DOI NUMBER: 10.19255/JMPM01411

KEYWORDS
Route Planning • Bee Algorithm • Railway Traveling Salesman Problem • Optimization Method • Optimum Route

BEE INSPIRED ROUTE MANAGEMENT APPROACH AND USE OF INTERNET OF THINGS

KAH HUO LEONG
• Ph.D. in Project Management candidate
• University of Malaya and Wales, Kuala Lumpur, Malásia
• *leong@expresswebdev.com*

HAMZAH ABDUL-RAHMAN
• PhD. - Vice-Chancellor of the International University of Malaya-Wale
• University of Malaya and Wales, Kuala Lumpur, Malásia
• *larhamzah@iumw.edu.my*

DR. CHEN WANG
• Professor at the Huaqiao University
• University of Malaya and Wales, Kuala Lumpur, Malásia
• *wcisabigguy@gmail.com*

SIAW-CHUING LOO
• PhD. - Senior Lecturer University of Malaya
• University of Malaya and Wales, Kuala Lumpur, Malásia
• *siawchuingg@um.edu.my*

• ABSTRACT •

Railway system (RS) is becoming a necessity and one of the popular choices of transportation among people, especially for business practitioners that operating and people living in the urban cities. The urbanization and population increase due to rapid development of the economy in the major cities are leading to a bigger demand for urban rail transit. The RS network expansion is necessary to cope with the increasing demand. However, the complexity of identifying the optimum route tends to increase due to the expansion of the system in accommodating the increase in demand. Despite Railway Traveling Salesman Problem (RTSP) being a popular variant of routing problems, it appears that the universal formula or techniques to solve the identified problems are yet to be found. The problem is easily recognized but proven to be difficult and impractical to solve without using the right approach. This paper presents a novel route management approach that was inspired by the way bees forage and share experience in a colony to solve Railway System Travelling Salesman Problem. It also discusses the results obtained from a test conducted to evaluate RS users route planning efficiency and how Internet of Things (IoT) can enhance the quality of the output. The approach has been tested and verified by comparing the results with one hundred RTSP exact solutions generated by using Malaysia RS dataset.

ROUTE AND SUPPLY CHAIN MANAGEMENT

Route management (RM) can be defined as a process to find the linkage and coordinate between the organization and other parties such as commuters, suppliers, manufacturers, dealers and customers to synchronize the efforts to meet the project needs with minimal use of time and resources (Christopher, 2016). RM is a subset of Supply Chain Management (SCM) where a supply chain consists of sequential activities of production, storage and distribution where each individual process is often planned and optimized using predetermined decisions from its preceding activities (Adulyasak, Cordeau, & Jans, 2015). An integrated supply chain operational planning system is a tool that issued to jointly optimize several planning decisions thereby capturing the additional benefits of coordination between sequential activities in the chain. Effective RM approach ensures cost savings, increase of productivity, improve stakeholder's flexibility and better adaptation to project environment changes.

RM helps logistics operators perform integrated routing and scheduling to minimize empty vehicle movements. The solutions of RM play an important role in overcoming problems in SCM and assist stakeholders in achieving operational efficiency (Awasthi, Adetiloye, & Crainic, 2016). Supply chain has become more complex over the years and lots of problems arise from it (Stevens & Johnson, 2016). Due to the increase in complexity of supply chain network, the efficiency of delivery service has become a very important part in internal productivity chain. By implementing RM solution, the delivery system in supply chain process can be planned in a more efficient manner where a better route can be taken to decrease the delivery time at the lowest operating cost possible (Tseng, Yue, & Taylor, 2005).

Many organizations turn to high profile fleet management solutions that are tailored to their needs (Danesh, n.d.). Fleet management and control systems provide information that is useful to automate product pickup and delivery process. Thus, companies that lead their activities on distributing goods are looking into finding ways to reduce transport costs and optimizing hired resources. SCM implementation enabled companies to plan the drop off routes of their products in the most cost-effective and in a timely manner despite the increase in demands or product volume. TSP solution is also vital in the planning and risk management aspects of SCM. Periodic assessments and re-designs are often needed in order to stay as efficient and effective as possible. In the end of year 2016, China and Japan have conducted multiple experiments and trials to deliver goods via RS (An, 2016; Ito & Okuda, 2016). All of these justify the need to manage the complexity of RS route planning in order to get a fruitful return by using the increasingly popular mode of transportation.

RAILWAY SYSTEM

Railway System (RS) is defined as a commercial organization responsible for operating a system of transportation for trains carrying passengers or freight (Azadeh, Ghaderi, & Izadbakhsh, 2008). Cited from Macmillan dictionary, there are more than 30 types of RS in the world. For instance, light railway transit, monorail, subway, underground, bullet train and mass railway transit. From the literature, little attention has been devoted to RS transportation even though it has been a main transportation mode in many cities. RS is becoming one of the popular choices of transportation among people especially those who live in urban cities (Gonsalves & Shiozaki, 2015). Urbanization and increasing population due to rapid development of economy in many cities are leading to a bigger demand for urban rail transit (Zhu, Mao, Liu, & Li, 2015). As a result of high demand, many cities are making rail transit more efficient. The attractive advantage of rail that causes the increase in demand includes providing a faster, more comfortable and quieter traveling experience (Young, 2014).

Some of the RSs have complex network design, with hundreds of stations, lines and interchanges. For example, Netherlands Railways operates about 5,000 passenger trains on a railway network of 2,800 to 325,000 kilometres (Vromans, 2005). There are about 1,000,000 passenger journeys each day, with an average distance of 44 km. The crisscross network of 100 different train lines along 380 stations ensures that almost 80% of the passenger trips are made without transit. Another example is the New York City Subway. According to the Metropolitan Transportation Authority it is the largest subway system in the world with 422 stations. In 2013, the subway delivered over 1.71 billion rides, averaging approximately 5.5 million rides on weekdays, about 3.2 million rides on Saturdays, and about 2.6 million rides on Sundays (MTA: Subway Ridership At Highest Level Since 1950", 2012).

When the RS network is expanded, choosing the shortest route to multiple destinations will be difficult due to the complexity of the network design (Dušan Teodorovic & Nikolic, 2013). Too many stations in the line will cause problems and delays to the users (Jr, 2015). Besides, the increase number of the interchange station will increase the travel time due to the transits involve (Hernandez & Monzon, 2016). RS poses a multitude of interesting optimization problem (Devaki, Prabhakar & Kumar, 2016). Route planning is ineffective without sufficient information especially when no tool is available to aid such process. Due to the complexity of rail transportation in major cities, most of the passengers only plan their journey through experience without referring to the map (Qiao, Zhao & Qin, 2013). Hence, obtaining optimum route to the desired station(s) will be difficult to achieve. Adding as little as two extra stations to visit in a tour may increase the possible routes to complete the tour significantly (Larose, 2014). Hence, with the use of right RM approach, users will able to plan their route in a more effective way (Li, Zhao, & Zhou, 2016).

SWARM INTELLIGENCE

Beni and Wang introduced the Swarm Intelligence (SI) in 1989 and defined as the emergent collective intelligence of groups (Bonabeau, Dorigo& Theraulaz, 1999). It is also broadly defined as a group of individuals acting collectively in ways that seem intelligent and often inspired by natural or artificial process (Bianchi, Dorigo, Gambardella, & Gutjahr, 2009). Swarm-based algorithms are population-based algorithms that are able to produce low cost, fast, and robust solutions to several complex problems (Panigrahi, Shi & Lim, 2011). The way collective intelligence is used in the colony to make better decisions were many researchers to solve various complex problems especially in engineering, operations and management related fields (Nikolić & Teodorović, 2013; Yuce, Packianather, Mastrocinque, Pham & Lambiase, 2013). Over the years, researchers have used various methods to produce solution to routing and optimization problems. Some of the popular swarm intelligence optimization methods introduced to solve routing problems were inspired by the way birds, fish, ant, bees, termites, bats and fireflies work in group. Optimization algorithms can be defined as methods with the objective to identify the best answer to a problem subject to a set of given constraints (Mastrocinque, Yuce, Lambiase, & Packianather, 2013).

