was not built in a day. The technologies the world uses to fight COVID-19 are achieved by uncountable researches of science and technology across multidisciplinary approaches. That is, ultimately, the goal of ISJET. This journal will be dedicated to serving as a bridge for scholars to share their discoveries on advanced research in all fields of sciences: Engineering, Technology, and Innovation. On behalf of the Editorial Board, I would like to take this opportunity to thank everyone who has complemented our goal by contributing to the ISJET.

With kind regards,

Dr. Wirin Sonsrettee
Associate Editor of Science
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CONTENTS


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A Novel Growth and Development of *Mesembryanthemum crystallinum* (Aizoaceae) in Thailand

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***Abstract*—We investigated the cultivation, growth and development of *Mesembryantheum crystallinum* L. (the common ice plant, Aizoaceae, Caryophyllales) in Thailand. *M. crystallinum* plant were grown indoor under light emitting diodes (LED)-lighting (16-h photoperiod) 25°C and 85±5% RH with adequate water supply. The life cycle of *M. crystallinum* were study in this research. Moreover, we also cultivated in field located in Phisanulok, Kanchanuri, Ratchaburi, Chonburi and Saraburi Province, during May to September 2018. The results shown that, the optimum area to grown the ice plant in Thailand was Phisanulok Province (16°49'29.32"N, 100°15'30.89"E) using plastic film to protect them from rain and fog. Moreover, the calcium concentration from ice plant cultivated in Thailand was three times higher than the one of China whilst the sodium concentration was forty-three times lower. There were no significant differences on the vitamin A and sugar content in the samples from both areas. Therefore, ice plant may have the potential to grow in Thailand and should be promoted as edible high-value crop**

***Index Terms*—Ice Plant, *Mesembryantheum crystallinum*, Growth, Antioxidants, Functional food**

I. INTRODUCTION

Ice Plant (*Mesembryanthemum crystallinum* L.) is a salt-accumulating halophyte originated in Namib Desert on the western coast of southern Africa and became leafy vegetable [1]. Large bladder cells covering the leaf and stem of *M. crystallinum* are enlarged epidermal cells that functions to reserve water and to store accumulated salt [2]. The ice plant Crassulacean Acid Metabolism (CAM) plant, but perform C_3 photosynthesis during the juvenile period [3]. The edible leaves of the *M. crystallinum* plants contain high nutritional values and were successfully grown inside greenhouses and plant factory with artificial lighting (PFAL) in China Japan and Taiwan under cool until low temperature. The growth of these plants were mostly studied in different treatments of soil [4]. To enhance local vegetable production, recently we have successfully grown them in land scarce Singapore using an indoor aeroponic farming system with adequate water supply under light emitting diodes (LEDs) lighting. However, there is no cultivate in Thailand. In this study, we focus on cultivation and development of *M. crystallinum* plant in Thailand.

II. MATERIALS AND METHODS

A. Plant materials under environment control

A series of experiments were conducted in the temperature control room of Panyapiwat Institute of Management in Nonthaburi Province (13° 51' 38.70"N, 100° 30' 53.17" E)

Ice plant seeds that obtained from the farmer in Shanghai, China were used in this research. Before sowing, the seed of ice plant were surface sterilized with 2.5% (v/v) sodium hypochlorite for 3 minutes and rinsed with distilled water for 20 minutes. The seed of ice plant were sown in plastic cell trays (50 long × 50 wide × 70 mm deep with an 8-mm-diameter hole at the bottom) filled with the growing medium (peat moss; Klasmann Potground H, Germany). The cell tray were place in plastic tray (450 long × 300 wide × 60 mm deep) filled with tap water at a depth of 10 mm for 3 weeks. After growing for 3 weeks, the ice plant seedlings were transferred to potted contained with mixed culture soil. After that, all potted ice plant were held under light emitting diodes (LED)-lighting (16-h photoperiod) 25°C and 85±5% RH with adequate water. After harvest (65 days after transplant), all plant were send to analyze the nutrition compare with *M. crystallinum* cultivated in China. Once flowering has begun, the plant are no longer watered.

B. Cultivation on field

The 3 weeks ice plant seedlings were transferred to local area in Thailand including Phisanulok, Kanchanuri, Ratchaburi, Chonburi and Saraburi Province. All plants were held under 200 micron plastic film to protect them from rain and fog with adequate water two times each day and natural lighting. Growth rate and development of the plant were observe.

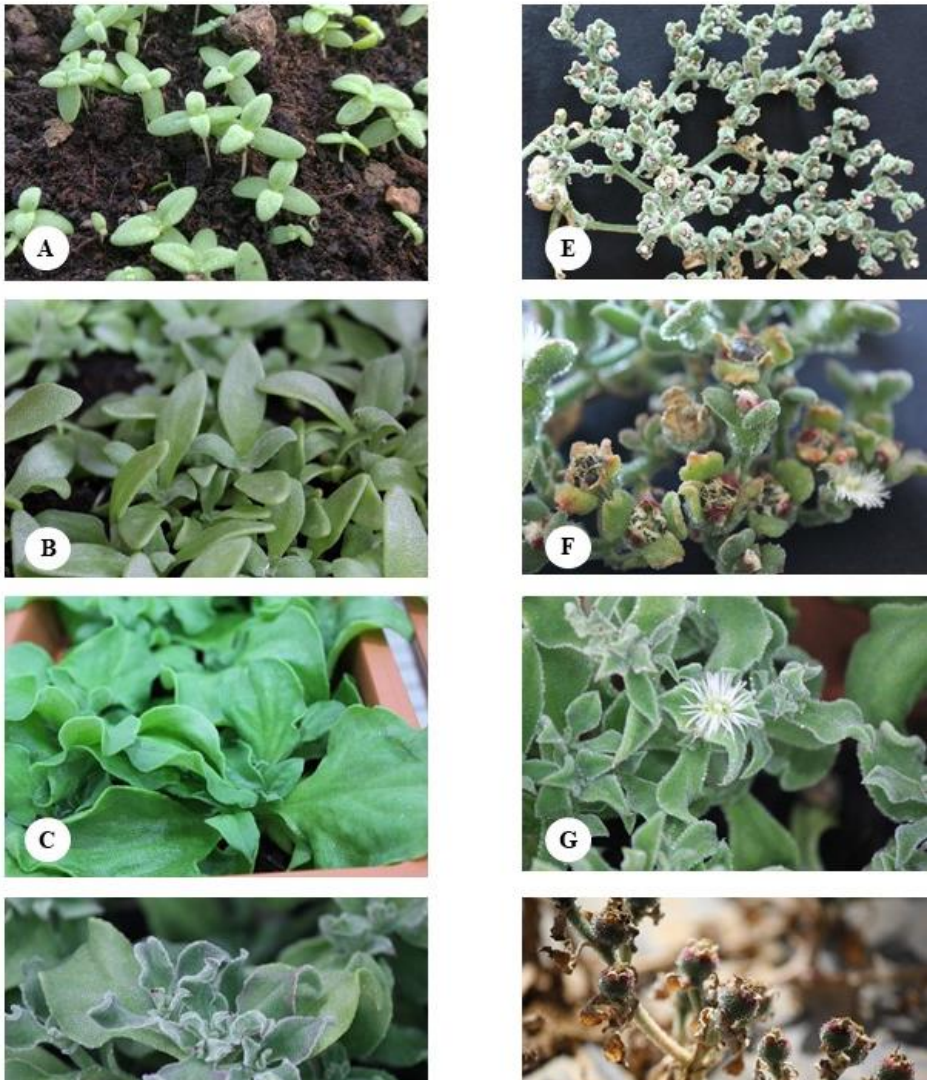

Fig. 1. Growth development of M. crystallinum. (A) Seedling with one primary leaf pair. (B) Juvenile plant (3-weeks old). (C) The stage transformation from juvenile to adult stage (6-weeks old). (D) Adult plant (12-weeks old). (E) Adult plant after stress (F) Size of plant and bladder cell depend on nutrition in medium and stress (14-weeks old). (G) Flowering at 12-weeks old. (H) Seed capsules, epidermal bladder cell are pigmented by betalaines.

III. Results and Discussion

The developmental stage are show in Fig. 1, and the pattern of growth and development are described following as below.

A. Growth and Development

1) Stage 1: Germination of seedlings
The seed germination were start within 3 days after sowing. The cotyledons are indistinct and 4-5 mm long (Fig. 1A). The germination rate depend on the quality of seed and suitable growth factors.

2) Stage 2: Juvenile leaves
After transplanted, the juvenile plants grow leaf pair (primary leaves) (Fig. 1B, 1C). One leaf pair a week occur in normal condition.

3) Stage 3: Adult stems and leaves
The mature stem and leaves start to appear on 8-weeks old plant. The bladder cell, unicellular trichomes functioning as peripheral salinity and water reservoirs covered on stem and leaves appeared in this stage [5].

4) State 4: Flowering
The onset of flowering is accelerated by any environmental stress including salt stress, lack of water and nutrition. In unstress plant; during mature growth they will produce the larger with a few flowers (Fig. 1G). While stress condition induced to end of juvenile growth smaller plant and many flowers (Fig. 1E, 1F).

5) Stage 5: Seed formation
The seed capsules were developed at 6-weeks old under stress condition, an is followed by senescence of roots, leaves and shoots whereas the seed capsules remain photosynthetically viable (Fig. 1F). This period in the last several weeks for plant [6]. The onset of seed formation is characterized by the appearance of intensely large epidermal bladder cell (Fig. 2)

III. Nutrition Facts

Once *M. crystallinum* plant growth to adult, all plants were harvested in early morning. Then all harvested plants were pack in the plastic box and transferred to laboratory at Kasetsart University Bangkhen within 1 hour. The nutrition fact in the plant were analyses compare with the plant growth in China following as TABLE I. All most of the nutrition, there were no significant differences among the both cultivation area. Accept sodium (Na) concentration in the plant cultivated in China was forty-three times higher than that cultivated in Thailand. Whereas, the calcium (Ca) concentration from ice plant cultivated in Thailand was three

Fig. II. Epidermal bladder cell (EBC) extremely appear when seed formation period. (A) EBC of the surface stem and leaves. (B) EBC on the surface of stem during seed formulation. (C) EBC on the surface of seed capsules. (D) The inside of seed capsule.

Fig. 2. Epidermal bladder cell (EBC) extremely appear when seed formation period. (A) EBC of the surface stem and leaves. (B) EBC on the surface of stem during seed formulation. (C) EBC on the surface of seed capsules. (D) The inside of seed capsule.

times higher than the one of China. Previous study reported that, the ice plant is contain abundant level of polyol and various minerals, as well as inositol, which is particular interest because it can in the treatment of diabetes mellitus [7]. At different stage and part, M. crystallinum shown different amount of sodium accumulation. The highest sodium accumulation was found in bladder cell at 1009 µmol g-1 f.wt. [2].

TABLE I
THE NUTRITION'S FACT IN 100 G PLANT IN BOTH AREA.

Nutrition	Cultivation area	
	China	Thailand
Energy	12.86 Kcal	11.68 Kcal
Fat	0.18 g	0.00 g
Protein	1.13 g	0.37 g
Carbohydrate	1.68 g	2.55 g
Fiber	1.07 g	0.00 g
Sugar	0.24 g	0.10 g
Na	708.62 mg	16.5 mg
Vitamin A	146.12 µg	117.61 µg
Ca	55.77 mg	174.22 mg
Mg	46.56 mg	26.91 mg
Ash	2.11 g	1.63 g
Moisture	94.90 g	95.45 g

Kcal = kilo calorie, g = gram, mg = milligram, µg = microgram

IV. SUITABLE AREA IN THAILAND

Growth of *M. crystallinum* can be influenced by temperature, light quantity and quality, and nutrient supply [8]. The plant cultivated in Kanchanuri, Ratchaburi, Chonburi and Saraburi Province have the abnormal physiology were shown in Fig.3. From these results, Phisanulok Province (16°49'29.32"N, 100°15'30.89"E) is consider as suitable area to produce *M. crystallinum* because suitability of factors and environment. However, in unsuitable are should more analysis by considering several limiting and supporting factor, such as accessibility infrastructure including water, soil and weather management.

Fig. 3. The physiology of M. crystallinum cultivated in (A) Kanchanaburi Province. (B) Chonburi Province. (C) Phisanulok Province

V. CONCLUDSION

In conclusion, the results suggest that the common ice plant or *M. crystallinum* are considered as proper crops with high commercial potential for the production in Thailand, especially at Phisanulok Province area. Because the relation of considering high quality, high production yield and operation costs in plant cultivation.

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Chairat Burana is a lecturer and researcher in the Faculty of Innovative Agricultural Management, Panyapiwat Institute of Management. He was born on 5th June 1983 at Sisaket Province. He received the B.Sc. (Agricultural Science) from Mahidol University, Thailand. He obtained his M.Sc. (Postharvest Technology) international program from King Mongkut's University of Technology Thonburi (KMUTT) Bangkok Thailand. During his Master's, He has a research exchange student at a laboratory of horticulture, the Faculty of Agriculture, Utsunomiya University, which was supported by Japan Student Services Organization (JASSO) Scholarship. His research topic was "Effects of 1-methylcyclopropene (1-MCP), Modified Atmosphere Packaging (MAP) and Intermittent temperatures on the Display Quality and Display

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Effect of Fermented Boiled Organic Soybean in Diet on Carcass Composition and Meat Quality of Broiler Chickens

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***Abstract*—This research aimed to investigate effects of fermented, boiled organic soybean in diets on carcass composition and meat quality of broiler chickens. Two hundred-thirty-four one-day old commercial broiler chickens were allocated into 6 groups with 3 replications and fed with soybean meal control diet, boiled organic soybean diet, boiled organic soybean supplement with fermented boiled soybean 25%, 50%, 75% and 100%, respectively. The results found that the fermented boiled organic soybean decreased percentage of carcass, dressing, loins and tender loins ($P<0.05$). The fermented boiled organic soybean no affects to the pH, color and shear force of the meat ($P<0.05$).**

***Index Terms*—Broiler chicken, Fermented of boiled organic soybean, Carcass composition, Meat quality**

I. INTRODUCTION

The organic animal feeds were derived from agricultural production sources that followed organic farming procedures. The organic production was excluded from genetically modified seeds, chemicals and fertilizers [1]. However, this processing was limited in that it required a very high amount of raw materials. Soybeans were considered one of the main raw materials widely used in animal feed. The organic soybean production had fewer problems compared to organic corn production, as soybeans were planted in the dry season after rice farming. Moreover, soybeans can be produced year-round [2].

Soybean (*Glycine max* (L) Merr) serves as a feed material that provides high nutritional value and is a major source of quality protein and fat [3, 4]. Furthermore, organic soybeans are raw materials that are considerably cheap and easy to acquire. They have similar nutritional value compared to that of soybean meal despite being cheaper. Nonetheless, the use of soybean was often limited by the anti-nutritional factors, including protease inhibitor, lectin, oligosaccharide, phytate, and anti-vitamin [5]. These factors reduce the nutritional value of food that will affect the utilization or metabolism of nutrients in animals.

There were several methods to eliminate the anti-nutritional factors in animal feed materials such as heating [6], microbial fermentation [7], and heating with fermentation. The reduction of anti-nutritional factors in fermented food ingredients was enhanced with increased lactic acid levels [8]. The trypsin inhibitor can be digested with bacterial enzymes [9]. In addition, boiling enhances digestibility of soybeans in the stomach as it increases the amount of sugars such as xylose, mannose, galactose, and glucose [10]. However, soybeans have high fat content which affects the efficiency of food production. Panya et al. [11] found that the use of boiled soybeans and fermented organic soybeans improved the performance in small broilers in terms of growth, the amount of food in Phase broiler, and carcass quality of the broilers.

In this study, we investigated the effects of different levels of fermented boiled organic soybeans in broiler diet on carcass composition and meat quality of a commercial broiler.

II. MATERIALS AND METHOD

The boiled organic soybeans and fermented boiled organic soybeans were prepared according to the method described in [11]. Both boiled and fermented, boiled organic soybeans were sun-dried and further dried in the hot air oven for 48-72 hours. They were ground thoroughly before use.

The present study followed the complete randomized design (CRD) setup that used 234 commercial broilers with the age of 1-day old. They were randomly divided into 6 groups. Each group was distributed into three replicates with thirteen broilers per replicate. The food compositions for broilers in different groups were:

Group 1: 100% soybean meal (control diet)

Group 2: 100% boiled organic soybeans

Group 3: 25% fermented boiled organic soybeans + 75% boiled organic soybean

Group 4: 50% fermented boiled organic soybeans + 50% boiled organic soybean

Group 5: 75% fermented boiled organic soybeans + 25% boiled organic soybean

Group 6: 100% fermented boiled organic soybeans

The experimental feed was prepared for broiler into 2 periods comprising as starter feed (age 0-3 weeks) and a grower feed (chicks age 3-7 weeks). The basal diet was based on organic broken rice and soybean meal (see Table I and II) and was balanced to meet the nutritional requirements for broiler chickens according to the NRC (1994) [12]. Feeding and water were provided ad libitum for 7 weeks.

Experimental data of the carcass characteristics and meat quality were collected. At the end of the experiments, all of the broilers were sacrificed in accordance with the animal welfare principles to investigate the animal live weight, warm carcass weight, percentage of dressed warm carcass weight, and the percentage of various parts from the carcasses. The chest and hip muscles were used for determination of the color, pH, percentage of drip loss from chilling and cooking, shear force and the meat oxidation.

All data were analyzed using Analysis of Variance (ANOVA). Significantly different means were separated according to the method of Duncan's New Multiple Rang Test (DMRT) according to the procedure described in Steel et al. (1997) [13].

TABLE I
INGREDIENTS AND CALCULATED CHEMICAL COMPOSITION OF THE EXPERIMENTAL DIETS (0-3 WEEKS)

Ingredient	**Groups**					
	1	**2**	**3**	**4**	**5**	**6**
Organic broken rice	43.6	43.6	43.6	43.6	43.6	43.6
Soybean meal (44% CP)	52.4	0	0	0	0	0
Boiled organic soybean	0	52.4	39.3	26.2	13.1	0
Fermented, boiled organic soybean	0	0	13.1	26.2	39.3	52.4
Dicalcium phosphate	2.65	2.65	2.65	2.65	2.65	2.65
Fine limestone	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Probiotic	0.05	0.05	0.05	0.05	0.05	0.05
Calculated Chemical composition (%)						
Crude Protein (%)	23.1	23.1	23.1	23.1	23.1	23.1
Metabolizable Energy (kcal/kg)	2877	2877	2906	2936	2965	2995
Calcium (%)	0.99	0.99	0.99	0.98	0.98	0.97
Available Phosphorus (%)	0.78	0.78	0.76	0.72	0.69	0.65

*Commercial premix

TABLE II
INGREDIENTS AND CALCULATED CHEMICAL COMPOSITION OF THE EXPERIMENTAL DIETS (4-7 WEEKS)

Ingredient	Groups					
	1	2	3	4	5	6
Organic broken rice	50.5	50.5	50.5	50.5	50.5	50.5
Soybean meal (44% CP)	45.5	0	0	0	0	0
Boiled organic soybean	0	45.5	34.2	22.8	11.4	0
Fermented, boiled organic soybean	0	0	11.4	228	34.2	45.6
Dicalcium phosphate	2.65	2.65	2.65	2.65	2.65	2.65
Fine limestone	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Probiotic	0.05	0.05	0.05	0.05	0.05	0.05
Calculated Chemical composition (%)						
Crude Protein (%)	20.1	20.1	20.1	20.1	20.1	20.1
Metabolizable energy (kcal/kg)	2940	2940	2966	2991	3017	3043
Calcium (%)	0.99	0.99	0.98	0.97	0.97	0.96
Available phosphorus (%)	0.77	0.77	0.73	0.70	0.67	0.64

*Commercial premix

III. RESULTS

The results showed that all 6 experimental groups were not significantly different ($P > 0.05$). (Table III). The hot carcass of all experimental groups was not significantly different ($P > 0.05$) although that of treatment 3 was lower than control (treatment 1) ($P > 0.05$). The dressing weight of the organic soybean treatments was lower than control although the weights of those under treatments 2 and 4 were not significantly different from control ($P < 0.05$). The percentages of legs in the hot carcass from the broilers in the organic soybeans group were higher than that of the control, while pectoralis minor and pectoralis major were lower than those of the control. The visceral fat was also not significantly different among the various experimental groups although that of group 5 was higher than that of the control ($P < 0.05$).

