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Research article

A Walking Route to Travel in Lopburi City

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Abstract: This article was a part of a research paper to present a walking route to travel in Lopburi City. It was to be the shortest distance of path and use the least travel time. The research methodology used the survey of 10 real locations together with viewing satellite maps and diagrams from Google.go.th/maps for graphing and weighting of edges (distance; time). The result analysis used the basic ideas of graph theory by finding the path that has all the vertex and the ideas of matrix by finding the adjacency matrix for verification using Gephi program. The result of the research showed that a suitable walking route to travel in Lopburi City was to be as follows: *Wat Puen* → *Ban Wichayen* → *Prang Khaek Temple* → *King Narai the Great Museum* → *Wat Phrasi Rattana Mahathat* → *Wat Bandai Hin* → *Wat Inthra* → *Wat Nakhon Kosa* → *Phra Kal Shrine* → *Phra Prang Sam Yot* (and reverse direction) with a total distance of 2,090 meters in 25 minutes.

Keywords: Graph theory; The adjacency matrix; A path; Gephi

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1. Introduction

Lopburi Province has a wide variety of tourist attractions, both natural attractions, and historical attractions, and historical tourism is very popular in all parts of Thailand nowadays. People were especially fond of watching movies or dramas and going on historical tours often took pictures that correspond to the stories from real historical places. Lopburi Province has many historical attractions known in the past as Lawo City, which in the reign of King Narai the Great who lived and built the remaining buildings to be seen today. In addition, there are many historical attractions in Lopburi such as Phra Kan Shrine, Phra Prang Sam Yot, Ban Wichayen, Wat Puen, Prang Khaek Temple, King Narai the Great Museum, Wat Phra Sri Rattana Mahathat, Wat Nakhon Kosa, Wat Bandai Hin and Wat Inthra, etc. The historical attractions in Lopburi are not far from each other and can be visited within a day's walk. If Lopburi has publicized it to the public in advance, it will be helpful to make decisions about choosing and traveling to all places. This article presents a suitable walking route for exploring the history of Lopburi. Which is the best walking path? How far is it and how long does it take to walk?

2. The purpose of this research is to find suitable walking route for historical tourism in Lopburi Province.

3. Background

3.1 Ten cultural and heritage attractions in Lopburi city

Fig1 (A). Phra Kan Shrine

Fig 1 (B). Phra Prang Sam Yot

Fig 1 (C). Ban Wichayen or Ban Luang) Royal House for ambassadors)

Fig 1 (D). Wat Puen

Fig 1 (E). Prang Khaek Temple

Fig 1 (F). Wat Phra Sri Rattana Mahathat

Fig 1 (G). King Narai the Great Museum

Fig 1 (H). Wat Nakhon Kosa

Fig 1 (I). Wat Bandai Hin

Fig 1 (J). Wat Inthra

Fig 1 (A) to Fig 1 (J) cited on Punthupun [1] as follows:

Fig 1 (A): Phra Kan Shrine is well known to the people of Lopburi Province.

Fig 1 (B): Phra Prang Sam Yot is an archaeological site and one of the important historical sites of Lopburi.

Fig 1 (C): After people watched the drama "Buppesanniwad", Ban Wichayen became popular.

Fig 1 (D): Wat Puen is an ancient temple in Lopburi.

Fig 1 (E): Prang Khaek Temple is considered to be one of the oldest Khmer castles in Lopburi.

Fig 1 (F): Wat Phra Sri Rattana Mahathat had been renovated many times both during the reign of King Narai the Great, King Ramesuan and His Majesty the Great Emperor.

Fig 1 (G): King Narai the Great Museum formerly known as a museum. In these buildings, antiques from prehistoric times to the Rattanakosin period are displayed, found in Lopburi and

nearby provinces as well as displaying various utensils that represent the way of life of the people in the central basin.

Fig 1 (H): A religious site that overlaps many times was originally a Khmer temple. There is a pagoda in the Lopburi style, around the 17th century in front.

Fig 1 (I): From the evidence that appears, Wat Bandai Hin is assumed that this temple was definitely built during the reign of King Narai.

Fig 1 (J): Wat Inthra is an ancient site located within the inner city wall.

