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The Impact of Stability Factor of Train Operations to Railway Line Capacity (Kroya-Kutoarjo-Yogyakarta) Indonesia

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ABSTRACT

Transportation is the backbone of development. It determines the economic growth of a country. Among any modes of transportation, railway is in need to be developed especially in the increasing of railway lines capacity in addition to the development of railway infrastructures, facilities, and the enhancement of rail operational. The determinant in rail operational is the stability in its operation. This stability can be seen by the punctuality of train arrival and departure, which is in accordance with the Graph Train Journey (Gapeka) and "delay" as the indicator. The study was conducted to determine the stability of railway operation and the delay of train travel as well as to identify the effect of the stability of railway operations to the capacity value of railway line. The study was conducted by collecting secondary data and conducting primary survey followed by data analysis. The results showed that the stability of rail operation for Kroya – Kutoarjo - Yogyakarta line was still low with an average delay of 15.60 minutes for double track and 21.68 minutes for single track. There was a decline in capacity when it was compared to the planned capacity or factual practical capacity at 22% on single track and 17% on double track. Further research on how to determine the cause of the instability of railway operation as input for the stability improvement would be needed in addition to the model or formulation to calculate line capacity in corresponding to the conditions in Indonesia.

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1. INTRODUCTION

1.1. Background

Transportation as the backbone of development determines the economic growth of a country. Railway is the mode of transportation that should be developed [1]. However, the development of railways in Indonesia is still relatively slow. There has been a tendency of decreasing in railways infrastructure operation during the period of 1939-2009 [2]. Moreover, punctuality in Indonesian railways is still relatively low [3].

Delays in railways field are not only on the infrastructure development, the facilities enhancement, and the number of passengers, but also on the development of human resources [4] and methods associated with railway planning, design, and operation. The instability in railways operation indicates that the train service has not yet been maximized. More over the capacity of existing railways cannot be used optimally that there are many delays in train travels.

Based on previous research, it is suggested that there are various factors that affect the railway line capacity, i.e. the number of trains, heterogeneity, operational stability, speed, infrastructure, operations, length of railway facilities, delay, junction, resources, scheduling, track number, track length, termination, and maintenance. Based on the background, this study tries to find out the effects of the railways operation stability on the railway lines capacity in the area of the research.

1.2. Railway Capacity

The railway line capacity is the maximum capacity of a railway line to be able to accommodate a number of train journeys within 24 hours or within a specific time period [5]. The capacity is a measure of the ability to move uncertain amount of traffic through the railway line which is determined by a set of resources based on operational plans that have been established, and according to UIC Code 406 defined capacity as the number of slots in uncertain time unit that takes into account the diversity of each slot or the development of traffic that has been planned and the time assumptions needed for the railway lines maintenances (on a node, a path or a particular part of the network path) in accordance with market orientation [6] [7]. There is also a definition of the railway capacity i.e. ability of across railroad to accommodate the operation of train travel in the period of 1440 minutes (24 hours), which can be implemented in the traffic concerned. Furthermore, according to Pachl (2009), capacity is defined as the maximum traffic flow (train per unit time) which can be accommodated by the railway infrastructure in accordance with the specific operating conditions [8] [9]. In general, the capacity of the vehicle is defined as the flow capability in units of time, but the capacity of the rail road is harder to define given the capacity of railways affected by infrastructure, scheduling and availability of facilities [10].

International Union of Railways (UIC) redefined that the capacity of railways is unspecified yet the railways capacity is affected by utilization on the railways specified. The capacity of the railway line is hard to define because of many factors; one of them is the relationship between the equilibriums of railway capacities[11] [13].

The correlations among variables i.e. stability, average speed, number of train, and train diversity are as follows: (1) In the urban/city railway services, the stability and the number of trains are relatively high in accordance with the trains varieties and average low-speed trains. (2) On the mix train service between urban and long- distance trains, the stability and the number of trains are relatively low in accordance with trains varieties and average high-speed trains.

