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Train Operation Plan on the Mojokerto – Wonokromo Route with Change from Single Track to Double Track

Haniva Mulyani[1*], Agus Nugroho[2], and Ta'tiina Nuril Ayuning Tyas[3]

[1,2,3] *Faculty of Transportation and Logistics Engineering, Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia*

* *Corresponding author:* hanivamulyani12@gmail.com

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Abstract: As one of the modes of transportation that is the prima donna of the community, of course the train will try to improve and provide services that are in accordance with the wishes of the community, therefore it is necessary to hold development and development in the railway. One of the double-track developments on the southern route that is currently underway is the Mojokerto – Sepanjang cross, but the Sepanjang – Wonokromo route still uses a single track, causing bottlenecks. Therefore, it is important to make a double track on the Wonokromo - Sepanjang crossing so that the entire Mojokerto - Surabaya Kota cross will become a double track. The construction of this double track will affect the travel time which was originally affected due to the crossing. Likewise, changes in traffic capacity will be more than before and there will be changes in the Rail Trip Chart after the construction of the double track from the Mojokerto - Surabaya Kota route. In this study, the research method used is quantitative with secondary data collection and primary data in the form of observation by means of direct surveys at Wonokromo and Throughout stations. The results of this study were obtained, when it was double track the travel time would be shorter because there were only up and down activities for passengers and follow-ups, no more crossings. Assuming the average graphic speed using the existing speed is 73.44 km/hour. Overall travel time savings can be made of 4 hours 30 minutes (270 minutes) on the Mojokerto - Sepanjang route and the traffic capacity will increase.

Keywords: Double Track, Gapeka, Travel Time, Cross Capacity

1. Introduction

The station is the place where trains stop, depart, overtake, catch up, overtake, diverge, and can operate to pick up and drop off passengers and/or load and unload goods, controlled by the conductor and with full responsibility. Movement problems and equipped with means of operation [1-3]. A train station is a place where trains depart and stop to serve the boarding and disembarking of passengers and loading and unloading of goods and for train operational purposes. A train station can also be defined as a center for organizing train travel, without approval from the station the train cannot run, in other words, the station is used as transportation [4-7].

Trains are a means of mass transportation that generally consists of a locomotive (a vehicle with self-propelled power) and a series of trains or carriages (connected to other vehicles) [8-11]. A train is a means of transportation in the form of a vehicle with propulsion, either running alone or in combination with other vehicles that will or are moving on rails [12-14]. There are various

advantages of the train mode which causes the train mode to be a favorite for the majority of Indonesian people. The railway mode also has a quite important role in the economy and social life of the Indonesian people, considering that transportation plays a strategic role in the easy distribution of goods and services to their destination [15-18].

According to Yuliantono, train operation in a broad sense means all activities related to the running of trains. To be precise, railway operations are about controlling problems that arise due to the movement and use of facilities [19-21]. According to Setiawan [22] and Sieber et al. [23] Planning train operation patterns is the preparation of operational plan concepts that will serve as a guideline in planning complete train operations. The main things covered in the concept plan for train operation patterns are the type of transport and number of trains per day, the length of the train series for passengers and goods, the maximum speed of passenger and goods trains, the location, function and class of stations, the types and activities in Station, road area and block area, track capacity and emplacement layout at the station.

Railway facilities are vehicles that move on rails. To achieve the goal of operating comfortable and safe railways, each railway facility must meet the technical and operational feasibility requirements that apply to each type of railway facility [24], [25]. Travel time is the time it takes a train to complete one. Travel cycle, time is influenced by several factors such as average travel time between stations, stopping time at each station, and delay time [26-29]. The train usage cycle is calculated from the increase in demand time required for passengers to board or depart from the train as well as the inspection time of facilities and personnel at departure and arrival stations [30], [31].

