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MEASURING RAILWAY TRACK CAPACITY AND UTILIZATION FOR KERETAPI TANAH MELAYU BERHAD (KTMB)

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Abstract. The issue of how to achieve maximum capacity in various systems operations in meeting the growing passenger and cargo demand has become an urgent task for railway managers and policy makers. The aims of this study is to evaluate an assessment of the current track capacity and its current utilization as well as assessment of the future of track utilization. In this study, the track capacity analysis covers four main Regions in Peninsular Malaysia, namely Northern, Central, Southern and East Coast which involved a total of 22 routes. There are complex components used to measure the track capacity in this study were the dwell time, train control and signalling system, operating margin, non-interference headway, turnbacks and junctions, and power supply. The Service Grade Indicator for Track Capacity (AAR "National Rail Freight Infrastructure Capacity and Investment Study", September 2007) was referred to determine the level of service. The findings of this study outlines that the average utilization of the whole KTMB track network is approximately 87% (Service Grade E), in which the Northern Region utilizes about 88% of track capacity (Service Grade E), the Central Region at 110% of track capacity (Service Grade F), the Southern Region 47% (Service Grade C) and the East Coast Region is utilizing about 25% of track capacity (Service Grade B). In order to increase efficiency of KTMB operations, based on all analysis conducted, this study provides important recommendations specifically at the bottleneck section. At the bottleneck section in the Klang Valley area, it is suggested that investment should be considered to construct a dedicated track for cargo and high speed train to ensure the efficiency of services by KTMB.

Keywords: KTMB, Railway, Track, Capacity, Utilization, Service Grade

Introduction

Background

Train operations in urban settings are much of the time upset by numerous variables, including fluctuations in passengers demand at stations, signal delays at intersections and many more (Ding and Chien 2001). The joint effect of these variables on train operations expands the trouble in keeping up transit headway adherence. The timetable for railway transportation is an important document for the organization of rail transport. The timetable portrays the time and space movement of the train. In earlier process, train timetabling is crucial in associating between passenger demand and train operation. A high-quality timetable for the use of rail infrastructure resources should be effective (Liu, Pei and Han, 2017). Therefore, in the scheduling process, minimum cycle times must be met to ensure sufficient track capacity and as many trains as possible must be scheduled to meet the anticipated passenger demand.

This study is an assessment of the current track capacity and its current utilization as well as assessment of the future of track utilization. This is important to ensure the success of KTMB in managing track capacity effectively as it forms a baseline or KTMB expansion, future development, and investment in playing its role in meeting their projected demand in future as well as moving towards a more sustainable as safer transportation for Malaysia. The history of KTMB began in 1885, when it was first built to transport tin during the British colonial era. It

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was previously known as the Federated Malay States Railways (FMSR), later known as the Malayan Railway Administration (MRA). The organization was corporatized in 1992 as the Keretapi Tanah Melayu Berhad (KTMB) but remains wholly owned by the Malaysian Government.

As an effort to increase the capacity of the railway network, several investments have been made in constructing double track projects in the West Coast sector and it is projected to be fully completed by the year 2020. As the main rail operator in Peninsular Malaysia, KTMB has gone through various transformations in the upgrading and modernization of the rolling stock as well as rail infrastructure. Most ridership comes from the commuter (KTM Komuter) service. Nevertheless, there is a significant decrease in the ridership of KTM Komuter. This is mainly due to the Klang Valley Double Track (KVDT) phase 1 rehabilitation project Rawang to Salak Selatan, which decreases the train's frequency (The Star, 2017). The ridership is expected to stabilize when the rehabilitation projects to upgrade the track and signal system are completed.

Keretapi Tanah Melayu Berhad (KTMB) Tracks and Trains

The history of the construction of Keretapi Tanah Melayu railways starts from early 1885. The networks cover from Padang Besar, Perlis to Woodlands Train Checkpoint in Singapore and Gemas, Negeri Sembilan to Tumpat, Kelantan. This brand KTMB as the main rail operator in Peninsular Malaysia. In addition, there are branch lines in operation which consist of several important lines such as the commuter train from Port Klang to Batu Caves, which serves Klang Valley commuters and also offers freight services within the networks to connect industrial locations to ports and borders. Based on KTMB's latest information, the total route length is 1,641 km which comprises a total of 176 stations.