SI is practically a concept where it is inspired by nature and motivated by normal bio systems consist of living things like termites, bees, ants, birds and fish in a populations (Ilie, 2014). SI is also one of the Artificial Intelligence techniques that use the collective behavioural patterns to supportively accomplish a task and widely used to solve many real world problems such as optimization problem, finding optimal routes, scheduling, image and data analysis (Belal, Gaber, El-Sayed & Almojel, 2005; Engelbrecht, 2007). These entities communicate with each other with certain behavioural patterns to execute tasks, in order for them to ensure their survival. These communications can be direct or indirect such as the bee performing a waggle dance or the ant that leaves pheromone trails. One of the most popular and effective SI to solve optimization problem is the bee algorithm.

Due to the capability of SI in solving complex problems, it has been used as an approach to solve optimization problems. Ilie (2014) said heuristic by nature means SI could generate an optimum solution or approximately best solution in reasonable time. SI uses local populations that interact naturally with the environment to generate optimal solutions and two ways communication model to accomplish tasks described as follows :

i) Get better solution, the entities communicate with the environment in order to help each other. For example, Ant Colony Optimization, Bee Colony Optimization

ii) Improve existing starting solutions, the entities will communicate within the solution space of the problem. For example, Particle Swarm Optimization, Cat Swarm Optimization.

Besides, there are characteristics owned by swarming entities identified by Bonabeau and Meyer in 2001 that can help in solving TSP. The entities are:

i) Flexibility where the entities can adapt to environment changing

ii) Robustness when the group can still succeed even though there are one or more entity does not achieve their tasks

iii) Self-organization where the tasks are not mainly controlled or locally supervised.

BEE INSPIRED ALGORITHM

In recent studies conducted by Nikolic and Teodorovic (2014), they highlighted that in order to design an effective transit network, several issues need to be solved in order to increase number of satisfied users and at the same time reduce the total time to complete a tour. The optimal solution of transit network design is difficult to find which makes it fall under the class of hard combinatorial optimization problem. It is difficult to be solved without a proper method applied. The approach presented was designed according to a relatively new optimization and swarm-based algorithm which is based on the bees foraging technique. It is capable of solving deterministic combinatorial problems and combinatorial problems that are characterized by uncertainty (Teodorovic & Orco, 2005). According to the Bee Colony Optimization (BCO) concept proposed by Teodorovic, bees would investigate through the search space for feasible solutions, collaborate and exchange information after each visit to the food source. The collective intelligence enhances the solutions produced by reducing the possibilities and concentrating on more promising areas. Therefore, the solutions can be improvised after every cycle and the final output is more likely to be the best one. Intensification and diversification are the 2 important characteristics of BCO where intensification is the process of selecting the best candidates from the best solutions gathered and diversification is to ensure that the algorithm works efficiently by exploring the search space randomly (Yang, 2014). In general, all bee inspired algorithms have similar concept but modified according to the problems that need to be solved (Table 1).

```
1. Initialization: an empty solution is assigned to every bee
2. For every bee // the forward pass
    i. Set k = 1 // counter for constructive moves in the forward pass
    ii. Evaluate all possible constructive moves
    iii. According to evaluation, choose one move in using the roulette wheel
3. All bees are back to the hive // backward pass starts
4. Evaluate (partial) objective function value for each bee
5. Every bee decides randomly to continue its own exploration and become a recruiter or become a follower
6. For every follower, choose a new solution from recruiter by the roulette wheel
7. If solutions are not completed, Go to Step 2
8. Evaluate all solutions and find the best one
9. If the stopping condition is not met, Go to Step 2
10. Output the best solution found
```

TABLE 01. Bee inspired algorithm

SOURCE.. (Teodorović, Selmic, & Davidovic, 2015)

The general idea of BCO is constructing multi agent system that consists of artificial bees in a colony, where the best solution will be identified during the process of collecting nectar. Bee behaviour in nature has inspired researchers to design various algorithms and solutions to solve difficult combinatorial optimization problems such as TSP (Dušan Teodorovic, 2009). Although several social insect species based algorithms have successfully solved various complex problems, Teodorovic claimed that bee behaviour in nature has inspired more significant solutions to the problems. Bees adapt their behaviour according to the environment to accomplish a task by using collective intelligence (Aghazadeh & Meybodi, 2011). For instance, honeybee colony is distributed in multiple directions for long distances at the same time to find more food sources (Mittal, S., Nirwal, N., & Sardana, 2014). The deployment of its foragers to better fields is the success criteria of the bee colony. The bee colony follows the rules that if the flower was patched with plenty amount of nectar then the flower will be visited by more bees and vice versa. Food and foragers are the two important criteria in a bee system (Baykasoùlu, Özbakır, & Tapkan, 2007).

RAILWAY TRAVELING SALESMAN PROBLEM

Railway Traveling Salesman Problem (RTSP) represents practical extensions of the classic Traveling Salesman Problem in consideration of a railway network and train schedules (Hu & Raidl, 2008). For instance, a salesman uses railway network to visit multiple cities to carry out business, starting and ending at the same station and having the optimal tour (Hadjicharalambous, Pop, Pyrga, Tsaggouris, & Zaroliagis, 2007). The RTSP is NP-hard and it is related to the Traveling Salesman Problem (Pop, Pintea, & Sitar, 2007). Unlike the general concept of TSP, RSTP allows stations to be visited more than once because it is inconvenient to restrict the usage of some backbone stations and to enforce the salesman to take alternative (Hu & Raidl, 2008). The goal of solving RTSP is to find set of train connections that can lead to the reduction of overall travelling time and cost using railway network (Hadjicharalambous et al., 2007; Matai, Singh & Mittal, 2010). In solving RTSP, timetable information comprising data concerning the trains, stations, connecting stations, departure and arrival time of trains at the stations in a RS is needed to generate a useful output. The TSP uses the given railway network and train schedule to minimize the overall journey time (Gonsalves & Shiozaki, 2015).

RESEARCH METHODOLOGY

A novel RM approach has been developed and presented in this paper to help RS users, researchers and business practitioners to identify the steps required to obtain the optimum route to multiple desired destinations in a complex RS network and improve the management of triple constraint in projects that involve routing problems. In the preliminary stage of the research, a survey was conducted to investigate whether the problems identified in the literature review are feasible for research, which helped to assess the effectiveness of users in identifying the optimum route via the RS, without the usage of any tools. The perceptions of different stakeholders on the research topic were explored by analysing the data collected from the survey. Experiment with one hundred RTSP cases was designed by using Malaysia RS datasets to verify and evaluate the efficiency of the approach under a controlled environment. Besides, computational experiment with five hundred TSP cases was conducted to test the reliability of the results generated by the RM approach presented.

NOVEL BEE INSPIRED APPROACH IN RS RM

Solving RTSP by using exhaustive search methods is possible but not practical when possible routes exponentially increased. Due to this reason, none efficient solution to the general case of TSP has been found yet (Osaba, et.al, 2015). In spite of the computational difficulty of the problem, various known techniques have been introduced by researchers to generate the best solution to the problem. The Figure 1 shows the conception view of the way bee work in colony to make a better decision in route planning when they forage. The framework shows in Figure 2 was derived from the concept presented (Figure 1). The framework serves as a guide to identify optimum route to a single or multiple destination via RS.

