



Application of Graph Coloring on Nurse Work Scheduling at H. Adam Malik Hospital Medan Using the Tabu Search Algorithm

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ABSTRACT

Complex problems that usually occur in every hospital, one of which is scheduling with so many aspects, for example: the number of nurses, the distribution of nurse shifts, time off or leave and others. With the manual method that is still used in compiling the nurse's work schedule, it makes it difficult for an irregular and regular schedule. In solving the scheduling problem, the graph coloring method can be used. This scheduling problem can be solved by graph coloring. One solution to solve the problem of concluding graphs in scheduling is the Tabu Search Algorithm. A method that works as an effective problem solving method in finding the best solution to a problem. A method is used to solve the problem by making a representation in the form of a graph where the nurse is a node and grouping nurses as an edge by implementing the graph coloring into the Tabu Search Algorithm.

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1. INTRODUCTION

The service sector that is closely related to people's lives is health services. In general, health services are in the form of hospitals. Therefore, the service sector also requires the implementation of operational functions. So business activities in hospital services must be carried out optimally, or in other words effective and efficient. It is explained in Law No. 44 of 2009 in Article 8 concerning Hospitals that it is explained that the operation of hospitals must be based on the principles of effectiveness and efficiency. Therefore, in all areas of hospital operations, it must be carried out optimally [5].

Often found in the service industry, in this case in hospitals. employee or nurse scheduling problems. The problem of scheduling nurses in hospitals is usually divided by several systems or also called the duty service, namely the morning, evening and night duty. Likewise, what happened at the H. Adam Malik Central General Hospital in Medan, nurse scheduling is part of a fairly complicated problem. There are many factors why nurse scheduling is still a fairly complicated problem, namely the fluctuating number of patients, organizational characteristics, different requests for nurses regarding leave or holidays, the specialization and qualifications of the nurses themselves, including the scheduling of nurses in different duty services at certain periods..

Maximum service at the Central General Hospital H. Adam Malik Medan is certainly a very important part. So that patient care runs effectively which is supported by optimal performance of nurses. All nurses also have different individual abilities such as educational background, level of knowledge and skills mastered. With a combination of several factors, different performances are obtained. Working conditions become an important part in the preparation of nurse scheduling. Working conditions are defined as a

series of conditions or work environment of the company that is a place to work for nurses, namely in hospitals.

In solving problems regarding equal and fair nurse scheduling by taking into account the working conditions of each nurse, one of the subjects of Discrete Mathematics is graph theory. Graph theory is a subject that has a function in its application in real life. The main topics in graph coloring include coloring vertices, edges, and regions. In this study, the coloring that will be used is node coloring, where the node is the nurse and the side is based on the individual ability grouping of each nurse.

There are several ways to solve graph coloring problems, namely: Welch-Powell Algorithm, Backtracking Algorithm, Recursive Largest First Algorithm and Tabu Search Algorithm. [14] The Tabu Search algorithm is one of the algorithms that is the right alternative to solve the problem of graph coloring. Tabu Search Algorithm has the advantage of finding neighboring solutions by moving from one solution to the next and trying to find a neighboring solution that is better than the current solution. By saving the solution steps that have been found as taboo, then that step will be used to guide the next search [6]. The use of taboo lists in the Tabu Search Algorithm functions as a place to store the obtained solutions and it is determined whether the solution is included in the taboo list or not. The solution contained in the taboo list, then the solution does not become a search criterion in the next iteration. If there are no more solutions that are not members of the taboo list, then the solution is said to be optimal if there are no two neighboring vertices with the same color. [12]. There are previous studies that discuss graph coloring related to scheduling problems which are the reference in this study, namely: Research on graph coloring related to scheduling problems has been carried out by [21] with the title "Implementation of the Tabu Search Algorithm in Subject Scheduling Applications (Case Study: SMA Negeri 4 Kendari)". This research uses the Tabu Search algorithm. In this study, it was found that scheduling based on the Tabu Search algorithm can optimize the learning process by suppressing schedule conflicts, such as having teachers teach in different classes, but at the same time. Meanwhile (Ageyman and Amponsah 2011) with the title "Graph Colouring, an Approach to Nurses Scheduling, Case Study: Ejura District Hospital, Ashanti Region, Ghana" which discusses the technique of graph coloring on nurse scheduling at Ejura Hospital with a hard constraint scheduling model. In this study, the graph coloring technique can be applied to the nurse scheduling problem and the optimal solution is obtained. From some of the research examples above, the graph coloring method can be applied to nurse scheduling problems at H. Adam Malik Hospital Medan.