Tracks Attributes and Characteristics

There are two types of tracks in the KTMB rail networks, which are single track and double tracks. The origin of the standard for the manufacture of the track comes from the International Union of Railways (UIC), founded in 1992, with the objective of promoting the global rail traffic and meet the transportation challenges and promote sustainable development. The UIC plays an important role in the standardization for the railway construction, and the UIC 54 and UIC 60 are the best examples of this. Meanwhile, BS standard is short of British standard and mainly used for the British railway track (Khadem Sameni, 2012). Besides UIC, KTMB also has rail tracks that use BS standard, specifically BS 80A. There are two types of sleeper which are concrete and wooden sleeper that support the rails in railway track. As different routes may have different track characteristics, there are differences in design speed and maximum axle load for each route.

Method

This study provides an analysis regarding the capacity of KTM's railway track. There are many definitions when measuring the railway capacity. The number of trains refers to the total number of trains that use the railway infrastructure per time interval.

Parameters

The capacity of the railway lines is determined by a large number of factors. This study uses Transit Capacity and Quality of Service Manual (TCQSM) as a guide to obtain findings related to line capacity. The calculation of the railway track capacity refers to the procedures obtained from Chapter 8 in TCQSM (3rd Edition) (Brinckerhoff, 2013). The components to measure the track capacity include Dwell Time, Train Control and Signalling System, Operating Margin, Non-interference Headway, Turnbacks and Junctions and Power Supply.

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Site Observation

Site observation was conducted from 6th February 2018 to 23rd February 2018 for all KTMB rail networks. The main purpose of this observation is to obtain information on the train's operation such as train speed, dwell time, and delays. Other than that, a face to face interview was conducted with the Station Masters of the selected stations. They were asked several questions such as maintenance frequency, operating margin, rehabilitation and safe distance for signalling. These information were gathered as the input in the headways analysis.

Steps of Analysis

Headway calculation is one of the key factors in determining track capacity and utilization (Hideo Nakamura, 1998) stated that the headway of the train is defined as the smallest time interval between two trains at which any train may run by maintaining the established driving pattern without any restriction caused by the preceding train at the target station or on the line. The track capacity and utilization is established following the of six (**6**) steps as follows:

Step 1: Determine the Non-Interference Headway

There are (4) four sub steps in determining Non-Interference Headway. There are: Determine the maximum load point (critical) station, Determine the control system's minimum train separation, Determine the average dwell time at the critical stations and Select an operating margin.

Step 2: Determine the Minimum Headway Associated with the Right-of-Way Type

There are (2) two sub steps in determining Non-Interference Headway. There are: Right-of-way (ROW) types considered, Minimum headway is the highest of the applicable ROW headways. Where the formula:

$$t_{st} = S_m \left[\left(\frac{N_{st} + 1}{2} \right) \left(\frac{3v_{max,st}}{d} + t_{jl} + t_{br} \right) + \frac{L_{st} + L_t}{v_{max,st}} \right] + N_{st} t_d + t_{sw} + t_{0m}$$

where: t_{st} = time to cover single-track section (s), L_{st} = length of single-track section (m), L_t = train length (m), N_{st} = number of stations on the single-track section, t_d = average station dwell time (s), $V_{max,st}$ = maximum speed on single-track section (m/s), d = deceleration rate (m/s^2), t_p = jerk limitation time (s), t_{br} = operator and braking system reaction time (s), S_m = speed margin, t_{sw} = switch throw and lock time (s), and t_{om} = operating margin (s).

Strep 3: Determine the Limiting Junction Headway

Major factors influencing junction headways including Train control separation, Train length, Maximum line speed, Switch angle (influences the speed of trains switching to a new track) and Operating margin.

Step 4: Power Supply Limitations

Power supply limitations are for Quality of service improvements and Construction of a new branch that adds more service to an existing line

Step 5: Determine the Controlling Headway

Controlling headway is the highest of the headways determined from Step 1 (train control system), Step 2 (right-of-way type), Step 3 (limiting junction) and Step 4 (power supply).