Meanwhile, the calculation for capacity of railway line in Indonesia is using the following formula or equation:

1. For single track line

$$K = \frac{1400}{H} \; x \; \eta \tag{1}$$

2. For double track line

$$K = \frac{1400}{H} \; x \; 2 \; x \; \eta \tag{2}$$

3. Headway

$$H = ta\text{-}b + tp + C \tag{3}$$

where:

K = Railway line capacity which calculated based on the lowest value on track segmen in the railway line

1440	=	Total time of 24 hours (24 x 60)
η	=	Efficiency or multiplier factor after deducting the time for maintenance and time for train journey operation patterns, 60% for single track and 70% for double track.
H	=	Headway (minutes)
ta-b	=	Travel time between station A to station B (minutes)
tp	=	Travel time of second train from approximately three km before advance signal of station A (minutes)
C	=	Service time blocks and signals (minutes)

There are several definitions of the railway capacity in Indonesia, namely: (a) Theoretical capacity; the capacity values obtained under the condition of the infrastructure. (b) Practical capacity, often called as capacity planning. Capacity value is obtained based on timetabling (Graph of Train Journey/Gapeka) in which time lost as a result of crossing, catch-up, train maintenance as well as the train operation has been counted. (c) The capacity used, often called as rail volume is the number of train journeys in accordance with timetabling. (d) The remaining capacity, the value of practical capacity is reduced by unused capacity [14] [15] [16].

1.3. Railway Operations Stability

According to KBBI (Indonesian Language Standard), stability means steadiness, solidity, balance, could also mean unchanging, fixed, no up and down. In the trains operation, it can be said to be stable if there are no delays in the arrival or departure of the train. In other words, a rail operations can be said to be more stable if the delay has narrowed so that no more delays in the next departure. Stability in the railway system is quite difficult to be maintained because the train punctuality itself depends on the railway system [17]. It is very difficult to evaluate the stability and the punctuality which has not yet entirely taken place. The punctuality estimation with little change in the schedule or in the infrastructure is gained through existing experience. Although it is very difficult to predict the punctuality in the future, generally in the rail traffic law, punctuality will decrease as capacity utilization increases [18] [19].

A. Delay

Stability in rail operation measured by possibility of delay. The higher rate of the delay, the more unstable the operational and likewise. Delay is the time difference between the time of departure and/or arrival compared to the planned schedule. Delay caused by various factors such as infrastructures (rail damage); mode factor (train damage and malfunction); operational or traffic factor (schedule error, signaling error); and human factor (operator) [20].

Delay occurred on a train journey would disrupt railway line utility. The presence of a train travel delay will affect the other train travel, especially on single lane crossing where it occurs. There will be a domino effect when there is a train delay and it affects another train continuously and takes a long time to normalize. Train delays are caused by various factors that occur from the beginning until the final departure of the train journey [21]. This study examined the value of delay in the difference between scheduled and actual time. For example, a train is scheduled to depart from the station A at 07.00 and arrive at the station B at 07.30, in the actual of departing time from the station A is at 07:15 and arrived at the station B at 07.45, then the delay time is 15 minutes although when seen from the side of the travel time there is not much time differences [22].

Based on Minister of the Republic of Indonesia regulation number PM 48 in 2015 on Minimum Service Standards of People on Railway Transport stated that the benchmark inter- city train delays were 10% of total time scheduled [23]. In order to analyze the delays and the operational stability of trains, the researcher classifies the delay of trains between cities into 5 (five) categories, as the stated in Table 1.

Table 1 – Inter-city railway service type

Types of services	Delays Value	Remarks
very good	< 5%	
good	5% - 10%	The value of delays compared to the scheduled travel time.
Average	10% - 15%	
Bad	15% - 20%	
Very Bad	>20%	

B. Train Journey Graph (Timetabling)

Time journey graph is setting guidelines for the implementation of a train journey depicted in the form of a line indicating the station, time, distance, speed, and position of the train journey start from left, crossed, successive, and stops which are depicted graphically for controlling the train travel. Headway is an interval of a train which is approaching and / or departing to the next train. Headway time unit is minute. Headway is also defined as the distance between the two ends of the two trains which are running in the same direction in the same destination path. Headway minimum is the minimum distance that allows the signal to follow the travel speed and security systems [11] [24]. Besides headway, there is also the frequency of train travel which is the number of train that travel on a railway line within 24 hours or within the time period specified by the railway unit of frequency [12] [13].

2. RESEARCH METHOD

2.1 Data Collection Methodologies

This study begins with the collection of data, secondary and primary. Secondary data were collected from Kereta Api (Persero) as the operator and the government, in this case the Directorate General of Railways Ministry of Transportation as the regulator. Primary data were collected by conducting surveys directly at the research site. The research site is determined based on the location that could represent two conditions of the railway lines; single track and double track [25]. Based on this consideration it was determined that the location of research is Kroya-Kutoarjo-Yogyakarta lines. Kroya- Kutoarjo line represents a single track and is also in the working area of Regional Operations (Daop) V Purwokerto while Kutoarjo-Yogyakarta lines represents double track and is in the working area of Regional Operations (Daop) VI Yogyakarta [26]. The main data in this research is Timetabling Data (Graph of Train Journey) in 2013 and the data is factual data worksheet Timetabling or the entire travel trains on 1st to 31st of March 2014 in research site i.e. Kroya-Kutoarjo–Yogyakarta lines, Indonesia.

