

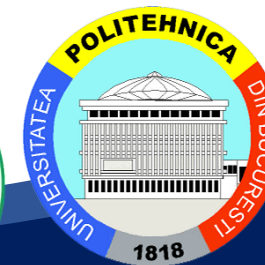


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of the European Union



Course 7:

Advanced Optimization: Techniques and Industrial Applications



Curriculum Development
of Master's Degree Program in
Industrial Engineering for Thailand Sustainable Smart Industry



Course Objective

- The objective of this course is to provide the students with knowledge on **the application of various optimization techniques** which can help making decisions for practical problems in industries.
- Modeling concepts and applications** of linear, integer, nonlinear, and dynamic programming as well as network models are addressed.
- Meta-heuristic techniques** are also discussed to obtain good solutions for large scale practical problems in a reasonable computational time.
- Optimization model and its applications are demonstrated for solving problems in **Industry 4 era**.
- **Prerequisite**: Operations Research



Learning Outcomes

- The students on the completion of this course would be able to
- **Formulate mathematical programs** for practical problems in production and supply chain systems (Create).
- Apply appropriate optimization techniques and write codes of optimization models using professional **optimization software** (i.e., MATLAB, LINGO, or MPL software) to solve single-objective practical problems in production systems, supply chain systems and specific operational problems (Create).
- Find appropriate trade-off solutions for **multiobjective decision making problems** in production systems, supply chain systems and specific operational problems (Create).
- Use **meta-heuristic techniques** to solve large scale NP-hard combinatorial problems for both single and multiple objective decision making problems where analytical methods cannot be used (Create)
- Conduct sensitivity analysis to examine the robustness of the solutions resulting from optimization models in order to ensure that appropriate solutions will be deployed in real world situations where input parameters are uncertain and cannot be estimated precisely (Evaluate).
- Understand how to apply digital technology for automated data-driven and in real-world optimization model. (Apply).





Course Outline

-Contents (45 hrs. in total)

Module 1: Theory of mathematical programming for convex optimization (19 hrs.)

Module 2 : Heuristics and Metaheuristics (16 hrs.)

Module 3: Optimization and Its Applications in Industry 4 Era (10 hrs.)



Evaluation Scheme

	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5	CLO 6
Formative assessment method						
Individual reports on home assignments (5%)	X	X			X	
Quizzes (5%)	X	X				
Midway reports and presentations in group projects (10%)		X	X	X	X	
Involvement in class discussions (5%)	X	X				
Demonstration of understanding of knowledge provided during the course (5%)	X	X			X	X
Case studies (20%)	X	X	X	X	X	X

	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5	CLO 6
Summative assessment method						
Final reports in group projects (10%)	X	X	X	X		X
Final group project presentation (5%)	X	X	X	X		X
Peer assessment in group projects (5%)			X	X		
Mid-Semester Examination (15%)	X	X				
Final Examination (15%)	X		X	X		

- **Module 1: Theory of mathematical programming for convex optimization (19 hrs. – 6 weeks)**
 - 1.1 Basic Modeling Concepts (1 hr.): Lecture: AC
 - 1.2 Linear Programming (6 hrs.): Lecture: AC + RO (Discussion, Home Assignment, Group project)
 - 1.3 Integer Programming, Mixed Integer Programming, and Combinatorial Optimization (5 hrs.): Lecture: AC + RO (Discussion, Home Assignment, Group project)
 - 1.4 Non-linear Optimization (3 hrs.) Lecture: AC + RO (Discussion, Home Assignment)
 - 1.5 Dynamic Programming (4 hrs.) Lecture: AC + RO (Discussion, Home Assignment)

- **Module 2: Heuristics and Metaheuristics (16 hrs. – 5 weeks)**
- 2.1 Concept of Heuristics and Metaheuristics (1 hr.) Lecture: AC + RO (Discussion)
- 2.2 Population-based algorithms: GA, PSO, DE (9 hrs.) Lecture: AC + RO (Discussion, Group project)
- 2.3 Local Search Methods: ALNS and Tabu Search (3 hrs.) Lecture: AC + RO (Discussion, Group project)
- 2.4 Multiobjective optimization (3 hrs.) Lecture: AC (Discussion)



Contents

- **Module 3: Optimization and Its Applications in Industry 4 Era (10 hrs. – 4 weeks)**

- **3.1 An Overview of Digital Technologies** (1 hr.)

