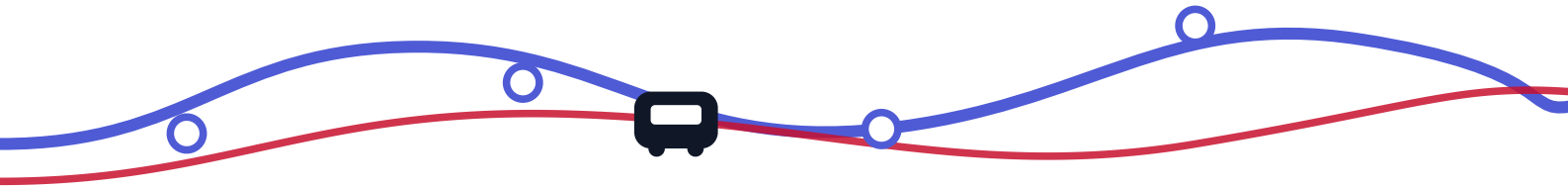
MALAYSIA TRANSIT + SG-JB TRANSIT

WHITE PAPER · NOVEMBER 2026

Malaysia Transit and SG-JB Transit

Free, live public transport information for Malaysia, Singapore and the border between them: why the two exist, what they give riders, how they work, what they cost to run, and how to work with them.



13

areas of Malaysia live, from Kangar to Kuching, plus Singapore and Johor Bahru

13

languages, from Malay, English and Chinese to Tamil, Iban and Bidayuh

RM 0

for riders: no ads, no subscription, no sign-up needed

Malaysia Transit · malaysiatransit.techmavie.digital · **SG-JB Transit** · sgjbtransit.techmavie.digital

Version 1.1 · 27 November 2026

AT A GLANCE

One platform, two apps, every bus and train we can see

Malaysia Transit shows live buses, trains and ferries across 13 areas of Malaysia, on a website and in apps for iPhone, iPad and Android. SG-JB Transit does the same for Singapore, Johor Bahru and the crossings between them. Both are free, with no ads and no subscription, and one person builds and runs them: Aliff, under TechMavie Digital in Penang.

13
areas of Malaysia live, with Kota Kinabalu next

4
ways in: two websites, and two apps on the App Store and Google Play

19M+
requests served by the Malaysia Transit API

53%
of live times within 2 minutes of the bus, up from 32% (21 November 2026)

In five points

- **Everything in one place, free.** Rapid KL, Rapid Penang, BAS.MY in ten cities, Bas Muafakat Johor, KTM, the Penang ferry, Causeway Link, Singapore's buses and the border trains, on one map, with no ads and nothing locked behind a subscription.
- **Live times from the bus itself.** Arrival times come from each bus's GPS, measured along its route at the pace its service is really making, and buses still at their first stop say "Not departed yet".
- **Every bus recorded.** Since 21 November 2026 every bus with a live GPS feed is recorded, so anyone can see how well each route keeps its timetable, stop by stop, day by day and week by week.
- **Our own journey planner.** Since 27 November 2026 journeys are planned by MOTIS, an open-source planner we run ourselves, on the operators' timetables and OpenStreetMap, with places from GrabMaps. Google Maps is no longer needed (Appendices D and E tell the whole story).
- **Open to work with.** Agencies, operators, developers, the media and funders can use the data, the API and the records, and help them grow. Part 6 says how.

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PART 1

Why they exist

Malaysia has good public transport in more places than most people think, and much of it publishes live data. What riders lacked was one clear, free place to see it all.

1 The gap we set out to fill

Information was scattered

Each operator has its own app, website or nothing at all: Rapid KL and Rapid Penang, BAS.MY in each city, KTM, the ferries, Causeway Link. A trip that uses two of them meant two apps, or guesswork.

The popular apps charge

Apps such as Moovit and Transit ask for a subscription to remove ads or unlock some features. A rider waiting for a bus in Kangar shouldn't have to pay to see when it comes.