2. RESEARCH METHODE

The research method used in this study is a quantitative approach. The research was carried out for retrieval with the case study method. The case study was conducted at the H. Adam Malik Central General Hospital Medan by taking information or data in the form of the name of the nurse in each inpatient room, the criteria for each nurse and the nurse's work schedule at the hospital. The steps in the research are as follows :

Conducted an interview with the head of the Rindu B installation room, H. Adam Malik Central General Hospital Medan

- a. Conducted an interview with the head of the Rindu B installation room H. Adam Malik Central General Hospital Medan
- b. Request the necessary information from the H. Adam Malik Central General Hospital Medan, namely the names of nurses, qualifications, work experience and job descriptions.
- c. Grouping nurses into groups based on senior-junior relationships and nurse qualifications.
- d. Make a neighbor matrix if there are nurses in the same grouping, entry ij is worth 1, if not neighbors is 0.
- e. Build a graph based on the matrix that has been created. If two nurses are in the same group, the corresponding vertices are joined using side.
- f. Perform graph coloring using the Tabu Search algorithm with the steps below :
 - Coloring the vertices with any color
 - See whether the first solution meets the requirements of the expected solution, namely that there are no two neighboring vertices with the same coloring.
 - Storing solutions that are considered not taboo into the taboo list and ignoring the solutions to taboos.
 - Applying the optimal solution to the graph, i.e. the solution is said to be optimal if there are no neighboring vertices with the same color.
 - If the conflict still occurs, return it to step 3, ignore it if the conflict does not occur and finish.
- g. Draw conclusions based on graph coloring using the Tabu Search Algorithm.

3. RESULT AND ANALYSIS

Data were collected by conducting surveys and direct interviews with each head of the room. The results obtained are in the form of scheduling rules at H. ADAM MALIK Hospital Medan as follows.

Information	Mark
Days	14 Days
Minimum number of nurses on duty on the <i>morning</i> shift	6 nurses
Minimum number of nurses on duty on the <i>afternoon</i> shift	4 nurses
Minimum number of nurses on duty on the <i>night</i> shift	4 nurses

- a. The head of the room only gets the morning shift.
- b. The need for nurses who are on duty during morning work hours are met every day.
- c. The need for nurses on duty during the afternoon working hours is met every day.
- d. The need for nurses on duty during night work hours is met every day.
- e. Each nurse only gets one hour of work, i.e. working hours (morning, afternoon, night) or one day off.
- f. Nurses on duty during night work are not allowed to work in the morning the following day.
- g. Nurses who are on duty during night work on the day are not allowed to have afternoon work the following day.
- h. Each nurse gets a minimum of 2 days of night work during one scheduling period.
- i. Each nurse is not assigned to work consecutively for more than 5 days.

- *Nurse Grouping*

In the inpatient room there are 28 nurses, then the schedule will be arranged, they are referred to as $P_1, P_2, P_3, \dots, P_{28}$. Then nurses are categorized into a number of groups consisting of :

- Group A : the most senior nurse
- Group B : the most junior nurse
- Group C : nurses based on the roles and functions of nurses
- Group D : nurse based on nurse identification
- Group E : nurses based on the limits of the nurse's authority

The grouping is formed in the form of the following table.