This topic aims to give overview information of the tools (digital technology) used in optimization problems in Industry 4.0 era.
Lecture: AC + RO (Discussion, Home Assignment)

- 3.1.1 Digital technology concept
- 3.1.2 Digital technology hardware & software
- 3.1.3 Digital technology applications

- **3.2 Optimization (Opt) concept and Its Applications in Industry 4.0 Era** (2 hr.)

- This topic aims to give a basic idea of how to apply optimization to the real-world problem in Industry 4.0. Lecture: AC + RO (Discussion, Home Assignment, Group project)

- 3.2.1 Optimization concept in Industry 4.0 era
- 3.2.2 Optimization applications in Industry 4.0 and mobile support
 - - Opt in Warehouse and Inventory Management
 - - Opt in Transportation problems
 - 1) Smart Pickup and Delivery system (i.e., customized and real time pick up scheduling)
 - 2) Real time fleet management, tracking service and transportation condition
 - - Opt in Scheduling problem





Contents

- **Module 3: Optimization and Its Applications in Industry 4 Era (10 hrs. – 4 weeks)**
- **3.3 Optimization (Opt) Design in Industry 4.0 (2 hr.)**
- This topic aim to enhance student capability to analyze the problem, design, implement and measuring to use the optimization problems in Industry 4.0. Lecture: AC + RO (Discussion, Home Assignment, Group project)
- 3.3.1 System analysis concept
- 3.3.2 System architecture, module and component design
- 3.3.3 Data input/output user interface design
- 3.3.4 Optimization programming, modeling, and simulation
- 3.3.5 Evaluating the designed system
- **3.4 Real-Time Optimization (2 hr.)**
- This topic aims to deal with practical optimization problems for automated input data. Lecture: AC + RO (Discussion, Home Assignment, Group project)
- 3.4.1 Checking optimality conditions when input data change
- 3.4.2 Setting initial solution when input data change
- **3.5 Case Study (3 hr.)**
- This topic aims to enable students to apply optimization concept in an Industry 4.0 real-world problem. Lecture: AC + RO (Discussion, Group project)
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Project Objective

1. To demonstrate students on how to apply optimization in Industry 4 Era.
2. To demonstrate students on how to develop the optimization model for solving problems in Industry 4 Era.
3. To demonstrate students on how to design an automated data-driven tool in real world optimization model.