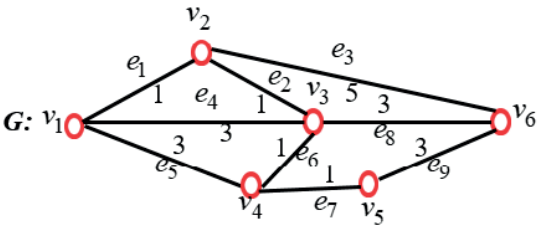
3.2 *Basic concepts of graph theory*

We apply the graph theory [2,3,4,5] to brief basic ideas as follows:

Graph G consists of finite sets $V(G)$ that is not an empty set and a set $E(G)$ can be an empty set. The member of $V(G)$ is denoted by v_i called the vertex, the member of $E(G)$ is denoted e_i as the edge, for each by i; $i \in \{1,2,3,...,k\}$

If then $|V(G)| = n$ the graph G is an ordered graph n, that is, the graph G has a number of n points.

If then $|E(G)| = m$ the graph G is a graph with size m, that is, the graph G has m lines. From the figure, for example, graph G:



$$V(G) = \{v_1, v_2, v_3, v_4, v_5, v_6\}$$
$$E(G) = \{e_1, e_2, e_3, e_4, e_5, e_6, e_7, e_8, e_9\}$$
$$|V(G)| = 6$$
$$|E(G)| = 9$$

The degree of point v_i in graph G is the number of lines that hit the point v_i in graph G

Weight of edge in each line of the graph G, there is a real number denoted by these real numbers called "Line weight" is written as $w(e_i)$

The weight of the graph G is denoted by $w(G)$; $w(G) = \sum_{e_i \in E(G)} w(e_i)$

If u and v are defined as points in the graph G

Walk $u - v$ in Graph G is a sequence of points and lines, where $u - v : u = u_0, \quad e_1, u_1, e_2, u_2, e_3, ..., u_{k-1}, e_k, u_k = v$ of line $e_i = u_{i-1} u_i \in E(G)$ for each by i; $i \in \{1,2,3,...,k\}$

Length of walk $u - v$ is the number of lines in the walk $u - v$

Trail $u - v$ as in graph G as walk $u - v$ as in graph G that do not have the same lines in the same walking path

Path $u - v$ as in graph G as walk $u - v$ as in graph G no duplicate point $u - v$

Circuit as in graph G, it is a closed walkway in the graph G (A closed trail is a walk that goes back to the starting point).

Cycle as in graph G is cycling in graph G which has no duplicate point except the starting point and the last point are the same point substituted by C which

$C : u = u_0, u_1, u_2, ..., u_{k-1}, u_k = u; u_i \neq u_j$ for each i, j by $k \geq 3$ and $1 \leq i < j \leq k$

Distance between u and v in graph G is the shortest length of $u - v$ compared to the length of the path $u - v$ all in graph G substituted by $d_G(u,v)$ as graph G:

3.3 *Algorithm of Graph to about shortest walk*

I. Munier et al. [6] suggested that the steps involved in Kruskal's Algorithm to generate a minimum spanning tree (MST):

Step 1: Sort all edges in increasing order of their edge weights.

Step 2: Pick the smallest edge.

Step 3: Check if the new edge creates a cycle or loop in a spanning tree.

Step 4: If it doesn't form the cycle, then include that edge in MST. Otherwise, discard it.

Step 5: Repeat from step 2 until it includes |V| - 1 edges in MST.

II. Abhilasha [7] suggested that the steps involved in Prim's Algorithm to generate a minimum:

Step 1: Determine the arbitrary starting vertex.

Step 2: Keep repeating steps 3 and 4 until the fringe vertices (vertices not included in MST) remain.

Step 3: Select an edge connecting the tree vertex and fringe vertex having the minimum weight.

Step 4: Add the chosen edge to MST if it doesn't form any closed cycle.

Step 5: Exit

III. Gray & Ping [3] introduce a path is a trail in which neither vertices nor edges are repeated we have compared three algorithms to find the shortest walk in the analysis a walking route to travel in Lopburi City.

3.4 *The ideas of matrix*

A matrix is a representation of data in the form of numbers or numbers. It consists of columns (vertical) and rows (horizontal). The matrix shows the relationship between two variables [8-9].