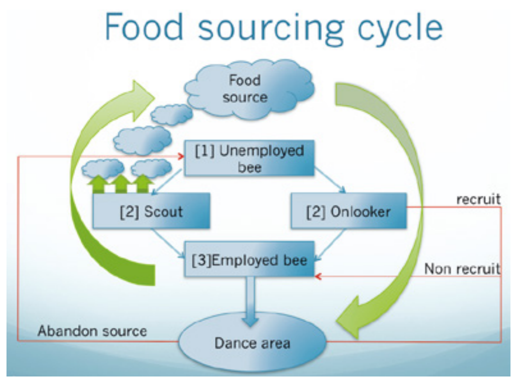


FIGURE 01. Bee concept used to locate the optimum route to multiple stations in the tour

Table 2 shows the symbols and variables used in the framework and Table 3 presents the processes involved in the approach to generate an output.

SYMBOL	NAME	FUNCTION
Y	YES	Process met the condition
N	NO	Process failed to meet the condition
i	Desired station's number	Used to check conditional statement for new path looping
Z	Total number of desired stations	As maximum condition in new path looping
S	Starting point	Indicates starting station/point
G	Desired station(s)	As desired destination/station(s)
IC	Interchange station	Interchange station to explore more possible routes
m, j	Number of possible routes	Indicate number of possible routes
n	Number of spread bees	As number of spread bees
Ns	Differences in number of station between IC to G/ multiple G	In certain situation, used to compare and check which routes is the best
Ts	Differences in time travelled for compared routes	In certain situation, used to compare and check which routes is the best
St	Temporary Starting point	Indicate temporary starting point

TABLE 02. Symbols and variables used in the framework (continues on the next page)

BEE INSPIRED RM FRAMEWORK

The objective function for this mathematical model (MM)(Equation 1) is to find the optimum route that has minimum travel time. This is a summation of T_{SG} and X_{SG}, where SG represents as node S to node G. This summation will keep increasing and repeating until m, where m represents number of stations. Furthermore, the value of X_{SG} depending on the travel time from node S to G is included in the route, that is the shortest travel time in comparison with other routes.

Min

$$Z = \sum^{m}_{S=1} \sum^{m}_{G=1} T_{SG} X_{SG} \quad \text{where } S \neq G \tag{1}$$

Parameter :

m: total number of station

n: number of routes

S: starting point or end station

G: stations that stop or destination

T_{SG}: travel time from node S to node G

X_{SG}: If the travel time for node S to G is included in the route, that is shortest travel time after comparing with other routes, then the value of X_{SG} is 1.

Otherwise, the value of X_{SG} is 0.

T_w: walking time from one station to another station in the interchange

There are the five constraints to be considered in the MM derived from the Framework.

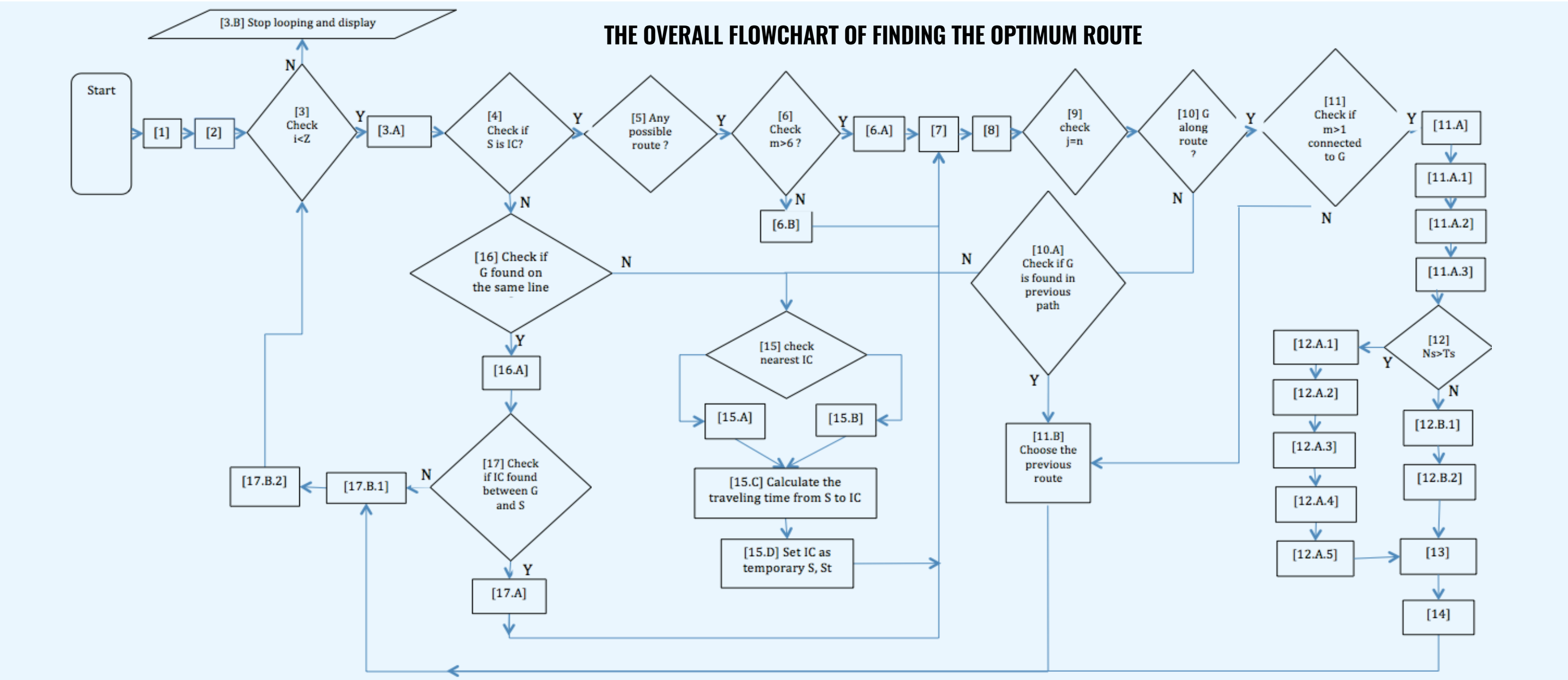

THE OVERALL FLOWCHART OF FINDING THE OPTIMUM ROUTE

FIGURE 02. Flowchart of finding the optimum route

Process	Description
1	Initialization S=starting point and ending point, desired destinations=G, station names and travel time will be stored in the list of T, n denotes as the number of bees spread, total number of desired destinations= Z, number of possible route=m/r.
2	Initialize i as zero.
3	Check conditional statement, repeat until i less than number of desired destination (i < Z).
3.A	Checking line of S
3.B	When all of the processes from [3] is finished, display the list of station that is stored in list T and total time travel calculated.
4	Check whether S is interchange.
5	check number of possible routes, denote as m, Check any possible route.
6	If any possible route, then check whether m is greater than or equal to 6 lines
6.A	If m ≥ 6 lines, then choose partial possible routes randomly, except for G identified
6.B	If m < 6, then choose all possible routes
7	Spread n bees according to explore better routes
8	Initialize j = 0
9	Repeat until j equal to number of possible routes (j=n)
10	Check whether any G along the route
10.A	Check if any G found in the previous path
11	If any G along the route, then check whether more than 1 possible route connected to any G/multiple G
11.A	If more than 1 possible route connected to any G / multiple G, then calculate travel time from IC to G
11.A.1	Check number of station between IC to G/multiple G
11.A.2	Calculate travel time difference for routes, denote as Ts
11.A.3	Calculate the difference in number of station for routes, denote as Ns
11.B	Choose the previous route which G is found
12	Check whether Ns > Ts
12.A.1	If Ns > Ts, then add 1 minute as train stopping time for each route
12.A.2	Calculate temporary travel time for routes from IC to G, denote as t
12.A.3	Compare the temporary travel time
12.A.4	Choose shortest temporary travel time
12.A.5	Calculate travel time (S to IC to G) being chosen, denote as T2
12.B.1	If Ns ≤ Ts, then ignored the train stopping time
12.B.2	Calculate travel time from S to IC to G, denote as T2
13	Compare T1 and T2
14	Choose shortest travel time
15	Check nearest Interchange station IC
15.A	If need to move to another line, then add 5 minute as walking time, denote as T_W
15.B	If NOT needed to move to another line, then neglected 5 minutes as walking time
15.C	Calculate travel time from S to IC
15.D	Set IC as temporary S
16	If S is not an interchange, check whether G is found on the same line
16.A	If G found on the same line as S, then calculate travel time, denote as T1
17	Check whether IC found between G and S
17.A	If IC found between G and S, then check possible routes for G / multiple G in different lines
17.B.1	Record travel time, denote as Tn
17.B.2	Set new starting point as new S