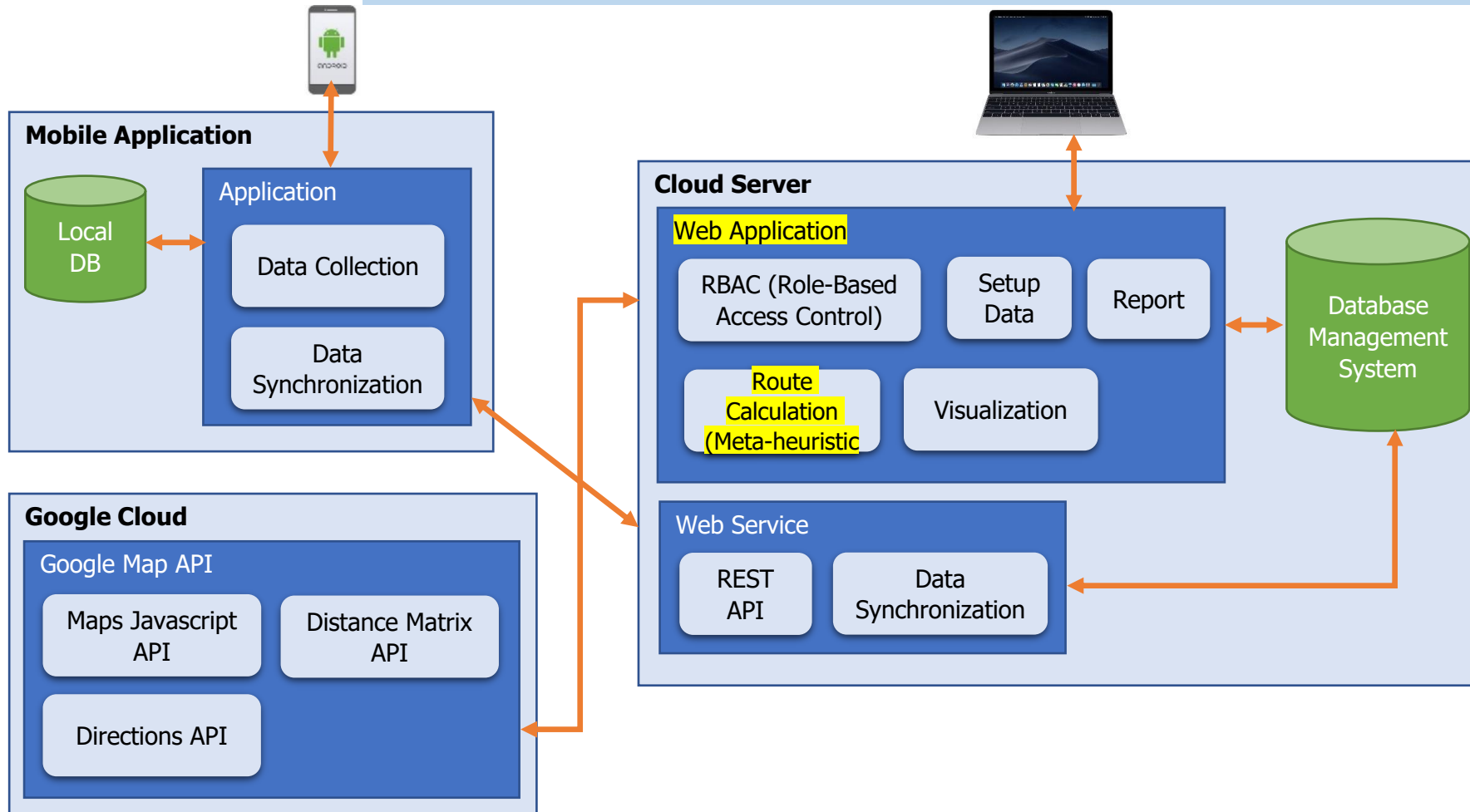
Group Assignment

Each group must do the following:

- Develop an algorithm to solve the problem using the “Ice App Program”.
 - As mentioned earlier, the “Ice App Program” was developed and installed the Web Application, Web Service, and Database Management System. The mobile application for ice transportation **takes advantage of the available demand data input to the IceApp software.**
 - To do this project, students will learn on how to apply optimization in Industry 4 Era and how to design an automated data-driven tool in real world optimization model.



Data input/output user interface design



- Sources of inputs:

- Imported files
- Mobile
- Google Cloud
- Sensors
- Camera
- Connected devices

- Kinds of outputs:

- Obj function
- Decision variables

- GUI:

- Reports
- Graphs & Tables



Web Application of Ice Transportation software

The screenshot shows a web browser window displaying the 'Product Sale System' interface. The browser's address bar shows the URL <http://119.59.103.118/ice-tran/site/index>. The interface is divided into three main sections: Report, Route, and Setup. The Report section contains buttons for 'Daily Sale Report', 'Sale Daily Report by product type', and 'Demand Report'. The Route section contains buttons for 'Update Distance & Time' and 'Route Determination'. The Setup section contains a grid of buttons for various configuration options: Name's Title, Province Data, Amphure, District Data, Types of Vehicles, Product Unit, Product Type, Product Data, Route No., Span of age, Vehicles, Ice Bucket Data, Types of Customers, Competitors, Share Market, Objective Data, Customer Data, Distribution/Factory, Distance/Time, and Salesman Data. The user is logged in as 'AdminAdministrator'.