The adjacency matrix of graph G substituted by $A(G)$ is the matrix size $n \times n$ by

$$A(G)=\left[a_{ij}\right]_{n\times n} \text{ and } a_{ij}=\begin{cases}1 & \text{If } v_i \text{ close to } v_j\\ 0\end{cases}$$

If the graph G is written in the form of an adjacency matrix by adding weights to the adjacent points, it can be written as follows:

$$A(W(G))=\begin{array}{c} \\ v_1\\ v_2\\ v_3\\ v_4\\ v_5\\ v_6\end{array}\begin{array}{c}\begin{array}{cccccc} v_1 & v_2 & v_3 & v_4 & v_5 & v_6\end{array}\\ \begin{bmatrix} 0 & 1(1) & 1(3) & 1(3) & 0 & 0\\ 1(1) & 0 & 1(1) & 0 & 0 & 1(5)\\ 1(3) & 1(1) & 0 & 1(1) & 0 & 1(3)\\ 1(3) & 0 & 1(1) & 0 & 1(1) & 0\\ 0 & 0 & 0 & 1(1) & 0 & 1(3)\\ 0 & 1(5) & 1(3) & 0 & 1(3) & 0\end{bmatrix}\end{array}$$

3.5 *Gephi*

Gephi is a free and open-source, graph network, display program that supports real-time data and graph display.

3.5.1 The Gephi method is divided into three parts as follows: 1) Community detection isolates data into related groups using modularity. 2) Centrality is the most centralization of a social network by means of Degree Centrality, Betweenness Centrality, and Closeness Centrality. 3) Find the shortest path between two nodes under the graph, that is, in the shortest path, the sum of the weights on each edge adds up to the shortest of all paths.

3.5.2 The Gephi features consist of three modes: 1) Mode 1 Overview is the mode of displaying the graph based on the input data in Mode 2 and selecting the shortest distance operation from two nodes and other operations using the mouse to click on. 2) Mode 2 Data Laboratory is an Excel-like data entry mode where point values (node) and edge are entered. This mode can process data to be used to find Degree Centrality, Betweenness, Centrality, and Closeness Centrality. And 3) Mode 3 Preview is a mode that shows the physical characteristics of the data such as size, color of points and size, color, weight of lines, etc [10].

4. Research Methodology

4.1 Research Instruments

4.1.1 Satellite map: google.co.th/maps to be displayed in a graph

4.1.2 The concept of graph theory uses paths (walks with no duplicate walking points) to find walkways that pass through every point. And three algorithms use to compare in finding the shortest walk in the analysis of walking. The adjacency matrix concept is used to determine the weight of a line (distance and time) to find the shortest path and the shortest time from the adjacent point. In addition, the Gephi program is used to check the resulting graph that the direction and path of travel are correct or not including checking the weight of the line (distance and time).

4.2 Research Method: The research process is divided into 6 phases:

4.2.1 Study the research documents of tourist attractions in Lopburi.

4.2.2 Explore the real location of the walking trails for sightseeing in Lopburi.

4.2.3 Calculate the distance and time it takes to walk for sightseeing in Lopburi by comparing it with google.co.th/maps.

4.2.4 Walking path for tourism in downtown Lopburi was analyzed by using the paths graph theory and adjacency matrix together with the Gephi examination.

4.2.5 Summarize suitable walking routes in Lopburi.

4.2.6 Public relation of A Walking Route to Travel in Lopburi City to The Public Relations Office Lopburi Province

(The researcher has submitted a reguest for public relation of a walking route to travel in lopburi city to The Public Relations Office Lopburi Province. And it has published walking routes for tourism in Lopburi a via Facebook fanpae on August 20, 2020.)