Table 4.1 : Nurse Grouping

Group	Nurse
A	$P_2, P_4, P_8, P_{13}, P_{18}$
B	$P_6, P_{17}, P_{25}, P_{26}, P_{27}, P_{28}$
C	$P_3, P_5, P_7, P_{14}, P_{20}$
D	$P_1, P_{11}, P_{12}, P_{21}, P_{23}, P_{24}$
E	$P_{16}, P_{15}, P_{10}, P_{19}, P_{22}$

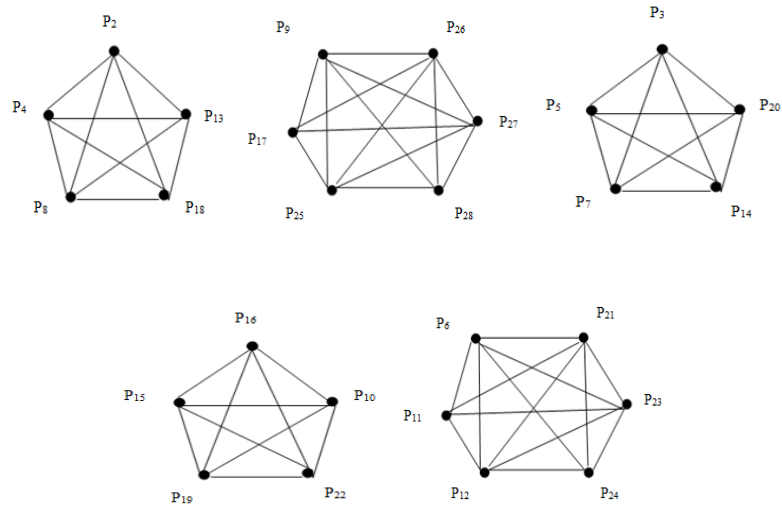
- *Neighborhood Matrix*

By using the table data above, a 27 x 27 matrix is formed for nurses. This matrix is called the adjacency matrix. In the matrix the nurse's name is referred to as the i -th row and j -th column. Then the ij entries are placed according to the table above. If two nurses are in the same group, then the entry ij is worth '1', otherwise the entry ij is worth '0'. The neighboring matrix obtained is listed in Table 4.2.

- *Build Graph*

Next, build a graph based on the matrix that has been created. If two nurses are in the same group, the corresponding knots are joined using sides. In this case, nurses are considered as nodes and for grouping nurses are used as sides.

Figure 4.1 Neighborhood Matrix Graph



	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28
P2	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P3	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
P4	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
P5	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
P6	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
P7	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
P8	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1
P10	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0
P11	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
P12	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
P13	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P14	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
P15	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
P16	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0
P17	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P18	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P19	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
P20	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
P21	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
P22	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0
P23	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
P24	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
P25	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1
P26	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	1
P27	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1
P28	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0

• Graph Coloring with Tabu Search Algorithm

To create groups after graph coloring, you can refer to the flowchart of the Tabu Search Algorithm. After carrying out the Tabu Search Algorithm process, the graph coloring results are obtained in Figure 4.2.

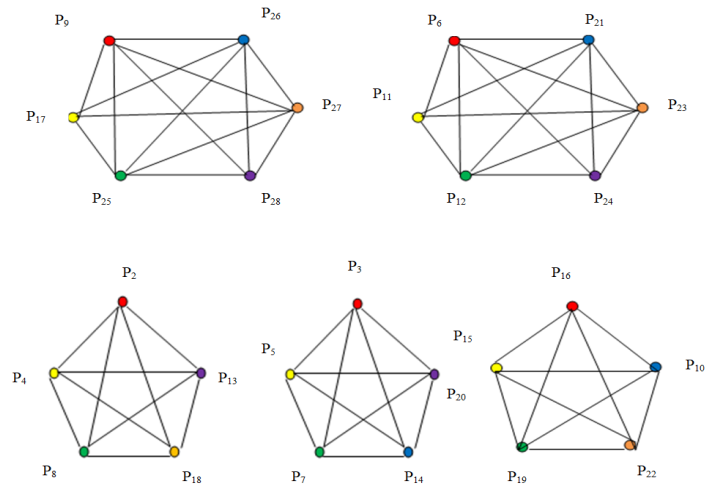


Figure 4.2 Tabu Search Algorithm Graph Coloring Results

By using the Tabu Search Algorithm, we get a graph that has 6 colors at its vertices. Based on the colored graph in Figure 4.1, the grouping of nurses can be presented as in Table 4.3. Color groups that have been formed can be a shift without any clashes.