<http://119.59.103.118/ice-tran/site/index>

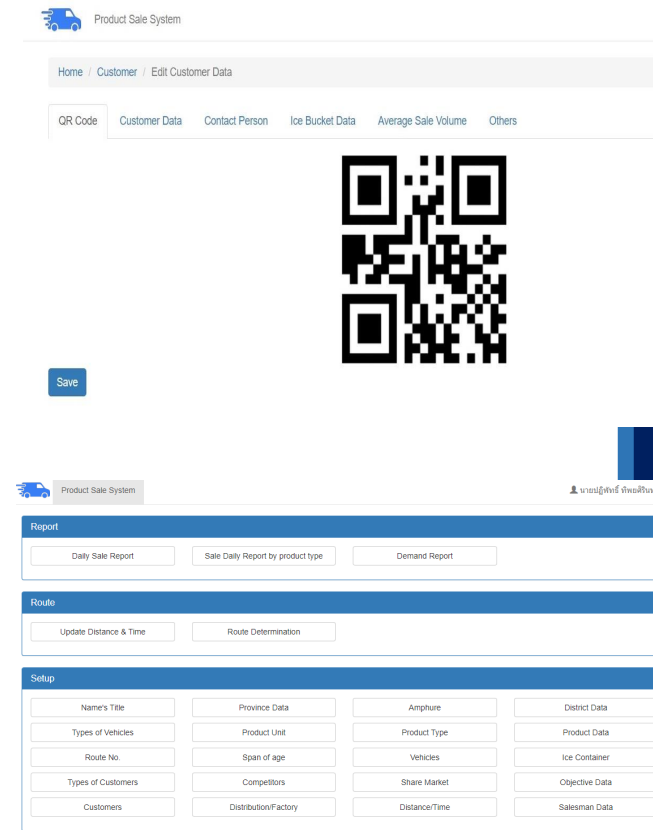
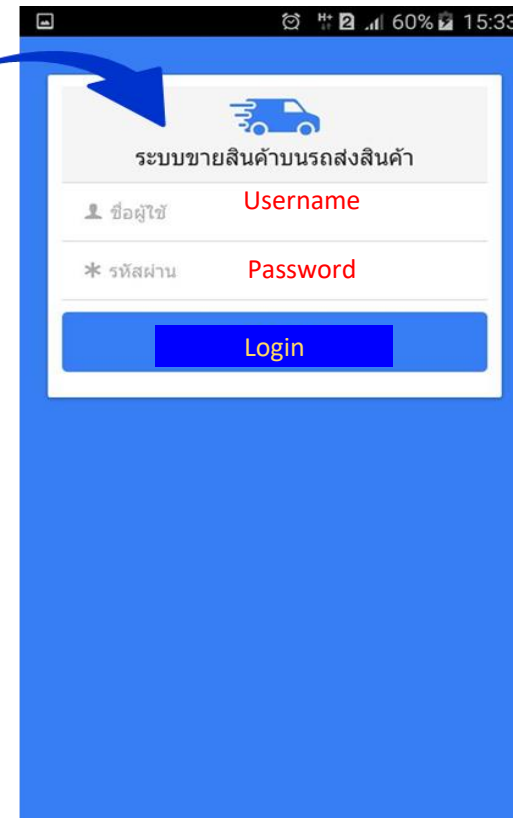
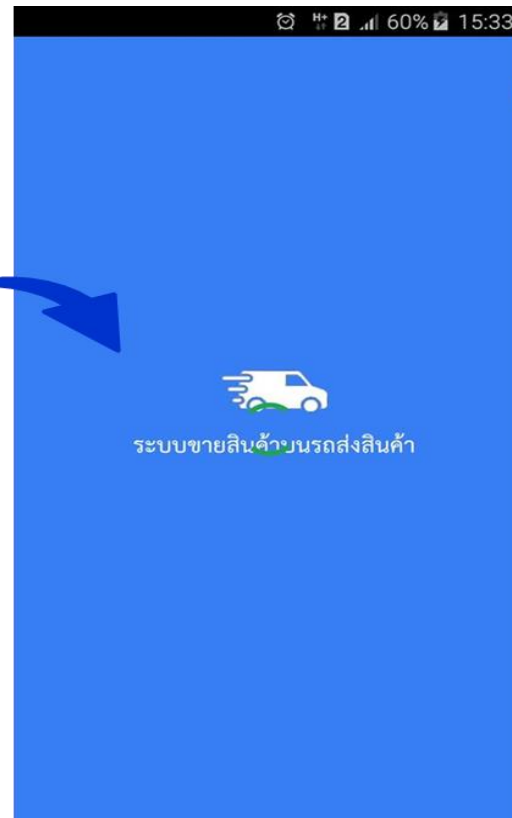
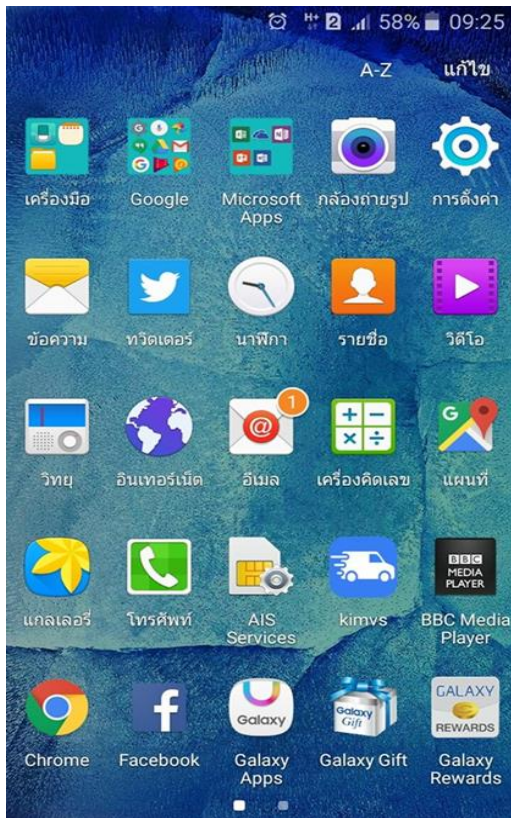