4.3 Data Collection Method

4.3.1 Show a satellite map of 10 tourist attractions in Lopburi from google.co.th/maps in schematics and satellite maps.

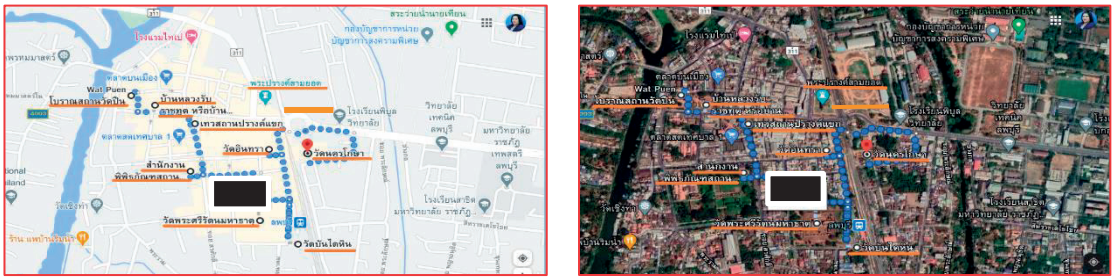


Figure 2. Satellite map of tourist attractions in Lopburi [11]

4.3.2 Measure the distance and time it takes to walk for sightseeing in Lopburi from google.co.th/maps as shown in Figure 1 together with the measurement of distance and time from the actual location.

4.3.3 Create a graph of the location of 10 attractions in Lopburi City and a route showing distance and time (meters; minute).

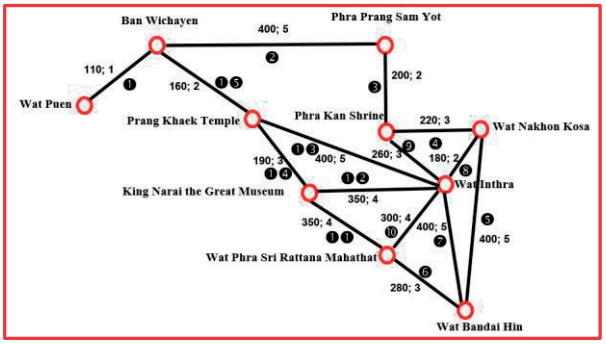


Figure 3. Graph showing walking routes for tourism in Lopburi (Distance (m); time (min))

4.4 Analysis

Watthanasiripong et al. [12] conducted research by visiting 9 temples on a trip to Ayutthaya. The Khruskhal's algorithm was then applied to the minimum spanning tree to find the travel route with the shortest distance to complete the worship trip.

● Use the path analysis of the graph with every places walking by Kruskal's Algorithm and Prim's Algorithm to find the shortest path is as follows.

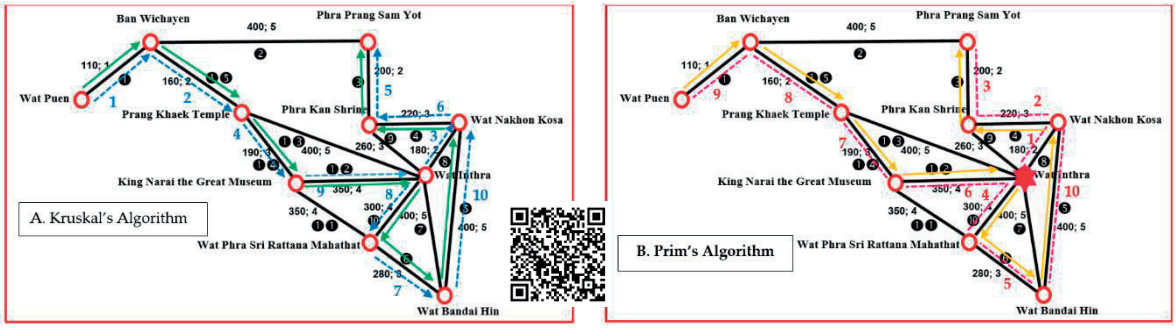


Figure 4. Graph showing walking routes for tourism in Lopburi by Kruskal's Algorithm (A) and Prim's Algorithm (B)

Wat Puen ⟶ *Ban Wichayen* ⟶ *Prang Khaek Temple* ⟶ *King Narai the Great Museum* ⟶ *Wat Inthra* ⟶ *Wat Phra Sri Rattana Mahathat* ⟶ *Wat Bandai Hin* ⟶ *Wat Nakhon Kosa* ⟶ *Phra Kan Shrine* ⟶ *Phra Prang Sam Yot*

With distance $110+160+190+350+300+280+400+220+200=2{,}210$ m.

● Use the path analysis of the graph with every walking way and the adjacency matrix that considers adjacent points to find the shortest path is as follows.