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Step 6: Determine Train Throughput

$$T = \frac{1440}{h_c}$$

Where: T = Track capacity (Number of Trains/day), rounded down, 1440 = Number of minutes in a day and h_c = Controlling headway in minutes.

Next, the number of trips per track capacity ratio can be generated in order to calculate the utilization rate for the rail **(Table 1)**.

Table 1. Service Grade /Service Grade Indicator for Tack Capacity

Service Grade	Service Grade Indicator	Descriptions	Track Utilization
A	Far Below Capacity	Far below train flow with capacity to accommodate maintenance and recover from incidents	0.0 to 0.20 **(0% - 20%)**
B	Moderately Below Capacity	Moderate below train flow with capacity to accommodate maintenance and recover from incidents	0.21 to 0.40 **(21% - 40%)**
C	Below Capacity	Below train flow with capacity to accommodate maintenance and recover from incidents	0.41 to 0.70 **(41% - 70%)**
D	Near Capacity	Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents	0.71 to 0.80 **(71% - 80%)**
E	At Capacity	Very heavy train flow with very limited capacity to accommodate maintenance and recover from incidents	0.81 to 1.00 **(81% - 100%)**
F	Above Capacity	Unstable flows; service break-down conditions	> 1.00 **(> 100%)**

Source: AAR "National Rail Freight Infrastructure Capacity and Investment Study", September 2007 . With amendments, MITRANS & KTMB, 2018.

Discussion and Result

The analysis is divided into (4) four major Regions. The Regions are Northern Region, Central Region, Southern Region and East Coast Region. Each Region has different important routes for track access capacity measurement. **Table 2** shows the list of routes for each Region involved in the track capacity analysis. The analysis also covered the (3) three types of services served by KTMB which are Passenger services, Cargo services and Mix services.

Table 2. List of Routes for Each Region

Route	Region
Padang Besar-Butterworth	Northern
Tasek Gelugor - Simpang Ampat	Northern
Butterworth - Ipoh	Northern

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Ipoh - Tanjung Malim	Northern
Tanjung Malim - Rawang	Central
Rawang - Simpang Batu	Central
Simpang Batu – KL Sentral	Central
KL Sentral - SPK	Central
SPK - Pelabuhan Klang	Central
Simpang Batu - Batu Caves	Central
SPK - Seremban	Central
Jalan Kastam - Pelabuhan Klang Utara	Central
Pelabuhan Klang - Pulau Indah	Central
Seremban -Tampin	Southern
Tampin - Gemas	Southern
Gemas – JB	Southern
JB – Woodlands	Southern
Kempas Baru-Pasir Gudang	Southern
Skudai - Tanjung Pelepas	Southern
Gemas –Kuala Lipis	East Coast
Kuala Lipis - Gua Musang	East Coast
Gua Musang - Tumpat	East Coast

Different services have a different number of trips which will affect the capacity ratio in the calculation. Current trips per day are obtained from the schedule provided by KTMB, last updated on January 2018 (Komuter) and December 2017 (ETS and Intercity). Based on the information, the trips for all the services are being included in the calculation.

Current Track Capacity

The current utilization of the KTMB railway track capacity is discussed in this section. The track across the main Regions, i.e. East-Coast, Southern, Northern and Central were considered in identifying the current track capacity utilization. Track information on the chosen routes is shown in **Table 7** which represent each Region used in calculating the capacity. The capacity utilization, which is indicated by Service Grade for the routes are discussed in the next following section. There are several factors which determine the track capacity. To maintain a safe separation between the trains, the actual operation factors are being included in the calculation. There must be a minimum distance between the trains so that there is long enough time for a train to make a complete stop time. Irregularities in the daily operation may introduce delays. To consider such irregularities, the operating margin is added to the combination of the signal system's minimum train separation time, and the critical station dwell time. Operating margin is the amount of time a train can run behind schedule without interfering with the following trains. Thus, it is an important factor contributing to the calculation of the line capacity. The combination of these factors is known as a non-interference headway.

