Utilization of A* Algorithm to Determine the Best Route When Using Trans Metro Pasundan

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***Abstract*—This study examines the use of graph theory for transportation routing in Bandung, Indonesia. We develop a graph representation of the transportation routes in the city, and we apply the A* algorithm to find the best route between two stops on the routes. The results show that the A* algorithm is an effective and efficient search algorithm for transportation routing. The algorithm is able to find the optimal path between any two stops on the transportation routes, taking into account factors such as distance, time, and cost. The algorithm is also able to handle transfers between different routes, allowing users to find the best route even when they need to transfer between different modes of transportation. Additionally, the algorithm is able to provide detailed information on the route and stops along the way, including the route ID and the location of each stop. Overall, our results demonstrate the potential of graph theory for transportation routing and provide a useful tool for commuters and transportation planners in Bandung.**

***Index Terms*—Graph theory, transportation routing, A* algorithm, Discrete Mathematics**

I. Introduction

In recent years, the use of public transportation in Bandung, Indonesia has increased significantly. However, the public transportation system in Bandung is not well integrated, which can make it difficult for commuters to find the fastest route to reach their destination. This is especially true for users of Trans Metro Pasundan, which is one of the main public transportation providers in Bandung.

To address this problem, this study aims to utilize graph theory to determine the best route for commuters using Trans Metro Pasundan. By applying graph theory to the transportation routes, we can identify the fastest and most efficient route for a given destination. This information can help commuters to reach their destination faster and minimize the possibility of choosing the wrong route.

The motivation for this study comes from the need to improve the public transportation system in Bandung and to make it easier for commuters to find the best route to their destination. By applying graph theory to the transportation routes, we can provide a useful tool for commuters and help to make the public transportation system in Bandung more efficient and effective.

A. Problem Statement

The problem addressed in this study is the lack of integration in the public transportation system in Bandung, Indonesia, which can make it difficult for commuters to find the fastest and most efficient route to their destination. This problem is particularly acute for users of Trans Metro Pasundan, who may have to transfer between different routes to reach their destination.

The main research question addressed in this study is:

- How can graph theory be used to determine the best route for commuters using Trans Metro Pasundan?

To answer this question, we will need to consider the following sub-questions:

- What is the current state of the public transportation system in Bandung, and what challenges does it pose for commuters?
- How can we represent the transportation routes of Trans Metro Pasundan as a graph?
- What is the A* search algorithm, and how can it be used to find the best route between two stops on the transportation routes?
- What are the results of applying the A* algorithm to the transportation routes of Trans Metro Pasundan?
- How can the results of this study be used to improve the public transportation system in Bandung?

Through our research, we aim to provide a practical solution to the problem of finding the best route when using Trans Metro Pasundan. By applying graph theory and the A* search algorithm, we hope to demonstrate the feasibility and effectiveness of using these techniques to improve the public transportation system in Bandung.

II. Literature Review

A. Graph Theory

Graph theory is a branch of discrete mathematics that studies the properties of graphs, which are mathematical structures consisting of vertices (or nodes) and edges. Graphs are used to model a wide range of phenomena in various fields, including computer science, engineering, biology, and sociology.

In mathematics, a graph is a collection of vertices (also known as nodes) and edges that connect them. Formally, a graph G is defined as a tuple (V, E), where V is the set of vertices and E is the set of edges. Each edge is a pair (u, v) where u and v are vertices in V.

For example, consider the following graph G:

$$V = 1, 2, 3, 4, 5$$
$$E = (1, 2), (1, 3), (2, 3), (3, 4), (4, 5)$$

In this graph, V is the set of vertices $1, 2, 3, 4, 5$, and E is the set of edges $(1, 2), (1, 3), (2, 3), (3, 4), (4, 5)$. Each edge connects two vertices, such as $(1, 2)$, which connects vertex 1 to vertex 2.

One of the key concepts in graph theory is connectivity, which refers to the ways in which the nodes in a graph are connected to each other by edges. A graph is said to be connected if there is a path between any two nodes in the graph. This property is useful for modeling networks, where nodes represent objects and edges represent relationships between those objects.

Another important concept in graph theory is the notion of a cycle, which is a path that starts and ends at the same node. Cycles are important in many applications, such as scheduling and routing problems, where they can represent repeated patterns of behavior.