Database system and mobile application in ice transportation

Mobile Application to Get Customer Data

Login to the system



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Database system and mobile application in ice transportation

“Input parameters”

Customer data

Code, name, route, contact info

Product Sale System

Report

Daily Sale Report Sale Daily Report by product type Demand Report

Route

Update Distance & Time Route Determination

Setup

Name's Title	Province Data	Amphure	District Data
Types of Vehicles	Product Unit	Product Type	Product Data
Route No.	Span of age	Vehicles	Ice Container
Types of Customers	Competitors	Share Market	Objective Data
Customers	Distribution/Factory	Distance/Time	Salesman Data

Product Sale System

Home / Customer

Customer


#	Customer Code	Customer	Route No.	Mobile Number
1	C2003015	Tawandang Khon Kaen	สาย 2	081 260 0760
2	C2003016	Tong Plapao	สาย 2	085 014 4140
3	C2003017	Green Hotel Khon Kaen	สาย 2	043 247 222
4	C2003018	KB coffee	สาย 2	087 796 5656

Make QR Code for customer

Product Sale System

Home / Customer / Edit Customer Data

QR Code Customer Data Contact Person Ice Bucket Data Average Sale Volume Others



Save

Algorithm 1: Combination of Particle Swam Optimization and Adaptive Large Neighborhood Search

Input : Problem size, Population size

Output: $P_{n,best}$

Set Population equal to 1 set $P_{n,best} \leftarrow$ great number

For $i=1$ until $i=$ Population size

$P_{velocity} \leftarrow$ random real number

$P_{position} \leftarrow$ random real number

Set $P_{n,best}$ equal to $P_{position}$

Perform Adaptive Large neighborhood search (ALNS)

While (termination condition of ALNS is not met)

Select Destroy method (4 destroy method, $ProbDesMethod$)

Select Repair method (2 repair method, $ProbReMethod$)

Update Score of destroy and repair method

End

If ($Cost(P_{n,best}) \leq Cost(P_{repair})$)

$P_{n,best} \leftarrow P_{repair}$

End

End

While (Stopping condition does not met)

For ($P \in$ Population)

$P_{velocity} \leftarrow UpdateVelocity(P_{velocity}, P_{n,best}, P_{n,best})$

$P_{position} \leftarrow UpdatePosition(P_{position}, P_{velocity})$

Perform Adaptive Large neighborhood search (ALNS)

While(termination condition of ALNS is not met)

Select Destroy method (6 destroy method, $ProbDesMethod$)

Select Repair method (3 repair method, $ProbReMethod$)

Update Score of destroy/repair methods

End

If ($Cost(P_{position}) \leq Cost(P_{n,best})$)

$P_{n,best} \leftarrow P_{position}$

If ($Cost(P_{n,best}) \leq Cost(P_{repair})$)