Free maps don't tell the whole story

Google Maps and Apple Maps show some live times, but not a stop's whole timetable, the fare and how to pay each operator, whether buses keep their times, or the border crossings' details. Nor are they laid out the way riders here travel.

Tourists and locals alike

Visitors from Thailand, Indonesia, China, Korea or Japan, and Malaysians of every language, need the same clear answers. Both apps and websites speak 13 languages, including Tamil, Iban and Bidayuh.

Accountability. A timetable is a promise. Recording every bus shows, plainly and for everyone, how well each route keeps it, which helps riders plan and gives operators and agencies the evidence to improve. Section 10 and the arrival-times white paper describe how.

2 Built for daily use

> "I want to design the app and the web version to fit my own day-to-day use."
>
> Aliff, who builds and runs both

Both products started from one rider's real trips in Penang and beyond, and grew from what was missing on them: which bus is coming and where it is now, whether it has left its terminal, which stop to wait at, what to pay and how, and what to do at the border. Every feature since has been tried on real journeys first, on an iPhone, an iPad and Android, and fixed when it didn't hold up.

3 Why SG-JB Transit is its own app

- **Border commuters.** People who cross the Causeway or the Second Link every day juggle Singapore's buses, Causeway Link, Johor's buses and KTM's Shuttle Tebrau, each with its own app or none. SG-JB Transit puts them together, the crossing included.
- **Singapore is different.** Its data comes from LTA DataMall, its buses carry no trip numbers, it prices in Singapore dollars and has its own rules and riders. An app built for it from the start serves them better than a corner of a Malaysian one.

- **A name people find.** Someone in Singapore or Johor Bahru searching an app store looks for Singapore and JB, not "Malaysia Transit".
- **Proving the platform.** SG-JB Transit runs on the same platform as Malaysia Transit, adapted for another country. It shows the platform can serve more places, and a Hat Yai version already does.

4 Principles

Free for riders

No ads, no paywall, no account needed. Riders who want to can leave a tip ("Buy me a matcha latte").

Honest about what it knows

A live time says it's live; a timetabled one says it's scheduled; a bus at its terminal says "Not departed yet". Records say where they come from and their limits.

The operators' own data

Timetables, fares and payment rules come from the operators and agencies, checked against their published sources and dated.

Independent

Neither is a government app, nor affiliated with or endorsed by any government body or operator, including the Ministry of Transport, APAD, Prasarana, KTMB, BAS.MY and LTA.

PART 2

What riders get

The websites and the apps share the same features and data, worked out by the same server. The apps add what phones do best: alerts, a lock-screen Live Activity, widgets and an offline copy of timetables.

5 The live map

Every bus with a live feed is on the map, labelled with its route and where it's going ("101 → Teluk Bahang"), with an arrow for its heading. Routes are drawn along OpenStreetMap's roads and railways, in one direction or both, with their stops. **Nearby stops** puts a pin where you are (or on a place you search for) and lists the closest stops with their next live buses.

6 Stops and arrivals

A stop's sheet lists its live arrivals, coloured by punctuality, then its timetable. **Bus approaching** shows a bus coming to your stop on a map, the stops still to go numbered from the bus, and the buses after it. **Today at this stop** says how today's buses kept to their timetable ("13 of 16 on time · 3 late"). Stops that two areas share, such as Sungai Petani's, list both areas' buses.

7 The journey planner

From any address or place to any other, by bus, train and ferry, now or at a chosen time. Each option reads down a **timeline**: where to walk, board and change, each ride's next bus or train (tap a live time to watch the bus come, or a timetabled one for its departures), the fare for adults and concessions, and **how to pay** on each operator. Journeys are planned by our own MOTIS planner and places come from GrabMaps (section 18). Trips into Singapore hand over to SG-JB Transit.

8 Departures and timetables

Every route's next departures from its first stops, the operators' official timetables, and for Rapid KL, the MRT feeders and Rapid Penang, the times their buses *usually* leave, learned from four weeks of records, because their published timetables don't hold. Under each timetabled time, a coloured line says how its bus ran over the last week, and each route's **actual timetable** can be downloaded as a PDF, made fresh from the records whenever it's asked for.