TABLE 03. Processes in the framework

--- 1. Possible routes to desired destinations ---

$$P_i = \begin{cases} \text{number of routes, n,} & N<6 \quad (a) \\ 0.5 * \text{number of routes, n,} & N\geq 6 \quad (b) \end{cases}$$

--- 2. Walking time ---

$$T_{SG} = \begin{cases} T_{SG} + T_w & \text{if walking time to other line} \geq 1 \text{ minute} \\ T_{SG}, & \text{otherwise} \end{cases}$$

--- 3. Stop time at station ---

$$T_{SG} = \begin{cases} T_{SG} + 1 \text{ minute to every station passed as stopping time, if more than 1 route can lead to any G} \\ TSG, \text{ otherwise} \end{cases}$$

--- 4. Obtain the shortest route ---

$$L' = \min\{(X_1, X_2, \ldots, X_n) \mid X_i \in L, \forall\, 1 \leq i \leq n\}$$

5. To include the route into the tour

$$X_{SG} = \begin{cases} 1, \text{ if travel time between node Sto G is included in the route.} \\ 0, \text{ otherwise.} \end{cases}$$

APPLICATION OF RM APPROACH

Railway transport is one of the most commonly used public transportation in Malaysia with more than half a million daily users in year 2014. The number is expected to double when the new lines are ready in the future (Brenda Ch'ng, 2014). Figure 3 shows the map of the Malaysia network used in the verification experiment and there are 104 stations connected in the RS network.

The Table 4 and Table 5 explain how the approach is applied to solve one of the cases in the verification experiment conducted.

SURVEY AND EXPERIMENT DATA ANALYSIS

In response to the 5 questions (Appendix A) which is related to the way one hundred respondents chose the optimum route based on their own assumption and experience, it is apparent that most of one hundred respondents failed to choose the best answers. Figure 6 presents number of respondents who managed to choose the optimum routes and Figure 7 summarize the overall results obtained related to route planning and optimization questions.

95 results generated by using the presented matched the exact solutions (Figure 8). The high percentage of matched results in the experiment shows that the solutions are efficient in solving the RTSP.

FINDINGS

Planning ahead journey to multiple destinations is essential especially to business practitioners and

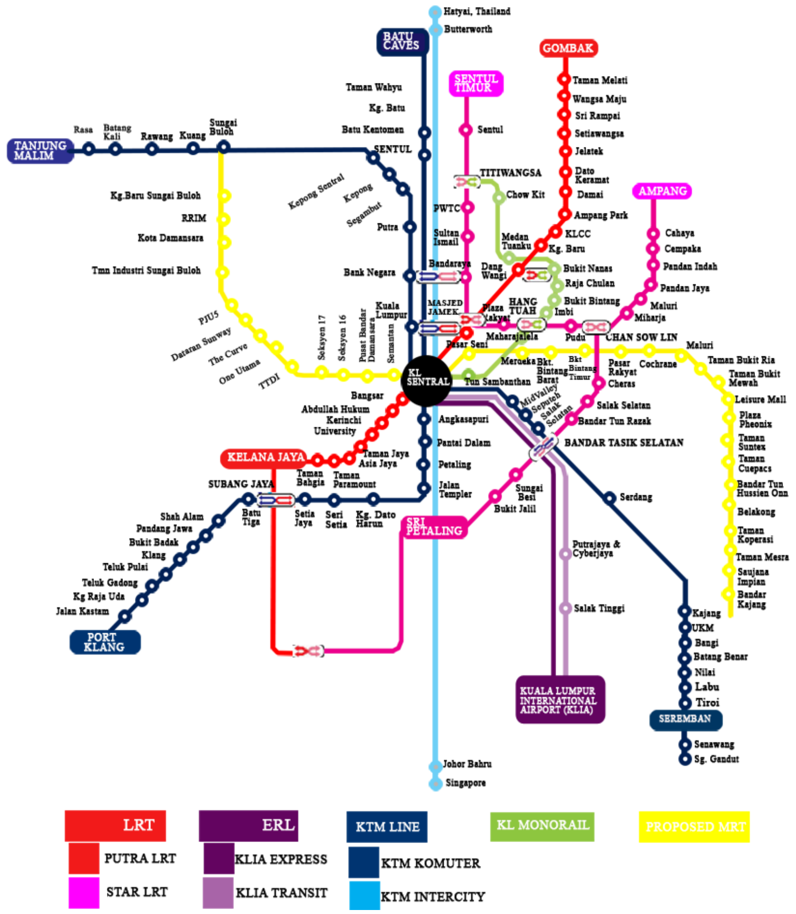
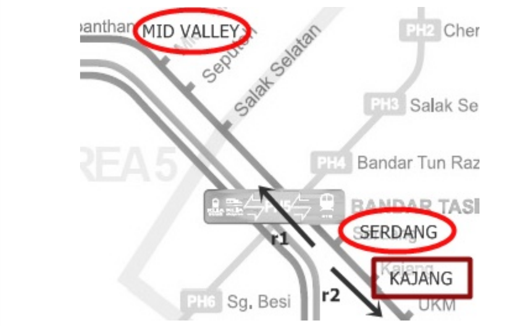


FIGURE 03. Malaysia RS Map

STARTING POINT	Starting point, S 1= Kajang Desired destinations, G = Mid Valley, Serdang, KL Sentral
PROCESS [1]: INITIALIZATION	Case 1 consists of 3 desired destinations, G, which are Serdang, Mid Valley and KL Sentral, with Kajang as the starting and end point.
PROCESS [2]: INITIALIZE I = 0	Initialization of the looping process is needed to ensure all destinations are reached before going back to the starting point.
PROCESS [3]: CHECK i < Z IS TRUE	Number of G in the tour is 3. Thus, Z = 3 If this condition is true, repeat all the next processes. Since i = 0 and it is less than Z = 3, this condition will return true.
PROCESS [3.A]: CHECKING LINE OF S1	From the case given, starting point,S1 is Kajang which was identified as KTM Seremban - Rawang line.
PROCESS [4]: CHECK STATION TYPE OF S1 WHETHER IS INTERCHANGE OR NOT	The S1, Kajang station is not interchange.
PROCESS [16]: IF IS NOT INTERCHANGE, THEN CHECK WHETHER G IS FOUND ON THE SAME LINE.	Referring to the map, bees can move up or down the KTM Seremban - Rawang line, thus the number of possible route, n, is 2. There are 2 possible routes from Kajang, S1. Desired destination Serdang, (G1) is found on the same line. Abandon.

TABLE 04. Solving RTSP in Experiment With RM Approach (cont.)