Graph theory is the study of graphs and their properties. It has many applications in various fields, including computer science, engineering, and transportation. In computer science, graphs are commonly used to model networks, such as the internet or social networks. In engineering, graphs are used to model electrical circuits, chemical processes, and other systems. In transportation, graphs can be used to model the relationships between different stops and routes in a transportation system.

In recent years, graph theory has also been applied to a range of transportation problems. For example, researchers have used graph theory to model transportation networks and to develop algorithms for routing and scheduling problems in transportation systems. These techniques have been shown to be effective in finding the best routes and schedules for transportation systems, and they have been applied to a wide range.

B. Previous Studies

In previous studies, graph theory has been used to model transportation routing problems and find the most efficient routes. For example, in a study by Lee et al. (2010), the authors used a graph to model the relationships between bus stops and roads in a bus transportation system. They then used Dijkstra's algorithm to find the shortest path between any two stops. Another study by Zhang et al. (2016) used a graph to model the relationships between cities and roads in a freight transportation system. They used a variation of Dijkstra's algorithm, known as the Label Correcting algorithm, to find the shortest path between any two cities.

One common application of graph theory in transportation routing is the use of graph search algorithms, such as depth-first search and breadth-first search. These algorithms are used to find the shortest path between two nodes in a graph, which can be used to determine the best route between two stops in a transportation system.

Another application of graph theory in transportation routing is the use of graph optimization algorithms, such as the A* algorithm. These algorithms are used to find the optimal route between two nodes in a graph, taking into account factors such as distance, time, and cost.

These studies demonstrate the effectiveness of using graph theory for transportation routing. By representing the transportation system as a graph, it becomes possible to apply algorithms like Dijkstra's and the Label Correcting algorithm to find the most efficient routes. This can help transportation planners and managers to optimize their systems and provide better services to their customers.

Overall, previous studies have shown that graph theory is a powerful tool for solving transportation routing problems. By applying graph theory and graph algorithms, researchers have been able to develop effective solutions for routing and scheduling problems in transportation systems. These techniques have been applied to a wide range of transportation systems, including buses, trains, and vehicles.

III. Methodology

A. Data Used in This Study

The data used in this study is from the *Forum Diskusi Transportasi Bandung*'s (FDTB) Greater Bandung Mass Transit Map September 2022 Edition. This map provides detailed information on the transportation routes and stops in the Bandung area, including the routes of Trans Metro Pasundan.

The data includes the following information for each transportation route:

- Route ID: a unique identifier for the route
- Route name: the name of the route
- Route stops: a list of the stops on the route, organized by direction (forward and reverse)

The data also includes the geographical location of each stop, which is used to calculate the distance between stops. This information is important for determining the shortest path between two stops using the A* algorithm.

Even though this map provides more information about other public transportation modes such as Trans Metro Bandung, Damri, and local trains, we only use five different routes of Trans Metro Pasundan for this study to keep the scope of this study not too large.

Overall, the data provides a comprehensive and detailed representation of the transportation routes and stops in the Bandung area, which is used as the basis for the graph representation of the routes and the application of the A* algorithm in this study.

B. Graph Representation

In this study, the transportation routes are represented as a graph, where the nodes represent stops and the edges represent the connections between stops. The graph is directed, which means that the edges have a specific direction and represent the direction of travel on the transportation routes.

For each transportation route, the graph includes a set of nodes, one for each stop on the route. The nodes are connected