2.2 Data Processing Method

In this study, the data obtained is processed by using a set of computer and analyzed by using computer programs (software) SPSS to determine the relationship between the stability and the capacity of the railways line. In addition, the analysis also applies regulations and references which containsupporting data both the study of literature and scientific research paper.

3. RESULTS AND DISCUSSION

Based on the data collection; data entry and timetabling data worksheet of train travel in Daop V Purwokerto and Daop VI Yogyakarta on March 1 to 31, 2014, the results are as follows:

3.1. Information on Tracks and Vehicles

The research was conducted at the Kroya-Kutoarjo- Yogyakarta lines. The Kroya-Kutoarjo line consists of 76.08 KM single tracks while Kutoarjo-Yogyakarta line consists of 63.65 KM double tracks. It was found that in the single track (Kroja-Kutoarjo lines) there was 73 trains consisting of 60 passenger trains and four freight trains as well as 9extraordinary trains (KLB), whereas in the double track (Kutoarjo-Yogyakarta lines) there was 62 trains consisting of 52 passenger trains and 4 freight trains as well as 6 extraordinary trains (KLB).

3.2. Delays

The delays obtained are the time difference between the scheduled arrivals in 2013 with the factual timetabling (Gapeka) arrivals on March 1 to 31, 2014. The delays found inthis research are presented in Figure 1 and Table 2. Based on the Table 2, it is identified that there was always delays on thetrain operation. Delays increased on single track and double track. Delays on the double track were lower than that on the single track; the average delay was 15.60 minutes for double track and 21.68 minutes for single track [27]. This showed that the stability of the double track network was sustained compared to that on the single track, this was due to, among others: the double track speeds were generally higher than those on the single track, there was no crossing in the double track, the trains travelled in the same direction on each track, and practically the capacity of double track was higher than that onthe single track [28].

