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Application of Prim Algorithm to an Electricity Network in Cimahi

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Abstract: Prim's algorithm is an algorithm that is applied to determine the minimum spanning tree to optimize a network. In this research, the Prim algorithm will be applied to minimize the length of electrical cables used in an electricity distribution network. The data needed to build an initial model is the number of electricity poles on an electricity network, the position of the electricity poles, and the length of the cable connecting the two electricity poles. The electricity network used is in the management area of PT. PLN UP3 Cimahi, West Java. This initial model is represented by a weighted connected graph, where an electricity substation or an electricity pole is a vertex and an electricity cable connecting two electricity poles is an edge in the graph. The weight of this graph is the length of the cable. After the Prim algorithm is run on this graph, the minimum spanning tree is obtained which is the shortest length of electrical cable needed to connect all electricity poles, namely 1258.05 meters. When compared to the length of the existing cable that is being used, which is 1275.86 meters, the results of this study provide a cable efficiency of 17.81 meters. Thus, it is expected to provide cost efficiency arising from the price of the cable and its installation costs. This result is expected to provide input to PT. PLN UP3 Cimahi as an energy efficiency effort launched by the government.

Keywords: electricity network, optimization, prim algorithm, weighted connected graph

Introduction

Theoretically, Prim's algorithm is used to obtain a minimum spanning tree from a graph. So, this algorithm does not aim to produce closed routes or routes that contain cycles. Therefore, the application of the Prim algorithm is used in optimization problems that do not require closed routes, for example fiber optic networks (Iqbal et al., 2017; Suhika et al., 2020), multi-period installations (Wamiliana et al., 2020), fuzzy environments (Dey & Pal, 2016), or electricity networks in power system (Łukaszewski et al., 2022).

In this study, the Prim algorithm will be applied to optimize the electricity network in an area in Cimahi, by minimizing the length of the electricity cables used. The minimum length of the cable will minimize the resistance caused by the cable and also minimize the cost of both the price of the cable and its installation. Therefore, the electrical cable network will be optimal if the length of the cable used is minimal.

This electrical network is represented by a simple and finite graph. So, this graph does not contain two edges for the same two vertices and does not contain a loop for a vertex. More specifically, this graph is called the initial model graph G. Graph G is a connected graph and its edges have weights, so it is called a weighted connected graph. Meanwhile, this weight is the length of the electric cable that connects two electric poles. The shortest length of electrical cable obtained from the process in this algorithm is a minimum spanning tree. A spanning tree of a graph is a subgraph that contains all the vertices, but not necessarily all the edges in the graph (Chartrand et al., 2016), so that the graph does

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not contain a cycle. A minimum spanning tree is a spanning tree with minimum possible total edge weights (Medak, 2018).

In 2020, Pop et al. (2020) have compiled a structure on the definition of the minimum spanning tree, its variations and practical applications, aspects of complexity, integer programming formulations, exact and heuristic solution approaches developed to solve this problem. Then, in 2021 the problem of finding a spanning tree of a set of moving points in the plane has been studied by Akitaya et al. (2021) by minimizing the maximum total weight or the maximum bottleneck throughout the motion. The total weight is the sum of Euclidean distances between edge endpoints (Akitaya et al., 2021). The Minimum Spanning Tree problem (MST) in population diversity optimization measured from the sum of pairs of edge overlaps has been studied by Bossek & Neumann (2021) in the context of evolutionary computation the calculation of diverse sets of high-quality solutions to a given optimization problem.

In addition, the study of the minimum spanning tree also includes the principles of the uncertainty theory with indeterminate problem parameters (Majumder et al., 2022), the Capacitated Minimum Spanning Tree with Arc Time Windows (CMSTP_ATW) (Kritikos & Ioannou, 2021), the Lagrangian relaxation approach (Carrabs & Gaudioso, 2021), and the probabilistic method for resolving computational issues in the Ant Colony Optimization Algorithm (ACOA) (Niluminda & Ekanayake, 2022), the internet of things network lifetime and energy issues (Doryanizadeh et al., 2021), the Euclidean minimum spanning tree problem in an imprecise setup (Dey et al., 2021), the network topology of the stock market in Poland during the COVID-19 pandemic (Tomeczek, 2022).