PROCESS [16.A]: CALCULATE TRAVEL TIME, DENOTE AS T1	Travel time from Kajang to Serdang is 600 seconds. T1 = 600 seconds
PROCESS [17]: CHECK WHETHER IC FOUND BETWEEN	**Process [17.B.1]**: If IC is NOT found between S1, Kajang and G1, Serdang , then record travel time, T1 **Process [17.B.2]**: Set G1, Serdang as new starting point, S2 Serdang, is set as a new starting point, S2 Repetition (S2 = Serdang)
PROCESS [3]: I = I + 1	Number of G in the tour is 3. Thus, Z = 3 i = 0 + 1 = 1 and it is less than Z = 3, this condition will return true.
PROCESS [3.A]: CHECKING LINE OF S2	From the case given, starting point, S2 is Serdang which was identified as the KTM Seremban - Rawang line.
PROCESS [4]: CHECK STATION TYPE OF S2 WHETHER IS INTERCHANGE	The S2, Serdang station is not interchange
PROCESS [16]: IF IS NOT INTERCHANGE, THEN CHECK WHETHER G IS FOUND IN SAME LINE	Yes, found G2=Mid Valley on the same line. New starting point, is Serdang which was identified as the KTM Seremban -Rawang line. Referring to the map, bees can move up or down the blue line, thus the number of possible route, n, is 2. There are 2 new possible routes from r1 and r2. So, 2 bees were sent to these routes to find the desired destinations. Along r1,G2= Mid Valley is found and the solution will return true and move on to the next process. There is no G found in r2 and there is no interchange down the route. Therefore, this route r2 is abandoned



PROCESS [16.A]: CALCULATE TRAVEL TIME, DENOTE AS T2	Travel time from Serdang to MidValley is 600 seconds. T2 = 1380 seconds
PROCESS [17]: CHECK WHETHER IC FOUND BETWEEN S2 AND G2	Interchange (IC1) Bandar Tasik Selatan is found before G2 **Process [17.A]**: Check possible routes to G or multiple G
PROCESS [7]: SPREAD N BEES ACCORDING TO EXPLORE BETTER ROUTES	There are 4 alternative routes, m, from Bandar Tasik Selatan (IC1).

TABLE 04. Solving RTSP in Experiment With RM Approach (cont.)

PROCESS [8]:	Initialization j= 0
PROCESS [9]:	Check j = n is true
PROCESS [10]: CHECK ANY G IS FOUND FROM BANDAR TASIK SELATAN, NO G FOUND.	**Process [10.A]:** Check any G is found from the previous route? Yes, G2, Mid Valley is found on the previous route.
PROCESS [11.B]: CHOOSE THE PREVIOUS ROUTE WHICH HAS FOUND G.	Choose route which G2, Mid Valley is found. G is not found on any of the alternative routes.
PROCESS [17.B.1]:	Follows current solution, record time traveled, T2 = 1380 seconds
PROCESS [17.B.2]:	Mid Valley, G2 is set as a new starting point, S3. Repetition (S3= Mid Valley)
PROCESS [3]: I = I + 1	Number of G in the tour is 3. Thus, Z = 3 i = 1 + 1 = 2 and it is less than Z =3, this condition will return true
PROCESS [3.A.1]: CHECKING LINE OF	From the case given, starting point is Mid Valley and it is on the blue line which was identified as the KTM Seremban - Rawang line.
PROCESS [4]: CHECK STATION TYPE OF S3 WHETHER IS INTERCHANGE	The S3, Mid Valley station is not interchange
PROCESS [16]: IF IS NOT INTERCHANGE, THEN, CHECK WHETHER G IS FOUND IN SAME LINE	New starting point, , is Mid Valley which was identified as the KTM Seremban -Rawang line. Referring to the map, bees can move up or down the KTM Seremban - Rawang line, thus the number of possible route, n, is 2. There are 2 new possible routes from Mid Valley, which are r1 and r2. So, 2 bees are sent to these routes to find the desired destinations. Along r1,G3= KL Sentral is found and return true and move on to the next process. There is no G found in r2 and there is no interchange down the route. Therefore, this route r2 is abandoned.

PROCESS [16.A]: IF G FOUND ON THE SAME LINE AS S, THEN CALCULATE TRAVEL TIME, DENOTE AS T3	Travel time 300 seconds. T3 = 300 seconds.
PROCESS [17]: CHECK WHETHER IC FOUND BETWEEN G AND S3	No IC found between S3,Mid Valley and G3, KL Sentral.
PROCESS [17.B.1]:	If IC is NOT found between G and S , then record travel time, T3
PROCESS [17.B.2]:	Set new starting point as S4 New = KL Sentral, Repetition (S4= KL Sentral)

TABLE 04. Solving RTSP in Experiment With RM Approach (cont.)

PROCESS [3]: I = I + 1	Number of G in the tour is 3. Thus, Z, i = 2 +1 = 3 Since i = 3 and it is equal to 3, this condition (i < Z) will return false. Thus, it will go to process [3.B].
PROCESS [3.B]: DISPLAY LIST T AND CALCULATE TRAVEL TIME	After all desired destinations are found, generate output in a list. The list will include the starting and end point.
RETURN TRIP:	All desired destinations are found. Identify optimum return route. Since the initial starting point and all the desired destinations are on the same line and no station transfer occurred, the return trip follows the same route. **Solution Obtained by Framework in Experiment 1 Case 1:** Solution Routes = Kajang → Serdang → Mid Valley → KL Sentral → Kajang **Total time** = (T1 + T2 + T3) seconds + return trip (2280 seconds) = (600 + 1380 + 300) seconds + return trip (2280 seconds = 4560 seconds

TABLE 04. Solving RTSP in Experiment With RM Approach

STARTING POINT	Starting point and end point, S: Jalan Templer (RD15). Desired destination (s), G: Petaling (RD16), Pasar Seni (KJ14), Salak Selatan (BL11) Start from RD15, it has 3 numbers of routes and placed in set L, L= N = 3

1)	First Constraint, number of routes is less than 6, thus using probability (a) • First probability P_1= n = 3 • Choose all the routes
2)	Excluded third constraints, there is no more than 1 route can lead to G for each possible route.

TABLE 05. Experiment Case Solved With Bee Inspired RM Mathematical Model (cont.)