According to Erlangga et al. [32], Track capacity is also referred to as the ability of a track to accommodate train trips which is generally expressed in 24 hours or 1440 minutes. [33], [34], traffic capacity is the ability of a track to pass a number of trains in a certain time unit. The electric signaling system must be able to serve reliably and safely for all train trips or meet capacity. Harald Kreuger states that traffic capacity is a measure of the ability to move a certain amount of traffic on a particular railway line with a set of resources based on a predetermined operational plan [35-37]. According to Muna & Rahman [38] and Rifai et al [39], double lanes are two or more lanes with the intention that each lane is used in a different direction cross.

2. Research Method

According to Sugiyono [40], research procedures are scientific methods used by researchers to collect data for certain purposes and uses. In this research procedure, the research process will be explained, starting from data collection which includes secondary and primary data to support the research, then analyzing the data to identify existing problems and find solutions. The steps for this research plan are as follows: First, identify the objectives of this research, as well as the limitations of the research problems being conducted. Second, collect data to support research, both secondary and primary data. Third, identify existing train travel schedules. Fourth, analyze travel time, speed, capacity under existing conditions and travel time, traffic capacity after the double lane on the Mojokerto - Surabaya City route. Fifth, providing changes to travel time after the double track on the Mojokerto - Surabaya City route. Sixth, explain the correct operating pattern after double track on the Mojokerto – Surabaya City route. Seventh, Make conclusions and suggestions based on the results of problem solving and analysis.

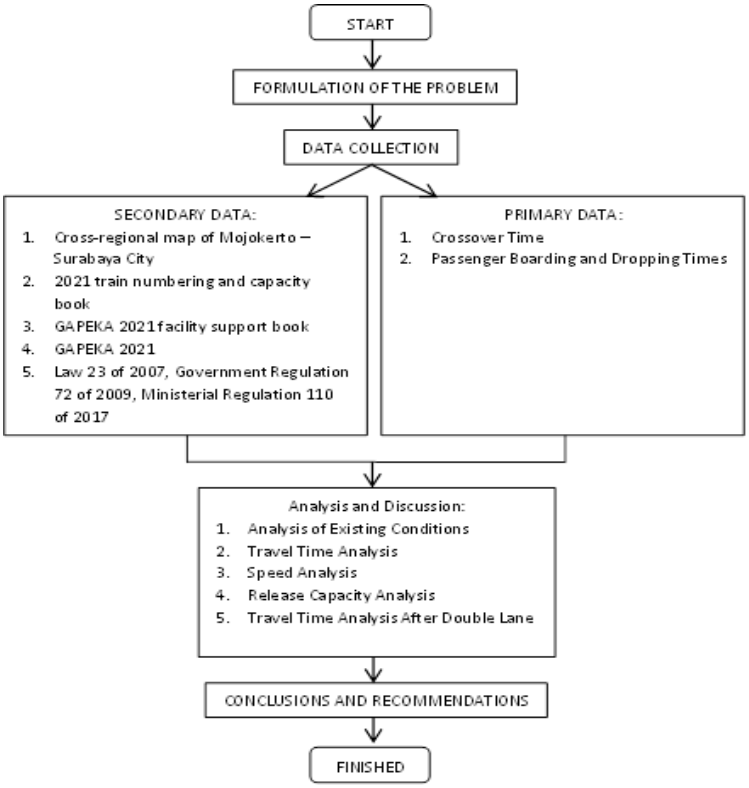

Fig. 1. Research Flow

Observations carried out by researchers were by direct survey at Wonokromo station and stations along. The survey carried out was an observation of the time when the train stopped at the train station to make the crossing and how long it took for passengers to get on and off.