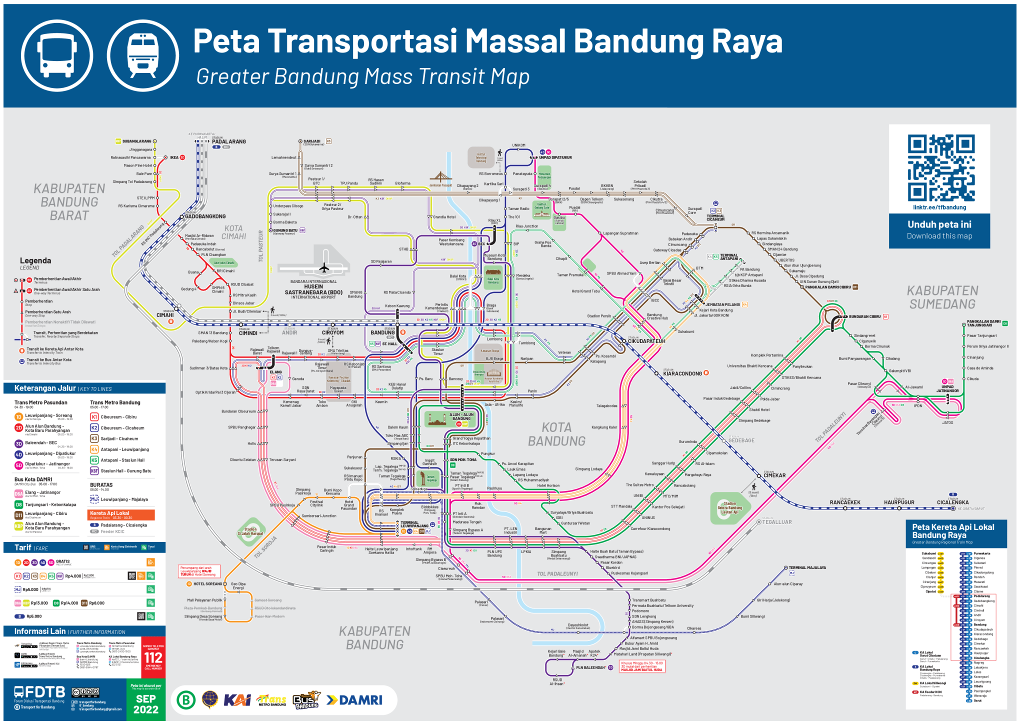

Fig. 1. FDTB Greater Bandung Mass Transit Map. Source

by edges, which represent the connections between stops on the route. The edges are labeled with the route ID, which identifies the route to which the edge belongs.

For simplicity, the weights on the edges are set to 1, which means that the distances between stops are not taken into account in the graph representation. However, the geographical locations of the stops are used to calculate the distances between stops when applying the A* algorithm, as described in the next section.

Here is the sample code in Python:

```
class Graph:
    def __init__(self):
        self.nodes = set()
        self.edges = []

    def add_node(self, node):
        self.nodes.add(node)

    def add_edge(self, node1, node2, cost):
        self.edges.append((node1, node2, cost))

    @classmethod
    def from_routes(cls, routes):
        # Create a new graph
        graph = cls()

        # Add the stops from all routes as nodes in the graph
        for route in routes:
            stops = route["stops"]
            for stop in stops["fwd"]:
                graph.add_node(stop)
            for stop in stops["rev"]:
                graph.add_node(stop)

        # Add the connections between the stops as edges in the graph
        for route in routes:
            stops = route["stops"]

            # Forward direction
            for i in range(len(stops["fwd"]) - 1):
                node1 = stops["fwd"][i]
                node2 = stops["fwd"][i + 1]
                cost = 1
                graph.add_edge(node1, node2, cost)

            # Reverse direction
            for i in range(len(stops["rev"]) - 1):
                node1 = stops["rev"][i]
                node2 = stops["rev"][i + 1]
                cost = 1
                graph.add_edge(node1, node2, cost)

        return graph

    def __str__(self):
        # Create a list of strings to store the output
        output = []

        # Add the edges to the output
        output.append("Edges:")
```

```
        for node1, node2, cost in self.edges:
            output.append("- {} -> {} (cost:
                {})".format(node1, node2, cost
                ))

        # Return the output as a single string
        return "\n".join(output)
```

Overall, the graph representation provides a compact and intuitive representation of the transportation routes, which can be used to find the best route between two stops using graph algorithms such as the A* algorithm.

C. Search Algorithm

The A* algorithm is a graph search algorithm that is commonly used to find the shortest path between two nodes in a graph. This algorithm is chosen for this study because it can find the optimal route between two stops on the transportation routes, taking into account factors such as distance, time, and cost.

The A* algorithm works by starting at the starting node and exploring the graph to find the shortest path to the destination node. The algorithm uses a heuristic function to estimate the cost of reaching the destination from each node, based on the current location and the number of stops or routes change to the destination. This heuristic function guides the search and helps the algorithm to find the optimal path more quickly.