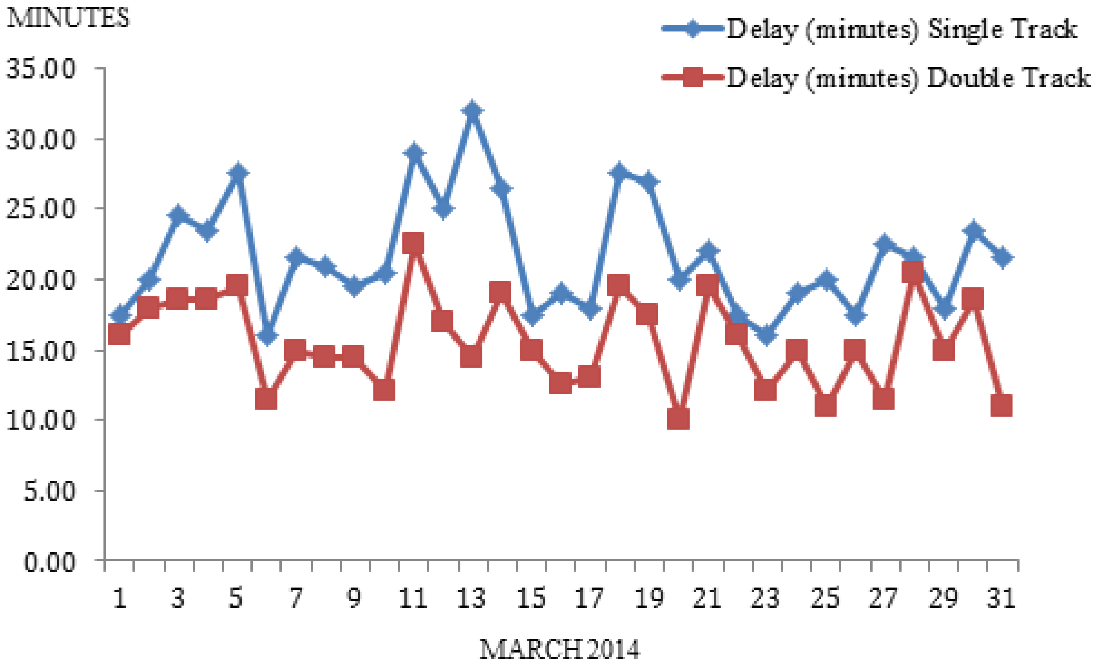

Figure 1. Delay of train journey

Table 2 –Train delay

DATE OF RESEARCH	DELAY (MINUTES)					
	SINGLE TRACK			DOUBLE TRACK		
	Kutoarjo -Kroya	Kroya-Kutoarjo	Average	Yogyakarta-Kutoarjo	Kutoarjo-Yogyakarta	Average
1-Mar-14	15	20	17.50	13	19	16.00
2-Mar-14	14	26	20.00	13	23	18.00
3-Mar-14	16	33	24.50	10	27	18.50
4-Mar-14	23	24	23.50	18	19	18.50
5-Mar-14	14	41	27.50	14	25	19.50
6-Mar-14	14	18	16.00	11	12	11.50
7-Mar-14	16	27	21.50	7	23	15.00
8-Mar-14	20	22	21.00	10	19	14.50
9-Mar-14	22	17	19.50	12	17	14.50
10-Mar-14	10	31	20.50	11	13	12.00
11-Mar-14	31	27	29.00	23	22	22.50
12-Mar-14	17	33	25.00	14	20	17.00
13-Mar-14	22	42	32.00	9	20	14.50
14-Mar-14	27	26	26.50	18	20	19.00
15-Mar-14	13	22	17.50	11	19	15.00
16-Mar-14	16	22	19.00	9	16	12.50
17-Mar-14	23	13	18.00	13	13	13.00
18-Mar-14	32	23	27.50	20	19	19.50
19-Mar-14	21	33	27.00	10	25	17.50

DATE OF RESEARCH	DELAY (MINUTES)					
	SINGLE TRACK			DOUBLE TRACK		
	Kutoarjo -Kroya	Kroya-Kutoarjo	Average	Yogyakarta-Kutoarjo	Kutoarjo-Yogyakarta	Average
20-Mar-14	19	21	20.00	8	12	10.00
21-Mar-14	16	28	22.00	9	30	19.50
22-Mar-14	11	24	17.50	12	20	16.00
23-Mar-14	20	12	16.00	12	12	12.00
24-Mar-14	14	24	19.00	6	24	15.00
25-Mar-14	23	17	20.00	6	16	11.00
26-Mar-14	13	22	17.50	8	22	15.00
27-Mar-14	25	20	22.50	7	16	11.50
28-Mar-14	23	20	21.50	19	22	20.50
29-Mar-14	23	13	18.00	11	19	15.00
30-Mar-14	17	30	23.50	7	30	18.50
31-Mar-14	22	21	21.50	6	16	11.00
Average	19.10	24.26	21.68	11.52	19.68	15.60

Table 2 also shows the delay heading to Kroya-Kutoarjo track that was at 24.26 minutes and 19.68 minutes; this delay was higher than that on Yogyakarta-Kutoarjo track i.e. 19.10 minutes and 11.52 minutes. This was because Yogyakarta andKutoarjo stations were dominated by passengers' arrival and the travel was largely managed by Timetabling which relatively had the same scheduled arrival in the morning and evening. Rush hours schedule in the morning and afternoon caused difficulties for the trains operation, especially in maintaining the stability of its operations [28] [29].

The percentage of trains travel delays compared to a predetermined schedule is 4.2% for double track while for single track is 6.3%. According to the type of service table, double-track service is in very good category while the single track service is in good categories [30] [27].

3.3. Practical capacity, current capacity and delay

Based on the data analysis of Train Journey Graphs (Timetabling) in 2013 and the survey data, it was identified thatthe practical capacity, current capacity and delays can be seenin Table 3 and 4 below.

Based on the tables, it is identified that the current capacityon the single track is the factual capacity at the time of the survey in average of 81 trains per day or 78% of practical capacity, therefore there was a capacity decline by 22%, whereas on the double track, average factual capacity was 143train per day or equal to 83% of practical capacity, in other words there was a decline of 17% capacity.