4.4.1 A suitable walking route for traveling in Lopburi without losing general meaning. The starting point at Wat Puen has the following path:

1. *Wat Puen* ⟶ *Ban Wichayen* ⟶ *Prang Khaek Temple* ⟶ *King Narai the Great Museum* ⟶ *Wat Phra Sri Rattana Mahathat* ⟶ *Wat Bandai Hin* ⟶ *Wat Inthra* ⟶ *Wat Nakhon Kosa* ⟶ *Phra Kan Shrine* ⟶ *Phra Prang Sam Yot*

With distance $110+160+190+350+280+400+180+220+200=2{,}090$ m.

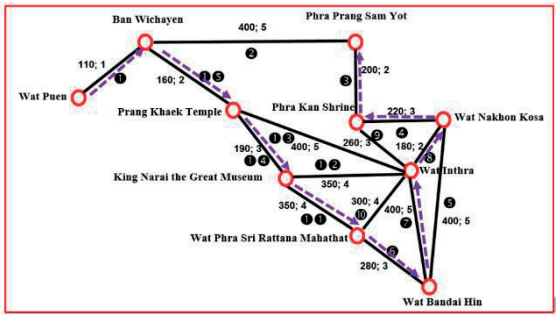


Figure 5. Graph showing walking routes for tourism in Lopburi by a path's Algorithm

2. *Wat Puen* ⟶ *Ban Wichayen* ⟶ *Prang Khaek Temple* ⟶ *King Narai the Great Museum* ⟶ *Wat Phra Sri Rattana Mahathat* ⟶ *Wat Bandai Hin* ⟶ *Wat Nakhon Kosa* ⟶ *Wat Inthra* ⟶ *Phra Kan Shrine* ⟶ *Phra Prang Sam Yot*

With distance $110+160+190+350+280+400+180+260+200=2{,}130$ m.

Therefore, path 1 of the walking graph by a path for tourism in Lopburi, 10 places with all walking lines. It is the shortest path with a distance of 2,090 meters and considering the adjacency matrix can be shown as follows:

	Puen	*Wichayen*	*Phra Pang*	*Prang Khaek*	*Phra Kal*	*Nakorn Kosa*	*Museum Lopburi*	*Wat Inthra*	*Mahathat*	*Bandai Hin*
Puen	0	1(110)	0	0	0	0	0	0	0	0
Wichayen	1(110)	0	1(400)	1(160)	0	0	0	0	0	0
Phra Pang	0	1(400)	0	0	1(200)	0	0	0	0	0
Prang Khaek	0	1(160)	0	0	0	0	1(190)	1(400)	0	0
Phra Kal	0	0	1(200)	0	0	1(220)	0	1(260)	0	0
Nakorn Kosa	0	0	0	0	1(220)	0	0	1(180)	0	1(400)
Museum Lopburi	0	0	0	1(190)	0	0	0	1(350)	1(350)	0
Wat Inthra	0	0	0	1(400)	1(260)	1(180)	1(350)	0	1(300)	1(400)
Mahathat	0	0	0	0	0	0	1(350)	1(300)	0	1(280)
Bandai Hin	0	0	0	0	0	1(400)	0	1(400)	1(280)	0

4.4.2 The suitable walking route for traveling in Lopburi in terms of time without losing general meaning the starting point at Wat Puen has the following path:

1. *Wat Puen* ⟶ *Ban Wichayen* ⟶ *Prang Khaek Temple* ⟶ *King Narai the Great Museum* ⟶ *Wat Phra Sri Rattana Mahathat* ⟶ *Wat Bandai Hin* ⟶ *Wat Inthra* ⟶ *Wat Nakhon Kosa* ⟶ *Phra Kan Shrine* ⟶ *Phra Prang Sam Yot* for $1+2+3+4+3+5+2+3+2=25$ minutes

2. *Wat Puen* ⟶ *Ban Wichayen* ⟶ *Prang Khaek Temple* ⟶ *King Narai the Great Museum* ⟶ *Wat Phra Sri Rattana Mahathat* ⟶ *Wat Bandai Hin* ⟶ *Wat Nakhon Kosa* ⟶ *Wat Inthra* ⟶ *Phra Kan Shrine* ⟶ *Phra Prang Sam Yot* for $1 + 2 + 3 + 4 + 3 + 5 + 2 + 3 + 2 = 25$ minutes