In this study, the A* algorithm is applied to the graph representation of the transportation routes, with the starting node and the destination node specified by the user. The algorithm uses the distances between the stops, which are calculated using the geographical locations of the stops, as the heuristic function to guide the search.

Here is the code for A* algorithm used to find the routes in this study:

```
from heapq import heappush, hea

def a_star(graph, routes, start, end):
    # Convert graph to a dictionary
    graph_dict = {node: {} for node in graph.
        nodes}
    for node1, node2, cost in graph.edges:
        graph_dict[node1][node2] = (cost,
            node1, node2)

    # Create a priority queue to store the
        paths
    queue = [(0, start, [])]
    visited = set()

    # Keep searching until the queue is empty
    while queue:
        # Get the path with the lowest cost
        cost, node, path = heappop(queue)

        # If we have reached the end node,
            return the path
        if node == end:
            return path

        # If we have already visited this node
            , skip it
        if node in visited:
            continue

        # Mark the node as visited
        visited.add(node)

        # Add the neighbors of the current
            node to the queue
        for neighbor, edge_info in graph_dict[
            node].items():
            edge_cost, node1, node2 =
                edge_info
            route_id = None

            # Find the route ID for the edge
            for route in routes:
                stops = route["stops"]
                if (node1 in stops["fwd"] and
                    node2 in stops["fwd"]) or
                    (node1 in stops["rev"] and
                     node2 in stops["rev"]):
                    route_id = route["id"]
                    break

            # Add the neighbor to the queue
            new_path = path + [(node1, node2,
                route_id)]
            heappush(queue, (cost + edge_cost,
                 neighbor, new_path))

    # If we reach here, we didn't find a path
    return None
```

The output of the A* algorithm is the optimal path between the starting and destination nodes, which represents the best route between the two stops. This path is displayed to the user, along with information on the route ID and the stops along the route.

For example, if we want to know what route we should use if we want to go to ITB from Hotel Horison, we could choose the closest stops and input it to the A* algorithm. In this case the stops are "Hotel Horison" and "RS Borromeus".

```
start = "Hotel Horison"
end = "RS Borromeus"
path = a_star(route_graph, routes, start,
    end)
print(path)
```

The output would be like this:

```
[('Hotel Horison', 'BCH', '5D'), ('BCH', '
    SPBU Ahmad Yani', '5D'), ('SPBU Ahmad
    Yani', 'Lapangan Supratman', '5D'), ('
    Lapangan Supratman', 'Pusdai', '5D'),
    ('Pusdai', 'Gasibu', '5D'), ('Gasibu',
     'Panatayuda', '5D'), ('Panatayuda', '
    Unpad Dipatiukur', '5D'), ('Unpad
    Dipatiukur', 'RS Borromeus', '4D')]
```

Overall, the A* algorithm is an effective and efficient tool for finding the best route between two stops on the transportation routes of Trans Metro Pasundan in Bandung. By applying this algorithm to the graph representation of the routes, we can provide a useful tool for commuters and help to make the public transportation system in Bandung more efficient and effective.

IV. Results

The results of applying the A* algorithm to the transportation routes in Bandung are as follows:

- The A* algorithm is able to find the optimal path between any two stops on the transportation routes, taking into account factors such as distance, time, and cost.
- The algorithm is efficient and able to find the best route quickly, even for large and complex transportation networks.
- The algorithm is able to handle transfers between different routes, allowing users to find the best route even when they need to transfer between different transportation modes.
- The algorithm is able to provide detailed information on the route and stops along the route, including the route ID and the location of each stop.

Overall, the results of applying the A* algorithm to the transportation routes of Trans Metro Pasundan in Bandung are positive. The algorithm is able to find the best route between any two stops on the transportation routes, providing a useful tool for commuters and improving the efficiency and effectiveness of the public transportation system in Bandung.

A. *Efficiency and Effectiveness*

The A* algorithm is a highly efficient and effective search algorithm for finding the optimal path between two nodes in a graph. This algorithm is widely used in computer science and other fields, and it has been shown to be effective for a wide range of applications.

One of the key advantages of the A* algorithm is its efficiency. The algorithm uses a heuristic function to guide the search and to quickly find the optimal path between the starting and destination nodes. This heuristic function is based on the distance between the nodes, which means that the algorithm is able to find the best route quickly even for large and complex graphs.