For travel time analysis, the aim is to determine the travel time under existing conditions and travel time without crossing the existing route. The formula for calculating travel time based on peak graphical speed is as follows:

$$T_{A-B} = \frac{60xS}{V} \qquad (1)$$

Information:
T_(A-B) : Travel time from station A to station B (minutes)
60 : Constant number to produce minutes (amount to minutes/km)
S : Distance (km)
V : Speed (km/hour)

Average speed analysis, the aim is to determine the average speed of passenger trains and goods trains. These speeds include:

a. Existing maximum peak speed;
b. Average speed of existing graphics

So we get the following formula:

$$V_{rata-rata=} \frac{(\sum KA\ pnp\ x\ V\ pnp+(\sum KA\ brg\ x\ V\ brg)}{\sum KA\ pnp+\sum KA\ brg} \qquad (2)$$

Information:
V average : Average speed (km/h)

pnp trains : Number of passenger trains
Brg trains : Number of goods trains
V pnp : Passenger train speed (km/hour)
V brg : Freight train speed (km/hour)

Traffic capacity analysis, this analysis relates to existing conditions and calculating new traffic capacity after the double track construction. Before calculating traffic capacity, the headway must first be determined. The amount of headaway for channels that use electrical signals with automatic closing blocks can be calculated using the following formula:

Single Path : H=(180+60.S_AB)/V+1.5 (3)
Dual Path : H=(150+60.S_AB)/V+1.5 (4)

Information:
H : Minimum headway (time interval between two trains in minutes)
S_AB : Distance between the two longest stations (calculated) on the route in question
1.5 : 1.5 minutes, the time required to connect the electrical signaling block with the automatically closed block connection.
V : Average speed
150 : Used for crossing

Cross capacity can be calculated using the following formula:

Single Path : H=1440/H+0.6 (5)
Double Path : H=1440/H+0.7×2 (6)

Information:
C : Cross Capacity
1440 : Conversion for 24 hours
H : Headway
0.6 (60%) : 60% of the time used for train operations, 20% for road maintenance, and 20% to reserve time lost due to waiting for crossings.
0.7 (70%) : 70% of the time used for train operations, 20% for road maintenance, and 10% to reserve time lost waiting for crossings.

3. Results and Discussion

The upgrade from a single to a double track on the Mojokerto - Surabaya City route is anticipated to significantly decrease train travel times by eliminating delays caused by trains waiting for others to pass. The analysis of travel times along various segments of this route provides a clear picture of the expected improvements. For the section from Mojokerto to Wonokromo, the maximum permissible speed is 105 km/hour. Applying an operational efficiency factor of 85%, the effective speed is calculated to be 89.25 km/hour. On the next segment, from Wonokromo to Surabaya Gubeng, the speed limit is lower at 90 km/hour. With the same efficiency factor, trains can travel at an effective speed of 76.5 km/hour. Finally, the speed limit from Surabaya Gubeng to Surabaya City drops to 50 km/hour, translating to an effective speed of 42.5 km/hour when considering the 85% operational efficiency.

This detailed breakdown of speeds along the different segments of the route highlights the expected reduction in travel time due to the infrastructure upgrade. By removing the delays associated with single-track operations, trains will be able to maintain these calculated effective speeds more consistently, resulting in a more efficient and timely travel experience for passengers on the Mojokerto - Surabaya City route.

Information:

105, 90, 50 km/hour is the maximum speed of infrastructure so that facilities crossing Mojokerto - Surabaya City are limited to 105, 90, 50 km/hour.

85% is graphics speed.

Travel time for the Wonokromo – Surabaya route $= \frac{60 \times distance}{v} = \frac{60 \times 4{,}406}{76{,}5} = 3{,}45$ minute

Tabel 2. Travel Time Per Plot

STA	DISTANCE	V	WT
MO-TRK	9,701	89,25	6,52
TRK-KDN	4,599	89,25	3,09
KDN-KRN	4,728	89,25	3,17
KRN-BH	4,463	89,25	3
BH-SPJ	9,7	89,25	6,52
SPJ-WO	6,806	89,25	4,57
WO-SGU	4,406	76,5	3,45
SGU-SB	3,176	42,5	4,48

The calculation of travel time obtained uses the graphical speed permitted in accordance with GAPEKA 2021. Increased travel time can be influenced by reduced speed due to infrastructure and facilities factors. Where travel time is dwelling time (terminal waiting time) plus travel time. There are 21 passenger trains and 4 trains. Goods that experience an increase in time due to crossing or overtaking.