Method

The initial model constructed in this case is a weighted connected graph as a representation of the electric cable network in the area of Kota Mas, Cimahi. A vertex in this graph is a substation or electric pole, while an edge in this graph is a piece of electric cable. Because this graph is a connected graph, so all electric poles are connected by this cable piece. This graph might contain a cycle, but this graph is not a complete graph because of some considerations in the installation of electric cables in the customer residential area. These considerations include, the electric cable cannot be installed by crossing a house or a building or a garden that interferes with customer privacy. Thus, the electric cable only crosses the edge of the road.

Actually, the electric current is distributed starting from the substation marked as vertex 1, towards the electrical substation, as shown in Figure 1. However, this research aims to find the tree with the shortest cable so that all the poles are connected, so this corresponds to finding the minimum spanning tree on a connected weighted graph. Meanwhile, Prim's algorithm is a precise and effective algorithm for finding the minimum spanning tree in a weighted connected graph. Therefore, for this case the Prim algorithm was chosen for the solution, although the way to find the minimum spanning tree does not always start from the substation as the starting point. In the method described below, the starting point is a electricity pole and not a electricity substation.

The existing spanning trees that have been used in electricity distribution in this area are shown in Figure 1. This spanning tree contains 29 edges with a length of 1275,86 meters. With the aim of optimizing, in this research, edges have been added as realistic and possible alternatives according to the considerations mentioned above, for customer convenience.

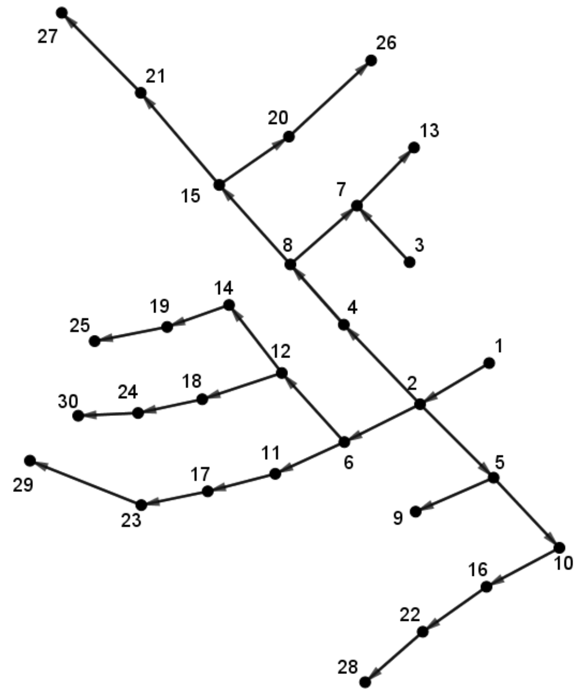

Figure 1. The Existing of The Spanning Tree

The Prim algorithm works on the initial model graph to determine the shortest path that connects all vertices, so that the minimum spanning tree is obtained with a minimum total weight. Prim algorithm to determine the minimum spanning tree from a weighted connected graph is stated as follows: "*For a weighted connected graph G(V, E) with the order n, a minimum spanning tree is built by taking any vertex* u_1 *in G, then an edge with a minimum weight that is incident on vertex* u_1 *is chosen as an* $(u_1, v_1) = e_1$ *of tree T. To obtain* $e_2, e_3, \dots, e_{n-1}$*, an edge was chosen with the minimum weight that was incident on exactly one vertex on tree T* ".