9 Track this bus and widgets

The bell beside a live arrival follows that bus and alerts you at 10 and 5 minutes, when it's almost there, and when to get off, on the lock screen as a Live Activity on iPhone or a live notification on Android. Home-screen widgets (My Stops and Where I Am) show your places' next buses at a glance.

10 Trip history and reports

Since 21 November 2026 every bus with a live GPS feed is recorded every 30 seconds. The Trip history page shows each area's figures, the buses that just left, departures by the hour, how each service ran today,

and any day or route since. On time means from 1 minute early to 5 minutes late against the bus's own timetabled time. Each area gets a **weekly report** (a PDF in 13 languages, ready every Monday at 04:00 from 30 November 2026), and Khazanah Research Institute's 2025 archive of Rapid KL and the MRT feeders is kept apart and labelled as such. SG-JB Transit records Singapore's cross-border services (160, 170, 170X and 950) and shows Johor Bahru's from Malaysia Transit's records.

11 Fares and how to pay

The fare calculator and every journey give each operator's own fares, adult and concession, with notes where they matter (Bas Muafakat Johor free for Malaysians, KTMB's promotional fares, Causeway Link's section fares). **How to pay** lists each operator's ways to pay (cash, cards, QR, e-wallets and passes) with who can use each and how to get it, checked city by city: BAS.MY takes bank cards in Ipoh, Melaka, Johor Bahru and Kota Kinabalu, on some of Seremban's routes and rarely elsewhere, and Kangar takes cash only.

12 Languages, accounts, privacy

- **13 languages:** English, Malay, Chinese (simplified and traditional), Tamil, Hindi, Thai, Indonesian, Vietnamese, Korean, Japanese, Iban and Bidayuh.
- **Accounts are optional:** sign in with Apple, Google or a passkey (no passwords) only to keep saved stops and routes in step across devices. One account works in both apps.
- **No ads, no advertising tracking:** each app's privacy policy lists exactly what is sent where, and why. A position is only sent to find nearby stops, plan a journey or name a place.

PART 3

Coverage

Thirteen areas of Malaysia are live, from Perlis to Sarawak, and SG-JB Transit covers Singapore, Johor Bahru and the crossings between them.

13 Malaysia, area by area

AREA	BUSES	TRAINS AND FERRIES
Klang Valley	Rapid Bus KL, MRT feeder buses	Rapid Rail KL (LRT, MRT, Monorail), KTM Komuter, KLIA Ekspres and KLIA Transit
Penang	Rapid Penang	Penang ferry, KTM Komuter Utara, SRT's shuttle to Hat Yai
Kangar	BAS.MY Kangar	KTM Komuter Utara, SRT's shuttle
Alor Setar	BAS.MY Alor Setar	KTM Komuter Utara, SRT's shuttle
Ipoh	BAS.MY Ipoh	KTM Komuter Utara
Kota Bharu	BAS.MY Kota Bharu	KTM Intercity
Kuala Terengganu	BAS.MY Kuala Terengganu	-
Kuantan	BAS.MY Kuantan	-
Seremban	BAS.MY Seremban (two operators)	KTM Komuter, KTM Intercity
Melaka	BAS.MY Melaka	KTM Komuter
Johor Bahru	BAS.MY Johor Bahru, Bas Muafakat Johor, Causeway Link, Singapore's cross-border buses	KTM Shuttle Tebrau, KTM Shuttle Selatan
Rest of Johor	Bas Muafakat Johor (Batu Pahat, Kluang, Muar, Segamat, Mersing and more)	KTM Shuttle Selatan
Kuching	BAS.MY Kuching, City Public Link's S19 to the Tebedu border	-
Kota Kinabalu	**Coming soon**	

Live positions are shown wherever the operator publishes them; timetables and fares cover the rest.

14 Singapore, Johor and the border

Singapore

Every bus service, with LTA's arrival times and where LTA places each bus, the MRT and LRT for journeys, and the cross-border buses: SBS Transit's and SMRT's 160, 170, 170X and 950, and Causeway Link's CW routes. Fares in Singapore dollars or ringgit, as the rider chooses.