As for the hot carcass, the percentages of head and neck, wings, drumsticks, thighs, and skeleton frame from all treatments were not significantly different ($P > 0.05$). Nevertheless, the percentages of the legs, loins, and tenderloins of the warm carcass were significantly different ($P < 0.05$). Interestingly, the leg percentages of the warm carcass from broilers fed with boiled organic soybeans and those fed with fermented boiled organic soybeans were higher than that of the control. In contrast, the percentages of loins and tenderloins from broilers fed with soybeans (25, 50, 75, and 100%) were lower than that of the control.

The examination of internal organ weights showed that the percentages (% live weight) of visceral organs, heart, liver, proventriculus gizzard, and spleen of broilers from all experimental groups were not significantly different ($P > 0.05$). However, the visceral fat percentages of broiler chickens fed with boiled organic soybeans and fermented boiled organic soybeans were higher than that of the control (Table III).

TABLE III
THE EFFECT FERMENTED OF BOILED ORGANIC SOYBEAN LEVEL ON CARCASS COMPOSITION IN BROILER CHICKEN

Items	Groups					
	1	2	3	4	5	6
Live weight (g)	1743.9	1558.2	1554.2	1560.6	1599.9	1624.8
Hot carcass weight (g)	1641.5	1292.7	1266.9	1289.4	1278.7	1322.3
Dressing weight (g)	1296.4	1136.7	1104.1	1131.0	1105.4	1157.2
Hot carcass (%)	83.58^{a}	81.68^{a}	75.85^{b}	81.08^{a}	79.59^{ab}	79.48^{ab}
Dressing (%)	74.00^{a}	70.92^{ab}	64.69^{c}	70.14^{ab}	68.74^{bc}	68.68^{bc}
Carcass percentage (Hot carcass %)						
Head and Neck	5.53	6.10	6.20	6.19	6.11	6.08
Legs	4.05^{b}	4.59^{a}	4.77^{a}	4.89^{a}	4.74^{a}	4.72^{a}
Wings	8.17	7.84	8.06	8.15	7.78	7.96
Drumsticks	11.18	11.48	10.91	10.96	11.13	10.96
Thighs	12.96	14.01	12.45	12.04	13.20	12.98
Loins	15.2^{a}	11.22^{c}	10.07^{c}	10.3^{c}	12.97^{b}	11.55^{bc}
Tenderloins	3.43^{a}	2.74b^{c}	2.71b^{c}	2.55^{c}	3.01^{b}	2.81^{bc}
Skeleton frame	17.40	18.99	18.14	18.37	17.89	18.59
Internal organ (Live weight %)						
Visceral organs	9.91	11.37	11.21	10.86	12.02	11.62
Heart	0.45	0.49	0.50	0.49	0.56	0.54
Liver	2.12	2.3	2.15	2.20	2.36	2.40
Proventriculus Gizzard	2.28	2.76	2.73	2.78	2.76	2.77
Spleen	0.24	0.11	0.14	0.14	0.17	0.16
Visceral fat	0.36^{b}	0.73^{ab}	0.49^{ab}	0.47^{ab}	0.85^{a}	0.67^{ab}

$^{a, b, c}$ The different letters in the same row represent statistically significant differences ($P<0.05$)

We then examine the meat quality by measuring the pH and color of the meat. We found the pH of the 24 hour postmortem thighs, the brightness of loin and the redness of drumsticks at 45 minutes postmortem, and the brightness of loin at 24 hours postmortem of the control were significantly different ($P < 0.05$) (Table IV). The pH of thighs at 24 hours postmortem and the brightness of loin at 45 minutes postmortem were highest in the broilers fed with the boiled organic soybeans and fermented boiled organic soybeans (25, 50, 75, and 100% compositions; see Materials and Methods). The

drumstick meat of broiler chickens fed with 100% boiled organic soybeans showed the highest degree of redness at 45 minutes postmortem. Moreover, the brightness of drumsticks at 24 hours postmortem of the control and that of the 50% fermented organic boiled soybeans group were considerably high (Table IV).

TABLE IV
THE EFFECT OF FERMENTED BOILED ORGANIC SOYBEAN LEVEL ON PH AND COLOR OF THE PECTORALIS AND THIGH MEAT IN BROILER CHICKENS

Item	Groups					
	1	2	3	4	5	6
pH of pectoralis major						
pH 45 min.	6.20	6.03	6.02	6.07	6.00	6.04
pH 24 hour	5.86	5.99	5.87	5.93	5.72	6.08
pH of thigh						
pH 45 min.	6.27	6.41	6.36	6.40	6.25	6.35
pH 24 hour	6.30^{a}	6.25^{a}	6.17^{abc}	6.20^{ab}	6.04^{c}	6.07^{bc}
Color of loin at 45 min. postmortem						
L*	60.82^{a}	58.59^{ab}	57.10^{bc}	55.53^{c}	59.33^{ab}	58.34^{abc}
a*	15.25	16.86	14.23	15.26	14.56	13.22
b*	8.40	6.69	5.16	5.82	6.47	7.86
Color of thigh at 24-hour postmortem						
L*	58.19	55.98	56.32	54.46	55.56	55.74
a*	16.55^{ab}	18.12^{a}	15.55^{b}	16.03^{b}	16.74^{ab}	15.56^{b}
b*	8.40	6.69	5.16	5.82	6.74	7.89
Color of loin at 45 min. postmortem						
L*	60.06	61.03	59.29	57.70	60.34	59.01
a*	12.91	13.96	13.35	14.83	14.37	14.16
b*	7.00	7.91	8.29	7.04	8.32	8.08
Color of thigh at 24 hour postmortem						
L*	58.03^{ab}	57.44^{ab}	56.70^{bc}	58.30^{a}	55.39^{ab}	54.90^{c}
a*	14.82	15.83	15.43	14.84	16.65	16.25
b*	7.68	8.25	9.22	7.17	8.36	8.47

[a,b,c]The different letters in the same row represent statistically significant differences (P<0.05)

The meat quality of the chickens fed with fermented organic boiled soybeans was determined by the level of drip loss, cooking loss, shear force, and TBARS of the meat. We found that the drip loss from chilling and cooking the loin and thigh as well as the meat oxidation were not statistically different. (P > 0.05) Nevertheless, shear force value of the thigh was significantly different (P < 0.05). The shear force values of the thighs of the broilers in the 100% boiled organic soybeans group and those in the 25% fermented boiled organic soybeans group were lower than that of the control and the rest of the experimental groups (P<0.05). Intriguingly, the shear force seemed to increase as the fermented boiled organic soybean percentage in the feeding composition increased (50% fermented boiled organic soybean in treatment 4, 75% in treatment 5, and 100% in treatment 6, respectively; Table V).

TABLE V
THE EFFECT OF FERMENTED BOILED ORGANIC SOYBEAN LEVEL ON DRIP LOSS, COOKING LOSS, SHEAR FORCE, AND TBARS OF THE LOIN AND THIGH MEAT OF BROILER CHICKENS

Item	Groups					
	1	2	3	4	5	6
Drip loss (%)						
Pectoralis major	7.33	6.96	6.81	7.72	7.05	7.61
Thigh	6.96	7.77	6.11	5.70	5.36	5.14
Cooking loss (%)						
Pectoralis major	15.57	16.68	14.88	23.66	22.16	18.56
Thigh	17.66	15.40	21.93	19.72	19.72	17.73
Shear force (Kg/cm^3)						
Pectoralis major	1.23	0.66	0.97	1.00	1.56	1.50
Thigh	1.49^{ab}	0.97^{b}	0.74^{b}	1.11^{ab}	1.67^{a}	1.80^{a}
TBARS of loin						
Day 0	0.02	0.03	0.02	0.03	0.03	0.03
Day 3	0.04	0.04	0.04	0.03	0.05	0.04
Day 7	0.05	0.05	0.04	0.05	0.06	0.06

[a,b,c] The different letters in the same row represent statistically significant differences (P<0.05)

IV. DISCUSSION

The fermented boiled organic soybean was used as ingredient of animal feed that decreased the percentages of hot carcass, dressing, loin and tenderloin. The live weight of broiler chicken fed with the fermented boiled organic soybean was low. The fermented boiled organic soybean increased the percentages of visceral organs and visceral fat. Ken-ichiro et al. [14] found that the fermented boiled organic soybean did not increase the hot carcass, thighs, and drumsticks. Kim et al. [15] reported that the fermented soybean meal did not increase the organ weight of grower chickens. Conversely the boiled organic soybean and fermented boiled organic soybean increased the percentage of visceral fat. The boiled organic soybean and fermented boiled organic soybean have high fat content that was reflected in the visceral organs and fat [16]. However, they barely affected the carcass composition in our experiments.

The fermented, boiled organic soybean in diet affected the meat quality, pH, color and shear force of broiler chickens. Similar to our observations, Lee et al. [17] reported that the fermented sprout soybean has an effect on the meat quality. The soybean contains isoflavone compounds such as genistein, daidzein, and glycitein. Isoflavone influences the meat color [18]. The accumulation of lactic acid from anaerobic respiration leads to low pH of the meat. The killing management, transportation, and timing also reduce a pH value [19]. The 25% fermented boiled organic soybean in broiler diet led to the low shear force value that indicated the

softness/tenderness of the meat [20]. However, the boiled organic soybean and fermented boiled organic soybean had no effects on meat oxidation. Nonetheless, Baranski et al. [21] reported that the organic materials in diet are composed of more antioxidants than the common materials. The antioxidant agents decrease the oxidation of fat in the loins and increase shelf life of the meat.

V. CONCLUSION

The present study used fermented boiled organic soybeans in the broiler diet to evaluate the carcass composition and meat quality of a commercial broiler. This research found that the fermented boiled organic soybeans decreased the percentage of carcass, dressing, loin, and tenderloin. In addition, the percentage of visceral fat was increased. They affected the quality of the chicken meat in terms of pH, color, and shear force.

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Global Problem-Based Learning with the Collaboration of Thai and Japanese Universities Companies Explaining the 3 - year Experience of our Kaizen PBL Program Development

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***Abstract*—This paper is about a global problem-based learning (gPBL), called KAIZEN gPBL, developed by Panyapiwat Institute of Technology (PIM) and Shibaura Institute of Technology (SIT), in which program participants identify, analyze and discuss the problem, and to propose Kaizen ideas (= solutions) for the production line of the industrial chains (for tractors) in Thai local (or Japan-Thai) factories. This paper first explains the brief history and the contents of the program, and then describes its three types of uniqueness and contributions to the Japanese and Thai engineering education. The three types of uniqueness are: 1) the applicability of the program in which everyone (regardless of their age, gender, and work experience, etc.) can learn something new, 2) the excellent collaboration with universities. and companies in Japan and Thailand, and 3) providing the opportunity to see "real-world" problems.**

***Index Terms*—Industry University Cooperation, Global PBL, Thailand, Engineering Education, Graduate/Professional Schools**

I. INTRODUCTION

In these days, Kaizen (The concept/activities of continuous improvement) has been widely applied to Japanese companies all over the world, and the technique has been widely adopted by the local companies in newly developing countries as well. [1-3] Despite its prevalence, not many engineers in Japanese companies have direct experiences with Kaizen activities even though they might have heard the words or have some understanding of the concept. In addition, graduate schools face a major challenge for their implementing global Problem-Based Learning or gPBLs because of the time limitation for adult students. While the time to stay abroad should be minimized, the contents of the program should be fruitful enough for them to gain some insights. In addition, it is very important for both Thai and Japanese students (as future engineers) to know how Kaizen activities are taking place in factories in developing countries.

Though the target participants of the program in Japan have changed from graduate (adult) students to undergraduates since 2018, the program continues to produce good educational effects and have received good/positive feedback from participants. The reason why the program has continued for more than three years is due to the following three types of uniqueness: they are 1) the applicability of the program in which everyone (regardless of their age, gender, and work experience, etc.) can learn something new, 2) the excellent collaboration with universities. and companies in Japan and Thailand, and 3) providing the opportunity to see "real-world" problems. These strength in turn would keep attracting participant not only from universities, but also from companies. The following sections first define Kaizen concept, describe the outline of the gPBL, and explain the three types of uniqueness of the program. This finally introduces survey results and voices from the participants and concludes with discussions as well.

II. DEFINITION AND THE REASON FOR CHOOSING KAIZEN FOR THE PROGRAM

According to Brunet and New [4], Kaizen is the Japanese word for improvement, carrying the connotation in industry of all the uncontracted and partially contracted activities which take place in the Japanese workplace to enhance the operations and the environment. The biggest competitive advantages of Kaizen are supposed to be simple,

low cost, low technology and people focused, which primarily aimed to continuously enhance the firm's capabilities, productivity and quality [5]. Kaizen has been widely applied to Japanese companies all over the world. Also, the technique has been widely adopted by the local companies in newly developing ASEAN countries such as Thailand, Vietnam, and Indonesia. In fact, literature review indicates that numeous authors have written about Kaizen application in variety of companies in Japan and other countries [5]. As results of numerous studies and experiments as well as tries and errors on sites, the quality of the products made by local factories in these developing countries have improved remarkably in these days. While the concept is now universally prevalent, Japanese engineers working domestically rarely see, learn and apply Kaizen concept to their work process because manufacturing bases in most Japanese companies have been moved abroad. In 2017, more than a quarter (25.4%) of production is made in other countries especially in a manufacturing sector [6]. This is one of the main reasons why only a few engineers have a chance to learn Kaizen activities of local supplies in developing countries. Since Kaizen is deeply-rooted in the history of Japanese (manufacturing) business, it is important for engineers to have not only knowledge but also skills to implement Kaizen in a real setting. Therefore, using Kaizen activities as a theme of global Problem-Based Learning (gPBL) will be suitable for adult education at a graduate school. This is also imperative for engineering students and future engineers, to see the world of Kaizen in developing countries as well.

III. The Outline of the gPBL

The purpose of the gPBL is to propose Kaizen ideas (= solutions) in which students will propose Kaizen ideas that improve a production system of the factory owned/operated by Thai companies. In the process, students make cross-border teams to:

II. visit and observe an actual workplace
(a factory) to identify problems,
III. develop Kaizen ideas based on their observations,
IV. try out their ideas, and finalize and present their Kaizen proposals.

Table I shows the counterparts and the participants of the gPBL. As seen in the table, the program was originally developed and organized by the two universities: Panyapiwat Institute of Management (PIM, Thailand) and Shibaura Institute of Technology (SIT, Japan). The corporate partners are as follows: Thai Metro Industry (1973) [7], Thai-German Boiler Manufacturing Limited (2018) [8], and SMC Thailand Ltd. Rayong Branch (2019) [9]. They are B to B manufacturing companies, and their product are quire various from a huge boiler to small equipment parts. Dr. Paritud of AME, PIM, who is the co-organizer of this program, has strong corporate connections in Thailand and the partners in the Table I are all from his networks. They were willing to provide their facilities as an "experimental site" of this program for participants.

TABLE I
Counterparts and the Participants of the gPBL

Year	2017	2018	2019
Organized & Designed by	Panyapiwat Institute of Management (PIM: Thailand) Shibaura Institute of Technology (SIT: Japan)	Panyapiwat Institute of Management (PIM: Thailand) Shibaura Institute of Technology (SIT: Japan)	Panyapiwat Institute of Management (PIM: Thailand) Shibaura Institute of Technology (SIT: Japan)
Particpant's of the program	-	King Mongkul's University of Technology Thonburi (KMUTI)	King Mongkul's University of Technology Thonburi (KMUTI)
Cooperate Partner	Thai Metro Industry 1973 (Manuf. Factory in Thailand)	Thai-German Boiler Manufacturing Limited. Bangkok, Thailand (Manuf. Factory in Thailand	SMC Thailand Ltd. Rayong Branch (Manuf. Factory in Thailand)
	-	a-Sol Co., Ltd. (Kaizen consulting firm)	-
Days in BKK	Nov. 3, 2017 - Nov. 5, 2017	Sep. 2, 2018 - Sep. 11, 2018	Sep. 1, 2019 - Sep. 10, 2019

III. The Schedule of 2018 and 2019

As shown in Table II, the total days of staying Thailand has changed in 2018 from 3 days to 10 days. Because the main participants have been undergraduates since 2018 (see Table I), programs can be held during their summer break. The longer stay in Thailand allowed two factory visits at interval, that turned out to be the biggest advantage of the program. For example, participants can focus on finding Kaizen points on the first visit, and they can spend time for prototyping for the second visit. The longer stay also enable students to spend more time together to build a good friendship.

TABLE I I

SCHEDULE OF THE PROGRAM (2017 – 2019)

2017			2018 & 2019		
Japan	Day 1	On-line lecture 1	Thailand	Day 1	Arrive at Bangkok
	Day 2	On-line lecture 2		Day 2	Orientation & lecture
				Day 3	Lectures & discussion
				Day 4	Factory visit - 1
				Day 5	Discussion & prep.
				Day 6	Factory visit - 2
				Day 7	Wrap-up
Thailand	Day 1	Lectures & discussion		Day 8	Making proposals
	Day 2	Factory visit - 1		Day 9	Presentation prep
	Day 3	Final presentation		Day 10	Final presentation

A. Preparations

Japanese students had English classes and one and a half-day Kaizen lecture in advance to the program in September. Thai students were recruited based on their interest in the program and were informed in advance about the important of English and/or Japanese as means or communication during the program.

The study in Bangkok

1) Orientation and Lectures

there are several lecturers who teach a part of Kaizen concepts as well as some knowledge of (international) group work. Dr. Kato (SIT) took a part of ice-breaking, explaining the outline, and the team development. Dr. Paritud of Automotive Manufacturing Engineering gave a lecture on basic knowledge of Toyota production methods at "Principles of Japanese Production Management (TQM, TPM, TPS)". A lecture on "Basic IE techniques" was given by Dr. Paitoon of Industrial Engineering, PIM. Finally, Mr. Kadowaki of a Sol Co., Ltd., a Japanese consulting firm with a branch in Bangkok gave a lecture on "Practical Kaizen - how to fix a problem". The explanation of Mr. Kadowaki based on practical experiences in consultation on productivity improvement for the manufacturing firms was also very good at capturing the students interests, and he was able to smoothly bring the concept of Kaizen, which was lectured by Dr. Paritud, into the actual workplace. The group worked to find the "seven wastes" while looking at the photos of the factory, and then made a presentation. Group work using visual evidences of actual factories would motivate them to visit the factories on the next day.

2) Factory visit

The boiler factory, in case of 2018, was created by German capital and is currently 100% Thai-owned (publicly owned), but the conceptual design of the boiler is done by a German company and the engineering design is done by its own company. Mr. Theerasak Thegrumphung, Vice President, gave a brief overview of the factory and its products, followed by a tour of the site. Since there were many "seven wastes" that students with little Kaizen knowledge could easily identify, they enthusiastically looked around the factory and ask questions to factory leaders and Thai students.

Fig. 1. Group introduction by participants.

Fig. 2. Group discussions and process observation at Thai-German Boiler Manufacturing Limited in 2018.