This statement can be written as steps as proposed by Djafar & Ibrahim (2017) in determining priorities for maintaining city road routes with minimal costs and Krishna & Kumar (2021) in improving cluster-based optimal energy-efficient routing in WSN. The steps of the Prim algorithm can be written as follows. First Step: take any vertex u_1 in G, insert it into the T; Second Step: select the edge $(u_1, v_1) = e_1$ that has the minimum weight and incident on the vertex in T, but the edges and vertices in T do not form a cycle in T. Add an edge $(u_1, v_1) = e_1$ to T; Third Step: repeat the second step (n – 1) times.

```
PRIM(V, E, w, r)
Q ← Ø
for each u ∈ V
    do key[u] ← ∞
       π[u] ← NIL
       INSERT(Q, u)
DECREASE-KEY(Q, r, 0)    ▷ key[r] ← 0
while Q ≠ Ø
    do u ← EXTRACT-MIN(Q)
       for each v ∈ Adj[u]
           do if v ∈ Q and w(u, v) < key[v]
                 then π[v] ← u
                      DECREASE-KEY(Q, v, w(u, v))
```

Figure 2. Pseudo-Code of Prim Algorithm

The number of steps in the Prim algorithm is $1 + (n - 1) = n$, which is as many edges as there are in the spanning tree with n vertices. Furthermore, the steps in the Prim algorithm to determine the minimum spanning tree can be learned from the pseudo-code stated by Corment et al. (2022). This is shown in Figure 2. The symbol V is a set of vertices, E is a set of edges, w is a weight function, and r is a root or a vertex of the graph $G(V, E)$.

The initial model constructed from 32 pieces of cable and 30 electric poles. Thus, this initial model is a connected weighted graph constructed from 32 edges and 30 vertices as shown in Figure 3. In this case, 3 edges are added, namely edge (1, 3), (8, 14), and (29, 30).

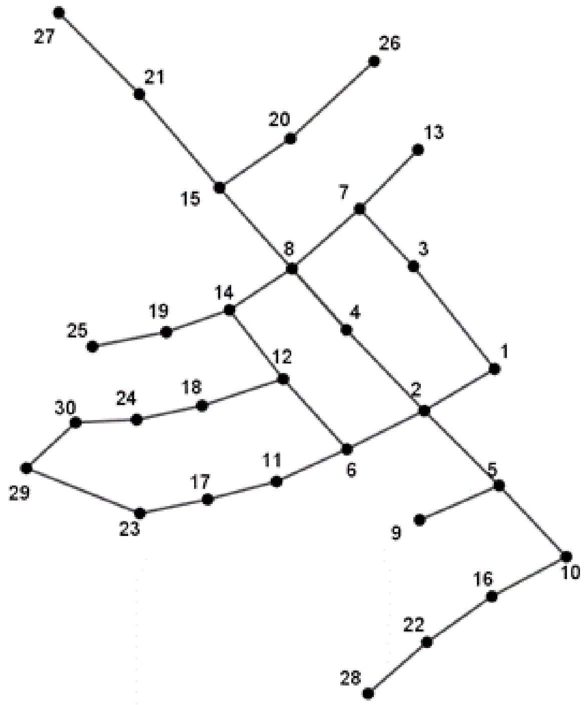

Figure 3. Graph G as The Initial Model

The weighted data for each edge in this graph is shown in Table 1, namely the length of the electrical cable in meters. For example, edge (2, 4) is an edge with a length of 53.26 meters connecting vertex 2 and 4. Meanwhile, there is no edge (2, 3) connecting points 2 and 3, because conditions in the field do not allow a cable to be installed connecting pole 2 and pole 3.