Johor Bahru and the crossing

Johor's buses as on Malaysia Transit, Causeway Link's routes as it publishes them, KTM's Shuttle Tebrau between JB Sentral and Woodlands, and the time it takes to clear the border, shown as its own step in every cross-border journey.

PART 4

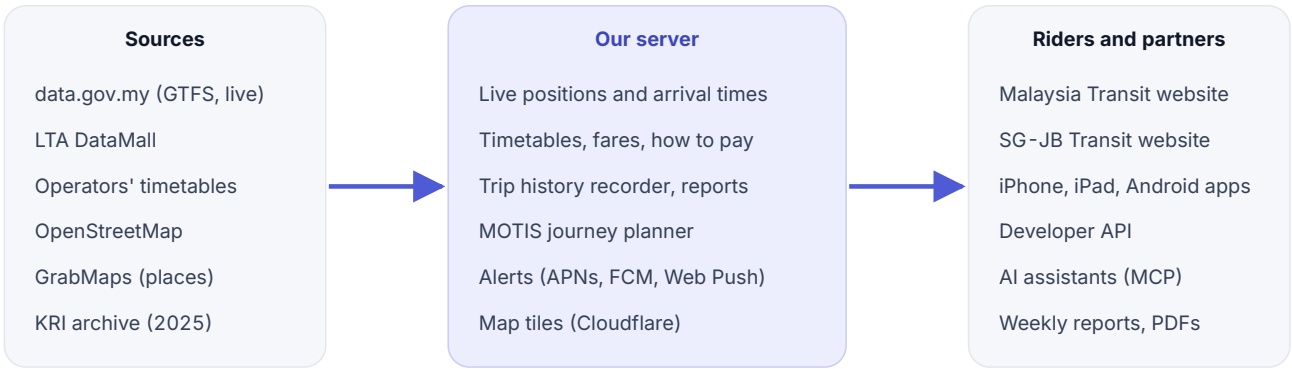
How it works

One server gathers the data, works out live times and records, plans journeys and answers the websites, the apps and other developers. Nearly everything it uses is open data or open source.

15 Where the data comes from

SOURCE	WHAT IT GIVES	LICENCE OR TERMS
data.gov.my	Timetables (GTFS) and live bus positions (GTFS Realtime) for Rapid KL, the MRT feeders, Rapid Penang, BAS.MY and KTM	CC BY 4.0
LTA DataMall	Singapore's bus arrivals, routes, stops and first and last buses	Singapore Open Data Licence
Operators' own pages	KTMB's timetable PDFs and fare tables, Causeway Link's routes and fares, Bas Muafakat Johor's live page (PAJ), the Penang ferry and SRT timetables	Published by the operators; checked and dated
OpenStreetMap	The base map, the streets for walking and planning, and the route lines along roads and railways (Appendix D)	ODbL (© OpenStreetMap contributors)
GrabMaps	Place and address search, through Amazon Location Service	Paid per request (section 20)
Khazanah Research Institute	A 2025 archive of Rapid KL's and the MRT feeders' bus positions, for history before our own records	As published, credited

16 How the platform fits together



One server per product, on a single small virtual server, with the journey planner beside it and the map tiles on Cloudflare.

- **The server** is a Node.js application on a virtual private server, deployed with EasyPanel. It checks the operators' timetables for new ones every hour, reads live positions as they're published, and answers every request from the websites and apps.
- **The apps** are built once for iPhone, iPad and Android (React Native with Expo). Fixes and most new features reach phones as over-the-air updates within minutes, without waiting for a store review.

- **The map** is our own: OpenStreetMap data, packed into one file of map tiles served from Cloudflare, so no map provider bills per view.
- **The websites** are plain, fast pages that work on any phone, installable as an app.