3) Group discussions

Fig. 1 shows the group introduction by participants and Fig. 2 and Fig. 3 shows the group discussions activities. Students brought several Kaizen points from the factory for discussed their proposal as a group and planned a prototype for the next visit. The also develop questionnaire for asking factory workers on the re-visit. The most difficult part for them (as engineering students) was the fact that they had to discuss conceptual issues (invisible issues), which is very different from their typical goals such as making materials. In addition, there is a language barrier

between Thai and Japanese students. Both students worked hard to communicate using smartphones and gestures. They sometime asked for help to teaching staffs for translation, but in general they managed themselves to solve the communication problems. Their attempt to solve the problem was very impressive. When it's time for breaks and meals, students talk happily with each other, such as "What is this in Japanese?" "What is this in Thai?" It's been a few days since it started, but the most drastic change has been the brilliance of each SIT student. And the expression is much richer than at the time of departure.

Fig. 3. Group discussions to prepare the proposal by participants with English as means for communication.

4) Factory re-visits

On the re-visit in 2019; there was time in which a factory manager and the staff of SMC Thailand walked around students' groups (Fig. 4) to listen to their ideas and give some advices for further improvement of their proposal. Students focused more on the particular process and the place, and asked more specific questions to factory workers. Some of the on-site staff are not very fluent in English, so Japanese students asked their Thai friend for an interpreter.

Fig. 4. Factory visit at SMC Thailand Ltd. Rayong Branch in 2019.

5) Group discussions

Based on the findings and advices from the factory staff, they finally wrapped-up their discussions and started preparing for the final presentations. On that day, teaching staffs announced evaluation criteria and prizes (the first to third places) and that the plant manager would attend and would be a main judge of the presentation.

6) Final presentations (Fig. 5)

Each group held 15 minutes of presentation and 5 minutes of Q and A. Thought it was very difficult to summarize Kaizen's proposal in English in a short time (about two business days), the five groups enthusiastically presented their proposals one after another. The three teams were selected by the plant manager and the direct manager to be commended as the best proposal with two runner - ups. After the commendation, the factory manager commented on the importance of thinking. Manufacturing is also important, but it is important to understand the reality and think first. Young people commented in particular that they should not neglect "think". The factory management commented that they were really grateful for hearing the ideas they did not even expect (especially the idea of having a larger wall clock in the factory for better operation control).

Fig. 5. Group final presentation attended by participants, teaching staff, and factory people.

IV. THE SCHEDULE OF 2017

The schedule for 2017 is very different from the schedule after 2018. As mentioned at the beginning, adult students cannot take a lot of breaks and travel abroad. Therefore, we divided the PBL into two parts: 1) Pre-Study period (studying in Japan) and 2) Staying in Bangkok.

A. The pre-study periods

In the pre-study period as shown in Fig. 6, Japanese graduate students had lectures for Kaizen, movies for coming up of the proposal, and exercises for the presentation in Bangkok. Throughout the both periods, Japanese and Thai universities closely working with companies in Japan and Thailand to provide lectures and opportunities for students.

Fig. 6. Pre-study of Thai-Japan tele-conference (left) and the lecture by Mr. Kadowaki (right).

The special feature in this period is two Kaizen-related lectures: "The Introduction to Industrial Engineering" by a Thai lecturer (through Teleconference), and "The Applied Kaizen" by Mr. Kadowaki of a-Sol Co., Ltd. Though the initial level of understanding and experiences of Kaizen were different among Japanese students, the lectures could enable them to understand the Kaizen concept for drawing up Kaizen proposals later on.

Another special feature in this period is to use the movies (taken by the Japanese consultant when visiting Bangkok) so that the Japanese students could understand the production line and potential Kaizen points while they were in Japan.

B. The study in Bangkok

The study in Bangkok had been done from November 3-5. On the first day, Japanese and Thai students visited the factory of the Thai Metro Industry (1973) Co., Ltd. to see and test their proposed Kaizen ideas/tools and then discussed with each other for brushing-up their final proposals. On the second and the final day, students had final presentations to wrap-up their three-month activities with all the faculty and staff who in charge of this program.

The special feature of this period is the generous support of the factory, allowing students to test their ideas/tools in the real production line. This opportunity made students realized the importance of 3-Gen principles (Genba, Genbutsu, and Genjitsu).

VI. THREE UNIQUENESS OF THE PROGRAM

A. 1st strength - Applicability

The first strength is the applicability of the program itself in which everyone (regardless of their age, gender, and work experience, etc.) can learn something new. The concept of Kaizen is consisted of the following components: 1) Understanding the concept of MUDA (= wastes), 2) Observing what happens in a (real) work setting, 3) problem identifying/solving skills, and 4) autonomous and pro-active behavior. These components are highly applicable to other areas of specialty.

B. 2nd strength – The excellent collaboration

In this program, there is an excellent collaboration among universities. and companies in Japan and Thailand. As introduced at the beginning, this program includes four players and each player has its own role. For PIM, KMUTT and SIT, this became the opportunity to 1) expand their network with Japanese (Thai) universities, 2) develop a new gPBL program that focuses on managing processes in an actual

workplace (different from making visible products). For the Japanese consultant, this was an excellent opportunity to 1) expand his business opportunity in Thailand, and 2) Increase his presence in academia by having a lecture for university students. Finally, for the factories, this is an excellent opportunity to 1) get Kaizen ideas by people who can take a fresh look at the factory, 2) encourage their employees to learn/conduct Kaizen activities by interacting with people outside the factory, and 3) expand its business network beyond Thailand.

C. 3rd strength - Seeing the "real world" problems

The third and the final strength of the program is to providing the opportunity to see "real-world" problems as shown in Fig. 2 and Fig. 7. In general, factories do not always welcome people outside to get in the site, because production process is usually the center of a factory and carries a lot of confidential information. The corporate partners of the program were, however, quite open in terms of sharing their Kaizen ideas/activities with others. As shown in the pictures below, students could actually talk with floor staff, ask them to change the arrangement of parts and stocks based on their Kaizen idea, and test the jig that they made and brought from Japan. With the interactions with the floor staff, students could analyze the feasibility of their Kaizen ideas/tools and adjust their final proposals accordingly. Prototyping at the factory also became the core feature of the program.

As for the three companies in particular, they could be classified as small and medium size enterprise or SME. The introduction of Japanese management techniques of Kaizen into the workplace is rather new or difficult due to the lack of knowledge or qualified technical personnel. [10-11] In fact Kaizen is an umbrella that covers other powerful operation improvement tools such as TQM, TPM, TPS, etc. So, the gPBL program could be initial learning for good manufacturing practices of these three.

Fig. 7. Process observation at Thai Metro Industry (1973)

in 2017.

For the graduated students (full-time engineers), this was an excellent opportunity to 1) have a chance to get in a local factory to see how it goes (seeing is believing), 2) try out their prototypes (e.g. JIGs) in a real setting at the factory, and 3) think about their business from a different point of views. For the undergraduate students, this was an excellent opportunity to 1) realize that parts of the products that they use in their everyday life are made in an environment such like this, 2) know that they may go abroad in the future to work with people like those in the factory, and 3) have some confidence that their ideas and creativity can help solve problems in real work settings.

VII. RESULTS

Though no quantitative/rigid experiment was implemented before and after the program, we collected the voice from participants before and after the program.

Voices before the program

In terms of voices before the program, 14 Japanese participants in 2018 described their expectations of the program when they created their profile. Their expectations are categorized/organized into the following Table III (multiple answers possible).

TABLE III
EXPECTATION OF THE JAPANESE PARTICIPANTS IN 2018

Item	Description	Frequency
1	Brushing up English (communication/presentation)	5
2	Communicating/interacting with students, faculty, and local people in other culture	13
3	Brushing up problem-identifying/ problem-solving skills	2
4	Seeing and learning new cultures	5
5	Having an experience of going abroad	5
6	Telling our culture to foreigners	2
7	Expanding my view/value	3
8	Learn Kaizen and a production system in Thai local factories	7

A. Voices after the program

In terms of voices after the program, we collected their voices by 1) having a survey (all participants) and 2) submitting a report (Japanese participants only). The aim of the survey is to see overall satisfaction of the program, and the aim of the report is to understand what they've learned from the program in detail.

TABLE IV
RESULTS FROM THE SATISFACTION ISURVEY ITEM DESCRIPTION

Item	Description	1	2	3	4	5
1	Sequence of the program			2	10	11
2	Contents of lectures			6	12	5
3	Lecturer: Dr. Paitoon/ IE Technique		2	7	5	9
4	Lecturer: Dr. Paritud/ Jap. Manu. Tech		1	3	9	10
5	Lecturer: Mr. Kadowaki/ Kaizen			2	11	10
6	Factory as a Case Study		1	5	10	7
7	Meeting Venue			2	12	9
8	Hotel		2	8	8	5
9	Transportation	1	2	4	11	5
10	Provided Food/ Break			6	10	7
11	Staff Assistant		1	1	7	14
12	Side trip (Koh Kred, Shopping, etc)			2	9	12

The survey results in 2018 are shown on the Table IV above. As the table shows, most of the participants (both Thai and Japanese) were satisfied with the contents of the program, thought there are some rooms for improvement in terms of their accommodation and transportation.

Voices from the participants' reports are organized by the uniqueness described in the previous section, In terms of applicability, there are following comments from participants.

From 2017 participants: "Though I've never used the Kaizen concept in my workplace, it's quite useful for me to learn and practice the concept in this PBL (Female - IT)". "The Kaizen concept seems to be quite applicable to my workplace in which serious labor shortage and productivity increase are the most imperative issues (Female - construction)". "I really felt the importance of 3-Gen principles (Male: R&D in manufacturing)".

From 2018 participants: "I found a lot of MUDAs at the factory, but it doesn't mean that I could develop a lot of Kaizen ideas. Actually, it was very difficult to come up ideas because we had to consider the cost of implementing these ideas at the factory (Female-sophomore)". "I found it's important to propose ideas that are feasible and acceptable as well as that make the process efficient (Female – Sophomore)". "Making each part of process efficient isn't very difficult, but we need to coordinate each part to maximize its efficiency, that is much more difficult (Female - Sophomore)". The key to develop Kaizen proposal is to imagine the whole production process (Male – Senior)".

In terms of seeing the "real world" problems, there are following comments from participants.

From 2017 participants: "I even felt some pressure to know that the factory manager and the floor staff deeply committed to work hard for Kaizen (Tech Trading: Consultant)". "It's quite rare and therefore very valuable opportunity to try our ideas and prototype in a real setting (The factory)". "Once again I realized how important to communicate with floor staff when we do something new (Tobacco: R&D)".

From 2018 and 2019 participants: "Seeing is believing. By observing the processes, we could find that there were problems to be solved but difficult to deal with. Changing working environment was much more difficult than we originally thought (Male – sophomore)". "Observing the actual workplace made us realized that the "real" Kaizen requires mutual agreement between workers and us in term of how to interpret Kaizen and how to implement it (Male – sophomore)".

VIII. DISCUSSIONS AND CONCLUSIONS

This paper first defines Kaizen concept, describes the outline of the gPBL, and then explains the three strengths of the program. As shown in the previous section, participants enjoyed the opportunity provided by the gPBL program such as "true experiences" of Kaizen activities in the "real" global context. In addition, there are several impressive comments from Japanese students. For example, some participants (mainly from business) appreciate the opportunity of observing what is happening in the other countries especially newly developed countries. Their comments are as follows:

"I was amazed to see the modern buildings neighboring with old ones/slums. I could find it because I went there (Male: tech-trading)". "I could see the enthusiasm of the plant manager and the staff to do the Kaizen, which gave me a sense of impending crisis (Male: grad student)".

Also, both graduate (adult) and undergraduate participants enjoyed the different culture and realized the importance of learning other language not just for study but for knowing a new world. Their comments are as follows:

"I really felt that I need to study English continuously (Female: construction)". "The most important thing is not how well I can speak English, but how well I can deliver my thoughts to my counterparts. I found it only because I went there to communicate with them in person (Male: grad student)". "This gPBL gave me a chance to break out of my shell in learning English (Male: R&D in construction)".

Although it was a tight program in which participants spent most of their days for learning, no one was able to make a sound. They even gathered voluntarily in the free time for discussions and presentations. It was quite impressive to see guts of students from both Japan and Thailand, their ability to adapt to the environment, and the changes in their eyes and attitudes. By hearing from participants in 2018, we realized that the program worked well for both graduate (adult) students and undergrad students. These results came solely from the excellent teamwork among PIM, SIT, and KMUTT, which developed the above-motioned uniqueness. These uniqueness in turn would keep attracting participants not only from universities, but also from companies. We believe that our own Kaizen spirit has made us one of widely-recognized programs in both universities (PIM and SIT).

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Impact of Electric Vehicles and Solar PV on Future Thailand's Electricity Daily Demand

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***Abstract*—In the next few decades, solar PV and electric vehicles (EVs) will become a major potion in Thailand's power system. In this paper, we aim to study the impact of future solar PV installation and EV charging on Thailand's power system and to provide the efficient load demand management policy. Firstly, the future power load demand, solar PV installation, and the number of EVs are forecasted by ARIMA models. Next, various scenarios of EV charging demand are generated by varying the charging schedule which is controlled by a smart grid system and charging policy. Future load demand curve in each EV charging scenario is analyzed based on demand response and the effect to electricity power producer is discussed.**

***Index Terms*—Demand Response, Electricity Demand, Electric Vehicles (EVs), Solar PV, Thailand's Power System**

I. INTRODUCTION

Renewable energy is the key point in a current electric power system. Plug-in renewable energy such as solar PV and wind power are encouraged over the past decade. Each country employs different renewable energy types depending on their location and technology. Moreover, each renewable type has different power output behavior which leads to the changing of production and demand curve. The most prevalent renewable energy type in Thailand is solar power since it has been supported by the government. The power output from solar energy make the load demand in midday decrease.

Another factor that will significantly affect the demand curve in the near future is the consumption from the electric vehicle (EV), which starts to break into the global automobile market. Although the increasing number of EV cars implies the decreasing of oil fuel consumption, EV car charging will cause the considerably increase in the electricity consumption.

If the renewable energy and EV charging enter the power system without control, the demand may be extremely high or extremely low in some periods. This leads to the high spinning reserve power. Therefore, the peaks of total load demand should be maintained or reduced to satisfy the demand management based on demand response. This can be accomplished by scheduling the EV charging to avoid the peak load periods and provide the most equally distributed load demand.

In this paper, the objective is to analyze the future effect of solar power and EV charging on Thailand's daily electricity demand and to provide policy recommendation on EV charging schedule. First, the future value of load demand and solar PV installation are forecasted by ARIMA model using historical data. Next, scenarios of charging are determined under the concept of a smart charging system. Then, the effect of EV charging schedules on Thailand's load demand with solar power are plugged into the system is analyzed. The scenario where the load demand is the most equally distributed throughout the day will be recommended. The benefit of the smart EV charging system will be discussed by comparing with other net load demand scenarios.

The remaining paper is organized as follows. The literature review about the power system, solar penetration, and electric vehicles is in the next section. Next, the research methodology which consists of the forecasting technique for the daily demand and the scenarios generation of EV charging is presented. Lastly, the research results and conclusion are discussed.

II. Literature Review

The solar PV power has penetrated Thailand's power system since 2002 and has significantly increased since 2011 [1]. References [2] and [3] shows that the solar PV installed in Thailand's industry sector would reach 3,131 MW and the solar PV installed in Thailand's household sector would reach 2,656 MW in 2037. Consequently, the projected power production from the installed solar PV would be large enough to affect the production planning of power system. The uncertainty of solar PV output made the power system management more complex. Good forecasted solar PV output data can help ease the production planning of the power system.

There are many research studies trying to forecast the power output from solar PV with various methods. Mellit, Benghanem, and Kalogirou proposed a combined method to forecast the solar radiation that includes wavelet theory and neural networks method [4]. In another study by Chen, Duan, Cai, and Liu, the daily solar PV output was forecasted by artificial neural network based on type of the weather [5]. According to Perez et al. in [6], they evaluated the solar irradiance that directly related to solar PV power output. Their result showed that as the number of solar PV plants increased, the fluctuate of solar PV output decreased.

In addition to the forecasting methods that were proposed to increase the accuracy, many production models were also proposed to handle the uncertainty from solar PV output. Osório, Lujano-Rojas, Matias, and Catalão, proposed the unit commitment problem with the penetration of renewable energy. A new scenario-based method was applied to generate scenarios of wind and solar. Then, they solve the unit commitment problem with these scenarios by priority list method [7]. Kaewpasuk, Intiyot, and Jeenanunta introduced the stochastic recourse model for unit commitment problem that integrated with renewable energy and analyzed the relation between the amount of renewable penetrated and the spinning reserve [8]. Moreover, Liu, Botterud, Zhou, and Du proposed the unit commitment model with a fuzzy variable in renewable output energy and reserve power, and then solved it with the fuzzy max-min method [9].

Electric vehicles (EVs) were recently introduced to automobile market and got a lot of attention. According to IEA report in [10], EVs would be promoted to reach 220 million cars in 2030. Having EVs in the system seems to affect the pattern of load demand. Since the demand response of the power system management must be preserved [11], the load demand when EV car charging is included should be equally distributed throughout the day. Qian et al. in [12] simulated EV charging effects on load demand by simulating daily load demand of power system where EV charging was assumed to be normally distributed. According to [13], the impact of EVs and solar PV on the electricity industry was studied where the overall productivity of the electricity industry was determined by a Monte-Carlo-based portfolio model. The solar PV output was simulated by the system advisor model. Their scenarios of EV charging were separated into unmanaged and managed charging. In [14], Yang, Li, Niu, and Xue studied the unit commitment problem of power systems with renewable generations and EV plug-in. Scenarios of renewable generating and EV charging were generated by Latin hypercube sampling and solved by a meta-heuristic method. The management of load demand for demand response is also studied in smart grid. In [15], Nguvauva and Kittipiyakul proposed an algorithm to schedule EV charging to reduce the peak demand in the evening. The limitation of this research was that the charging station must be smart charging, meaning the power charging must be fully controlled by the smart grid.

III. Research Methodology

A. Forecasting electricity demand data

The study began with preprocessing the data which were then used for forecasting the future yearly and daily demand by ARIMA model. The data of load demand power were obtained from the Electricity Generating Authority of Thailand (EGAT) that is the major electricity production sector in Thailand. The obtained data consisted of yearly load demands and daily load demands. The future yearly load demands were forecasted using historical data directly whereas the future daily load demands were forecasted using preprocessed data. In the preprocessing of the daily data, the daily load demands were classified into 7 groups based on the pattern of daily load demand which were summer-weekday group, summer-weekend group, rainy-weekday group, rainy-weekend group, winter-weekday group, winter-weekend group, and long-vocation group. The pattern of daily load demands in the same group had similar peak and off-peak periods. Therefore, a day in each group can represent other days in the same group. In this study, the daily demand from 2006 to 2017 was collected as the data for the forecasting. Then, the ARIMA model with 48-time-period cycles was used to forecast the future demands.

B. Forecasting solar PV daily production

Installed solar PV in Thailand has been started in 2002. The cumulative installed capacity was only 3 MW in 2002 and increased to 2,667 MW in 2017 [1]. Installed capacity from 2002 to 2017 from GIZ was

the data for an ARIMA model of the forecasting process. Not only installed solar PV but also solar PV production was forecasted. A solar PV production that directly affects the load demand can be calculated from the installed capacity, a function of external factors, and efficiency of solar PV technology. According to the report from [16], a value of the efficiency of solar PV was less than 10 percent in 2007 and increased to 46 percent in 2017. By this historical data, the value of efficiency was estimated by linear regression model and approximated to be 80 percent in the next 10 years. In this research, the external factors consist of irradiance and temperature, whose function values were calculated from historical installed solar PV and its production data. Finally, the solar power was computed from the product of solar PV installed, the efficiency value, and the value of the function of external factors in each time period.