Table 1. The weight of the edges

Edge	Weight	Edge	Weight	Edge	Weight
(1, 2)	54.47	(7, 8)	50.54	(16, 22)	34.39
(1, 3)	63	(7, 13)	41.51	(17, 23)	36.5
(2, 4)	53.26	(8, 14)	45.5	(18, 24)	26.25
(2, 5)	50.09	(8, 15)	47.75	(19, 25)	22.75
(2, 6)	51.29	(10, 16)	44.5	(20, 26)	43.56
(3, 7)	35.17	(11, 17)	32.4	(21, 27)	68.35
(4, 8)	38.53	(12, 14)	43.87	(22, 28)	37.35
(5, 9)	41.85	(12, 18)	36.32	(23, 29)	50.3
(5, 10)	54.97	(14, 19)	31.72	(24, 30)	34.47
(6, 11)	41.95	(15, 20)	54.87	(29, 30)	40.25
(6, 12)	48.53	(15, 21)	68.35		

Then, the next model is built by running the Prim Algorithm as shown in the following figures, so that a minimum span tree T is obtained. The first and second steps of Prim's algorithm for obtaining T from a connected weighted graph G are as follows:

First step: Take any vertex in the connected weighted graph G, such as vertex 8. So, vertex 8 is in the tree T. Vertex 8 is colored blue.

Second step: Mark the edges that incident on vertex 8 with dotted line segments. Choose an edge that incident on vertex a8 with a minimum weight, namely edge (8, 4) with a minimum weight of 38.53 meters. Thus, edge (8, 4) and vertices {8, 4} are in tree T. Edge (8, 4) and vertex a are colored blue.

The results of the two steps above are shown in the following Figure 4 and Figure 5.

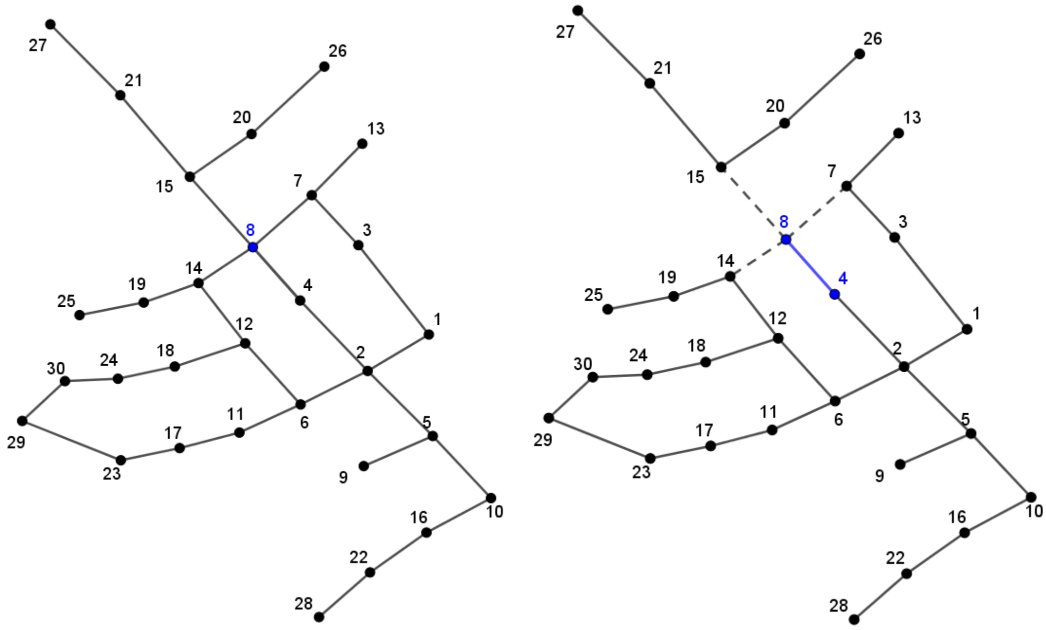

Figure 4. Graph *G* in The First and Second Step of Algorithm Prim

The next step is a repetition of the second step 29 times. Here are steps 23 and 26, along with figures from the corresponding graphs.