Table 3 - Capacity and delay of single track

DATE OF RESEARCH	SINGLE TRACK			
	Practical Capacity (trainper day)	Current Capacity (trainper day)	Capacity Decline	Delay (minutes)
1-Mar-14	105	84	20%	17.50
2-Mar-14	105	81	23%	20.00
3-Mar-14	105	78	26%	24.50
4-Mar-14	105	85	19%	23.50
5-Mar-14	105	81	23%	27.50
6-Mar-14	105	82	22%	16.00
7-Mar-14	105	78	26%	21.50
8-Mar-14	105	77	27%	21.00
9-Mar-14	105	78	26%	19.50
10-Mar-14	105	80	24%	20.50

DATE OF RESEARCH	SINGLE TRACK			
	Practical Capacity (trainper day)	Current Capacity (trainper day)	Capacity Decline	Delay (minutes)
11-Mar-14	105	85	19%	29.00
12-Mar-14	105	80	24%	25.00
13-Mar-14	105	80	24%	32.00
14-Mar-14	105	82	22%	26.50
15-Mar-14	105	81	23%	17.50
16-Mar-14	105	85	19%	19.00
17-Mar-14	105	77	27%	18.00
18-Mar-14	105	82	22%	27.50
19-Mar-14	105	81	23%	27.00
20-Mar-14	105	78	26%	20.00
21-Mar-14	105	82	22%	22.00
22-Mar-14	105	82	22%	17.50
23-Mar-14	105	82	22%	16.00
24-Mar-14	105	81	23%	19.00
25-Mar-14	105	84	20%	20.00
26-Mar-14	105	89	15%	17.50
27-Mar-14	105	81	23%	22.50
28-Mar-14	105	82	22%	21.50
29-Mar-14	105	82	22%	18.00
30-Mar-14	105	82	22%	23.50
31-Mar-14	105	82	22%	21.50
Average	105.00	81.42	0.22	21.68

3.4. Capacity Decline and Delay Analysis

A. Kroya-Kutoarjo Track (Single Track)

Based on Table 3, the result of the correlation between thecapacity decline and delay is shown in Figure 2 below. Based on the Table 4, the result of the correlation between the capacity decline and the delay on the single track is shown in Figure 2.

The correlation between these variables is weak; it is seen from the value of R square near to 0 (small) because the smaller number of R square showed the weaker correlation between the two variables. The regression equation is $Y = 21.48 + 0.045X$, where Y is the percentage of decline in doubletrack capacity and X is the delay of the train travel within minutes.

Table 4 - Capacity and delay of single track

DATE OF RESEARCH	DOUBLE TRACK			
	Practical Capacity (trainper day)	Current Capacity (train per day)	CapacityDecline	Delay (minutes)
1-Mar-14	172	138	20%	16.00
2-Mar-14	172	138	20%	18.00
3-Mar-14	172	140	19%	18.50
4-Mar-14	172	146	15%	18.50

DATE OF RESEARCH	DOUBLE TRACK			
	Practical Capacity (train per day)	**Current Capacity (train per day)**	**Capacity Decline**	**Delay (minutes)**
5-Mar-14	172	140	19%	19.50
6-Mar-14	172	146	15%	11.50
7-Mar-14	172	138	20%	15.00
8-Mar-14	172	146	15%	14.50
9-Mar-14	172	146	15%	14.50
10-Mar-14	172	144	16%	12.00
11-Mar-14	172	142	17%	22.50
12-Mar-14	172	148	14%	17.00
13-Mar-14	172	142	17%	14.50
14-Mar-14	172	142	17%	19.00
15-Mar-14	172	144	16%	15.00
16-Mar-14	172	146	15%	12.50
17-Mar-14	172	142	17%	13.00
18-Mar-14	172	144	16%	19.50
19-Mar-14	172	144	16%	17.50
20-Mar-14	172	142	17%	10.00
21-Mar-14	172	142	17%	19.50
22-Mar-14	172	144	16%	16.00
23-Mar-14	172	142	17%	12.00
24-Mar-14	172	144	16%	15.00
25-Mar-14	172	144	16%	11.00
26-Mar-14	172	138	20%	15.00
27-Mar-14	172	142	17%	11.50
28-Mar-14	172	140	19%	20.50
29-Mar-14	172	140	19%	15.00
30-Mar-14	172	144	16%	18.50
31-Mar-14	172	144	16%	11.00
Average	172.00	142.65	0.17	15.60

B. Kutoarjo – Yogyakarta Track (Double Track)

Based on the Table 4, the result of the correlation betweenthe capacity decline and the delay on the double track is shownin figure 3. Based on the figure 3, it can be seen that there is acorrelation between capacity decline and the delay on thedouble track. The correlation between these variables is weak.However, it is still stronger than that on a single track. It is seenfrom the value of R square near to 0 (small) because the smaller number of R square showed the weaker correlation between the two variables [31]. The regression equation is Y = 15.48 + 0.101X, where Y is the percentage of decline in doubletrack capacity and X is the delay of the train travel within minutes.