C. Forecasting EV charging demands

Forecasting EV charging demand requires the estimation of the number of EVs and their battery capacities in the future as well as the future amount of each type of the charging systems. In this study, the forecasted amounts of EVs were obtained from the previous study of Electricity Generating Authority of Thailand, Metropolitan Electricity Authority, and Provincial Electricity Authority in [17]. However, the forecasted EV data did not specify their battery capacities. To approximate the proportion of EV battery capacities in the future market, the data from EVs plug-in U.S. data in [18] were used. This data contained the current number of EVs with more than 28 EV models e.g. Tesla model X, BMW Active E, Nissan LEAF, and BMW i8. Knowing the model of an EV implies knowing its battery capacity. Hence this can be used to serve our purpose. The amount of charging systems was assumed to be the same as the number of EVs. However, proportion of each type was estimated using the data from [10], which classified the types of charging system of U.S. into 3 types i.e. level-1 charging (AC current with 3.7 kW), level-2 charging (AC current with 22 kW), and fast charging (AC current or tri-phase with 43.5 kW).

D. Generating scenarios of load demand, solar PV power, and EV charging

The forecasted values of load demands, solar PV installed, and EV charging in the previous section were combined to generate the possible net load demand of the power system. Firstly, the simulation of load demand and solar PV were generated from a normal distribution with mean f and standard deviation $(u - l)/6$where f, u, l are the forecasted value, upper bounded forecasted value at the 80% confidence interval, and lower bounded forecasted value at the 80% confidence interval, respectively. The simulation was generated for 500 replications.

After scenarios of load demand with solar PV output were generated, scenarios of EVs charging were set up. EV models and charging systems were grouped by their battery capacity and type of charging station, respectively. This study separated EVs model into three groups based on the size of the battery regardless of their battery type. The first group was EVs with small battery whose capacity less than 10kWh. The second group was EVs with medium battery whose capacity was 10-30 kWh. The third group was EVs with large battery whose capacity was more than 30 kWh.

This study assumed that every EV was charged fully only 1 time a day and the number of charging stations equaled to the number of EVs. For simplicity, each EV was assigned to only one charging station and vice versa. In this study, it was assumed that the large size battery group was assigned to the fast charging stations for charging. If the number of large size battery EVs is larger than the number of fast charging stations, the remaining large size battery EVs will be assigned to the level-2 charging stations, and so on. On the other hand, if the number of large size battery EVs is less than the number of fast charging stations, the remaining fast charging stations will be assigned to the medium size battery EVs and so on. Given the forecasted values, the EV charging was classified into 5 groups as shown in **Error! Reference source not found.**. In order to generate scenarios of EVs charging, the period of charging in each group was varied and different distributions was applied, namely normal distribution and uniform distribution. Initially, scenarios of EVs charging were set up based on the current charging system power consumption and human behavior. After that, more scenarios were generated by changing the period of charging to generate the load demand corresponding to the demand response. The period of charging for every station was scheduled under a concept of smart EV charging in [15].

Lastly, all scenarios of EV charging schedules were applied to 500 simulated of load demands with solar PV output for each demand group that was assumed in section forecasting electricity demand data. To achieve the best demand response of demand management, the load demand curve should be flat as much as possible because it requires less ramp up/ramp down in the generator units.

E. Analyzing the future load demand following solar PV installation and EV charging schedule

To analyze the range of load demand in the future, the extreme case of them also observed. Scenarios of load demand and power output of solar PV were obtained from three values, namely the forecasted

value, upper bounded forecasted value, and lower bounded forecasted value at the 0.8-confidence interval. Scenarios of load demand integrated with solar PV consisted of two extreme cases and a normal case. The first extreme case, denoted by D1, was a combination of the upper bounded forecasted value of load demand and lower bounded forecasted value of solar PV output. The second extreme case, denoted by D3, was a combination of the lower bounded forecasted value of load demand and upper bounded forecasted value of solar PV output. The normal case, denoted by D2, was obtained from a combination of the forecasted value of load demand and solar PV output. For example, assumed that the forecasted value, lower bounded forecasted value, and upper bounded forecasted value in midday period of load demand were 26.7GWh, 25.4 GWh, and 28.1 GWh, respectively and the forecasted value, lower bounded forecasted value, and upper bounded forecasted value in midday period solar PV output were 3.5 GWh, 3.2 GWh, and 3.8 GWh, respectively. Then, a total demand in a midday of scenario D1 was 24.9 GWh, which was calculated by subtracting 3.2 GWh of lower bounded forecasted value of solar PV output from 28.1 Ghof upper bounded forecasted value of load demand. Similarly, total demand in a midday of scenario D2 and D3 were 23.2 GWh and 21.6 GWh, respectively.

All EV charging schedules were applied to scenarios D1–D3. The scenario with the smallest fluctuation in load demand throughout the 48-time period provided the best charging policy. The range of the future net load under the best policy was also recommended.

IV. Research Results

A. *Forecasting electricity demand results*

The load demand forecasting process started with yearly demand forecasting. The result of yearly demand forecasting is shown in Fig. 2. For example, in 2028, yearly consumption was approximately 260 GWh. In 2038, yearly consumption was more than 310 GWh. The trend of yearly consumption was almost linearly increasing.

Examples of the forecasted daily load demands from summer-weekday group are shown in Fig. 3. The patterns of peak and off-peak periods were similar in every year e.g. the evening peak period occurs between 8-11 pm. Meanwhile, the mean of load demand increased every year corresponding to the trend of the yearly consumption.

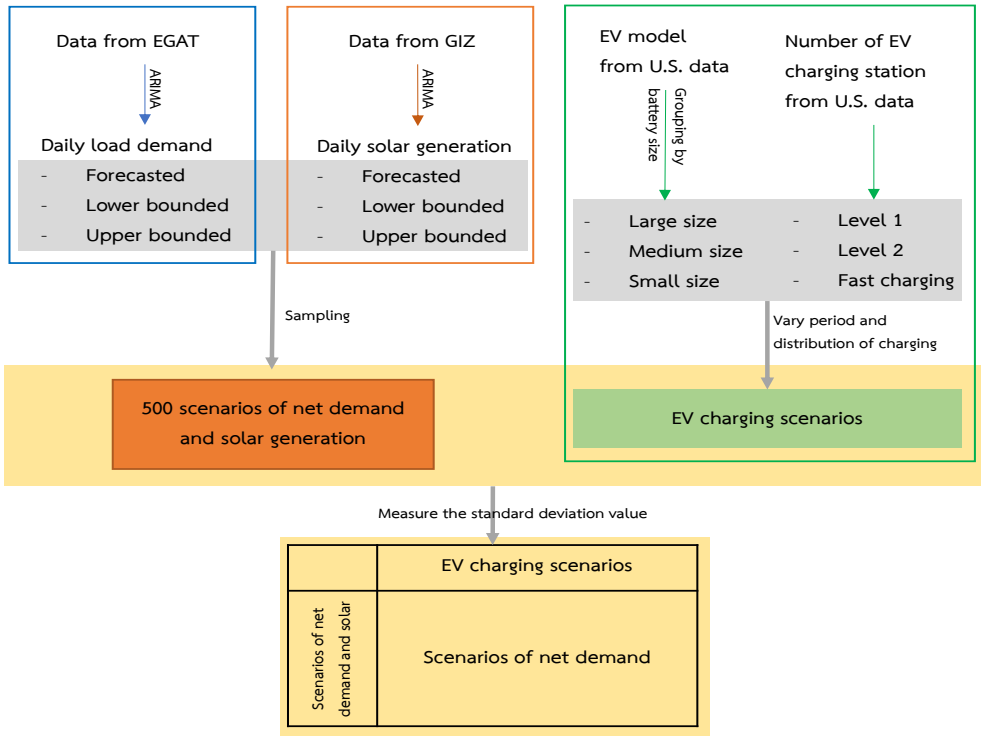

Fig. 1. Over all of research methodology

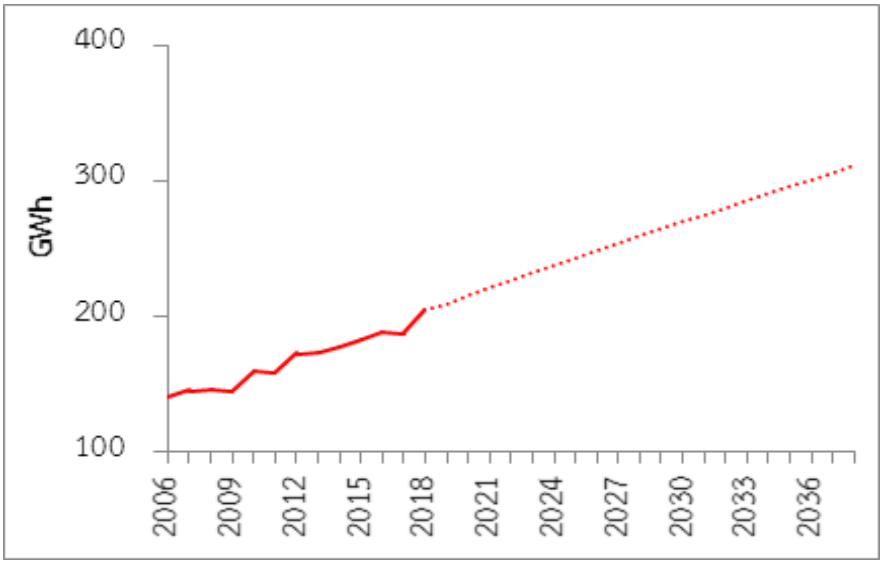

Fig. 2. Yearly power consumption

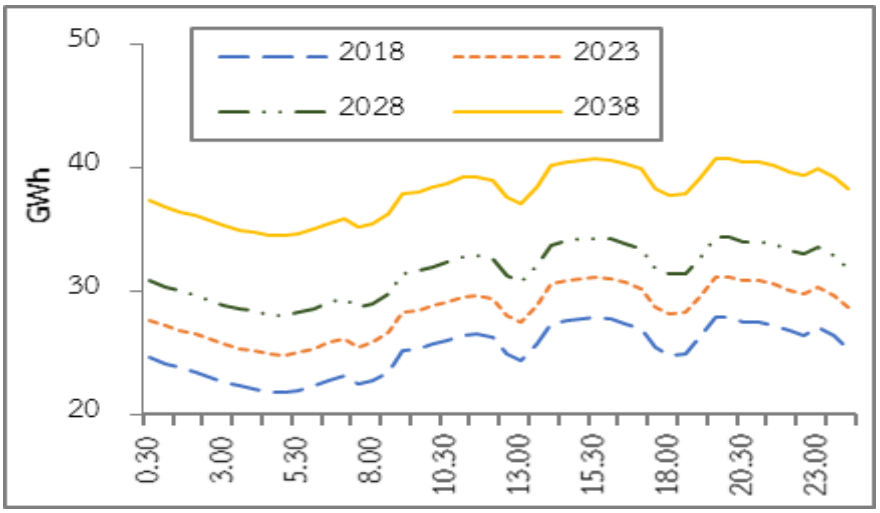

Fig. 3. Forecasted daily load demand of summer-weekday.

B. Forecasting solar PV daily production results

Solar PV daily productions in Thailand were approximated in the second process at the efficiency of solar production equal to 80%. The examples of solar daily production are shown in Fig. 4. This figure illustrates similar production pattern each year i.e. the solar power has high power output at midday and has zero power output in the evening until sunrise.

C. Forecasting EV charging demand results

For EV data, the proportions of EV cars based on battery size were investigated and are shown in Fig. 5. In the early stages, the medium group was a majority but as time went by, its size stayed approximately the same and no longer the dominant one. On the contrary, the small and the large groups which came later but grew faster than the medium group. For example, the number of EV cars in large group increased approximately 65% from 2014 to 2015. The data from Fig. 5 was used to forecast the proportion of each group in future based on linear regression and approximation. In our forecast, we assume the proportion of each group stayed the same for 2018-2038 although the number of EV cars increased. As the result, the forecasted proportions were 60%, 30%, and 10% for large, medium, and small size battery groups, respectively.

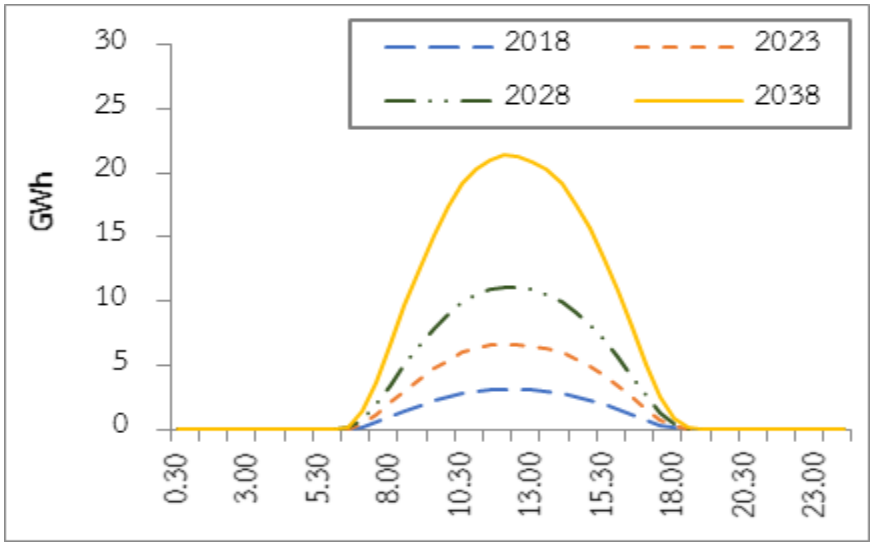

Fig. 4. Forecasted solar PV daily production

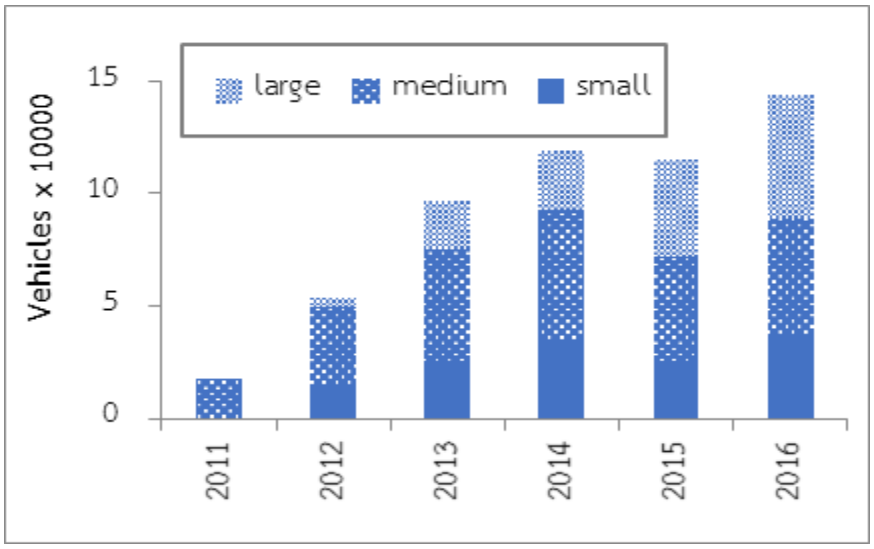

Fig. 5. U.S. EV sales in each battery size.

The proportions of EV charging stations were obtained from U.S. charging station in [10]. Their proportions of level-1, level-2, and fast charging were 6%, 80.7%, and 13.3%, respectively. Groups of EV charging were established by applying the assumption shown in section 3.4 to the proportion of EV cars and charging stations which were obtained in the previous step. The proportion of each charging group are shown in **Error! Reference source not found.**. Moreover, the power consumption and charging time were also calculated and are shown in this table.

D. EV charging schedules

In this section, we discuss how to generate the EV charging scenarios. The scenarios were set up under the smart charging system where the power of charging was controllable by the policy maker. These scenarios were generated by varying the starting and ending charging time period of each group that depends on 1) their power consumption of EV charging, 2) the pattern of load demand, and 3) solar power output. In this paper, we assumed the starting charging time of EV was classified into 6 types that were 6 p.m. –12 a.m. called Nighttime, 6 a.m. –7 p.m. called Solar operation time, 12 a.m. – 6 a.m. called After midnight time, 7 p.m. – 6 a.m. in next day called Non-solar operation time, 4 a.m. – 9 p.m. called Extended solar operation time, and All day. The distribution of the starting and ending charging time was either normally distributed [N] or uniformly distributed [U]. For example, the first scenario (S1) assumes that the starting charging times of all groups occur in 6 p.m. – 12 a.m. and are distributed normally during that period with mean at 9 p.m. and S.D. equals 1 hour represented by [N] Night. This scenario did not involve smart charging and therefore was the most possible situation in current technology of EV charging station.

TABLE I
THE CHARGING PERIOD OF EACH EV CHARGING GROUP

EV charging Group		1	2	3	4	5
Detail of charging		Small size battery by level1	Small size battery by level2	Medium size battery by level2	Large size battery by level2	Large size battery charging by fast charging
Percentage respect whole EV car		6%	4%	30%	46.70%	13.30%
Charging time(hour)		3	0.5	1	4	2
Total power consumption of EV charging (MWh)	2028	541.24	357.58	5363.66	33397.73	9403.47
	2038	5097.53	3367.74	50516.1	314546.89	88563.9
	S1	[N] Night (6 p.m. – 12 a.m.)	[N] Night	[N] Night	[N] Night	[N] Night
	S2	[N] After midnight (12 a.m. – 6 a.m.)	[N] After midnight	[N] After midnight	[N] Solar operation time	[N] After midnight
	S3	[N] Solar operation time	[N] Solar operation time	[N] Solar operation time	[N] Solar operation time	[N] Solar operation time
	S4	[U] All day	[U] All day	[U] All day	[N] Solar operation time: 40% [U] All day: 60%	[U] All day
	S5	[U] Non-solar operation time	[U] Non-solar operation time	[U] Non-solar operation time	[N] Extended solar operation time (4 a.m. - 9 p.m.)	[N] Extended solar operation time

The motivation of these smart charging scenarios is as follows. If the solar power output is high, the pattern of the total load demand in the midday will be a concave curve. Therefore, the starting charging times should be moved to the solar operation time in order to keep the load demand most equally distributed throughout the day. Since the total charging power consumption was dominated by the 3rd, the 4th, and the 5th groups, these groups had high priority when the moving of starting charging times was required. The distribution of the staring charging times was chosen so that the total load demand curve was flat as much as possible. For example, in case that the period of the starting charging time was the same as the solar operation time, the distribution of the staring charging times should be normal since the solar power output curve throughout the day is similar to the curve of a normal distribution function. The resulting scenarios (S2 – S5) are shown in **Error! Reference source not found.**.

E. The effect of solar PV and EV charging schedule on future load demand

To study the effect of solar PV and EV charging schedule on future load demand, the scenario of no EV charging (S0), the scenario of current charging without any control policy(S1), and four scenarios of charging schedule controlled by smart charging system (S2 – S5) were applied to the 500 simulated of load demands integrated with solar power for each load demand group and compared. The results of net load demand in 2028 and 2038 are shown. To investigate the effect of EV and solar PV on load demand, the average of the standard deviation value for each load demand group and each EV charging scenario were observed. The standard deviation value of each case in 2028 and 2038 are shown in **Error! Reference source not found.** and **Error! Reference source not found.**, respectively. The values in boldface indicate the best scenarios for each demand group.