23^{rd} step. Before the 23^{rd} step in the Prim algorithm was executed, the number of vertices in the G graph that had not yet entered the T tree was as many as 8 vertices. These vertices are {10, 16, 20, 21, 22, 26, 27, 28}. After selecting an edge that incident on exactly a vertex in {1, 2, 3, …, 30} except for a vertex in {10, 16, 20, 21, 22, 26, 27, 28} with minimum weight. Obtained edge (5, 10) with a minimum weight of 54.97 meters. So, vertex 10 and edge (5, 10) are in the tree T and they are colored blue. The graph of the results of step 23^{rd} is shown by the figure on the left below. Thus, the vertices that are in the T tree are {1, 2, 3, ..., 9, 11, …, 15, 17, 18, 19, 23, 24, 25, 29, 30}.

26th step. Before the 26th step in the Prim algorithm was executed, the number of vertices in the G graph that had not yet entered the T tree was as many as 5 vertices. These vertices are {20, 21, 26, 27, 28}. After selecting an edge that incident on exactly a vertex in {1, 2, 3, …, 30} except for a vertex in {20, 21, 26, 27, 28} with minimum weight. Obtained edge (22, 28) with a minimum weight of 37.35 meters. So, vertex 28 and edge (22, 28) are in the tree T and they are colored blue. The graph of the results of step 26^{th} is shown by the figure on the right below. Thus, the vertices that are in the T tree are {1, 2, 3, ..., 9, 11, …, 15, …, 19, 22, 23, 24, 25, 28, 29, 30}.

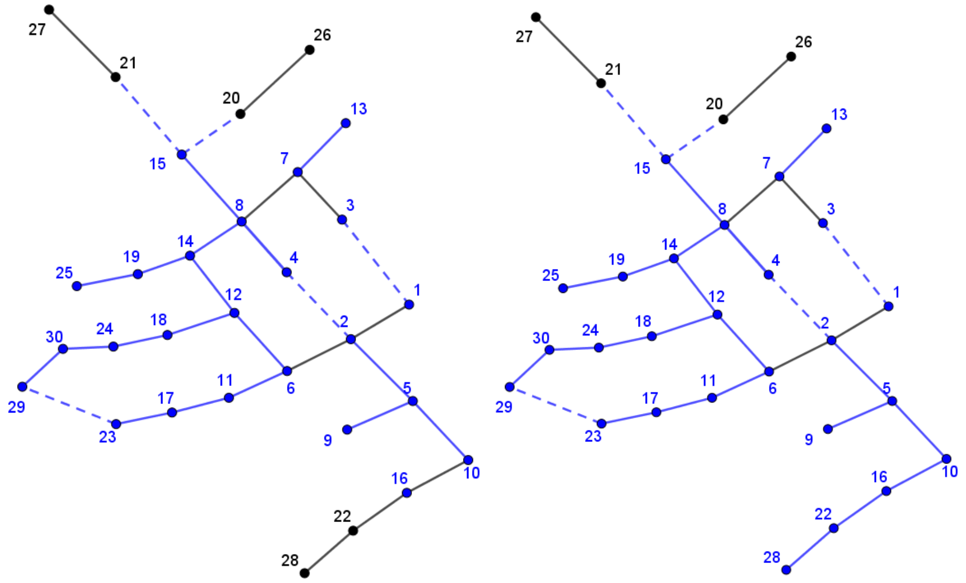

Figure 5. Graph *G* in The 23th and 26th Step of Algorithm Prim

Final step (30th step). The vertex that is not yet included in the T tree is vertex 27. So, choose an edge that incident exactly on one of the vertices in {1, 2, 3, ..., 26, 28, 29, 30} with minimum weight. Obtained edge (21, 27) with a minimum weight of 68.35 meters. This step can also be done by directly including vertex 27 and the edge connecting vertex 27 to tree T as members of tree T, because there are no other edges connecting vertex 27 to tree T. So vertex 27 and edge (21, 27) are in the tree T and they are colored blue. So, all edges in graph G are in tree T except edges (1, 3), (2, 4), and (23, 29). All vertices are in tree T. Because all vertices in graph G are already in tree T, this step is the final step.