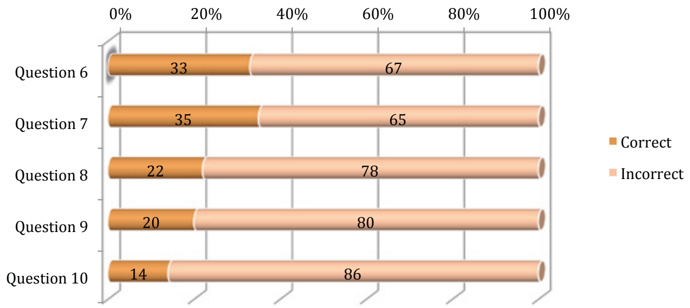
3)	Fourth Constraint all the routes become possible routes and placed in set L' • $L' = \min \{X_1, X_2, X_3 \mid X_i \in L, \forall\ 1 \le i \le 3\}$, $X\_1 = T_{RD15,RD16}$ $X\_2 = T_{RD15,KJ14}$ $X\_3 = T_{RD15,BL11}$ • $L' = \min \{T_{RD15,RD16}, T_{RD15,KJ14}, T_{RD15,BL11}\}$ $= \min \{120, 1206, 1980$ $= 120$ In the set L', the shortest travel time is 120 seconds and it will include in the total traveling time. Also, the 120 seconds will be assign in$T_{RD15,RD16}$, • ChooseX$_1$, and record travel time, $T_{RD15,RD16} = 120$ because it is shortest travel time • Record station name, $L'_1 = X_1 = T_{RD15,RD16}$
4)	Fifth constraint, • $S_{RD15,RD16} = 1, S_{BRD15,KJ14} = 0, S_{RD15,BL11} = 0$ **Repeat:** Start from RD16, it has 2 possible routes, placed all the routes in set L, L= N = 2 = $\{X_1, X_2\}$
1)	First Constraint, number of routes is less than 6, thus using probability (a) • First probability $P_2 = n = 2$ • Choose all the routes
2)	Excluded third constraints, there is no more than 1 route can lead to G for each possible route.
3)	Fourth Constraint all the routes become possible routes and placed in set L' • $L' = \min \{X_1, X_2 \mid X_i \in L, \forall\ 1 \le i \le 2\}$ $X_1 = T_{RD16,KJ14}$ $X_2 = T_{RD16,BL11}$ • $L' = \min \{T_{RD16,KJ14}, T_{RD16,BL11}\}$ $= \min \{1086, 1860\}$ $= 1086$ In the set L', the shortest travel time is 1086 seconds and it will include in the total traveling time. Also, the 1380 seconds will be assign in$T_{RD16,KJ14}$, ChooseX$_1$, and record travel time, $T_{RD16,KJ14} = 1086$ because it is shortest travel time. Record station name, $L'_2 = X_1 = T_{RD16,KJ14}$
4)	Fifth constraint, $S_{RD16,KJ14} = 1, S_{RD16,BL11} = 0$ **Repeat:** Start from KJ14, it only has 1 possible route and placed all the routes in set L, L= N=1
1)	First constraint, number of routes less than 6, thus using probability (a) • First probability $P_3 = n = 1$ • Choose all the routes
2)	Excluded third constraints, because there is only single route to reach BL14
3)	Fourth Constraint, all the routes become possible routes and placed in set L' • $L' = \{X_1\}$ $X_1 = T_{KJ14,BL11}$ • $L' = \min \{T_{KJ14,BL11}\}$ $= \min \{1026\}$ $= 1026$

TABLE 05. Experiment Case Solved With Bee Inspired RM Mathematical Model (cont.)

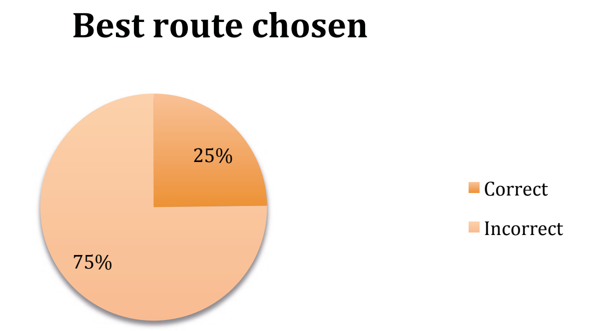
3) (CONT.)	In the set L', the shortest travel time is 1026 seconds and it will include in the total traveling time. Also, the 1026 seconds will be assign in $T_{KJ14,BL11}$, ChooseX$_1$, and record travel time, $T_{KJ14,BL11} = 1026$, because it is single route from KJ14 to BL11. Record station name, $L'_3 = X_1 = T_{KJ14,BL11}$
4)	Fifth constraint, $S_{KJ14,BL11} = 1$ **Return trip:** Start from BL11, no station transfer occurred and thus the return trip follows the same route.
1)	First constraint, number of routes less than 6, thus using probability (a) • First probability $P_4 = n = 1$ • Choose all the routes
2)	Excluded third constraints, because there is only single route to reach RD15
3)	Fourth Constraint, all the routes become possible routes and placed in set L' • $L' = \{X_1\}$ $X_1 = T_{BL11,RD15}$ • $L' = \min \{ T_{BL11,RD15}\}$ $= \min \{1980\}$ $= 1980$ In the set L', the shortest travel time is 1980 seconds and it will include in the total traveling time. Also, the 1980 seconds will be assign in $T_{BL11,RD15}$, ChooseX$_1$, and record travel time, $T_{BL11,RD15} = 1980$, because it is single route from BL11 to RD15. Record station name, $L'_4 = X_1 = T_{BL11,RD15}$
4)	Fifth constraint, $S_{BL11,RD15} = 1$
MATHEMATICAL MODEL:	$Z = {}_{TRD15,RD16}\ S_{RD15,RD16} + T_{RD15,KJ14}\ S_{RD15,KJ14} + T_{RD15,BL11}\ S_{RD15,BL11} + T_{RD16,KJ14}\ S_{RD16,KJ14} + T_{RD16,BL11}\ S_{RD16,BL11} + T_{KJ14,BL11}\ S_{KJ14,BL11} + T_{BL11,RD15}\ S_{BL11,RD15}$ $= (120)(1) + (1206)(0) + (1980)(0) + (1086)(1) + (1860)(0) + (1026)(1) + (1980)(1)$ $= 4212$ By using the mathematical model, the shortest traveling time of the route is 24minute. According to mathematical model, the shortest route represent are $L'_1 \rightarrow L'_2 \rightarrow L'_3 \rightarrow L'_4$, Where $L'_k = T_{SG}$ $T_{RD15,RD16} \rightarrow T_{RD16,KJ14} \rightarrow T_{KJ14,BL11} \rightarrow T_{BL11,RD15}$ $T_{Jalan\ Templer,Petaling} \rightarrow T_{Petaling,Pasar\ Seni} \rightarrow T_{Pasar\ Seni,Salak\ Selatan} \rightarrow T_{Salak\ Selatan,Jalan\ Templer}$ **Display station name**: Jalan Templer-Petaling-Pasar Seni-Salak Selatan-Jalan Templer

TABLE 05. Experiment Case Solved With Bee Inspired RM Mathematical Model

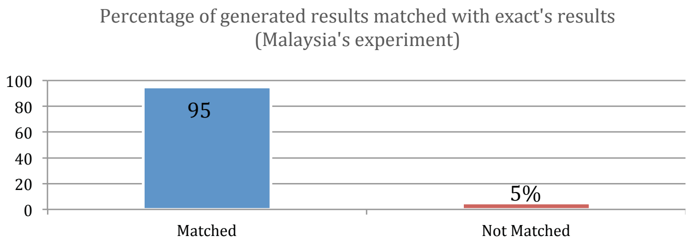
tourists around the world. Such Planning can be an exhausting ordeal but unplanned journey could lead to longer total travel time and directly increase the cost of traveling. The action of planning might sound simple but without a proper planner or tool, the process of determining the optimal route will never be easy and might not even serve the purpose. The results showed the approach was capable of generating results similar to exact solution as presented in Figure 8. This proved that the approach used to solve RTSP could generate highly reliable results in cases with different complexity. The finding has significant implications for the understanding of how swarm intelligence can be used to solve complex problems and serve as a base for future studies in complex routing and optimization problems. However, these findings could not be extrapolated to all RS in the world due to various constraints that will affect the reliability of the solutions. The experiment was successful as it managed to demonstrate that the effectiveness of the model in solving the routing problem discussed. Further studies, which take these variables into account, can be undertaken to enhance the algorithm so it can be applied in different RS network without much modification. The solutions generated will be more reliable if real time data can be obtained by leveraging big data and Internet of Things (IoT).



FUGIRE 06. Respondents capability in identifying optimum route via RS



FUGIRE 07. Percentage of best route chosen by the respondents



FUGIRE 08. The Percentage of matched exact method results

FUTURE USE OF IOT IN RM

The solution presented were converted to a program and operated as intelligent system to monitor and control the railway system traffic with the use of IoT. The solution has been tested by using smart devices (Raspberry Pi) to capture live data in the stations before sending to local processing module. Google Vision cloud service was used to capture data required such as when the trains arrive, how long was the stop time and traffic of the station by using deep learning method to improve the output generated. Raspberry Pi worked as mini computer that processed the data locally by performing classification of data obtained before sending to the cloud server via the Internet. Once the cloud server received the data, the values were assigned to the program with algorithm derived from the presented framework for route analysis purposes. The MM with IoT can be presented as in Equation 2 subject to capacity of the train. This constraint directly enhanced processes labeled [4] and [10] in the framework. It ensured recommendation to transfer will not increase the overall traveling time and reduce the quality of the tour.