Tabel 3. Existing Travel Time

No. KA	GAPEKA 2021				
	Sta	**Ber**	**Sta**	**Dat**	**WP**
103	SGU	12:00:00	MR	12:45:00	00:45:00
115	SGU	18:12:00	MR	18:55:00	00:43:00
177F	SGU	17:55:00	MR	18:36:00	00:41:00
179	SGU	00:10:00	MR	00:56:00	00:46:00
285	SGU	05:50:00	MR	06:40:00	00:50:00
359	SB	05:00:00	MR	06:19:00	01:19:00
363	SB	12:00:00	MR	13:15:00	01:15:00
365	SB	18:10:00	MR	19:31:00	01:21:00
401	SB	20:50:00	MR	22:08:00	01:18:00
623	SB	07:20:00	MR	08:49:00	01:29:00
2607	SGU	12:51:00	MR	14:00:00	01:09:00
2635F	SGU	23:06:00	MR	00:41:00	01:35:00
104	MR	23:51:00	SGU	00:40:00	00:49:00
248	MR	13:17:00	SGU	14:00:00	00:43:00
288	MR	11:41:00	SB	12:52:00	01:11:00
360	MR	08:36:00	SB	09:42:00	01:06:00
362	MR	14:10:00	SB	15:31:00	01:21:00
364	MR	17:07:00	SB	18:44:00	01:37:00
366	MR	20:30:00	SB	21:39:00	01:09:00
402	MR	05:44:00	SB	07:28:00	01:44:00
626	MR	12:00:00	SB	13:34:00	01:34:00
242F	MR	07:02:00	SB	08:05:00	01:03:00
324f	MR	08:51:00	SGU	09:49:00	00:58:00
300	MR	10:43:00	SB	11:35:00	00:52:00
2636F	MR	14:25:00	SGU	15:45:00	01:20:00

The maximum peak speed of road infrastructure is 90 km/hour in accordance with GAPEKA 2021, with trains passing through:

Table 4. Train speed

Type of train	Number of trains	Vmaks
Argo Train	2 KA	105
Executive Train	4 KA	105
Mixed Executive Train	18 KA	90
Long Distance Economy Train	8 KA	90
Local Economy Train	10 KA	90
Economic KRD	2 KA	90
KA Parcel	2 KA	100
Fuel Train	4 KA	60

The maximum graphical speed for a line is 85% of the calculated maximum speed (lowest maximum speed between railway infrastructure and facilities). Here are the maximum speeds and geographic speeds:

Passenger trains = 44 trains Vmax 90 km/hour
Parcel Goods Train = 2 Trains Vmax 100 km/hour
BBM trains = 4 trains Vmax 60 km/hour

The peak graphics speed is:

Vg Passenger Train = 90 km/hour x 85% = 76.5 km/h
Vg Freight Train = 60 km/hour x 85% = 51 km/h

So the average speed of the existing graphics is:

$$Vg_{average} = \frac{(\Sigma KA\ pnp \times \text{Vg KA pnp}) + (\sum KA\ brg \times Vg\ brg)}{\sum KA\ pnp + \sum KA\ brg} = \frac{(44 \times 76{,}5) + (6 \times 51)}{44+6} = 73{,}44 \text{ km/hour}$$

Changing a single track to a double track will increase traffic capacity so that the increase in traffic capacity will also affect the frequency of trains passing. Several factors influence the increase in traffic capacity, namely speed, headway, time and distance of signaling services. On the Mojokerto - Surabaya City route, closed electrical signaling is used, with 50 trains being analyzed per day. The maximum speed of passenger trains is 90 km/hour, on the Wonokromo – Surabaya Gubeng route, it is 90 km/hour and on the Surabaya Gubeng – Surabaya City route, it is 50 km/hour. By knowing the distance per plot on the Mojokerto Surabaya City route and the speed limit, you can calculate the headway. The following is an example of headway calculation on the Mojokerto – Tarik route