In the last step, an edge that is incident on vertex 21 with a minimum length of 68.35 meters is obtained. Thus, all edges in graph G are in T except for edges (1, 3), (2, 4), and (23, 29). All vertices in graph G are in T as well. Therefore, tree T is the minimum spanning tree that is sought in this process. T is the minimum spanning tree with a weight, which is the length of the electrical cable from the G graph obtained from the steps of the Prim Algorithm, which is 1258.05 meters. Tree T is shown in Figure 6.

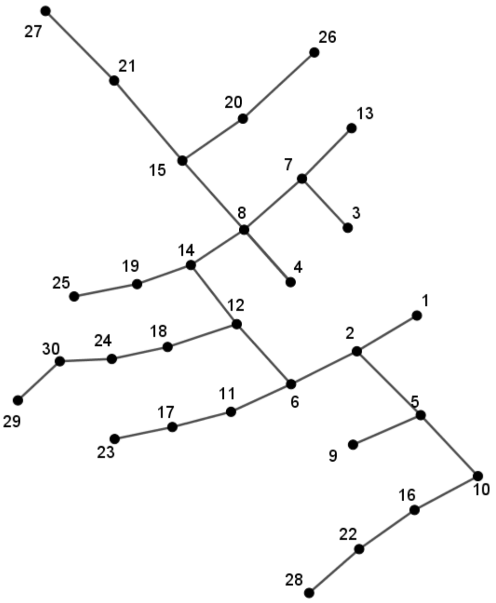

Figure 6. Minimum Spanning Tree T

Results and Discussion

A cable efficiency of 17.81 meters is provided by the study's findings in comparison to the length of the currently in use cable, which is 1275.86 meters. As a result, cost effectiveness is anticipated in relation to the cable's pricing and installation expenses. It is anticipated that this outcome will support PT. PLN UP3 Cimahi's energy efficiency initiative, which the government started. In line with this, related to the condition of the global disease outbreak, the Prim algorithm has also been used (Lusiani et al., 2021) to obtain a minimum spanning tree in the study of the shortest trajectory and the fastest trajectory in logistics distribution during the COVID-19 period.

```
KRUSKAL(V, E, w)
A ← Ø
for each vertex v ∈ V
    do MAKE-SET(v)
sort E into nondecreasing order by weight w
for each (u, v) taken from the sorted list
    do if FIND-SET(u) ≠ FIND-SET(v)
          then A ← A ∪ {(u, v)}
               UNION(u, v)
return A
```

Figure 7. Pseudo-Code of Kruskal Algorithm

Determining a minimum spaning tree, the shortest path, or the fastest path of a distribution problem with a simple graph representation can be done using several algorithms. In addition to the Prim algorithm, such as the Kruskal algorithm, the Boruvka algorithm, the Dijkstra algorithm, the Floyd-Warshall algorithm, or the Traveling Salesman Problem method, can be used to determine this optimization. In 2020, Rachmawati & Pakpahan (2020) state that the Kruskal algorithm is more effective than the Boruvka to find the minimum spanning tree in a complete graph. Based on this, the Kruskal algorithm will also produce the same minimum spanning tree in the problem of electricity distribution at PLN UP3 Cimahi. Especially, if you pay attention to the pseudo-code side of the Kruskal algorithm as follows (Cormen et al., 2022), it is expected to produce the same minimum spanning tree as the Prim algorithm.

The Dijkstra algorithm has been studied by Lusiani et al. to determine the fastest path in logistics distribution by Bulog in the West Java region (Lusiani et al., 2021) and to optimize the distance of delivery of goods packages carried by a courier in one delivery trip (Lusiani et al., 2023a). Recently, the shortest route using the Traveling Salesman Problem method has also been studied ((Lusiani et al., 2023b) based on travel distance data from the drop point of PT. J&T Express Sarijadi Bandung.