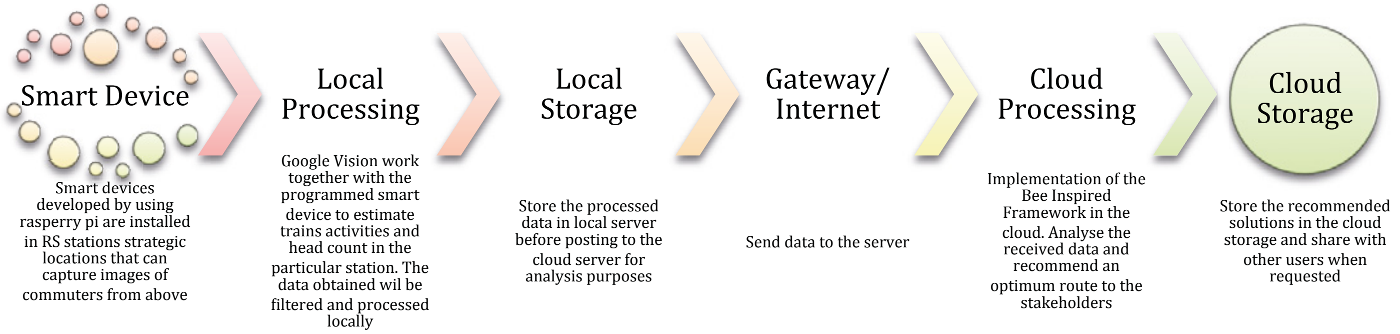
$$Z = \sum^{m}_{S=1} \sum^{m}_{G=1} T_{SG}\ X_{SG} + NTWZT \text{ , where } S \neq G \quad (2)$$

NTWT = Waiting time for the next available train

Tensorflow library was used to process and convert the data to valuable information (recommended solutions to the stakeholders) before storing in the cloud server for future and machine learning purposes. Figure 8 shows high-level diagram of the solution with the use of IoT to improve the reliability and quality of the results with real time data.

CONCLUSION

The paper presented a novel RM approach that can be beneficial to business practitioners in enhancing the supply chain and RS transportation users who travel in a complex network with hundreds of stations and interchanges. Besides of serving as a future reference on the subject of SI in transportation planning and scheduling, the potential of using bee intelligence in solving complex approximation and routing problems was uncovered. The research demonstrated that bee concept works effectively in RS route planning and could be groundbreaking approaches that will change the way people solve other related optimization problems. This research also strengthened the idea that approach is highly customizable and reliable comparing to the exact methods that require higher computational time and resources. Most importantly, the findings help to uncover critical areas in the RS route optimization that many researchers have not explored and provide opportunity to advance the understanding how swarm intelligence such as bees can be used in route planning and optimization. ◆



FUGIRE 09. Integration of IoT and RM Approach

• AUTHORS •

KAH HUO LEONG is working as Chief Operation Officer with WebDev International Group, one of the top IT development and eCommerce Consultancy companies in Asia. With more than 15 years experience in managing medium to large scale ICT projects, he has served as IT and eCommerce consultant to Fortune 500, medical groups in USA and Europe, public listed companies and government agencies in Australia, Singapore and Malaysia. His major area of interest include swarm intelligence, logistics and transportation optimisations, operations research, knowledge and information management, machine learning, artificial intelligence, ICT project management, search engine optimisation, decision and management science. He is a Ph.D. in Project Management candidate at International University of Malaya and Wales, Kuala Lumpur, Malásia.

PROF. DR. HAMZAH ABDUL-RAHMAN Dip.Bldg (UiTM), BSc.(Hons) Central Missouri State University, M.Sc. University of Florida, PhD University of Manchester Institute of Science and Technology, FRICS, MCIOB, MIVMM, is currently the Vice-Chancellor of the International University of Malaya-Wales(IUMW), which is one of the world's first Malaysia-British university among research led universities. He has served as the Deputy Vice Chancellor (Research & Innovation), University of Malaya and a full professor in the Faculty of Built Environment, University of Malaya. He has served as the Deputy Vice Chancellor for Development and Estate Management in charge of development policies and construction projects from 1996 to 2003, and the Deputy Vice Chancellor (Academic & International) from 2009-2010 in University of Malaya. He holds a PhD degree from the University of Manchester Institute of Science and Technology (UMIST, UK), M.Sc. from University of Florida and BSc. (Hons) from Central Missouri State University, Dip. Bldg (UiTM). His research interests include the construction innovation & sustainability, green buildings, project & facility management, building energy efficiency, industrialized building system (IBS), and renewable energy application in buildings, supported by his vast publications. He is also a fellow member of the Chartered Institute of Surveyors, United Kingdom (International).

PROF. DR. CHEN WANG is Professor of Huaqiao university and Faculty of Built Environment, University of Malaya. He was a senior engineer of China State Construction Engineering Corporation (CSCEC), which is the main contractor of the 2008 Olympics Beijing National Aquatics Center known as "Water Cube". His research interests include Vertical Greenery System (VGS), Mathematics Modeling for Civil Engineering, swarm intelligence, Ant Colony Optimization (ACO), Fuzzy-QFD, Tensile Membrane Steel Structure, Vertical Greenery Systems, Repertory Grid, sustainability in construction management, international BOT projects, energy conservation, and building integrated solar application, supported by his vast publications. He is an IEEE member (U.S.), RICS member (U.K.), and also a perpetual member of The Chinese Research Institute of Construction Management (CRIOCM), Hong Kong (International).

SIAW-CHUING LOO is a senior lecturer at the Department of Quantity Surveying, University of Malaya, Kuala Lumpur. Before becoming an academic, she was a quantity surveyor with an international consultancy conglomerate specializing in construction cost and contract management. She was involved in both private residential and commercial projects and large scale government facility projects. She obtained both her MSc in building and PhD in construction and project management from the University of Malaya. Her research interests are in project management, risk assessment, international construction, construction and building materials and construction research trends.

• REFERENCES •

Adulyasak, Y., Cordeau, J.-F., & Jans, R. (2015). The production routing problem: A review of formulations and solution algorithms. Computers & Operations Research, 55(C), 141–152. http://doi.org/10.1016/j.cor.2014.01.011

Aghazadeh, F., & Meybodi, M. R. (2011). Learning Bees Algorithm For optimization. 2011 International Conference on Information and Intelligent Computing, 18, 115–122.

An. (2016). Xinhua Insight: China-Europe railway to drive cross-border e-commerce - Xinhua | English.news.cn. Retrieved November 4, 2016, from http://news.xinhuanet.com/english/2016-10/25/c_135780112.htm

Awasthi, A., Adetiloye, T., & Crainic, T. G. (2016). Collaboration partner selection for city logistics planning under municipal freight regulations. Applied Mathematical Modelling, 40(1), 510–525. http://doi.org/10.1016/j.apm.2015.04.058

Azadeh, A., Ghaderi, S. F., & Izadbakhsh, H. (2008). Integration of DEA and AHP with computer simulation for railway system improvement and optimization. Applied Mathematics and Computation, 195(2), 775–785. http://doi.org/10.1016/j.amc.2007.05.023

Baykasoùlu, A., Özbakır, L., & Tapkan, P. (2007). Artificial Bee Colony Algorithm and Its Application to Generalized Assignment Problem. Swarm Intelligence:Focus on Ant and Particle Swarm Optimization (Vol. 1).