17 Live times and punctuality

A live time is worked out from the bus's own position: it is placed on its route line, the distance left to the stop is measured along that line, and it is timed at the pace that service's buses are making right now, plus a short stop at each stop on the way. Run on the same buses at the same moments, times within 2 minutes of the real arrival went from 32% to **53%**, and from 45% to **92%** when the bus was under 3 minutes away. Punctuality is measured from the records, never assumed. The full method, with every figure, is in the white paper *Live arrival times and punctuality* (Appendix A).

18 Journey planning without Google

Until November 2026 journeys and place search came from Google Maps. Two things made us move. Google's terms don't allow its route and place results to be shown on a non-Google map, and both products use their own OpenStreetMap map. And Google bills per request, so every new free rider would have raised the bill as the products grew.

MOTIS plans the journeys

An open-source journey planner (MIT licence), run on our own server. It plans on the operators' timetables and OpenStreetMap's streets, including the services Malaysia Transit puts together itself: KLIA Ekspres, the Penang ferry, SRT's shuttle to Hat Yai, Causeway Link's AA1, and Singapore's buses (from LTA's first and last buses and frequencies), MRT and LRT. Its data is refreshed every night and checked with a test journey before use. It was chosen over OpenTripPlanner, the best-known alternative, because it needs a fraction of the memory (it runs within 1.5 GB and answers in 9 to 110 milliseconds), so it fits beside the apps on one small server. On 25 test journeys across Malaysia it matched or beat Google on most, and it planned Seremban to KL Sentral, which Google couldn't.

GrabMaps finds the places

Place and address search comes from GrabMaps, through Amazon Location Service, for Malaysia, Singapore and Thailand, reordered so places near the rider come first. GrabMaps is built for South-East Asia, its terms allow its results on our own maps, and it costs a fraction of Google's prices (section 21). It is weaker than Google on English descriptions and short names, which the server's reordering partly makes up for.

The planner's answers keep the same shape as before, so the websites and apps needed no change to use them. Fares, payment guides, live times and tracking are added on top, as before. Appendix E tells the whole story: how MOTIS and GrabMaps work, how they compare with OpenTripPlanner and Google, and what they cost. Appendix D explains how the route lines are drawn along OpenStreetMap's roads and railways.

19 Quality and checks

- **Tested code:** over 3,000 automated tests across the servers, websites and apps, run on every change. The apps port the websites' logic function by function, with tests, so both give the same answers.

- **Checked sources:** timetables and fares are compared with the operators' own pages and PDFs, with the date checked kept beside them.
- **13 languages kept whole:** every screen's words exist in every language, checked automatically, so nothing falls back to a half-translated page.
- **Watched in use:** live times are replayed against where buses really went, and the records are checked against each bus's GPS track (92% of recorded stop times within 30 seconds).

PART 5

Costs and sustainability

Both products run on very little, by design: open data, open source and one small server, so they can stay free for riders.

20 Running costs

ITEM	WHAT IT DOES	COST
Server (netcup VPS)	Both products' servers, the MOTIS journey planner, the trip history recorder and the analytics	€12.60 a month
Journey planning (MOTIS)	Every journey on both websites and both apps	Nothing per journey
Place search (GrabMaps)	Suggestions as you type, the chosen place, addresses	US$0.20 per 1,000 suggestions, US$0.50 per 1,000 lookups
Map tiles (Cloudflare)	The base map, stored on R2 and served by a Worker	Free tier; US$5 a month once traffic needs it
App builds and updates (Expo)	Building both apps, and over-the-air updates	US$19 a month, then US$0.005 per user over 3,000
Apple Developer Program	Publishing on the App Store	US$99 a year
Google Play	Publishing on Google Play	US$25, once
Data, alerts	data.gov.my, LTA DataMall, OpenStreetMap; Apple's and Firebase's push alerts	Free
All in, at today's traffic	**Server, Expo, the App Store fee spread over the year, and a little place search**	**About US$45 a month**

Prices as published on 27 November 2026: netcup's plan, Expo's Starter plan, Amazon Location Service in Asia Pacific (Malaysia), Cloudflare's Workers plans, Apple's and Google's developer fees. Amazon gives place search a free allowance for the first three months: 10,000 suggestions and 20,000 lookups a month.