Table 4.3 : Nurses Grouping After Graph Coloring

Red	Yellow	Green	Blue	Orange	Purple
P ₂	P ₄	P ₈		P ₁₈	P ₁₃
P ₉	P ₁₇	P ₂₅	P ₂₆	P ₂₇	P ₂₈
P ₃	P ₅	P ₇	P ₁₄		P ₂₀
P ₆	P ₁₁	P ₁₂	P ₂₁	P ₂₃	P ₂₄
P ₁₆	P ₁₅	P ₁₉	P ₁₀	P ₂₂	

- *Scheduling using the Constraint Programming (CP) Method*

Color groups formed can be a shift on the same day. Therefore, nurse scheduling can be arranged that refers to the scheduling rules of Adam Malik Hospital Medan with the Constraint Programming (CP) method. Constraint Programming (CP) is a computational or mathematical computational approach to problems related to variable boundaries with the aim of finding solutions that satisfy these constraints. The problem to be solved in CP is called the Constraint Satisfaction Problem (CSP). A complete CSP modeling consists of a set of variables (data whose values can change), a set of domains (possible values for each variable), and a set of constraints (constraints that each variable must satisfy).

In this case, the constraints that must be met based on the results of the interview with the head of the room are: :

- Hard constraints are conditions that must be met during troubleshooting and must be met. In this study, the difficult limitation is:
 - In the Integrated Inpatient Room, H. Adam Malik Hospital Medan there are different categories of staff, namely room managers and nurses.
 - The list of duties consists of guard duty in 24 hours, namely morning, afternoon and night.
 - The Headmaster's task list only shows the initial shift.
 - After 2 consecutive night shifts, the nurse on duty has 1 day off the next day.
 - After the night shift, there is no morning shift the next day.
- Soft constraint is an additional condition which is a special desire. In this study, the soft constraint is:
 - There are only 5 consecutive working days in a week in the Headmaster's schedule.
 - National holidays per month are 4-5 days or between 7 working days there is 1 day off.
 - The head of the room receives 8 days off in one month. At least 3 nurses present per shift.

Based on the results of graph coloring using the Tabu Search Algorithm, a nurse schedule is made where the same coloring group gets the same shift in one period by paying attention to Hard Constraints and Soft Constraints in H. Adam Malik Hospital Medan. The results of the work scheduling of nurses at H. Adam Malik Hospital Medan are listed in Table 4.4.

Table 4.4 : Scheduling Results Using the Graph Coloring Method Tabu Search Algorithm