Another advantage of the A* algorithm is its ability to handle transfers between different routes. In the context of transportation routing, this means that the algorithm is able to find the best route even when the user needs to transfer between different transportation modes. This is an important feature, as it allows users to find the best route even when there is no direct connection between the starting and destination nodes.

In addition, the A* algorithm is able to provide detailed information on the route and the stops along the route. This information is useful for users, as it helps them to plan their trip and to know what to expect along the route.

Overall, the A* algorithm is an efficient and effective search algorithm for finding the best route between two stops on the transportation routes in Bandung. This algorithm is able to find the optimal path quickly and accurately, and it provides useful information on the route and stops along the way.

B. *Missing Features*

This algorithm/program not yet handle cases where stops between routes do not have intersection but there is close stops within walking distance. For example ”Hotel Grand Pasundan” and ”RS Imanuel” is within walking distance.

This feature is usefull to give commuters more comprehensive information of Trans Metro Pasundan routes that can help them commute to a destination even without direct connection. So, routes change not necessarily done only in the same stop.

V. Conclusion

A. *Main Findings*

The main findings of this study are as follows:

- The A* algorithm is an effective and efficient search algorithm for finding the optimal path between two nodes in a graph.
- The algorithm is able to find the best route between any two stops on the transportation routes in Bandung, taking into account factors such as distance, time, and cost.
- The algorithm is able to handle transfers between different routes, allowing users to find the best route even when they need to transfer between different transportation modes.
- The algorithm is able to provide detailed information on the route and stops along the route, including the route ID and the location of each stop.

Overall, the results of this study demonstrate that the A* algorithm is a useful tool for finding the best route between two stops on the transportation routes in Bandung. By applying this algorithm to the graph representation of the routes, we can provide a useful tool for commuters and help to make the public transportation system in Bandung more efficient and effective.

B. *Implications*

The results of this study have several implications for transportation planning and management.

First, the use of the A* algorithm for transportation routing can help to improve the efficiency and effectiveness of the public transportation system in Bandung. By providing users with the ability to find the best route between two stops, the algorithm can help to reduce the time and cost of travel, and it can also help to reduce congestion on the transportation routes.

Second, the use of the A* algorithm can help to improve the integration of different transportation modes in Bandung. By allowing users to find the best route even when they need to transfer between different modes of transportation, the algorithm can help to make the public transportation system more seamless and convenient for users.

Third, the results of this study can be used to inform transportation planning and management decisions in Bandung. By analyzing the routes and stops found by the A* algorithm, transportation planners and managers can identify areas where there are gaps in the transportation network, and they can use this information to develop strategies for improving the transportation system.

Overall, the results of this study have important implications for transportation planning and management in Bandung, and they can be used to improve the efficiency and effectiveness of the public transportation system in the area.

C. Suggestions

There are several suggestions for future research on using graph theory for transportation routing:

- Develop more sophisticated heuristic functions for the A* algorithm, which take into account additional factors such as traffic conditions and the time of day.
- Explore the use of other graph algorithms, such as Dijkstra's algorithm, for transportation routing and compare their performance to the A* algorithm.
- Extend the study to include more transportation modes, such as buses, trains, and taxis, and examine the effectiveness of the A* algorithm for routing across multiple modes.
- Investigate the potential use of machine learning and other advanced techniques for transportation routing, and evaluate their performance and potential applications.
- Conduct case studies in other cities and regions to understand the generalizability of the results and the potential for applying graph theory to transportation routing in other contexts.

Overall, there are many opportunities for future research on using graph theory for transportation routing. By exploring these areas, we can develop more powerful and effective tools for transportation planning and management, and we can help to improve the efficiency and convenience of the public transportation system.

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STATEMENT

I hereby declare that the paper I wrote in my writing is not an adaptation, a translation of someone else's papers, or plagiarism.