TABLE II
AVERAGE OF STANDARD DEVIATION VALUE IN 2028

Demand groups	Scenarios of EV charging					
	S0	S1	S2	S3	S4	S5
summer weekday	3,628.00	5,039.05	2,838.77	**2,611.79**	3,300.65	2,870.95
summer weekend	3,820.78	8,521.57	3,472.60	**2,686.42**	2,984.56	5,239.27
rainy weekday	3,575.83	4,996.99	2,861.31	**2,698.25**	3,274.01	2,894.44
rainy weekend	3,739.01	5,189.15	3,015.17	**2,765.65**	3,424.20	3,000.87
winter weekday	3,476.63	4,831.05	2,673.62	**2,493.29**	3,154.76	2,727.99
winter weekend	3,701.55	5,044.42	2,914.64	**2,597.10**	3,356.40	2,873.51
vocation	4,744.24	5,974.84	3,964.34	**3,421.17**	4,358.47	3,788.03

TABLE III
AVERAGE OF STANDARD DEVIATION VALUE IN 2038

Demand groups	Scenarios of EV charging					
	S0	S1	S2	S3	S4	S5
summer weekday	5,789.12	21,650.39	7,620.14	11,126.93	**3,311.22**	6,178.50
summer weekend	6,017.89	26,031.04	**3,332.72**	10,824.41	5,822.83	2,1843.14
rainy weekday	5,729.38	21,646.66	7,881.65	11,447.79	**3,531.11**	6,519.59
rainy weekend	5,888.68	21,816.48	7,835.64	11,187.51	**3,492.68**	6,234.09
winter weekday	5,569.14	21,372.64	7,580.27	11,232.94	**3,128.48**	6,211.04
winter weekend	5,865.24	21,560.52	7,639.80	10,924.04	**3,221.46**	5,869.64
vocation	7,034.31	22,230.16	7,657.91	9,930.80	**3,958.57**	4,935.71

The result from **Error! Reference source not found.** and **Error! Reference source not found.** shows that the scenario S1, in which all groups were charged with the starting times normally distributed from 6 p.m. to 12 a.m. has the highest standard deviation value in every case. In 2028, the lowest average value of the standard deviation value of each demand group comes from applying EV charging scenario S3 to the load demand. Since solar power plug-in makes the net load demand dropped during midday, charging EVs during that time as in S3 can fill up the drop demand. In 2038, EV charging scenario S4 gives the smallest standard deviation value. Due to the amount of solar penetration, appropriate amount of charging with the starting times normally distributed in the solar PV operation time of the biggest group can fill in the drop of the net load demand. Others are charged with starting times uniformly distributed all day and therefore did not affect the standard deviation value much. Examples of the comparison among the netload demand without EV charging, the demand without controlled EV charging schedule, and the demand with controlled EV charging schedule for 2028 and 2038 for each demand group are shown in Fig. 6 to Fig. 11. The results illustrate that the charging of EV with appropriate timing leads to a more effective load demand management of the power system which will provide efficient generator units operations.

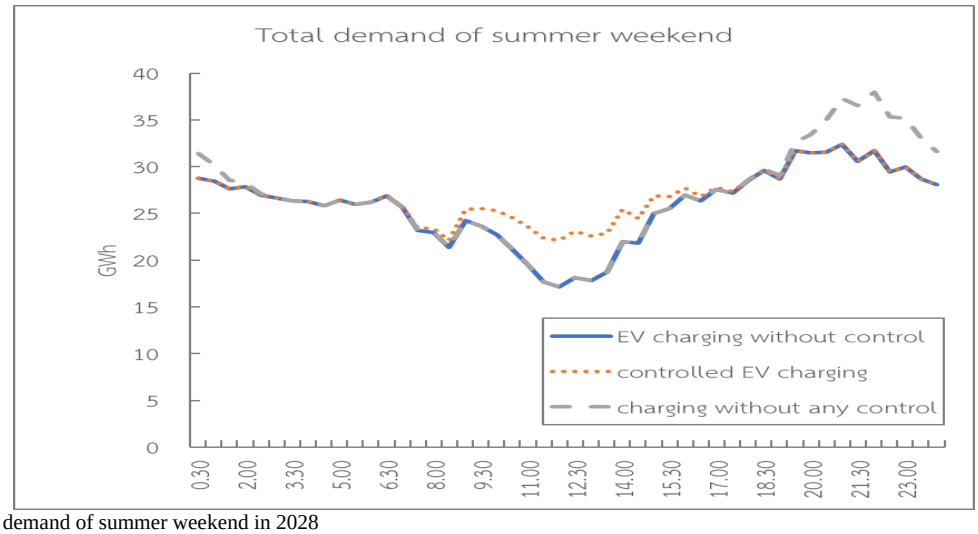

Fig. 6. Total demand of summer weekend in 2028

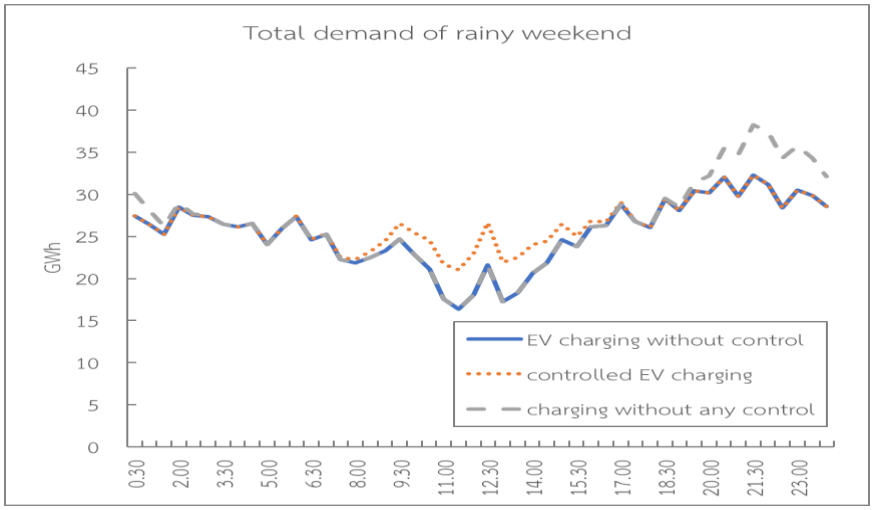

Fig. 7. Total demand of rainy weekend in 2028

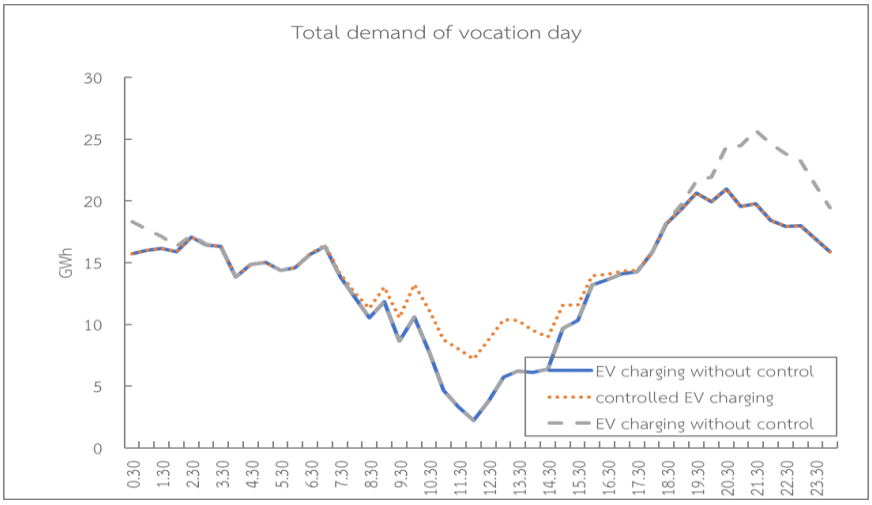

Fig. 8. Total demand of vocation day in 2028

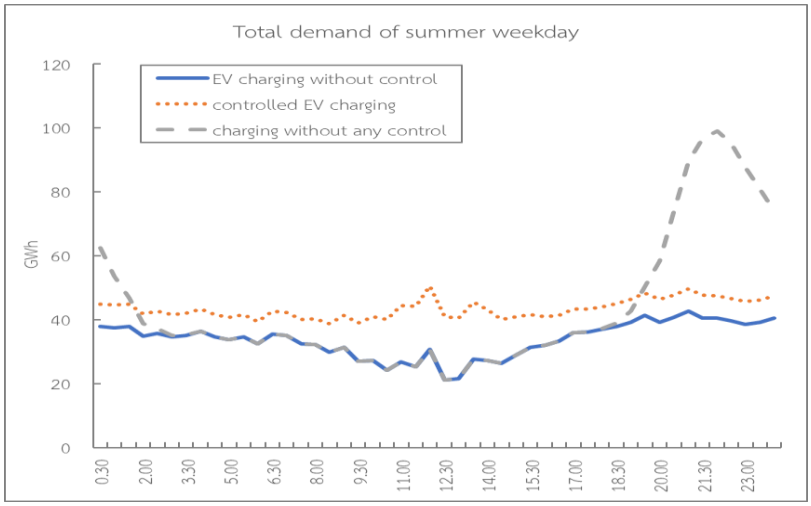

Fig. 9. Total demand of summer weekday in 2038

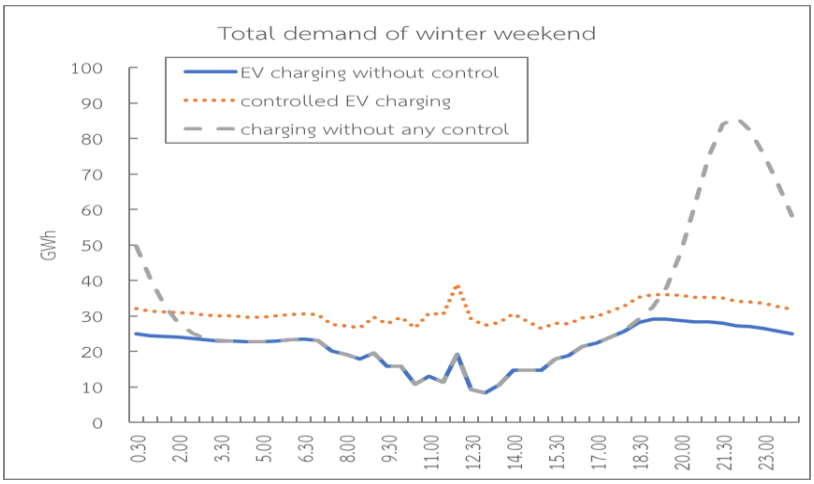

Fig. 10. Total demand of winter weekend in 2038

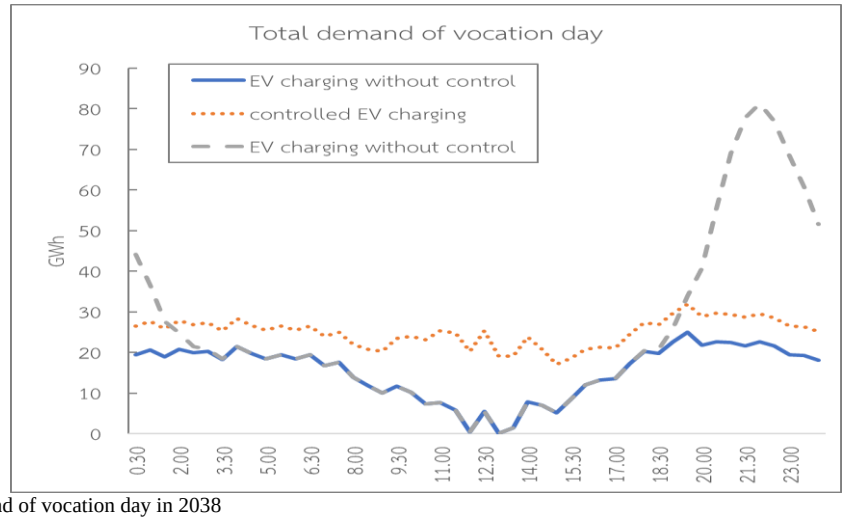

Fig. 11. Total demand of vocation day in 2038

TABLE IV
THE STANDARD DEVIATION VALUE OF LOAD DEMAND FOR EACH EV CHARGING SCHEDULE SCENARIO (MWH)

Year	2028			2038		
Load demand with solar power cases / EV charging scenario	D1	D2	D3	D1	D2	D3
without EV charging	2178.587	3422.03	5116.309	2007.732	5335.304	9884.803
S1	**3730.570**	**4890.604**	**6435.925**	**19192.840**	**21532.410**	**24570.980**
S2	**1649.608**	2566.629	4237.480	10010.450	7270.744	7094.198
S3	2094.521	**2312.019**	**3715.659**	15245.340	10885.570	7027.118
S4	2028.445	3071.839	4718.059	**4374.174**	**2393.391**	6093.654
S5	1986.199	2602.342	4135.414	10186.260	5736.129	**2618.362**

F. The resulting future load demand following solar PV installation and EV charging schedule

To construct the future load demand range, the most equally distributed of the load demand with solar power and EV charging in the three cases D1 – D3 was analyzed. The result from Table IV shows that the scenario S1, in which all groups were charged with the starting times normally distributed from 6 p.m. to 12 a.m., has the highest standard deviation value in every case. For D1 case in 2028, the lowest standard deviation value comes from applying EV charging scenario S2 to the load demand. Since the D1 case comes from the upper bound of load demand and the lower bound of solar power, the peak of the resulting load demand appears from 8 p.m. to 11 p.m. The scenario S5 makes the net load demand for this case fluctuated the least because the starting times are not in the peak period i.e. the most power consumption group starts charging during solar operation time while the starting times of other groups are normally distributed after midnight until 6 a.m. For the cases with more solar PV penetration (D2 and D3), the lowest standard deviation value comes from applying EV charging scenario S3. Since solar power plug-in makes the net load demand dropped during midday, charging EVs during that time as in S3 can fill up the drop demand. In 2038, the projected net load demand curve of D1 is almost flat. Thus, EV charging scenario S4, where all groups were charged with the starting times uniformly distributed all day, cause the curve fluctuated the least. The standard deviation value of the load with EV charging has the lowest value, which is the same as the load without EV charging. For load demand D2 in 2038, EV charging scenario S4 gives the smallest standard deviation value. Due to the amount of solar penetration, appropriate amount of charging with the starting times normally distributed in the solar PV operation time of the biggest group can fill in the drop of the net load demand. Others are charged with starting times uniformly distributed all day and therefore did not affect the standard deviation value much. In the case D3, the solar power penetration is very high. Therefore, EV charging scenario S5 which mainly charging in extended solar operation time give the smallest value of standard deviation. Scenario D2 that includes the forecasted value of load demand and solar power was the most possible load demand whereas scenarios D1 and D3 that were the extreme cases were the possible largest and smallest load demand in the future, respectively. Therefore, the estimated power load demand in 2028 and 2038 come from the demand which is the most equally distributed in case D2 whereas the possible largest and smallest value come from the most equally distributed cases D1 and D3, respectively. The estimated power load demand range of 2028 is shown in Fig. 12. In this figure, the estimated load demand was generated from the load demand case D2 integrated with the scenario of EV charging S3.The possible largest was generated the from load demand case D1 with the scenario of EV charging S2 and the possible smallest was generated from the load demand case D3 with the scenario of EV charging S3. The estimated power load demand range of 2038 is shown in Fig. 13. In 2038, the estimated power load demand was generated from the load demand case D2 with the scenario of EV charging S4. The possible largest and smallest were generated from the load demand case D1 with the scenario of EV charging S4 and the load demand case D3 with the scenario of EV charging S5, respectively.

The peak of the estimated load demand is also considered. The most possible load demand when solar PV and EV integrated to the system in 2028 has peak 34,312 MW whereas the peak of possible largest load demand is 38,646 MW and the peak of possible smallest load demand is 29,978 MW. In 2038, the most possible load demand when solar PV and EV integrated to the system has peaked at 47,732 MW. The peak of possible largest load demand is 56,265 MW and the peak of possible smallest load demand is 38,457 MW.

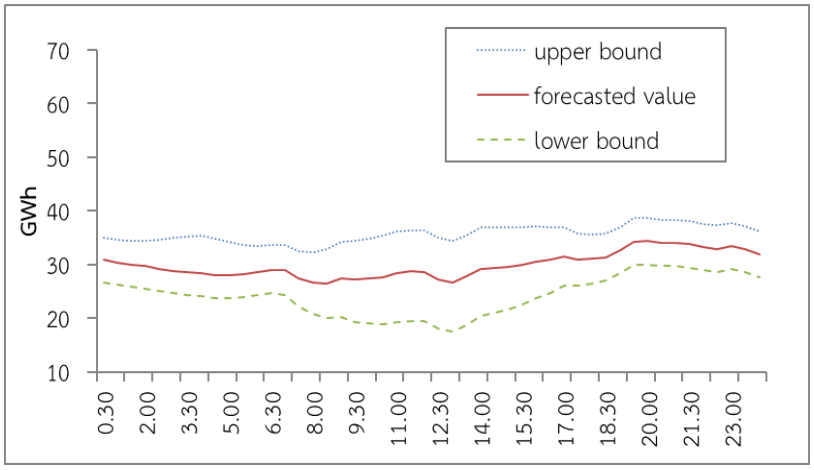

Fig. 12. Estimated power consumption when controlled EV charging is scheduled in 2028.

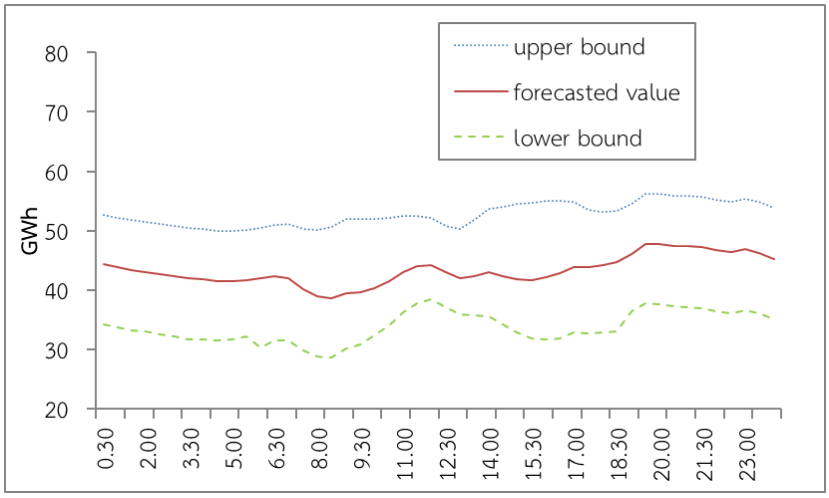

Fig. 13. Estimated power consumption when controlled EV charging is scheduled in 2038.

V. Conclusion and Discussion

In this paper, the effect of solar PV and EV charging on daily load demand was studied. The possible load demand in the future was analyzed by varying the periods and distribution of EV charging. The future load demand and solar PV installation were forecasted by ARIMA model. Scenarios of EV charging were generated under the concept of a smart charging system and integrated into the load demand with solar power and then the most equally distributed scenario of load demand was observed and applied to construct the estimated load demand range in the future.

The result shows that when the solar power is integrated to the power system, the net load demand in solar operation time is dropping. The more increase in solar PV installation in 2028 and 2038 implies the more decrease of the net load demand in solar operation time period. The consumption from the EV charging integrated to the power system increases the total consumption of load demand. If the EV charging plugs into the power system without any control, the power consumption from EV charging will increase the peak of load demand at night that affects the stability of the power system. More effective demand management provides a more stable system. Therefore, the appropriate net load demand could only be obtained from the controlled scheduling of EV charging by the smart charging technology. This is the key future technology to provide better EV charging policy. It can be suggested that the EV should be promoted with the controlled charging period. From the most equally distributed load demand in results, the suitable charging period is during the solar operation period (6 a.m. – 7 p.m.) and after midnight period (12 a.m. – 6 a.m.). Alternatively, if the smart charging technology is not a viable option, the government may use the pricing policy to provide incentive for EV charging during the certain period.

From the point of view of the production sector, the most equally distributed load implied the stability of power production and reservation. Therefore, the best scenario that is suggested in this research can be applied to be the EV charging policy in the future. Moreover, the estimated load demand range can be the support information for power system management. For example, the peak of

forecasted total load demand in 2028 is 35,000 MW approximately, then EGAT which has current capacity of only 25,000 MW should have a plan for the increase of total consumption in 2028.