The use of the Floyd-Warshall algorithm for the problem of electricity distribution is less than optimal, because this algorithm can only find the shortest path from one starting point to one last point, without the guarantee that this path will pass through all vertices on the graph. Therefore, after the last step of the Floyd-Warshall algorithm, a step must be added to obtain a minimum spanning tree as the final result of optimization. This has been done by Usman et al. (2022) on the electricity network in Gorontalo City.

Conclusions

The minimum spanning tree T is obtained after the Prim algorithm is run on the graph of the initial model G. This algorithm gives optimal results. The total weight of the T tree is 1258.05, which is the minimum weight required to connect all vertices in graph G. Thus, the cable length required for the distribution of electricity is optimal to all poles is 1258.05 meters. The results of this study have an impact on the efficiency of cable usage used by PT. PLN UP3 Cimahi in distributing electricity in its service area. Although the efficiency achieved is only around 1.4%, this is very useful for reducing the company's operational costs. The limitations in this study are technical constraints in installing cables that not only consider the distance from one electric pole to another, but also consider customer comfort, so that the installed cables do not interfere with privacy and endanger customer safety. In terms of algorithm usage, it is recommended to use other algorithms such as the Kruskal algorithm or the Djikstra algorithm for further research.

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Author Contribution

All authors contributed to data collection and preparation of the report. The first and second authors processed the data and wrote the article.

References

Akitaya, H. A., Biniaz, A., Bose, P., Carufel, J. L., Maheshwari, A., Silveira, L. F. S. X., & Smid, M. (2021). *The minimum moving spanning tree problem* Algorithms and Data Structures: 17th International Symposium, WADS 2021, Virtual Event, *August 9–11, 2021, Proceedings 17*, 15–28.

Bossek, J., & Neumann, F. (2021, 2021). *Evolutionary diversity optimization and the minimum spanning tree problem* Proceedings of the Genetic and Evolutionary Computation Conference, 198–206.

Carrabs, F., & Gaudioso, M. (2021). A Lagrangian approach for the minimum spanning tree problem with conflicting edge pairs. *Networks*, *78*(1), 32–45.

Chartrand, G., Lesniak, L., & Zhang, P. (2016). *Graphs & Digraphs. Textbooks in Mathematics*. CRC Press.

Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. (2022). *Introduction to algorithms*. MIT press.

Dey, A., & Pal, A. (2016). Prim's algorithm for solving minimum spanning tree problem in fuzzy environment. *Annals of Fuzzy Mathematics and Informatics*, *12*(3), 419–430.

Dey, S., Jallu, R. K., & Nandy, S. C. (2021). On the minimum spanning tree problem in imprecise set-up. http://arxiv.org/abs/2104.04229

Djafar, I., & Ibrahim, A. (2017). Implementasi Pohon Merentang Minimum Dalam Menentukan Prioritas Pemeliharaan Jalur Jalan Kota Dengan Biaya Minimal. *Jurnal Digit: Digital of Information Technology*, *1*(2).

Doryanizadeh, V., Keshavarzi, A., Derikvand, T., & Bohlouli, M. (2021). Energy Efficient Cluster Head Selection in Internet of Things Using Minimum Spanning Tree (EEMST).

Applied Artificial Intelligence, *35*(15), 1777-1802. https://doi.org/10.1080/08839514.2021.1992961

Iqbal, M., Siahaan, A. P. U., Purba, N. E., & Purwanto, D. (2017). Prim's Algorithm for Optimizing Fiber Optic Trajectory Planning. *Int. J. Sci. Res. Sci. Technol*, *3*(6), 504–509.

Krishna, G. S., & Kumar, D. D. (2021). An Enhanced Cluster-based Energy Efficient Optimal Routing in WSN. *International Journal of Scientific Research in Science and Technology*.