Belal, M., Gaber, J., El-Sayed, H. & Almojel, A. (2005). Swarm Intelligence. Handbook of Bio-Inspired Algorithms and Applications, Chapman & Hall/CRC, 7, 55–62.

Bianchi, L., Dorigo, M., Gambardella, L. M., & Gutjahr, W. J. (2009). A survey on metaheuristics for stochastic combinatorial optimization. Natural Computing, 8(2), 239–287. http://doi.org/10.1007/s11047-008-9098-4

Bonabeau, E., Dorigo, M., & Theraulaz, G. (1999). Swarm intelligence: from natural to artificial systems. Oxford university press.

Brenda Ch'ng. (2014). Building of new MRT second line to begin next November. The Star. Retrieved from http://www.thestar.com.my/news/community/2014/12/03/building-a-new-%09%09artery-mrt-corp-says-work-on-second-line-to-begin-next-november/

C**hristopher, M.** (2016). Logistics & supply chain management. Pearson Higher Ed. Retrieved from https://books.google.com.my/books?hl=en&lr=lang_en&id=NIfQCwAAQBAJ&oi=fnd&pg=PT7&dq=Christopher,+M.+(2016).Logistics+%26+supply+chain+management.+Pearson+Higher+Ed.&ots=x1a3DvFkkA&sig=TFf_zY1QDpmryvYUgnW3ZVauOLY&redir_esc=y#v=onepage&q&f=false

Danesh, Z. (n.d.). Modelos y métodos de la distribución de mercancías. bibing.us.es. Retrieved from http://bibing.us.es/proyectos/abreproy/70067/fichero/Thesis del master-Zoha Danesh.pdf

Devaki, P., Prabhakar, P. M., & Kumar, S. M. (2016). Easy Searching of Train Details by Railway Route Optimization System. IJITR, (4), 2841–2843.

Engelbrecht, A. (2007). Computational intelligence: an introduction. Retrieved from https://books.google.com/books?hl=en&lr=&id=IZosIcgJMjUC&oi=fnd&pg=PR7&dq=Computational+Intelligence:+An+Introduction,+2nd+Edition&ots=D-vnAxbEqMj&sig=xGeQq5nVdYWfzaojMhuVNqyDXUg

Gonsalves, T., & Shiozaki, T. (2015). Solving Capacity Problems As Asymmetric Travelling Salesman Problems. International Journal of Artificial Intelligence & Applications (IJAIA), 6(2), 53–65.

Hadjicharalambous, G., Pop, P., Pyrga, E., Tsaggouris, G., & Zaroliagis, C. (2007). The Railway Traveling Salesman Problem. Optimization, 104, 264–275.

Hernandez, S., & Monzon, A. (2016). Key factors for defining an efficient urban transport interchange: Users' perceptions. Cities, 50, 158–167. http://doi.org/10.1016/j.cities.2015.09.009

Hu, B., & Raidl, G. R. (2008). Solving the railway traveling salesman problem via a transformation into the classical traveling salesman problem. Proceedings - 8th International Conference on Hybrid Intelligent Systems, HIS 2008, 73–77. http://doi.org/10.1109/HIS.2008.30

Ilie, S. (2014). Survey on distributed approaches to swarm intelligence for graph search problems. Annals of the University of Craiova, Mathematics and Computer Science Series, 41(2), 251–270.

Ito, Y., & Okuda, T. (2016). Tokyo to test subway system for parcel delivery service�The Asahi Shimbun. Retrieved February 28, 2017, from http://www.asahi.com/ajw/articles/AJ201609080004.html

Jr, T. U. G. (2015). Exploring the Emerging Impact of Metro Rail Transit (MRT-3) in Metro Manila. International Journal of Advanced Science and Technology, Vol. 74, 11–24. Retrieved from http://www.earticle.net/Article.aspx?sn=239145

Larose, A. R. (2014). Planning for Passenger Rail in Small Cities and Towns, (February).

Li, P., Zhao, Y., & Zhou, X. (2016). Displacement characteristics of high-speed railway tunnel construction in loess ground by using multi-step excavation method. Tunnelling and Underground Space Technology, 51(October), 41–55. http://doi.org/10.1016/j.tust.2015.10.009

Mastrocinque, E., Yuce, B., Lambiase, A., & Packianather, M. S. (2013). A multi-objective optimization for supply chain network using the bees algorithm. International Journal of Engineering Business Management, 5(1), 1–11. http://doi.org/10.5772/56754

Matai, R., Singh, S. P., & Mittal, M. L. (2010). "Traveling Salesman Problem : An Overview of Applications, Formulations, and Solution Approaches."

Mittal, S., Nirwal, N., & Sardana, H. (2014). Enhanced artificial bees colony algorithm for traveling salesman problem. Journal of Advanced Computing and Communication Technologies, (2), 2–4.

Nikolić, M., & Teodorović, D. (2013). Transit network design by bee colony optimization. Expert Systems with Applications,.

Panigrahi, B. K., Shi, Y., & Lim, M. H. (Eds.). (2011). Handbook of swarm intelligence: concepts, principles and applications (Vol. Vol. 8).

Pop, P. C., Pintea, C. M., & Sitar, C. P. (2007). An ant-based heuristic for the railway traveling salesman problem. In Workshops on Applications of Evolutionary Computation, 702–711.

Qiao, K., Zhao, P., & Qin, Z. P. (2013). Passenger route choice model and algorithm in the urban rail transit network. Journal of Industrial Engineering and Management, Vol. 6. Retrieved from http://www.jiem.org/index.php/jiem/article/view/595/358

Stevens, G., & Johnson, M. (2016). Integrating the Supply Chain… 25 years on. International Journal of Physical Distribution & Logistics Management.

Teodorovic, D. (2009). Bee Colony Optimization (BCO). Optimization, 39–60.

Teodorovic, D., & Dell' Orco, M. (2005). Bee Colony Optimization-Cooperative Learning Approach to Complex Transportation Problems. Advanced OR and AI Methods in Transportation, 51–60. Retrieved from http://216.108.236.130/ewgt/16conference/ID161.pdf

Teodorovic, D., & Nikolic, M. (2013). Expert Systems with Applications Transit network design by Bee Colony Optimization, 40(May), 5945–5955. http://doi.org/10.1016/j.eswa.2013.05.002

Teodorović, D., Selmic, M., & Davidovic, T. (2014). Bee Colony Optimization Part II: The Application Survey. Yugoslav Journal of Operations Research, 25(1), 185–218. http://doi.org/10.2298/YJOR131029020T

Tseng, Y., Yue, W. L., & Taylor, M. A. P. (2005). The role of transportation in logistics chain. Eastern Asia Society for Transportation Studies, 5, 1657–1672. http://doi.org/10.1017/CBO9781107415324.004

Vromans, M. J. C. M. (2005). Reliability of Railway Systems.

Yang, X.-S. (2014). Nature-inspired optimization algorithms.

Young, J. (2014). Mass Transit in 19th- and 20th-Century Urban America, (December), 1–15. Retrieved from http://doi.org/10.1093/acrefore/9780199329175.013.28

Yuce, B., Packianather, M. S., Mastrocinque, E., Pham, D. T., & Lambiase, A. (2013). Honey bees inspired optimization method: the Bees Algorithm.Insects, 646–662.

Zhu, Y.-T., Mao, B.-H., Liu, L., & Li, M.-G. (2015). Timetable Design for Urban Rail Line with Capacity Constraints. Discrete Dynamics in Nature and Society, 2015, 1–11. http://doi.org/10.1155/2015/429219