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Motorcycle Route Planning in Phuket Province for Tourist

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***Abstract*—The tourism in Phuket province has organized routes toa variety of tourist attractions. The vehicles to be used depend on the tourist decision such as taxi car/van/bus service, private car, and motorcycle. Which, the tourist traveling by motorcycle is very popular. The variety of tourist attractions in Phuket province and the duration of tourists stay is limited. And, most tourists plan by a limit visiting tourist attractions. Therefore, the motorcycle route planning will help tourists to reach more tourist destinations by using VRP spreadsheet solver of Microsoft Excel workbook. An open-source unified platform for solving, representing, and visualizing the results of vehicle routing problems (VRPs). By the way, the results shown how many plans and how many places of tourist point to visit and under the condition of time, speed, and vehicle restrictions used as motorcycles.**

***Index Terms*—VRP, VRP spreadsheet solver, Route Management**

I. INTRODUCTION

Phuket is the 3rd largest province of Thailand that has the most tourists visiting after Bangkok and Chonburi. The statistics visitor of the Ministry of tourism and sport [1] shows the number of visitors and more than 60 million people visiting Bangkok 18 million people visiting Chonburi and there are has about 14 million people in 2018.

Arranging travel routes is a priority for tourism planning for value and convenience. That is to be punctual and spend time effectively on the journey, travel safely, having accurate information about the location and the needs of various tourist groups. Phuket has an area of around 576 square kilometers [2]. Tourist destinations such as beaches and the Andaman sea are a highlight of Phuket province. In 2018, there are about 10 million foreigners and 4 million Thai citizens visiting Phuket province as shown in Fig. 1.

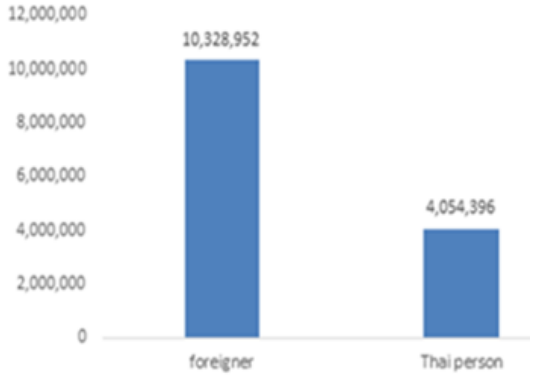

Fig. 1. Tourist proportion in Phuket

Tourism in Phuket province has organized travel routes and facilitated services to many tourist attractions. There is many alternative traveling such as package tours and self-traveling. In this research, Arranging the tourist destination routes by using motorcycle to be a vehicle and the tourists decide on the tourist attractions. There is also a service to recommend popular tourist attractions that tourists are interested in.

This research aims to assist a travel plan for tourists of Phuket.

1) To survey attractive destinations in Phuket, that are popular among tourists.

2) To investigate possible routes passes attractive destinations in Phuket, that suit timing conditions.

3) To suggest a travel plan that takes shortest time to travel and nearest distances of attraction in Phuket by program VRP spreadsheet solver.

II. BACKGROUND

A. Transportation in Phuket province.

The public transportations take many times to wait and limited place to passing. Traveling by public transport such as bus and local bus still has a small amount and takes a lot of time to wait for each. Usually, tourists will use a private transport service. And shuttle service such as taxi and motorcycle, which will be delivered to various locations depending on the needs of tourists.

Transportation services for tourists are available to the driver service and to drive by themselves. Service with a driver usually called a taxi. The types of taxis use different types of cars, as in Fig.2 and Fig.3, such as motorcycles, cars, and minibus or van. Most of the tourists are self-driving will be using motorbikes than a car because of flexibility and faster than cars with trouble traffic in the city.

Fig.2. Vehicle for rent and transport service

Fig. 3. Taxi service and transport in Phuket

B Theory

Tourism route management is service that adds value to products or services of hotels and tour business. There is a competitive advantage in business. Phuket is a small island with many diverse attractions. Each location has both a distance close to each other, and some places are very far apart. Which depend on the customer required to visit each location.

The demand for travel to each location of each tourist is different, especially independent travelers, who like to travel themselves without relying on tour companies. Allocation of travel routes, travel planning is important. Because the distance to each location takes a different time. If tourists have limited time and do not plan the routing wells. There will result in visiting fewer places from the desired. Described the simple theory of vehicle routing problems.

In this research, we will consider the scope of transportation route problem. According to customer needs. There has time limit for Time Windows and specify the weight and distance limitations which tourists use to go to various attractions by the beginning and end. There is only one point. The house or hotel where the customer live. Customers will receive services for traveling only one vehicle. The route used must be the shortest route and pass through all the planed locations. There is a certain amount of demand for tourist attractions. The number is uncertain. Used vehicle have restrictions on loading, weight, number of passengers and the appropriate route. The problem distance and each point not far from each other. The route must be the shortest route and pass all points or attractions of the planned location. This issue is called. Capacitated and Distance-Constrained VRP: DCVRP and Vehicle Routing Problem with Time Windows. Abbreviated is VRPTW.

Clarke and Wright [3]. The economical way of transporting products or goods has developed a route-based route that has the needs of many places. Vehicles with limited capacity to transport of a single warehouse. From Fig. 6, the products are transported from the beginning at point O. Transportation from warehouse going to many places such as going to point i and point j by transporting to each point separately. It is necessary to transport products to point i and then return to point j again that will be increased the cost of transport, which can be calculated from the equation one (1) The cost of transporting each item is one point and back to the warehouse.

$$C_{0i} + C_{ij} + C_{j0} \quad (1)$$

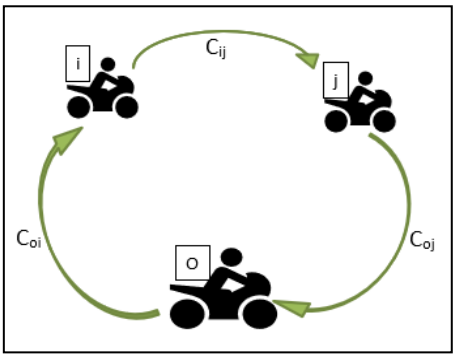

Fig. 4. Shipping to each delivery point and return to a single warehouse.

Products are transported to point i and point j, but transport to point i and go straight to point j and then returns to the warehouse at point O as shown at Fig. 4. The cost of transportation will calculate for one route and could help reduce transportation costs by calculating from equation two and three ((2) and (3)).

Shipping costs for each delivery point and return to the warehouse only:

$$C_{0i} + C_{ij} + C_{j0} \quad (2)$$

Save transportation costs:

$$S_{ij} = C_{0i} + C_{i0} + C_{j0} + C_{0j} - C_{0i} - C_{ij} - C_{j0}$$

$$S_{ij} = C_{0i} + C_{0j} - C_{ij} \quad (3)$$

$$S_{ij} = [C_{0i} + C_{i0} + C_{j0} + C_{0j}] - [C_{0i} + C_{ij} + C_{j0}]$$

How to route vehicles using economical methods.

Step 1 Calculate Savings from equation (3) $S_{ij} = C0i + C0j - Cij$ for all point (i, j).

Step 2 Sorting order Sij. From more to less.

Step 3 Transportations arranging routes based on Sij starting from the highest value. And to consider the Sij value to include the path i, j into the given path. If not, transportation conditions are violated. Capacity of vehicles and if one of these three conditions is true.

1) If i and j are not in the same path, then i and j are the new paths.

2) Only if i or j is included in the existing path. And the point connected with. The warehouse includes routes (i, j) into that route.

3) If both i and j do not use the same path. And not a point to both warehouses. Include two routes together.

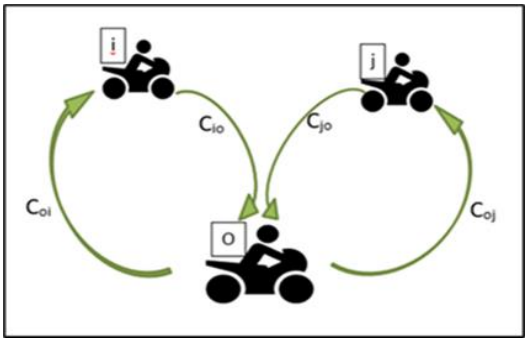

Fig. 5. Each shipment is delivered at one point and returned to the warehouse.

C. Literature review

Takerrngsak [4]. Research about Tourism logistics management for Wang Nam Khiew district in Nakhon Ratchasima province has objects to 1. study the behaviors of tourists visiting Wang Nam Khiew. 2. satisfying of tourism logistics managements and then 3. To investigate for developing logistics management for tourism in this perspective of those directly evolved. The methods of this research are using survey research for correct the information and descriptive statistical analysis. The result can divide into 4 part as follows 1. general information of tourist 2. Tourism behavior 3.the satisfaction of tourists 4. guidelines for development of tourist route management. The Recreational activities that are made along with tourism are views of the scenery. And almost all want to come back to travel in Wang Nam Khiew District.

Watchar in [5]. Research about traveling behavior of Oceania tourists during the low season in Phuket. The behavior of middle east countries tourists for 1. To know the needs of customers in the Middle East countries. 2. To increase satisfaction in prices, time and place for middle eastern customers and 3. To reduce the cost and travel time of each tourist attraction of the tourism program. Determination of sample group the researcher used purposive sampling method by collecting data from middle eastern tourists who use the company's tourism services. The data obtained from the questionnaire were analyzed to find the basic information, behavior and needs of the middle east tourists. Statistical tools used in the analysis are descriptive statistics by presenting a percentage distribution. Then, analyze the results of each tourist destination to change the tourist attraction in the tourism route

of the program for a period of 10 days, considering the saving time of each route for each day to reduce costs. And compare the cost and value of each package in the route to increase revenue and reduce the time spent by changing the program. After changing the travel route of each tourism program, can reduce the total cost of each program, reduce time, increase revenue and increase quality which results in increased customer satisfaction.

Kamonrat and the group [6]. Research about an examination for factors and routing impacting tourism logistic in Ubonratchathani. Tourism logistics is a new discipline gaining popular from multi-disciplinarians, in the research investigate various factor that impact satisfaction of tourists by using mixed research method, which evaluates data based on quantitative and qualitative analysis and using information related preferred locations analyzed from the first part, the theory in this research is study travel routing based on Traveling Salesman Problem (TSP) and then provide suggestions for optimal traveling route under time limit. The results in this research is suggest route of travel time at the time is the least hour which is the same answer as the shortest distance in this case found that the minimum travel time is 6.65 hours

Sanphob and Varin [7]. Research about the appropriate travel route planning to improve efficiency of the concrete monitoring unit. Planning and development of travel routes to inspect concrete production units the objective is to check the number of cycles according to the needs and plans that have been presented to the management. By using logistics principles to help solve these problems to help reduce travel costs as well as increasing the efficiency of inspecting concrete production units. This research uses the A-B-C segmentation technique, Saving Algorithm and Nearest Neighborhood as follows:

1) Nearest Neighborhood Technique. Consider organizing travel routes using the nearest distance. By calculating the routing table in Microsoft Excel

2) Travel line arrangement with the saving method. Consider traveling routes using the nearest distance and the highest save value. You can choose the most suitable vehicle route.

3) How to divide the unit type A-B-C. Consider the route arrangement using the nearest distance and save the most.

The first step is to use the analysis to find the real problem by the fishbone method. Then, using the data obtained using all 3 techniques, the result shows that the suitable method for management assessed from the cost and travel expenses is the route arrangement by dividing the A-B-C group or the Saving Algorithm.

III. Research Methodology

This research would like to solve the problem of route planning tourist destination of tourists an dan additional service to guiding and planning routed, who use the motorcycle rentals service to travel. The theory of routing the shortest and passing all the designated attraction sand then return to starting point. Underneath with capacity and time limit is VRP or vehicle routing problem sand the technology that helps to manage is Microsoft Office Excel. An open-source unified platform for solving, representing, and visualizing.

A. Collected data

1) Tourist attraction

Phuket is the third most popular tourist destination in Thailand. Phuket's tourist attractions are popular such as beaches around the island, waterfall, mountains, island, entertainment places and night markets. The popular tourist destination in Phuket

2) Research tools

The tool used in this research is a questionnaire for tourists who come to use the motorcycle rentals service and then using program route for attraction. The research tool of survey was created to collect tourist information about tourists and the satisfaction of using the services of hotels and motorcycle rentals shop.

The VRP spreadsheet solver program has the window page like the same as Microsoft Excel because this program is developed from Microsoft Excel and using VBA and coding to developing and then added routing function to tab bar add-in function at Microsoft Excel.

B Route management

In this topic, we will discuss software of routing by using the VRP spreadsheet solver program, which describes the procedure for using the program as shown at Fig. 6 Process of program VRP spreadsheet solver.

First step of process is starting program. The VRP program will show first worksheet name called "VRP Solver Console" and then provide the data that program require. In a case study, the research specifies the vehicle is a motorcycle and the requirements of the data used in the program for the operation of the VRP spreadsheet program are as follows.

1) Vehicle: Set the speed at 50 km/hr. Specify information at average vehicle speed

2) The amount of depot which is determined to have only 1 places to be the starting point

3) Departure start time depend on tourists determine such as 9:00 - 18:00 p.m. or 09:00 - 19:00 p.m. (Thailand time zone)

4) Set service time or time limit like 1 day, 2 days and 3 days.

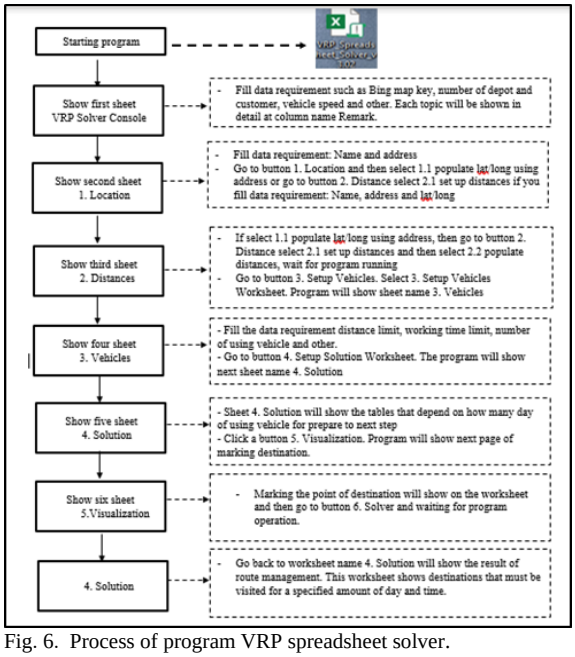

Fig. 6. Process of program VRP spreadsheet solver.

Second step will be coming before enter data requirement already at worksheet name "1. Location" and then follow step of this program for populate coordinates and set up distances, step three worksheet name "2.distance" will appear for program running to next step four, worksheet name "3.Vehicles" will require the data kind of limit distance, how many hours per day and number of days. All the data requirement fills in last worksheet of vehicle and then go to click button solution for running program in to step five, worksheet name "4. Solution" will show the tables of detail for tourist destinations all plans and then click the button visualization for show visual of map point to many destinations at worksheet name "5. Visualization".

IV. Research Methodology

The information details of the research results from the data collected from questionnaires and show the database of tourist attractions and motorcycle route plans from tourists' requirement.

A. Surveying and collecting data

Information about tourist destinations collected by self-survey in Phuket and survey on internet for basic information such as coordinates, name of place, available time, condition to used, location, and characteristics of tourist attractions. The initial survey method from the questionnaire, surveying the actual area, on internet and tourist spots from tour operators.

Motorcycle ware set up to use in this research for taking tourists into a tourist destination. The basic information of vehicle speed ware setup to 50 kilometer per hour and capacity for two people on a motorcycle.

B Tourism database

After collecting detail information of tourist attractions, coordinates, maps and behavioral queries of tourist's interest. The basic data was collected by creating table in Microsoft Excel document, especially tourist information and map coordinates as shown at Table I database travel coordinates of Phuket province. Using to calculate the distance and planning tourist sites with limited duration.

TABLE I
DATABASE TRAVEL COORDINATES OF PHUKET PROVINCE

No.	Destination	Lat	Long	Category
1	Sino-Portuguese Building	7.904	98.307	Old town museum
2	Thaihua Museum	7.886	98.387	Museum
3	Rang Hill	7.893	98.380	Viewpoint
4	Promthep cape	7.759	98.304	Viewpoint
5	Chaithararam Temple	7.847	98.336	Temple
6	WatPhraThong	8.034	98.338	Temple
7	Thao ThepKasattri	7.982	98.364	Take picture
8	Kamala Beach	7.956	98.283	Beach
9	Patong beach	7.899	98.296	Beach
10	Phuket Karon beach	7.846	98.294	Beach
11	Kata Noi Beach	7.808	98.299	Beach
12	Big Buddha	7.828	98.313	Temple
13	Phuket FantaSea	7.956	98.288	Entertain
14	Water park	8.118	98.306	Waterpark
15	Laem krating	7.776	98.289	Viewpoint
16	Baan Teelanka	7.939	98.380	Take picture
17	Trickeye Museum	7.884	98.392	Museum
18	Simon Cabaret	7.879	98.292	Entertain
19	Windmill	7.770	98.307	Viewpoint
20	Aquaria	7.889	98.367	Aquarium
21	Jungle Bungy Jump	7.908	98.338	Adventure
22	Flying Hanuman	7.925	98.323	Adventure
23	Chinpracha House	7.886	98.384	Take picture
24	Sarasin Bridge	8.201	98.298	Take picture
25	Three beaches viewpoint	7.798	98.302	Viewpoint
26	Mai khao beach	8.126	98.301	Beach/take picture
27	Hanuman World	7.877	98.351	Adventure
28	Bangla Road	7.894	98.297	Entertain/Night party
29	Dolphins Bay	7.843	98.357	Aquarium
30	Kathu Waterfall	7.935	98.323	Waterfall
31	Go kart	7.913	98.328	Adventure
32	Shooting Rang	7.796	98.311	Sport

TABLE I
DATABASE TRAVEL COORDINATES OF PHUKET PROVINCE (CONT.)

No.	Destination	Lat	Long	Category
33	Monkey spot	7.886	98.421	Zoo
34	Sino-Portuguese Building	7.904	98.307	Old town museum
35	Thaihua Museum	7.886	98.387	Museum
36	Rang Hill	7.893	98.380	Viewpoint

*Destination = Show name of tourist destination in phuket.
*Lat = Latitudeis a geographic coordinate that specifies the north–south position of a point on the Earth's surface.
*Long = Longitudeto specify the precise location of features on the surface of the earth.

The database file will record the data from the questionnaire, customer information, tourist list, area coordinates and basic information that will be used to route the tourist attraction by the VRP spreadsheet solver program. As show visualization at Fig. 8 until Fig. 18. The information on all 8 route plans, which include information on tourist spots, starting time from the depot, time end for return to the depot, time spent for each area and time of service.

The information of plan travel used data as shown in Table I database travel coordinates of Phuket province. Take the data into the program VRP spreadsheet solver. From the 8 plans tables as shown at Table II until IX. The data file name VRP plan data indicates all the desired destinations not including the first place starting point. There is a specified time of departure until the time of arrival at the accommodation. An example from plan name called the VRP1starting time is 9:00 am, ending time at 18:00 pm (Thailand time zone), the amount of time to relax in each area will depending on the customers how much time they want to enjoy each area and the table name called "the duration of the service" is based on the number of days tourist desire and example from the VRP2 data plan. The data is recorded in the same format. It will be different only for the specific details of each customer, the customer requirement one day rental and 7 places the tourist attraction that must be visit.