Kritikos, M. N., & Ioannou, G. (2021). The capacitated minimum spanning tree problem with arc time windows. *Expert Systems with Applications*, *176*. https://doi.org/10.1016/j.eswa.2021.114859

Łukaszewski, A., Nogal, Ł., & Januszewski, M. (2022). The Application of the Modified Prim's Algorithm to Restore the Power System Using Renewable Energy Sources. *Symmetry*, *14*(5). https://doi.org/10.3390/sym14051012

Lusiani, A., Purwaningsih, S. S., & Sartika, E. (2023a). Dijkstra Algorithm in Determining the Shortest Route for Delivery Service by J&T Express in Bandung. *Jurnal Lebesgue : Jurnal Ilmiah Pendidikan Matematika, Matematika dan Statistika*, *4*(2), 940-948. https://doi.org/10.46306/lb.v4i2.337

Lusiani, A., Purwaningsih, S. S., & Sartika, E. (2023b). Tsp Method Using Nearest Neighbor Algorithm at Pt. J&T Express in Bandung. *Jurnal Lebesgue : Jurnal Ilmiah Pendidikan Matematika, Matematika dan Statistika*, *4*(3), 1560-1568. https://doi.org/10.46306/lb.v4i3.449

Lusiani, A., Sartika, E., Binarto, A., Habinuddin, E., & Azis, I. (2021). Determination of the Fastest Path on Logistics Distribution by Using Dijkstra Algorithm. In *2nd International Seminar of Science and Applied Technology (ISSAT 2021* (pp. 246–250).

Majumder, S., Barma, P. S., Biswas, A., Banerjee, P., Mandal, B. K., Kar, S., & Ziemba, P. (2022). On Multi-Objective Minimum Spanning Tree Problem under Uncertain Paradigm. *Symmetry*, *14*(1). https://doi.org/10.3390/sym14010106

Medak, J. (2018). Review and Analysis of Minimum Spanning Tree Using Prim's Algorithm. *International Journal of Computer Science Trends and Technology*, *Volume*, *6*.

Niluminda, K. P. O., & Ekanayake, E. (2022). An approach for solving minimum spanning tree problem using a modified ant colony optimization algorithm. *American Journal of Applied Mathematics*, *10*(6), 223.

Pop, P. C. (2020). The generalized minimum spanning tree problem: An overview of formulations, solution procedures and latest advances. *European Journal of Operational Research*, *283*(1), 1-15. https://doi.org/10.1016/j.ejor.2019.05.017

Rachmawati, D., & Pakpahan, F. Y. P. (2020, 2020). *Comparative analysis of the Kruskal and Boruvka algorithms in solving minimum spanning tree on complete graph* 2020 International Conference on Data Science, Artificial Intelligence, and Business Analytics (DATABIA), 55–62.

Suhika, D., Muliawati, T., & Ruwandar, H. (2020). Optimalisasi Rencana Pemasangan Kabel Fiber Optic Di Itera Dengan Algoritma Prim. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *9*(1). https://doi.org/10.24127/ajpm.v9i1.2597

Tomeczek, A. F. (2022). A minimum spanning tree analysis of the Polish stock market. *Journal of Economics and Management*, *44*, 420-445. https://doi.org/10.22367/jem.2022.44.17

Usman, S., Wiranto, I., & Nurwan, N. (2022). Aplikasi Algoritma Floyd-Warshall untuk Mengoptimalkan Distribusi Listrik di PLN Kota Gorontalo. *Research in the Mathematical and Natural Sciences*, *1*(1), 47-53. https://doi.org/10.55657/rmns.v1i1.24

Wamiliana, W., Usman, M., Warsito, W., Warsono, W., & Daoud, J. I. (2020). Using Modification of Prim's Algorithm and Gnu Octave and to Solve the Multiperiods Installation Problem. *IIUM Engineering Journal*, *21*(1), 100-112. https://doi.org/10.31436/iiumej.v21i1.1088