Therefore, the walking route graph for tourism in Lopburi province, 10 places, all places, all routes the shortest path takes 25 minutes. The distance in path 1. was chosen because it is the shortest. And consider the adjacency matrix as follows:

	Puen	*Wichayen*	*Phra Pang*	*Prang Khaek*	*Phra Kal*	*Nakorn Kosa*	*Museum Lopburi*	*Wat Inthra*	*Mahathat*	*Bandai Hin*
Puen	0	1(1)	0	0	0	0	0	0	0	0
Wichayen	1(1)	0	1(5)	1(2)	0	0	0	0	0	0
Phra Pang	0	1(5)	0	0	1(2)	0	0	0	0	0
Prang Khaek	0	1(2)	0	0	0	0	1(3)	1(5)	0	0
Phra Kal	0	0	1(2)	0	0	1(3)	0	1(3)	0	0
Nakorn Kosa	0	0	0	0	1(3)	0	0	1(2)	0	1(5)
Museum Lopburi	0	0	0	1(3)	0	0	0	1(4)	1(4)	0
Wat Inthra	0	0	0	1(5)	1(3)	1(2)	1(4)	0	1(4)	1(5)
Mahathat	0	0	0	0	0	0	1(4)	1(4)	0	1(3)
Bandai Hin	0	0	0	0	0	1(5)	0	1(5)	1(3)	0

4.4.3 Verification using Gephi

4.4.3.2 Checking the graph

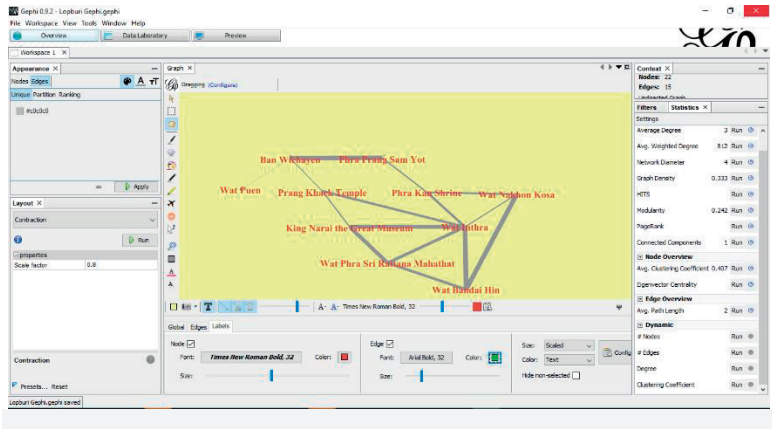


Figure 6. Graph showing walking routes for tourism in Lopburi by Verification using Gephi

Checking the graph obtained from the Gephi has a similar pattern to the graph obtained by drawing the graph with the actual site survey data and the data from the google.co.th/ maps.

4.4.3.2 Checking the data

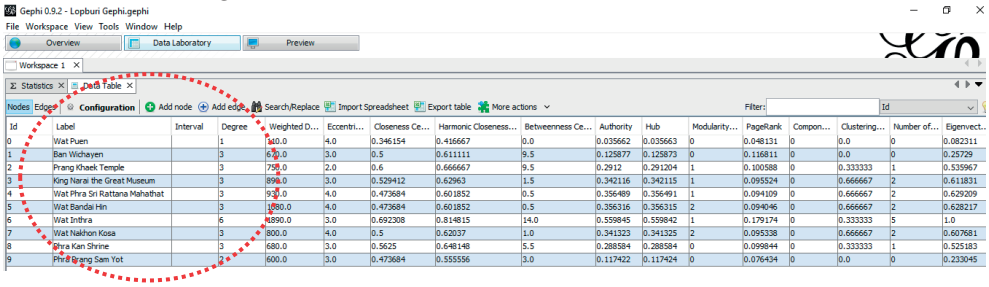


Figure 7. Graph showing distance, degrees, and weights by verificaiton using Gephi

Distance data entered into Gephi, degrees, and weights of each graph corresponding to the graph obtained using graph theory analysis.