NO	NAME	POSITION	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	PURNAMA SITORUS	Head Room	M	M	O	M	M	M	M	M	O	O	M	M	M	M
2	HJ JUMROH	Team Head	M	M	O	M	M	M	N	N	O	O	M	M	A	O
3	ITONA MANIK	Team Head	M	M	O	M	M	M	N	N	O	O	M	M	A	O
4	KRIATINA, AMK	Team Head	M	O	O	M	A	A	M	O	M	M	M	A	N	N
5	AMIRIA	Executive	M	O	O	M	A	A	M	O	M	M	M	A	N	N
6	BABARATI KARO	Executive	M	M	O	M	M	M	N	N	O	O	M	M	A	O
7	HARTANNTA	Executive	M	O	M	M	N	N	O	M	N	N	O	M	M	M
8	RITA PINTA ULI PANJAITAN	Executive	M	O	M	M	N	N	O	M	N	N	O	M	M	M
9	NEHEMIA	Executive	M	M	O	M	M	M	N	N	O	O	M	M	A	O
10	SRI ULINA	Executive	A	A	A	O	M	O	M	M	M	M	A	O	M	M
11	ELPINA PANJAITAN	Executive	M	O	O	M	A	A	M	O	M	M	M	A	N	N
12	RISMA	Executive	M	O	M	M	N	N	O	M	N	N	O	M	M	M
13	RESLIANA	Executive	O	O	N	N	O	M	M	M	A	A	N	N	O	M
14	IKUT MULI	Executive	A	A	A	O	M	O	M	M	M	M	A	O	M	M
15	ENI SYAHPUTRI	Executive	M	O	O	M	A	A	M	O	M	M	M	A	N	N
16	NURLELI	Executive	O	M	O	M	M	M	N	N	O	O	M	M	A	O
17	LYDIA VEGA	Executive	M	O	O	M	A	A	M	O	M	M	M	A	N	N
18	TUTIK PRIHATIN	Executive	N	N	O	A	A	M	A	A	O	O	M	M	M	A
19	ARIE SISWANA	Executive	M	O	M	M	N	N	O	M	N	N	O	M	M	M
20	LASMARIA	Executive	O	O	N	N	O	M	M	M	A	A	N	N	O	M
21	MASTUTI MARLIANA HARAHAP	Executive	A	A	A	O	M	O	M	M	M	M	A	O	M	M
22	OKTISA SOFIANA SAFRIL	Executive	N	N	O	A	M	M	A	A	O	O	M	M	M	A
23	ARISANTI SIANTURI	Executive	N	N	O	A	M	M	A	A	O	O	M	M	M	A
24	FRSKA ROSAULINA SITORUS	Executive	O	O	N	N	O	M	M	M	A	A	N	N	O	M
25	DEDEK NOVIYANTI TARIGAN	Executive	M	O	M	M	N	N	O	M	N	N	O	M	M	M
26	PRATIWI PAUJIA LESTARI RITONGA	Executive	A	A	A	O	M	O	M	M	M	M	A	O	M	M
27	EVA MERLINA HARIANJA	Executive	N	N	O	A	M	M	A	A	O	O	M	M	M	A
28	NOVA LAMBOK SILAEN	Executive	O	O	N	N	O	M	M	M	A	A	N	N	O	M
	MORNING		15	6	5	16	13	14	14	14	9	9	15	15	14	14
	AFTERNOON		4	4	4	4	6	5	4	4	4	4	4	5	5	4
	NIGHT		4	4	4	4	5	5	5	5	5	5	4	4	5	5
	DAY OFF		5	14	15	4	4	4	5	5	10	10	5	4	4	5

4. CONCLUSION

The most important thing in the Tabu Search algorithm to solve the problem of graph coloring is the neighborhood and tabu list management. The graph coloring problem in this study determines the least number of colors or the optimal coloring used to color the graph. Based on the results of the discussion the Tabu Search Algorithm can provide an optimal solution in determining the coloring. The Tabu Search algorithm functions as an optimizer in compiling the work schedule of H. Adam Malik Hospital Medan compared to using the manual method thereby facilitating the creation of an effective work schedule compared to the old method.