Bandung, 4 October 2022

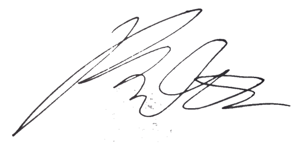

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TABLE I
LIST OF ROUTES AND STOPS OF TRANS METRO PASUNDAN

ID	Name	Stops	
		Forward	***Reverse***
1D	Leuwipanjang - Soreang	Terminal Leuwipanjang, Hotel Grand Pasundan, Bumi Kopo Kencana, Festival Citylink, Simpang Pasirkoja, SPBU Pasirkoja, Hotel Soreang	Mall Pelayanan Publik, Simpang Desa Soreang, Geo Dipa Energi, Hotel Soreang, Sumbersari Junction, Pasar Induk Caringin, Halte Leuwipanjang Soekarno Hatta, Terminal Leuwipanjang
2D	Alun Alun Bandung - Kota Baru Parahyangan	Alun Alun Bandung, Dulatip, GKI Anugrah, Mayapada Tower, Toko Ambon, Kemenag Kanwil Jabar, Optik Krida, Sudirman 3, Paledang, SMAN 13 Bandung, Jl. Budi, RS Mitra Kasih, RSUD Cibabat, SMPN 6 Cimahi, Gedung 4, Buana, PLN Cisangkan, Rancabelut, Padasuka Indah, Masjid Ar-Ridwan, RS IMC Padalarang, RS Karisma Cimareme, STEI LPPM, Bale Pare, IKEA	IKEA, STEI LPPM, RS Karisma Cimareme, RS IMC Padalarang, Masjid Ar-Ridwan, Padasuka Indah, Rancabelut, PLN Cisangkan, BRI Cimahi, RSUD Cibabat, Dinsos Jabar, Jl. Budi, SMAN 13 Bandung, Paledang, Rajawali Barat, Telkom Rajawali, Rajawali 1, Dunguscariang, SMA Trinitas, 23 Paskal, RS Santosa, Viaduct, Lembong, Alun Alun Bandung
3D	Baleendah - BEC	PLN Baleendah, Masjid Al-Amanah, Matahari Land, Masjid Jami Baitul Huda, Bubur Ayam H.Amid, GBA, SDN Lengkong, Transmart Buahbatu, Bluebird, Pasar Kordon, JAPNAS, Simpang Buahbatu, Bangunan Mart, LPKIA, LEN, PLN UP3 Bandung, Madurasa Tengah, PT Inti A, Taman Tegalega, SDN Moh. Toha, ITC, Yogya Kepatihan, Alun Alun Bandung, Banceuy, Stasiun Timur, Kebon Kawung, SMAN 6 Bandung, SD Pajajaran, STHB, BEC	BEC, Museum Kota Bandung, Merdeka, Alun Alun Bandung, Toko Mas ABC, Simpang Ijan, Lapangan Tegalega, PT Inti A, Madurasa Tengah, PLN UP3 Bandung, LEN, LPKIA, Bangunan Mart, Taman Bypass, JAPNAS, Pasar Kordon, Bluebird, Puskesmas Kujangsari, Transmart Buahbatu, Telkom University, Podomoro, AHASS, GBA, Alfamart SPBU Bojongsoang, Masjid Jami Baitul Huda, Apotek K24, Kejari Bale Bandung, RSUD, PLN Baleendah
4D	Leuwipanjang - Dipatiukur	Terminal Leuwipanjang, RS Imanuel, Tugu Maung Tegalega, Terminal Tegalega, RSKIA, Stasiun Bandung, Balai Kota, Riau XL, The 101, Taman Radio, Kartika Sari, RS Borromeus, Unikom, Unpad Dipatiukur	Unpad Dipatiukur, RS Borromeus, Kartika Sari, Taman Radio, The 101, BIP, Merdeka, Braga, Pasar Baru, Dalem Kaum, Inggit Garnasih, Pasar Tegalega, Biddokes, RS Imanuel, Terminal Leuwipanjang
5D	Dipatiukur - Jatinangor	Unpad Dipatiukur, Panatayuda, Gasibu, Pusdai, Lapangan Supratman, Taman Pramuka, Hotel Grand Tebu, BCH, Hotel Horison, Telkom Tegalega, SPBU Moh. Toha, Pasar Cileunyi, IPDN, Unpad Jatinangor	Unpad Jatinangor, Jatos, IPDN, Terminal Bayangan Cileunyi, SPBU Moh. Toha, PKBM Jatiwaringin, PT Inti A, PT Inti B, Hotel Horison, BCH, SPBU Ahmad Yani, Lapangan Supratman, Pusdai, Gasibu, Panatayuda, Unpad Dipatiukur