Descriptive Statistics			
	Mean	Std. Deviation	**N**
CapacityDecline	22.4568	2.49250	31
Delays	21.6774	4.06929	31

Correlations		
	CapacityDecline	**Delays**
Pearson Correlation CapacityDecline	1.000	.073
Delays	.073	1.000
Sig. (1-tailed Capacity Decline Delays	.548	.348
N CapacityDecline	31	31
Delays	31	31

Model Summary[b]				
Model	R	R Squere	Adjusted R Square	**Std. Error of the Estimate**
1	.073[a]	.005	-.029	2.52833

a. Predictors: (Constant), Delays
b. Dependent Variable : CapacityDecline

ANOVA[b]					
Model	Sum of Squares	df	Mean Square	F	**Sig.**
1 Regression	.996	1	.996	.156	.696[a]
Residual	185.381	29	6.392		
Total	186.377	30			

a. Predictors: (Constant), Delays
b. Dependent Variable: Capacity Decline

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	21.486	2.501.11 3		8.592	.000
	Delays	.045		.073	.395	.696

a. Dependent Variable: CapacityDecline

Figure 2. The correlation between the capacity decline and delays in single track

Descriptive Statistics			
	Mean	Std. Deviation	**N**
CapacityDecline	17.0668	1.57037	31
Delays	15.5968	3.26961	31

Correlations			
		CapacityDecline	**Delays**
Pearson Correlation	Capacity Decline	1.000	.211
	Delays	.211	1.000
Sig. (1-tailed)	Capacity Decline	.128	.128
	Delays		
N	Capacity Decline	31	31
	Delays	31	31

Model Summary[b]				
Model	R	R Square	Adjusted R Square	**Std. Error of the Estimate**
1	**.211a**	**.044**	**.011**	1.56139

a. Predictors: (Constant), Delays
b. Dependent Variable : CapacityDecline

ANOVA[b]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	3.282	1	3.282	1.346	.255[a]
	Residual	70.700	29	2.438		
	Total	73.982	30			

a. Predictors: (Constant), Delays
b. Dependent Variable: CapacityDecline

Coefficients[a]						
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	15.489	1.388		11.155	.000
	Delays	.101	.087	.211	1.160	.255

a. Dependent Variable: CapacityDecline

Figure 3. The correlation between the capacity decline and delays in single track

Indicators of train operational stability in this delay have afairly weak correlation with capacity decline of the railway lines; this is happened due to two perceptions of delay, namely: (a) The time difference between scheduled to factual. For example, a train is scheduled to depart from the station Aat 07.00 and arrive at the station B at 07.30, in factual condition; trains departed from station A at 07:15 and arrived at the station B at 07.45. It can be seen that there was 15 minutes delay. However, if it is seen in terms of travel time, there was no delay, so that when it was inserted into the formula for calculating the current valueof the headway, there was no difference, therefore the capacity does not change (decline) from when it was planned. (b) The difference in travel time between planned speed andthe factual speed. Delay caused by the speed difference affected the value of headway and the factual of the railway line capacity. Based on the analysis above, it is necessary to develop a model or formula to calculate the line capacity corresponding to the conditions in Indonesia by calculating the value of delaysoccurred in the field [25] [26].

4. CONCLUSION

From the results of the analysis and series of discussions, the research obtained some conclusions as follows : The stability of the trains operation in Kroya-Kutoarjo- Yogyakarta track has not been established and yet to perform well; the delays, as the indicator of train operation stability, are still occurred, the average delays that occurred 15.60 minutes for double track and 21.68 minutes for single track. There is a capacity decline compared to Timetabling (Gapeka) capacity at 22% on the single track and 17% on the double track. Declining capacity on double track is lower; it indicates that maintaining the stability of the trains operation on a double track is easier because of the absence of crossing in train travel. There is a relationship between the capacity decline and delays that occurs in both single track and double track. The equation to explain is Y = 21.48 + 0.045 X for single track and Y = 15.48 + 0.101X for double track. The stability of train operation is one of the factors that affect the capacity of the railway track. The train operation is more stable as it is indicated by less train delays. In other words, the indication of the train operation stability is when there is always punctuality in train travel. The service of train operation on double track is in very good category, while on the single track is in good category. It is necessary to develop models / formulations to calculate line capacity corresponding to the conditions in Indonesia by calculating the value of delays occurred in the field

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