$P_{n,best} \leftarrow P_{repair}$

End

End

End

End

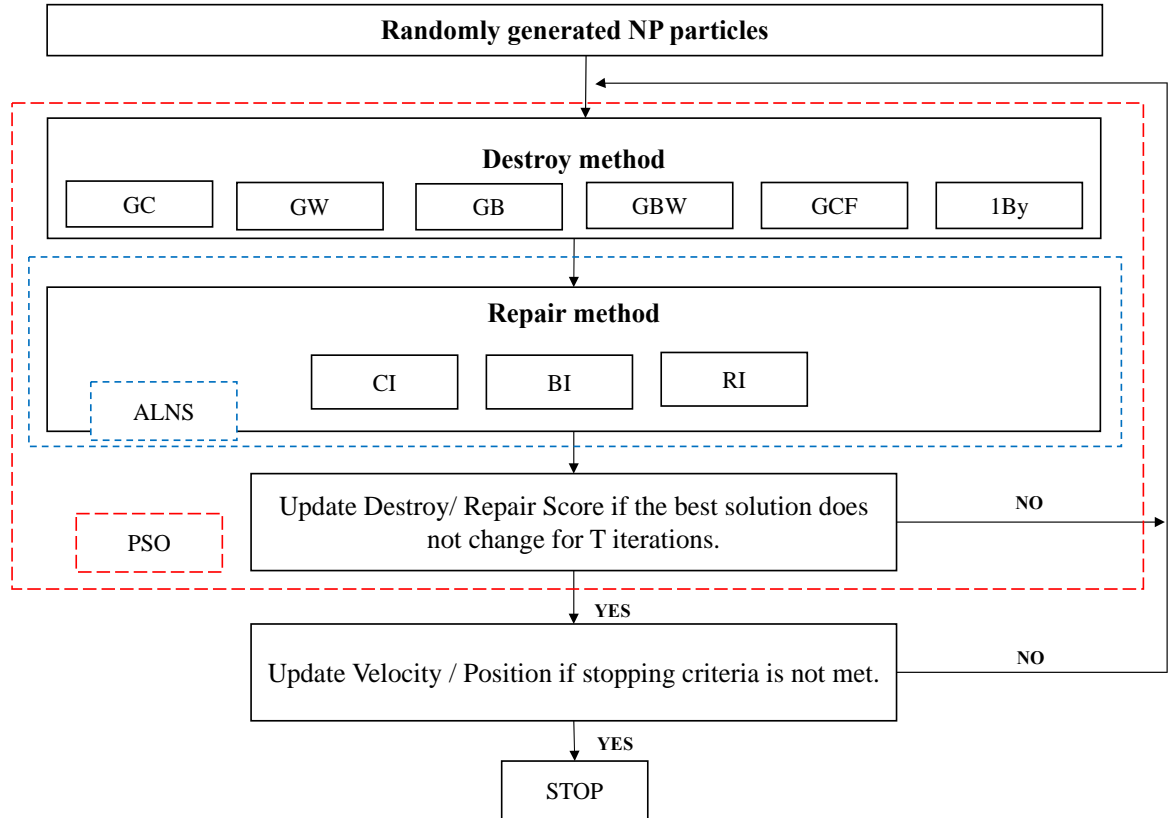
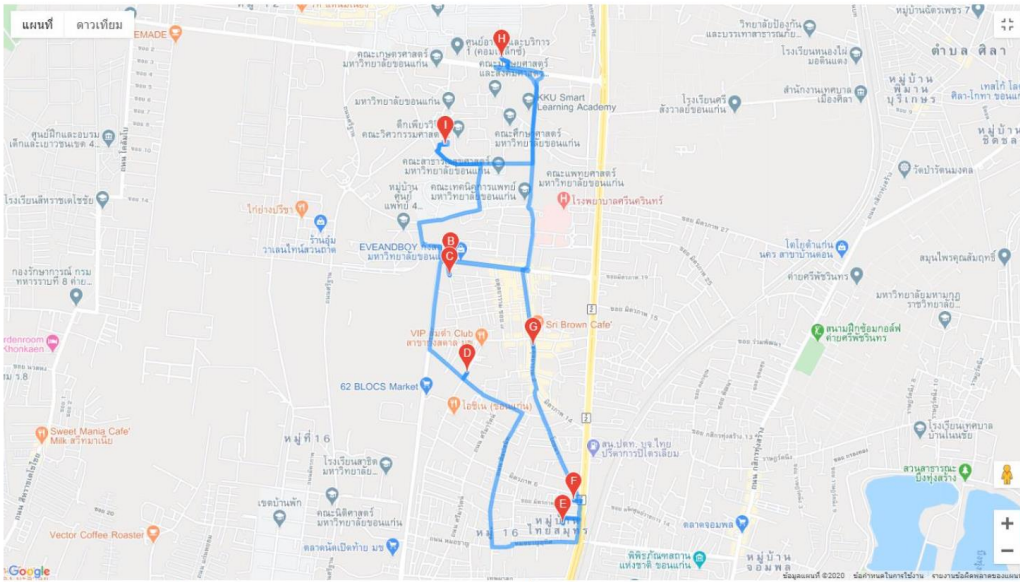