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This non-interference headway is applicable for eighteen (18) routes that have been analyzed in this study.

Overall Track Capacity and Utilization

Table 3 shows the current track capacity utilization for the overall track network. Central Region stated the maximum track utilization and Southern Region stated the minimum track utilization. The average track utilization is 85% (Service Grade E) – At Capacity.

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Region	Trips					Head way (min)	Capacity (Trains /day)	Track Utiliza tion	Serv ice Grad e	Service Grade Indicator
	ET S	Kom uter	Inter city	Car go	To tal					
Northern	12	16	0	15	43	24.62	49	88%	E	At Capacity
Central	7	32	0	7	46	38.18	39	118%	F	Above Capacity
Southern	1	5	6	2	14	54.41	30	47%	C	Below Capacity
East Coast	0	0	12	0	12	71.60	17	71%	D	Near Capacity
Average	5	13	5	6	29	47.20	34	85%	E	At Capacity

Table 3. Current Track Capacity Utilization of Overall Services by Region

East Cost Region Track Capacity and Utilization

This paper only presents East Coast routes as in **Table 4**. Route Gua Musang to Tumpat shows the highest capacity (44%) among others. However, it is still under capacity and there is plenty of space for additional trips.

Table 4. Current Track Capacity Utilization for East Coast Region

Route	Trips	Headway (Min)	Capacity (Trains/day)	Track Utilization	Service Grade	Service Grade Indicator
Gemas - Kuala Lipis	2	38.00	32	6%	A	Far Below Capacity
Kuala Lipis-Gua Musang	10	32.00	38	26%	B	Moderately Below Capacity
Gua Musang-Tumpat	12	45.00	27	44%	C	Below Capacity

Sample Calculation

Sample calculation shown is for Gua Musang to Tumpat route.

Headway = ∑ (Minimum train control Separation + Operating Margin + Dwell time)

30 + 10 + 5 = 45.00 Minutes

$$\text{Capacity (Train/Day)} = \frac{1440-240}{45.00}$$

$$= 27.00$$

Track Utilization = Total Trips

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Capacity

$$= \frac{12}{27} \times 100\%$$

= 44% (Service Grade: C)

Conclusion and Recommendation

There is an increasing emphasis on the importance of transporting people and goods in the most sustainable, economical ways and the environmentally friendly modes. With the current infrastructure, it is suggested that the government and KTMB consider the following recommendations:

For the Southern Region, it is suggested Seremban to Tampin, and Tampin to Gemas routes operate at 20 minute headway, Gemas to JB route at 30 minute headway and 60 minutes headway for JB to Woodlands route. These headways are suggested based on the maximum travel time applied through these routes. However, for JB to Woodlands route, although the actual running time is only 5 minutes, but due to Custom, Immigration and Quarantine (CIQ) procedures, it takes approximately one hour for its clearance.

For the East Coast Region, 60 minute headway is recommended because 60 minutes is the maximum travel time between some of the stations in the East Coast Region. In order to operate at 10 minutes and 15 minutes headways in the Southern and East Coast Regions, the infrastructure should be upgraded to electrified double track.

For the Central Region, in order to implement at 7.5 minute headway, it is suggested that the signalling system should be upgraded. It is because the travel time between stations is less than 7.5 minutes. Specifically, at the bottleneck section in the Klang Valley area, it is suggested that investment should be considered to construct a dedicated track for cargo and high speed train to ensure the efficiency of services. In order to reduce delays and signal clearance time, it is suggested that the turnout time should be improved through the signal system upgrade and construction of a dedicated track. A new short distance train (KTM Komuter) is also suggested to operate from (1) Klang to Pantai Dalam station, and (2) Sungai Buloh to Bank Negara station (within Pelabuhan Klang to Tanjung Malim route) and (3) Mid Valley to Bangi station (within Tampin to Batu Caves route) to reduce congestion at the bottleneck section. It is suggested the investment should be considered dedicated track for high speed train. Even though cargo and passenger services share the same track, cargo services can operate at 40-minutes headway based on the maximum cargo travel time for Northern, Central and Southern Regions. Otherwise cargo service can be operated after 12 midnight to avoid delay passenger services.

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