Single lane headway:

$$H = \frac{60 \times S_{A-B} + 180}{V} + 1{,}5 = \frac{60 \times 9{,}701 + 180}{73} + 1{,}5 = 11{,}87 \text{ minute}$$

Double Lane Headway:

$$H = \frac{60 \times S_{A-B} + 150}{V} + 1{,}5 = \frac{60 \times 9{,}701 + 150}{73} + 1{,}5 = 11{,}46 \text{ minute}$$

After calculating the headway, an example of calculating the Mojokerto - Pull capacity is as follows:

Single line crossing capacity:

$C = \frac{1440}{H} \times 0{,}6 = \frac{1440}{11{,}87} \times 0{,}6$ = 72,7 KA/day

Double track crossing capacity:

$C = \frac{1440}{H} \times 2 \times 0{,}7 = \frac{1440}{11{,}46} \times 2 \times 0{,}7$ = 175,79 KA/day

Tabel 5. Cross Capacity

Plot Road	Distance	VG Average	Single Tracks		Double Track	
			Headway	Kaplin	Headway	Kaplin
Mr-Trk	9,701	73,44	11,8	72	11,5	175
Trk-Kdn	4,599	73,44	7,7	112	7,3	276
Kdn-Krn	4,728	73,44	7,8	110	7,4	272
Krn-Bh	4,463	73,44	7,6	113	7,2	280
Bh-Spj	9,7	73,44	11,8	72	11,5	175
Spj-Wo	6,806	73,44	9,5	90	9,1	221

Traffic capacity is calculated based on the capacity of the smallest road plot on the relevant route, so that on the Wonokromo - Surabaya City route, the original capacity was 90 trains, namely on the Along - Wonokromo section, with double track, the determining traffic capacity is the Mojokerto - Tarik road section, namely 175 trains/day so that the traffic capacity increases.

n = Traffic Capacity – Number of Trains.

Tabel 6. Potential for Additional Trains

Cross	Dual Lane Crossing Capacity	Train frequency Existing	Potential Additions Train frequency
Mr - Trk	175	50	125
Trk - Kdn	276	50	226
Kdn - Krn	272	50	222
Krn - BH	280	50	230
Bh - Spj	175	50	125
Spj - Wo	221	50	171

The potential for additional trains for this route can still be increased by 125 trains, assuming that 100% of the traffic capacity is used. This analysis aims to eliminate crossings so that the arrival and departure times of trains at the station will also change. The changes in travel time used are by using the graphical speed plan.