REFERENCE

- [1] Ageyman, E., dan Amponsah, S., (2011): Graph Colouring, an Approach to PerawatsScheduling, Case Study:Ejura District Hospital, Ashanti Region, Ghana,*American-Eurasian Journal of Scientific Research*,
- [2] Andreas (2012): Aplikasi Pewarnaan Graf pada Pengaturan Warna Lampu Lalu Lintas, *Jurnal Sekolah Teknik Elektro dan Informatika Institut Teknologi Bandung*, .
- [3] Ariani dan Fahriza (2004): Optimasi Penjadwalan Mata Kuliah Di Jurusan Teknik Informatika PENS dengan Menggunakan Algoritma Particle Swarm Optimization (PSO).
- [4] Budayasa dan I.K (2007): *Teori Graph dan Aplikasinya*, Unesa University Press, Surabaya.
- [5] Dep.Kesehatan (2009): Undang Undang Republik Indonesia Nomor 44 tahun 2009tentang Rumah Sakit, *Kementrian Kesehatan Republik Indonesia*, .
- [6] Glover dan Laguna, M., (1997): *Tabu Search*, Kluwer Norwell, MA.
- [7] Griffith (1987): *Kepuasan Pasien Terhadap Pelayanan Rumah Sakit*, Guna Jaya,Jakarta.
- [8] Ilyas, Y., (2004): *Perencanaan SDM Rumah Sakit, Teori, Metoda dan Formula*, Pusat Kajian Ekonomi Kesehatan, Fakultas Kesehatan Masyarakat, Univer- sitas Indonesia, Jakarta.
- [9] Johnsonbaugh, R., (1998): *Discrete Mathematics, Fourth Edition*, DePaul University, Chicago.
- [10] Jusuf, H., (2009): Pewarnaan Graph Pada Simpul Untuk Mendeteksi Konflik Penjadwalan Kuliah.
- [11] Kiki, S., (2017): *Teori Graf dan Aplikasinya*, Departemen Matematika UniversitasIndonesia, Jakarta.
- [12] Kusumadewi, S., (2005): *Penyelesaian Masalah Optimasi dengan Teknikteknik Heuristik*, Graha Ilmu, Yogyakarta.
- [13] Leo, C. S., (2016): Penerapan Algoritma Tabu Search untuk Penjadwalan Mata Pelajaran di SMK Swasta Pelita-2 AEKKANOPAN, *Jurnal Riset Komputer*, **3**(6).
- [14] Malaguti dan Enrico (2010): *Tabu Search for The Graph Coloring Problem*, University of Bologna., Italy.
- [15] Maryana (2015): Pewarnaan Graf pada Penyusunan Jadwal Perkuliahan di Politeknik Akamigas Palembang, *Jurnal Teknik Patra Akademika*,
- [16] Miswanto (2018): Implementasi Algoritma Tabu Search Untuk Mengoptimasi Penjadwalan Preventive Maintenance (Studi Kasus Pt Xyz), *Jurnal STMIK Nusa Mandiri Jakarta*, .
- [17] Munir, R., (2014): *Matematika Diskrit Revisi Kelima*, Penerbit Informatika, Bandung.
- [18] Musaffi, N. S. M., (2015): Penerapan Greedy Coloring Algorithm Pada Peta Kotamadya Yogyakarta Berbasis Four-Colour Theorem, *Jurnal Teknik PatraAkademika*, **XI**(1).
- [19] Nursalam (2007): *Manajemen keperawatan aplikasi dalam praktik keperawatan*, Salemba Media, Jakarta.
- [20] Purnomo, H. D., (2014): *Cara Mudah Untuk Belajar Optimasi Matheriustik*, Andi,Yogyakarta.
- [21] Putri, M., (2018): Implementasi Algoritma Tabu Search pada Aplikasi Penjadwalan Mata Pelajaran(Studi Kasus : SMA Negeri 4 Kendari, *Jurnal Semantik*, **2**(2).
- [22] Rosen, K., (2012): *Discrete Mathematics and Itss Applications, Seventh Edition*, The McGraw-Hill Companies, New York.
- [23] Rosyida, I., (2016): *Pengembangan Metode Pewarnaan Simpul dan Bilangan kromatik pada Graf-Graf tak Deterministik*, Universitas Gajah Mada, Yogyakarta.
- [24] Ruohonen, K., (n.d.): *Graph Theory*, Tampere University of Technology, ADDRESS = Finlandia, YEAR = 2013,.
- [25] Suryani, I., (2013): Implementasi Masalah Pewarnaan Graf dengan Algoritma Tabu Search pada Penjadwalan Kuliah, *Jurnal Universitas Negeri Malang*, .
- [26] Suyanto (2010): *Algoritma Optimasi Deterministik atau Probabilistik*, Graha Ilmu,Yogyakarta.