TABLE II
THE INFORMATION OF PLAN TRAVEL NO. VRP1

VRP1					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	18:00	0:30	2
2	Sino-Portuguese Building , TH	9:00	18:00	2:00	
3	Kathu Waterfall, TH	9:00	18:00	1:00	
4	Promthep cape, TH	9:00	18:00	2:00	
5	Big Buddha Phuket, TH	9:00	18:00	2:00	
6	Tiger Kingdom, TH	9:00	18:00	2:00	
7	Surin beach Phuket, TH	9:00	18:00	3:00	
8	Siam Niramit Phuket	9:00	18:00	1:00	
9	Three beaches viewpoint Phuket, T	9:00	18:00	2:00	

TABLE III
THE INFORMATION OF PLAN TRAVEL NO. VRP2

VRP2					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	18:00	0:10	1
2	Patong beach, TH	9:00	18:00	3:00	
3	Mai khao beach, TH	9:00	18:00	2:00	
4	Promthep cape, TH	9:00	18:00	2:00	
5	Chaithararam Temple, TH	9:00	18:00	1:00	
6	Elephant Sanctuary, TH	9:00	18:00	2:00	
7	Big Buddha, TH	9:00	18:00	1:00	
8	Monkey spot	9:00	18:00	1:00	

TABLE IV
THE INFORMATION OF PLAN TRAVEL NO. VRP3

VRP3					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	18:00	0:00	2
2	Three beaches viewpoint, TH	9:00	18:00	1:00	
3	Sino-Portuguese Building, TH	9:00	18:00	3:00	
4	Baan Teelanka - The UpsideDown	9:00	18:00	2:00	
5	Kathu waterfall, TH	9:00	18:00	2:00	
6	Surin beach, TH	9:00	18:00	2:00	
7	Thaihua Museum, TH	9:00	18:00	2:00	
8	FantaSea, TH	9:00	18:00	3:00	
9	Monkey spot	9:00	18:00	2:00	

TABLE V
THE INFORMATION OF PLAN TRAVEL NO. VRP4

VRP7					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	19:00	0:00	3
2	Big Buddha, TH	9:00	19:00	1:00	
3	Mai khao beach, TH	9:00	19:00	2:00	
4	Three beaches viewpoint, TH	9:00	19:00	1:00	
5	Aquaria, TH	9:00	19:00	2:00	
6	Promthep cape, TH	9:00	19:00	2:00	
7	Rang Hill view point, TH	9:00	19:00	1:00	
8	Kata Beach,TH	9:00	19:00	1:00	
9	Karon beach, TH	9:00	19:00	1:00	
10	Surin beach, TH	9:00	19:00	2:00	
11	Patong beach, TH	9:00	19:00	2:00	
12	Kamala Beach, TH	9:00	19:00	1:00	
13	Tiger Kingdom, TH	9:00	19:00	1:00	
14	Monkey spot	9:00	19:00	1:00	

TABLE VI
THE INFORMATION OF PLAN TRAVEL NO. VRP5

VRP4					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	19:00	0:00	4
2	Mai khao beach, TH	9:00	19:00	1:00	
3	Phuket town, TH	9:00	19:00	1:00	
4	Sino-Portuguese Building, TH	9:00	19:00	2:00	
5	Saphan Hin, TH	9:00	19:00	1:00	
6	Three beaches viewpoint, TH	9:00	19:00	1:00	
7	Promthep cape, TH	9:00	19:00	2:00	
8	Rang Hill view point, TH	9:00	19:00	1:00	
9	Big Buddha, TH	9:00	19:00	1:00	
10	Tiger Kingdom, TH	9:00	19:00	1:00	
11	Go kart Phuket, TH	9:00	19:00	1:00	
12	Shooting Range,TH	9:00	19:00	1:00	
13	Hanuman World, TH	9:00	19:00	2:00	
14	Aquaria, TH	9:00	19:00	2:00	
15	Laem krating, TH	9:00	19:00	1:00	
16	Scpo,WatPhraThong (Phrabhud)	9:00	19:00	1:00	
17	Monkey spot	9:00	19:00	1:00	
18	Jungle Bungy Jump	9:00	19:00	2:00	
19	Flying Hanuman	9:00	19:00	1:00	
20	Phuket Tiger Kingdom, TH	9:00	19:00	1:00	

TABLE VII
THE INFORMATION OF PLAN TRAVEL NO. VRP6

VRP5					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	19:00	0:00	3
2	Windmill Viewpoint	9:00	19:00	1:00	
3	Aquaria, TH	9:00	19:00	2:00	
4	Promthep cape, TH	9:00	19:00	2:00	
5	Mai khao beach, TH	9:00	19:00	1:00	
6	Three beaches viewpoint, TH	9:00	19:00	2:00	
7	Dolphins Bay, TH	9:00	19:00	2:00	
8	Big Buddha, TH	9:00	19:00	1:00	
9	Hanuman World, TH	9:00	19:00	2:00	
10	Tiger Kingdom, TH	9:00	19:00	1:00	
11	Baan Teelanka - The UpsideDown	9:00	19:00	1:00	
12	Kata Beach,TH	9:00	19:00	2:00	
13	Karon beach, TH	9:00	19:00	2:00	
14	Surin beach, TH	9:00	19:00	2:00	
15	Elephant Sanctuary, TH	9:00	19:00	2:00	
16	Chaithararam Temple, TH	9:00	19:00	1:00	

TABLE VIII
THE INFORMATION OF PLAN TRAVEL NO. VRP7

VRP6					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	19:00	0:00	2
2	Chaithararam Temple, TH	0:00	19:00	1:00	
3	Big Buddha, TH	0:00	19:00	1:00	
4	Phuket town, TH	0:00	19:00	1:00	
5	Sino-Portuguese Building, TH	0:00	19:00	1:00	
6	Thaihua Museum, TH	0:00	19:00	1:00	
7	Mining Museum, TH	0:00	19:00	1:00	
8	Promthep cape, TH	0:00	19:00	2:00	
9	Three beaches viewpoint, TH	0:00	19:00	2:00	
10	Kathu waterfall, TH	0:00	19:00	1:00	
11	Patong beach, TH	0:00	19:00	2:00	
12	Rang Hill view point, TH	0:00	19:00	1:00	
13	Scpo,WatPhraThong (Phrabhud)	0:00	19:00	1:00	

TABLE IX
THE INFORMATION OF PLAN TRAVEL NO. VRP8

VRP8					
No.	Name	Time Start(AM)	Time End (PM)	Time spent (hr)	Time of service (Day)
1	White sky boutique, TH	9:00	19:00	0:00	3
2	Elephant Sanctuary, TH	9:00	19:00	2:00	
3	Three beaches viewpoint, TH	9:00	19:00	1:00	
4	Promthep cape, TH	9:00	19:00	2:00	
5	Tiger Kingdom, TH	9:00	19:00	1:00	
6	Go kart Phuket, TH	9:00	19:00	1:00	
7	Mai khao beach, TH	9:00	19:00	1:00	
8	Scpo,WatPhraThong (Phrabhud)	9:00	19:00	1:00	
9	Monkey spot	9:00	19:00	1:00	
10	Rang Hill view point, TH	9:00	19:00	1:00	
11	Baan Teelanka - The UpsideDown	9:00	19:00	1:00	
12	Kathu waterfall, TH	9:00	19:00	2:00	
13	Dolphins Bay, TH	9:00	19:00	2:00	
14	Big Buddha, TH	9:00	19:00	1:00	
15	Kata Beach,TH	9:00	19:00	1:00	
16	Karon beach, TH	9:00	19:00	1:00	
17	Surin beach, TH	9:00	19:00	2:00	
18	Patong beach, TH	9:00	19:00	2:00	
19	Kamala Beach, TH	9:00	19:00	1:00	

C Arranging tourist attractions.

From the objectives of planning a travel route with conditions of limited time and vehicles used for traveling in this section, it will show the travel plans that are based on the needs of customers. With conditions for using the motorcycle for a limited period such as the number of days needed to use the motorbike, the amount of time needed to use in each area, the total number of tourist spots that need to visit throughout the service period

In this research, the researcher has created8tourism route plans from customers who stay in hotels and use motorcycle rentals. Advising for customers to choose the tourist attractions that they want to visit. The time limit of stay each area decide by tourists and configuring time from the starting point until returning into accommodation in to program planning, and then program VRP spreadsheet solver will process visualization map plan as shown in Fig. 8 until Fig. 15.

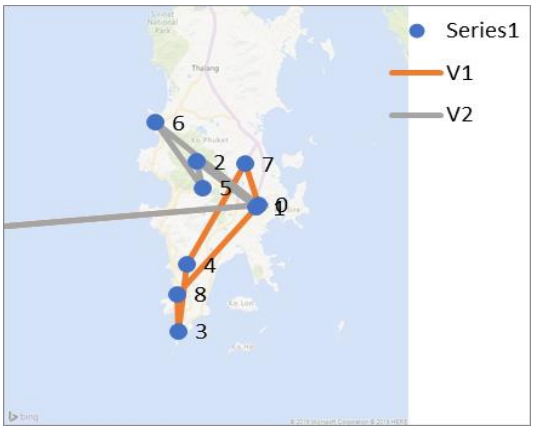

Fig. 8. VRP1 plans visualization routing by Bing map.

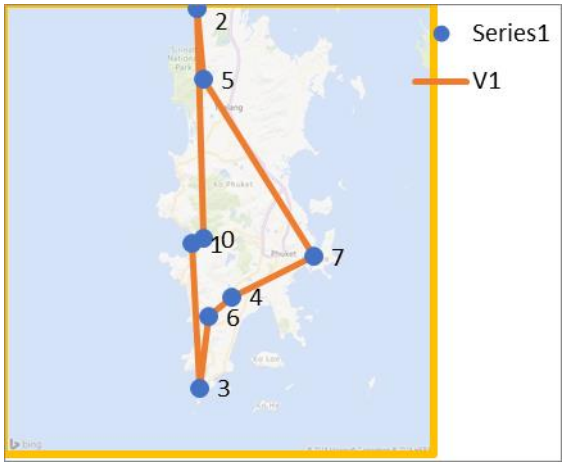

Fig. 9. VRP2 plans visualization routing by Bing map.

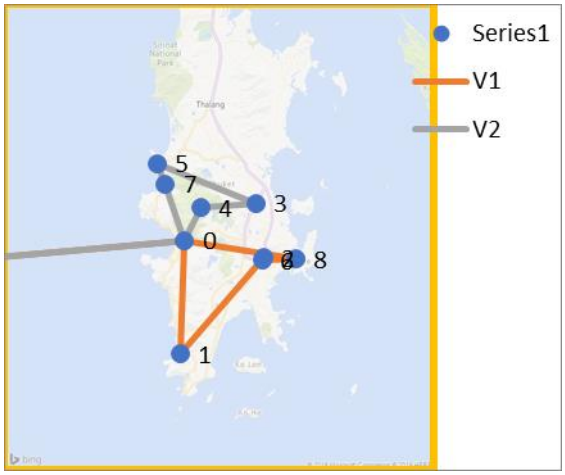

Fig. 10. VRP3 plans visualization routing by Bing map.

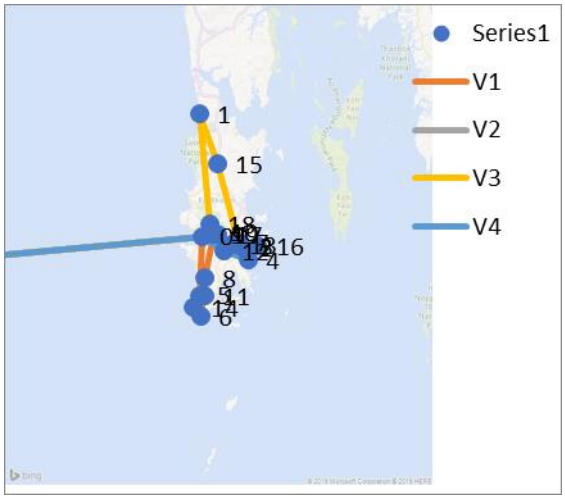

Fig. 11. VRP4 plans visualization routing by Bing map.

Fig. 8-11 shown the priority of the route from the starting point to many destinations. In which the locations are shown in figures as shown in the pictures for each plan. Line color and V symbol followed by numbers meaning as the number of days specified for use in tourism.

Fig. 12. VRP5 plans visualization routing by Bing map.

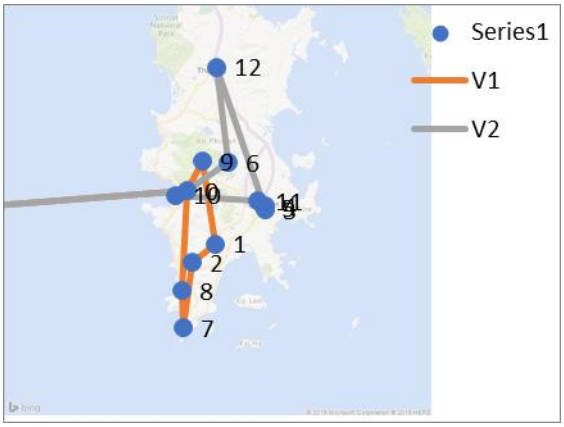

Fig. 13. VRP6 plans visualization routing by Bing map.

Fig. 14. VRP7 plans visualization routing by Bing map.

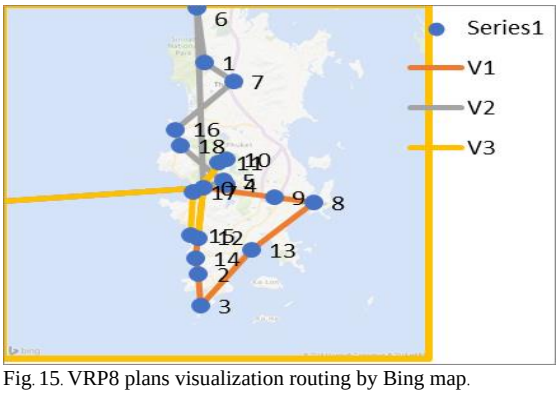

Fig. 15. VRP8 plans visualization routing by Bing map.

V. DISCUSSION

Phuket is a popular tourist destinations for Thai people and foreigners. The popularity of tourists depends on private interesting of the sea and mountains that suitable for recreation and seek new experiences in life. Phuket is an interested place. Phuket province is a large island with many beautiful points. The prominent tourist attraction in Phuket is the sea surrounded by mountains, including small and large islands around Phuket islands.

Tourism within Phuket is organized as a commercial activity and provides tourism facilitation services. For an example, a brochure recommends package tour within 1 day, 2 days or more, according to tourist desire. Complete services such as, booking travel tickets, travel plans, food, drink, accommodations, hotel services and the motorcycle rentals are very popular among tourists who would like to be relaxing and planning their own travel for living with the local people and made new experience life.

Tourism motorcycle route plans using basic information about popular tourist destinations and can be searched online and collecting from recommendation and agent tours. The data from Table I database travel coordinates of Phuket province, the collected data, surveys from local people and questionnaires from tourists interested to visit Phuket. then the researcher suggests motorcycle rentals and the route planning for tourists. Most places have been choosing from tourists and suggesting to tourists is island trips, seaside beaches, viewpoint, and temple.

Tourist information from the database shown at Table I database travel coordinates of Phuket province and in section 4 tourism database. The researcher collected tourist information to make a tourist attraction document for tourists' alternatives decision. After that, they must be recommended tourist attractions and propose a tourist attraction motorcycle route plans within a limited time.

Besides, behavioral data from the questionnaire can be analyzed to prepare ready-made travel routes that are like package tours. So that tourists can pick up this instant routing plan in the future.

IV. CONCLUSION

From the objectives of surveying tourist attractions and Motorcycle planning travel routes using appropriate time and distance, with conditions regarding the vehicle and limit time restrictions, can be summarized as follows.

Researcher surveying attractive destinations in Phuket, that are popular among tourists by questionnaire from tourist and agents' tours service. The data of tourist attraction and behavior of tourists from the questionnaire have been collected separate worksheets into Table I database travel coordinates of Phuket province. The information on the Table I has been used to planning route and destination management by program VRP spreadsheet solver, the information on the behavior of tourist customers will be used for considering and suggesting to tourists.

The program VRP investigate possible routes passes attractive destinations in Phuket, that suit time limit and vehicle conditions. Tourist attractions are allocated based on the distance of nearby tourist sites and the limit time. Section 4 shows the details of the plan's motorcycle route and show the result of the route planning details with time and vehicle constraints. The VRP spreadsheet solver program can provide similar routes and allocate time to restrict tourists to the desired location.

Suggestion a motorcycle travel plan that takes the shortest time to travel and nearest distances with the underneath condition of a time limit and vehicle by program VRP spreadsheet solver. The researcher decides to take the select method for selecting tourist attractions based on the popularity of tourists, who use the services. And then, the researcher takes all the data required to fill into the VRP program. Finally, the motorcycle route planning from the VRP program will show routes detail and for example, as shown in section 4 will show motorcycle route 8 plans that some plan spends time than specified. Due to the number of tourist destinations to visit and may take more time to travel. The researcher recommends increasing service time conditions to increase sales opportunities and appropriately meet tourists' desires.

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Resilient Supplier Selection under Uncertainty Using the Extended TOPSIS Method: The Case of Electronic Components Procurement

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***Abstract*—Due to globalization, supply chains are interrupted by unpredictable natural or man-made disasters, as well as other kinds of disruptive events. The selection of suppliers based on resilience strategies, therefore, has been considered a necessary factor for mitigating such uncertainties. However, the studies that provide practical methods using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to support resilient supplier selection in the electronic industry is still limited. Most of electronic products are made up of a variety of components. Logical supplier selection process is therefore necessary in this industry. This study aims to identify critical criteria for the resilient supplier selection that is applicable to electronic manufacturers. The extended TOPSIS method is then adopted to facilitate the selection process. Uncertain and unavailable data, which tends to exist in actual resilient supplier selection problems, can be managed logically. The effective use of the supplier resilience strategies helps electronic firms be prepared for unpredictable disasters. The proposed method can be applied not only for resilient supplier selection but also any cases of multi-criteria decision making.**

***Index Terms*—Disaster, Disruption, Electronic Industry, Resilience, Supplier selection**

I. INTRODUCTION

In the current business environment, supply chain management (SCM) has received increasing attention and has become an important factor for enterprises to achieve competitiveness [1]. The success or failure of SCM depends on a suitable SCM system and on appropriate suppliers. A review of the relevant literature shows that supplier selection is a critical element in the procurement process, as it enables a firm to have high quality products, enhance its customer satisfaction, and increase its competitive advantage [2]. Therefore, effective supplier selection is considered to be a key strategy in the industrial purchasing process [3].

Recently, supply chains (SC) have been disrupted by unpredictable disasters or events that can be natural (e.g., earthquakes, hurricanes, tsunamis, floods), man-made (e.g., labor strikes, fires, traffic accidents, terrorist attacks) or technological; these disasters have tended to occur more frequently and to be more severe. Due to this, the term 'resilience' has gained in importance in business management, as it is a necessary factor in supplier selection. Relatedly, supply chain resilience is the ability of the system to recover its performance to its original state after being disrupted.

Supplier resilience capability is multidimensional, and it is highly likely that it needs to be assessed using uncertain information. This is because some disasters or disruptive events might never have happened in the past, and suppliers may have no experience to deal with them. Therefore, the ability of suppliers to handle these situations may be difficult to assess with definite information.

Thus, the purpose of this study is to identify critical criteria for the assessment of supplier resilience capability and to apply the extended TOPSIS method to the case of resilient supplier selection. This method is developed by Sureeyatanapas et al. [3] as a method to solve multiple criteria decision making (MCDM) problems when uncertain or unavailable data exists. This study focuses on the case of components procurement for electronic manufacturers, due to a wide range of sub-components required for electronic products and because the electronic industry is one of the significant sectors influencing the global economy.

This paper is organized as follows. Section II describes the research methodologies. Section III presents a review of criteria for resilient supplier selection and typical criteria generally used in the

electronic industry. Section IV then present a numerical example to demonstrate the application of the extended TOPSIS for the resilient supplier selection in the electronic industry. The last section concludes and provides suggestions for future research.

II. Research Methodology

The research methodology starts from a review of the literature, with the aim of gathering critical criteria that are suitable for resilient supplier selection in the face of disruptive events in the electronic industry. To this end, two groups of studies have been reviewed, which are articles addressing cases of supplier selection under catastrophic, disaster or crisis situations and articles that mention problems of supplier selection within the electronic industry. The gathered criteria were grouped according to their meanings or definitions, and they were then classified into two categories: (i) resilience capabilities and (ii) general criteria for the electronic industry. The extended TOPSIS method is then applied to solve the selection problem. This method can deal with uncertain or unavailable information in MCDM problems [3]. A numerical example was created to demonstrate the application of the extended TOPSIS to a case of resilient supplier selection. The calculation process is described step by step to show that the proposed method can logically solve the problem.