Fig. 2. Framework of the proposed Method

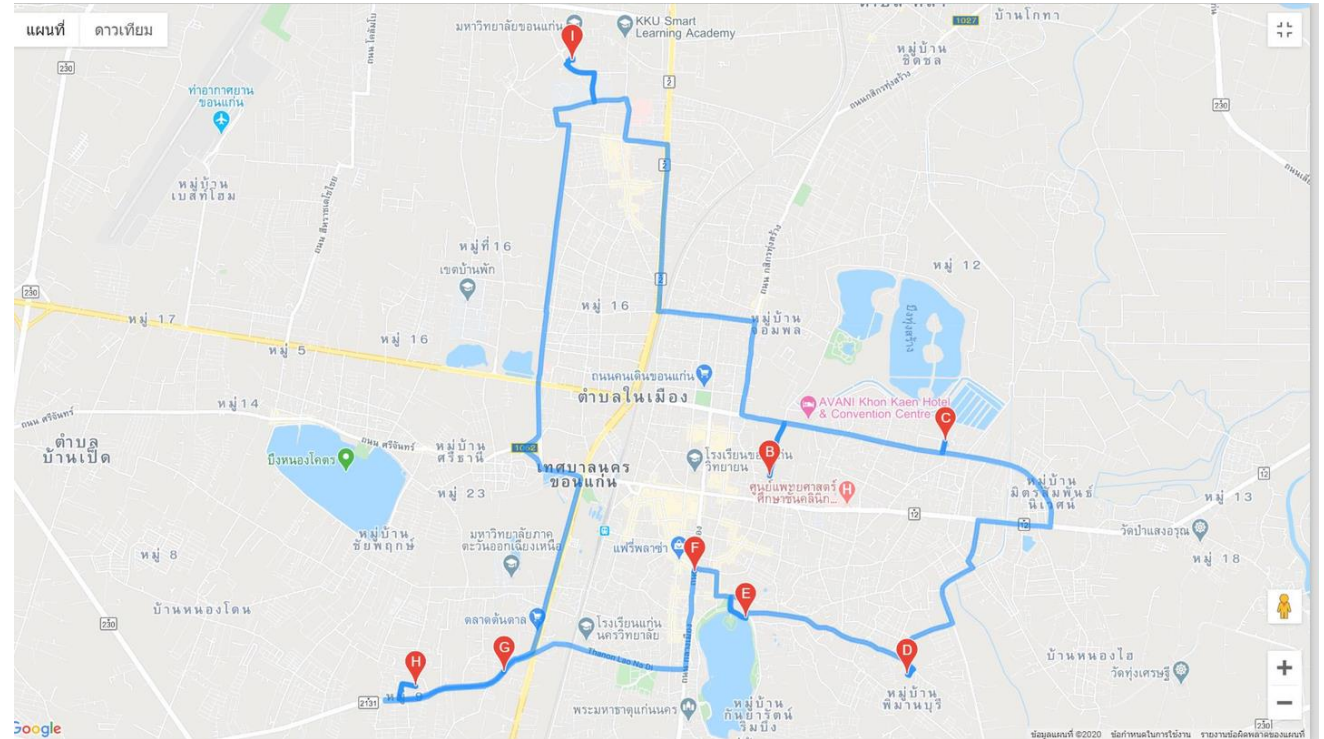
Examples of Results Running the IceTrans program (Students' work)



ภาพที่ 1 ผลลัพธ์การคำนวณของรถสายที่ 1 ผ่านแอปพลิเคชัน



Route 1



Route 2



Feedback from the Students

- It was tough for students to learn the optimization class. Too many topics but time was very tight.
- Some students had not much background on coding an algorithm.
- Students understood more on how to design an automated data-driven tool in real world optimization model and also were able to develop the optimization model for solving problems in Industry 4 Era.
- Students were excited to learn advanced optimization in a new way.