Tabel 7. Running Time Changes

No KA	GAPEKA 2021					GAPEKA PLAN					WP Difference
	Sta	Ber	Sta	Dat	WP	Sta	Ber	Sta	Dat	WP	
103	SGU	12:00:00	MR	12:45:00	00:45:00	SGU	12:00:00	MR	12:44:00	00:44:00	00:01:00
115	SGU	18:12:00	MR	18:55:00	00:43:00	SGU	18:12:00	MR	18:47:00	00:35:00	00:08:00
177F	SGU	17:55:00	MR	18:36:00	00:41:00	SGU	17:55:00	MR	18:28:00	00:33:00	00:08:00
179	SGU	00:10:00	MR	00:56:00	00:46:00	SGU	00:10:00	MR	00:50:00	00:40:00	00:06:00
285	SGU	05:50:00	MR	06:40:00	00:50:00	SGU	05:50:00	MR	06:32:00	00:42:00	00:08:00
359	SB	05:00:00	MR	06:19:00	01:19:00	SB	05:00:00	MR	06:11:00	01:11:00	00:08:00
363	SB	12:00:00	MR	13:15:00	01:15:00	SB	12:00:00	MR	13:06:00	01:06:00	00:09:00
365	SB	18:10:00	MR	19:31:00	01:21:00	SB	18:10:00	MR	19:15:00	01:05:00	00:16:00
401	SB	20:50:00	MR	22:08:00	01:18:00	SB	20:50:00	MR	21:59:00	01:09:00	00:09:00
623	SB	07:20:00	MR	08:49:00	01:29:00	SB	07:20:00	MR	08:38:00	01:18:00	00:11:00
2607	SGU	12:51:00	MR	14:00:00	01:09:00	SGU	12:51:00	MR	13:47:00	11:56:00	00:13:00
2635F	SGU	23:06:00	MR	00:41:00	01:35:00	SGU	23:06:00	MR	24:00:00	00:54:00	00:41:00
104	MR	23:51:00	SGU	00:40:00	00:49:00	MR	23:51:00	SGU	00:37:00	00:46:00	00:30:00
248	MR	13:17:00	SGU	14:00:00	00:43:00	MR	13:17:00	SGU	13:58:00	00:43:00	00:00:00
288	MR	11:41:00	SB	12:52:00	01:11:00	MR	11:41:00	SB	12:41:00	01:00:00	00:11:00
360	MR	08:36:00	SB	09:42:00	01:06:00	MR	08:32:00	SB	09:41:00	01:09:00	00:03:00
362	MR	14:10:00	SB	15:31:00	01:21:00	MR	14:10:00	SB	15:23:00	01:13:00	00:08:00
364	MR	17:07:00	SB	18:44:00	01:37:00	MR	17:07:00	SB	18:19:00	01:12:00	00:25:00
366	MR	20:30:00	SB	21:39:00	01:09:00	MR	20:30:00	SB	21:38:00	01:08:00	00:01:00
402	MR	05:44:00	SB	07:28:00	01:44:00	MR	05:44:00	SB	07:08:00	01:24:00	00:20:00
626	MR	12:00:00	SB	13:34:00	01:34:00	MR	12:00:00	SB	13:15:00	01:15:00	00:19:00
242F	MR	07:02:00	SB	08:05:00	01:03:00	MR	07:02:00	SB	08:01:00	00:59:00	00:04:00
324F	MR	08:51:00	SGU	09:49:00	00:58:00	MR	08:50:00	SGU	09:40:00	00:50:00	00:08:00
300	MR	10:43:00	SB	11:35:00	00:52:00	MR	10:39:00	SB	11:23:00	00:44:00	00:08:00
2636F	MR	14:25:00	SGU	15:45:00	01:20:00	MR	14:25:00	SGU	15:23:00	00:58:00	00:22:00
					Total						04:30:00

From the results of the analysis in Table 7, it is known that there has been a change in the schedule from single route to double route. The smallest difference in travel time is 1 minute, but the largest difference in travel time is 41 minutes. This is because there is a change in travel time and the loss of crossings so that the travel time from Surabaya City to Mojokerto (for odd train numbers) and the travel time from Mojokerto Station to Surabaya City Station (for Even train numbers) will be faster than before. Overall (in total) travel time savings of 4 hours 30 minutes (270 minutes) can be achieved. Attached below are changes to the train travel chart (GAPEKA) for the double track plan.

4. Conclusion

Existing travel time on the Mojokerto – Tarik route is 6.52 minutes, for the Tarik – Kedinding route 3.09 minutes, Kedinding – Krian 3.17 minutes, Krian – Boharan 3 minutes, Boharan – Along 6.52 minutes, Along – Wonokromo 4.57 minutes, Wonokromo – Surabaya Gubeng 3.45 minutes and for the Surabaya Gubeng – Surabaya City route it is 4.48 minutes. This travel time has become shorter because there are only passengers getting on and off and overtaking, no longer crossings. Assuming the average graphics speed uses the existing speed, namely 73.44 km/hour. The plan to change to a double track across Mojokerto - Along will also change the current train travel graph (GAPEKA) so that travel times will be faster, traffic capacity will increase, and no more trains will be found crossing at stations. With the plan to change single lane to double lane on the Mojokerto – Wonokromo route, overall travel time can be saved by 4 hours 30 minutes (270 minutes) and traffic capacity will increase.

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