III. A Review of Criteria for Resilient Supplier Selection in the Electronic Industry

A number of relevant literature sources were reviewed. They include studies on resilient supplier selection in several sectors, such as the automotive industry [4][5][6], plastic manufacturing [7], logistics [8], construction supply chain [9] and resilient supplier selection in general [1][10][11][12][13]. Studies relating specifically to supplier selection in the electronic industry were also reviewed to identify specific characteristics or concerns of electronic components procurement [14][15][16][17][18]. Many criteria were collected, and they were eventually synthesized and classified into 17 criteria, as shown in Table I.

TABLE I
SYNTHESIZED CRITERIA FOR RESILIENT SUPPLIER SELECTION FOR THE ELECTRONIC INDUSTRY

Category	Criteria	Definition
Resilience capabilities	1. Responsiveness	The ability to quickly react or respond to customer requirements.
	2. Safety stock inventory	The supplier's capacity to hold adequate amounts of essential materials and goods to support a customer during disruptive events.
	3. Invulnerable location	The supplier's location, which should be in a place with no risk of natural disasters to minimize impacts on the supply chain processes, or be in a safe or low-risk area.
	4. Backup supplier contracts	The presence of a supplier's outsourcing contracts, which enables a customer to overcome a shortage of supply capacity in the case of disruption.
	5. Robustness	Physical protection infrastructure and safety system of a supplier's building and facilities, to minimize negative impacts of disruption, especially in the case of natural disasters.
	6. Delivery rerouting	Rerouting options (based on the supplier's location) or the supplier's capability to adjust transportation routes during disruptive events.
	7. Restoration	The supplier's capability to restore damaged facilities and equipment or to resume production to a normal state of operations.
	8. Risk of production shutdown	The possibility of production shutdown, which might be caused by failure of the facilities, machine breakdown, labor strikes, natural disaster, and technological problems.
	9. Risk of transportation failure	The possibility of transportation failure, which might be caused by vehicles failure, route insecurity, terrorist attacks, and natural disasters.
	10. Risk of communication breakdown and losing information	The possibility of the communication and transactions breakdown which might be caused by system errors and instability, as well as the insecurity of the information system.

TABLE I
SYNTHESIZED CRITERIA FOR RESILIENT SUPPLIER SELECTION FOR THE ELECTRONIC INDUSTRY(CONT.)

Category	Criteria	Definition
General criteria for the electronic industry	1. Production capacity	The volume of products that can be produced and delivered by the supplier using their current resources.
	2. Delivery performance	2.1 The supplier's order cycle time. 2.2 The supplier's on-time delivery performance. 2.3 The supplier's shipping accuracy.
	3. Service and support	3.1 The supplier's ability and willingness to assist with the design process. 3.2 The supplier's ability to provide technical assistance and support for post-sales services.
	4. Innovation and technology	The supplier's innovation and technological advances.
	5. Firm's image and reputation	The supplier's profile, image, market share, and brand recognition.
	6. Product quality	6.1 Defect rate found at the customer's plant. 6.2 The supplier's process capability.
	7. Product price	The unit price of the product.

IV. A NUMERICAL EXAMPLE

This section presents a numerical example to demonstrate the application of the extended TOPSIS to the case of resilient supplier selection in the electronic industry. The numerical example is employed, instead of the report of actual data, due to the confidential information concerned by most electronic manufacturers. In practice, when companies select suppliers, it is highly likely that most companies do not consider all the above-mentioned criteria. They generally select only the criteria that are critical or significant for their business strategy. In this research, five criteria were selected based on an interview of a purchasing engineer of a company producing various components of a computer system. Three criteria were selected to represent the resilience capability: 'responsiveness', 'safety stock inventory', and 'restoration'; two criteria were selected as the general criteria for the electronic industry, which were 'innovation and technology' and 'product quality'. Examples of their indicators and measurement units are shown in Table II. In fact, each criterion can be measured in either qualitative or quantitative ways, or both, depending on the assessor's perception and preference. However, for this study, 'responsiveness', 'restoration', and 'innovation and technology' were set as qualitative criteria, while the other two were quantitative criteria. For qualitative criteria, a rating scale was used and definitions were attached to each point on the scale. For quantitative criteria, an indicator and measurement unit were defined for each criterion.

TABLE II
EXAMPLE OF INDICATORS AND MEASUREMENT UNITS FOR EACH CRITERION

Criteria	Indicator and measurement unit
Responsiveness	Rating scale 1-4 (1) Excellent: Very fast response (within an hour). (2) Good: Fast response (within three hours). (3) Fair: Response within one day. (4) Poor: Slow response (longer than one day).
Safety stock inventory	The length of time that the supplier can supply raw material (days).
Restoration	Rating scale 1-4 (1) Excellent: Evidence shows that the risks and impacts of disruptive events that affect business operations have been identified and managed according to their business continuity plan (BCP) for each scenario. The procedures and tools are specified for responding to the damage and restoring the operations, including the recovery time objective (RTO) for each scenario. (2) Good: Evidence shows that the risks and impacts of disruptive events that affect business operations have been identified. The BCP is provided for each scenario. However, there is no clear evidence of procedure and tools for responding to the damage and restoring the operations for each scenario. (3) Fair: Evidence shows that the risks and impacts of disruptive events that affect business operations have been identified. The supplier is in the process of developing the BCP for each scenario. There is no evidence of procedure and tools for responding to the damage and restoring the operations for each scenario. (4) Poor: There is no evidence of identifying any disruptive events that tend to impact on business operations.
Innovation and Technology	Rating scale 1-4 (1) Excellent: Supplier uses state-of-the-art technologies for manufacturing new products and new process developments. (2) Good: Supplier uses new technologies in their new product and new process development. (3) Fair: Supplier applies commonly used technologies to their products but there is no new process development. (4) Poor: Supplier uses the obsolete or out-of-date technologies in their product and there is no new process development.
Product Quality	Average rate of defects per lot.

Three candidate suppliers were then taken into

consideration, and they were assessed using the five criteria. The assessment data were generated to include all feasible forms, including precise information, a range of possible information, and unknown information, as shown in Table III. For instance, for supplier 3, the restoration performance was completely unknown, since this supplier had no experience dealing with a disruptive event. Next, to normalize the assessment data, the data of each criterion is transformed into the utility scores using the equivalent rules shown in Table IV. For this example, the equivalent rules are given by the authors in order to only demonstrate the calculation method. In reality, practitioners or decision makers can determine the equivalent rules by themselves in order to reflect their preferences. The data of quantitative criteria is transformed using (1) and (2) [3], while the data of qualitative criteria can be transformed directly using the equivalent rules. The transformed utility scores are then displayed in Table V.

TABLE III
THE ASSESSMENT MATRIX OF 3 ALTERNATIVES WITH 5 SELECTED CRITERIA (BEFORE TRANSFORMATION)

Criteria	**Weight**	**Supplier**		
		1	2	3
1.Responsiveness (rating scale 1-4)	0.20	2	2-3	3-4
2.Safety stock inventory (days)	0.20	7	5	10
3.Restoration (rating scale 1-4)	0.35	2-3	3	Unknown
4.Innovation and Technology (rating scale 1-4)	0.15	1	2	2
5.Product quality (average rate of defects per lot)	0.10	0.50%	1.05%	0.85%

TABLE IV
EQUIVALENCE OF ASSESSMENT DATA AND UTILITY SCORES

Criteria	Rating scale or numerical data	Utility scores
1. Responsiveness	1	100
	2	80
	3	50
	4	0
2.Safety stock inventory	10 days (or above)	100
	3 days (or lower)	0
3.Restoration	1	100
	2	70
	3	40
	4	0

TABLE IV
EQUIVALENCE OF ASSESSMENT DATA AND UTILITY SCORES (Cont.)

Criteria	Rating scale or numerical data	Utility scores
4.Innovation and Technology	1	100
	2	80
	3	50
	4	0
5.Product quality	0.3% (or lower)	100
	1.5% (or above)	0

TABLE V
THE ASSESSMENT MATRIX OF 3 ALTERNATIVES WITH 5 SELECTED CRITERIA (AFTER TRANSFORMATION)

Criteria	Utility	Supplier		
		1	2	3
1.Responsiveness	Min	80	50	0
	Max	80	80	50
2.Safety stock inventory	Min	57.14	28.57	100
	Max	57.14	28.57	100
3.Restoration	Min	40	40	0
	Max	70	40	100
4.Innovation and Technology	Min	100	80	80
	Max	100	80	80
5.Product quality	Min	83.33	37.50	54.17
	Max	83.33	37.50	54.17

For quantitative criteria, the utility of the benefit criteria can be calculated by (1), where $u(h_{i,j})$ denotes the utility score of alternative i on criterion j, $h_{max,j}$ is the best value of criterion j when comparing all alternatives, and $h_{min,j}$ is the worst value.

$$u(h_{i,j}) = \left(\frac{h_{i,j}-h_{min,j}}{h_{max,j}-h_{min,j}}\right).100 \quad (1)$$

To exemplify the transformation, the safety stock inventory data could be transformed as follow:

Supplier 1: $u(h_{1,2}) = \left(\frac{7-3}{10-3}\right).100 = 57.14$

Supplier 2: $u(h_{2,2}) = \left(\frac{5-3}{10-3}\right).100 = 28.57$

Supplier 3: $u(h_{3,2}) = \left(\frac{10-3}{10-3}\right).100 = 100$

The utility of cost criteria can be calculated using (2), where $h_{min,j}$ is the best value of criterion j when comparing all alternatives, and $h_{max,j}$ becomes the worst value.

$$u(h_{i,j}) = \left(\frac{h_{max,j}-h_{i,j}}{h_{max,j}-h_{min,j}}\right).100 \quad (2)$$

For example, the average rate of defect per lot could be transformed as follows:

Supplier 1: $u(h_{1,5}) = \left(\frac{1.5-0.5}{1.5-0.3}\right).100 = 83.33$

Supplier 2: $u(h_{2,5}) = \left(\frac{1.5-1.05}{1.5-0.3}\right) . 100 = 37.50$

Supplier 3: $u(h_{3,5}) = \left(\frac{1.5-0.85}{1.5-0.3}\right) . 100 = 54.17$

After the transformation of the data, the extended TOPSIS was applied as an MCDM technique for selecting the best alternative. The underlying concept of TOPSIS is to choose alternatives with the shortest distance from the positive ideal solution (PIS) and the longest distance from the negative ideal solution (NIS) of each criterion. The closeness coefficient to the ideal solutions *(CC_i)* can then be calculated for each alternative *i*, and it can be used as an indicator to compare and rank alternatives. The extended TOPSIS has been developed by Sureeyatanapas et al. [3] to enhance the ability of the TOPSIS method to deal with uncertainties and unavailability of information. In resilience supplier selection, suppliers' performances may not be precisely assessed for some criteria since the assessor may have only limited information or a complete lack of information. For these cases, their performance could be of any value, as it falls within a range of possible information. Thus, the traditional TOPSIS has been modified to allow for the input of a possible range of values (minimum and maximum values) for each criterion, as shown in Table V, where each element Z_{ij} in the table (the transformed assessment data of alternative *i* on criterion *j*) is now in the form of a utility score. When the assessment is precise and certain, $Z_{ijMin} = Z_{ijMax}$.

Because the input information can be of any value in the specified range, the minimum CC_i (Min CC_i) and maximum CC_i (Max CC_i) for alternative *i* can also be determined. The extended TOPSIS clarifies that the alternative *i* will reach the minimum value (Min CC_i) only when all Z_i ($Z_{i1}, Z_{i2}, \ldots, Z_{ij}$) are at the lowest level and all Z_k ($k \neq i$) are at the highest level. Meanwhile, the alternative *i* will reach the maximum score (Max CC_i) only when all Z_i ($Z_{i1}, Z_{i2}, \ldots, Z_{ij}$) are at the highest level and all Z_k ($k \neq i$) are at the lowest level, as described by (3) and (4). For example, Table VI shows the modified decision matrix when Min CC_1 is considered. Overall, the extended TOPSIS method can be described using (3) – (10) [3].

If objective function = *Min* CC_i,

$$\hat{Z}_{kj} = \begin{cases} Z_{kj(min)}, & k = i \\ Z_{kj(max)}, & k \neq i \end{cases} \quad (3)$$

If objective function = *Max* CC_i,

$$\hat{Z}_{kj} = \begin{cases} Z_{kj(max)}, & k = i \\ Z_{kj(min)}, & k \neq i \end{cases} \quad (4)$$

$$V_{ij} = W_j Z_{ij} \quad (5)$$

$$PIS_j = Max\ (V_{ij}) \quad (6)$$

$$NIS_j = Min\ (V_{ij}) \quad (7)$$

$$S_{PIS_i} = \sqrt{\sum_{j=1}^{n} (V_{ij} - PIS_j)^2} \quad (8)$$

$$S_{NIS_i} = \sqrt{\sum_{j=1}^{n} (V_{ij} - NIS_j)^2} \quad (9)$$

$$CC_i = S_{NISi}/(S_{PISi} + S_{NISi}) \quad (10)$$

TABLE VI
EXAMPLE OF MATRIX $\hat{Z}$ OF MIN CC_1 WITH 3 ALTERNATIVES

Criteria	Weight	Supplier		
		1	2	3
1.Responsiveness	0.20	80	80	50
2.Safety stock inventory	0.20	57.14	28.57	100
3.Restoration	0.35	40	40	100
4.Innovation and technology	0.15	100	80	80
5.Product quality	0.10	83.33	37.50	54.17

For the numerical example, the Min CC_i and Max CC_i were calculated for each alternative *i*, as shown in Table VII. To consider the best alternative, the decision maker (DM) may refer to the average of Min CC_i and Max CC_i (hereafter Avg CC_i). Since it appears that supplier 1 has the greatest Avg CC_i, it would be selected. However, this decision approach may overlook the uncertainty of the information. For example, at the date of purchasing, it is possible that supplier 1's performance will drop to its worst level (Min CC_1 = 0.3045), which is lower than the worst level of supplier 3. Therefore, it is suggested that Min CC_i and Max CC_i should be considered in the decision-making process along with the DM's risk attitudes. For example, if the DM has a 'risk-seeking' attitude, they may select the alternative with the highest Max CC_i, which is still supplier 1 (Max CC_1 = 0.7796). On the other hand, if the DM has a 'risk-averse' attitude, they may select supplier 3, as it has the highest level of Min CC_i (Min CC_3 = 0.3660).

TABLE VII
THE CLOSENESS COEFFICIENT TO THE IDEAL SOLUTIONS *(CC_i)* OF THE THREE CANDIDATE SUPPLIERS

Supplier	Min and Max CC_i		Avg CC_i
Supplier 1	Min	0.3045	0.5421
	Max	0.7796	
Supplier 2	Min	0.0000	0.2929
	Max	0.5857	
Supplier 3	Min	0.3660	0.4013
	Max	0.4366	

V. CONCLUSION

This study has identified criteria from the literature review that can be applied to resilient supplier selections in the case of a disruptive event in the electronic industry. The criteria are then synthesized and classified into two groups. Ten criteria are identified for the first group that reflect

supplier resilience capabilities, while another seven criteria are identified for the second group that present general criteria for electronic components procurement. These criteria can be also generalized to every industry for the consideration of supplier selection under the supplier resilience strategy. The application of the extended TOPSIS method is proposed for cases of supplier selection with uncertain information, which will likely occur in resilient supplier selection processes. This method allows DMs to make a decision by considering the range of CC_i together with their risk attitudes, as described in Section IV. Since the input information is uncertain, the output should be also uncertain. Therefore, this solution can preserve uncertain characteristics and avoid a potential loss of important information.

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[7] E. P. Wigner, "Theory of traveling-wave optical laser," *Phys. Rev*., vol. 134, pp. A635–A646, Dec. 1965.

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[11] J. H. Davis and J. R. Cogdell, "Calibration program for the 16-foot antenna," Elect. Eng. Res. Lab., Univ. Texas, Austin, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

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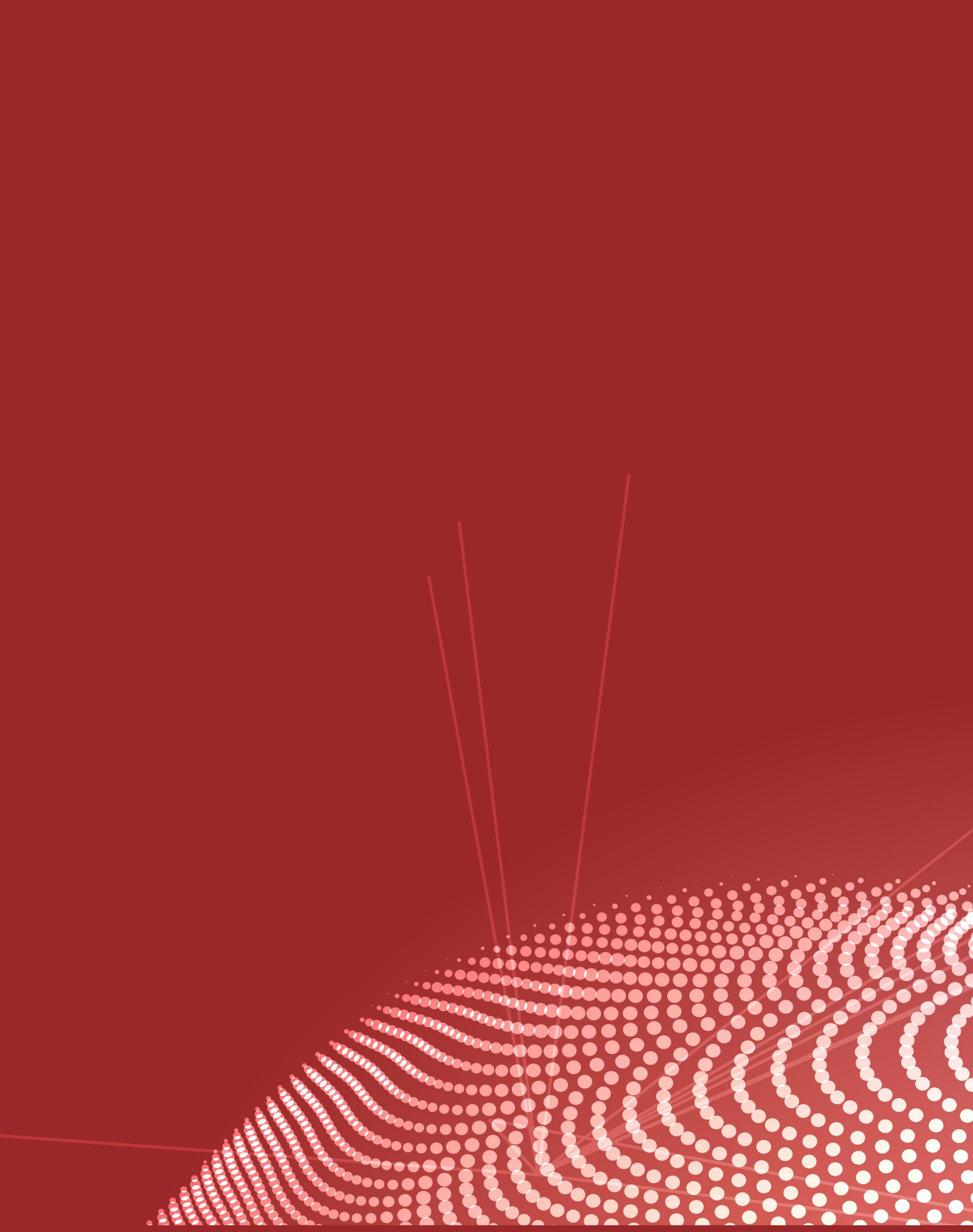

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