5. Results

The walking route for tourism in Lopburi has a walking distance of 2,090 meters and takes 10 places in 25 minutes to reach 10 places

When analyzing the data obtained from the basic concepts of graph theory and matrix concepts, with satellite maps and schematics from google.co.th/maps Along with exploring the real place, the suitable walking routes for traveling in Lopburi are as follows:

1. If arriving by private car, bus (where parking is available), or train, it is best to start from *Phra Prang Sam Yot* $\longrightarrow$ *Phra Kan Shrine* $\longrightarrow$ *Wat Nakhon Kosa* $\longrightarrow$ *Wat Inthra* $\longrightarrow$ *Wat Bandai Hin* $\longrightarrow$ *Wat Phra Sri Rattana Mahathat* $\longrightarrow$ *King Narai the Great Museum* $\longrightarrow$ *Prang Khaek Temple* $\longrightarrow$ *Ban Wichayen* $\longrightarrow$ *Wat Puen*

2. If traveling by motorcycle may start from no. 1 above or start from *Wat Puen* $\longrightarrow$ *Ban Wichayen* $\longrightarrow$ *Prang Khaek Temple* $\longrightarrow$ *King Narai the Great Museum* $\longrightarrow$ *Wat Phra Sri Rattana Mahathat* $\longrightarrow$ *Wat Bandai Hin* $\longrightarrow$ *Wat Inthra* $\longrightarrow$ *Wat Nakhon Kosa* $\longrightarrow$ *Phra Kan Shrine* $\longrightarrow$ *Phra Prang Sam Yot*

Both routes have a total walking distance of 2,090 meters and a total walking time of 25 minutes to each location (does not count the distance and visit time at each location).

6. Discussion and Conclusion

6.1 *Discussion*

Research trends in graph theory applied to multiple dimensions such as architecture, Tourism, medical, transportation, etc [13,14]. Similarly, this research presents the application of graph theory in the form of a combination of computer programming technology to more than examine the reliability of mathematical proofs. The Lopburi walking route graph is a path graph with 10 walking points and 9 routes corresponding to the definition of a path graph, that is, a graph with order n and size $n-1$

If set P_n as a path graph *Which* $n \geq 1$ *by (distance) between* u *and* G *in graph* v *is the shortest length of* $u-v$ *comparing with path* $u-v$ *all in graph* G *substituted by* $d_G(u,v)$

Because the walking route graph for tourism in the city of Lopburi contains a path. *Wat Puen* $\rightarrow$ *Ban Wichayen* $\rightarrow$ *Prang Khaek Temple* $\rightarrow$ *King Narai the Great Museum* $\rightarrow$ *Wat Phra Sri Rattana Mahathat* $\rightarrow$ *Wat Bandai Hin* $\rightarrow$ *Wat Inthra* $\rightarrow$ *Wat Nakhon Kosa* $\rightarrow$ *Phra Kan Shrine* $\rightarrow$ *Phra Prang Sam Yot* which is the shortest path, The graph must not be longer than 9.

6.2 *Conclusion*

6.2.1 In this research, the resulting graph is not a cycle graph. The starting point and the ending point, if it is the same point, must repeat the same route at the location of *Wat Puen* $\leftrightarrow$ *Ban Wichayen.*

6.2.2 If the resulting graph is a cycle graph, It can compare to the algorithm of the traveling salesman problem [15].

6.2.3 This research uses an adjacency matrix to find paths that walk to adjacent locations.

6.2.4 In this research, the resulting graph has 10 points. Using the path, nine walking routes are obtained.

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Author Contributions:

1. Nisara Suthisung 70%
   1.1) Introduction 0% 1.2) The purpose of this research 0% .3) Background 12.5% 1.4) Research Methodology 30% 1.5) Results 10% 1.6) Discussion and Conclusion 10% 1.7) Acknowledgments 2.5% 1.8) References 5%
2. Sukjit Tangcharoen 30% 2.1) Introduction 10% 2.2) The purpose of this research 2.5% 2.3) Background 17.5% 2.4) Research Methodology 0% 2.5) Results 0% 2.6) Discussion and Conclusion 0% 2.7) Acknowledgments 0% 2.8) References –

Remark: % instead of research study, synthesis and analysis for presenting the writing and editing of research articles

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Conflicts of Interest: -

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