What grows with riders: place search, a little per search; Expo's updates, once the apps pass 3,000 monthly users (US$85 a month at 20,000, for example); and in time, a larger server. What doesn't: journey planning, the map's data and the live feeds.

21 Before and after Google

Google Maps Platform gives each service a free allowance of 5,000 to 10,000 requests a month, then charges for every 1,000 more. GrabMaps and MOTIS cost a fraction of that, and MOTIS nothing per journey:

FOR	GOOGLE MAPS PLATFORM	NOW
Planning a journey	Directions: US$5.00 per 1,000 after 10,000 free a month, and each plan made several calls	MOTIS: nothing per journey
Suggestions as you type	Autocomplete: US$2.83 per 1,000 after 10,000 free	GrabMaps: US$0.20 per 1,000
The chosen place	Place Details: US$5 to US$20 per 1,000, by detail level	GrabMaps: US$0.50 per 1,000
Address to position	Geocoding: US$5.00 per 1,000 after 10,000 free	GrabMaps: US$0.50 per 1,000

US$0
for 100,000 journeys a month with MOTIS, against at least US$450 with Google Directions

US$70
for 100,000 place searches a month with GrabMaps, against about US$990 with Google's Places UI Kit

95%
less for the two together at that traffic: about US$70 against about US$1,440

1
set of terms that fits our own maps: Google's don't allow its results on a non-Google map

Google's prices from its pricing page and Amazon's from its price list for Asia Pacific (Malaysia), both read on 27 November 2026; one suggestion request and one lookup per search, after the free allowances. A rider typing sends several suggestion requests, so real searches cost a little more on both.

22 How it is funded

- **The builder pays the running costs.** Both products are built and run by one person, under TechMavie Digital.
- **Riders can tip** through "Buy me a matcha latte", on the websites and in the apps. Nothing is locked behind it.
- **No ads, no selling of data.** Neither product shows advertising or sells riders' data.
- **The developer API** lets businesses and other developers build on the same data.
- **Sponsors and grants are welcome** where they keep the apps free and independent (Part 6).

PART 6

Working together

This paper is for anyone who wants to work in this field with Malaysia Transit and SG-JB Transit: government and agencies, operators and partners, developers and the media, funders and sponsors.

23 Ways to work together

Government and agencies

The records show how every route keeps its timetable, stop by stop and week by week. Live feeds with trip numbers, and timetables published as data rather than PDFs, would make every rider's times better. We would gladly share findings and help pilot improvements.

Operators and partners

Your routes, timetables, fares and ways to pay, shown correctly, in 13 languages, beside every other operator a rider needs. Send us changes before they happen, or a live feed, and riders see them on day one.

Developers and the media

The Malaysia Transit API (developer portal at developers.malaysiatransit.techmavie.digital) and AI assistant tools (MCP) give stops, live arrivals, timetables, fares and journeys. Journalists and researchers can ask for records and reports.

Funders and sponsors

Support keeps both products free and lets them reach more places: Kota Kinabalu next, more live feeds, more languages. Sponsorship that keeps the apps ad-free and independent is welcome.

24 What comes next

- **More places:** Kota Kinabalu, and any city whose buses publish live positions.
- **More from the records:** longer histories, usual times for more services, and reports agencies can use.
- **The apps:** Malaysia Transit's iPhone app through App Store review, then updates to both apps every few days.
- **Better data:** working with operators so timetables, fares and live feeds match what runs on the road.

Get in touch

Email **hello@techmavie.digital** · Threads **@hiiialanhere**
Malaysia Transit: **malaysiatransit.techmavie.digital** · SG-JB Transit: **sgjbtransit.techmavie.digital**
Built by Aliff under TechMavie Digital, Penang, Malaysia.

APPENDICES

Documents, glossary and sources

A Documents and downloads

DOCUMENT	WHERE
Enhanced route lines (white paper, Appendix D)	malaysiatransit.techmavie.digital/white-paper-route-lines.html, and as a PDF
MOTIS and GrabMaps (white paper, Appendix E)	malaysiatransit.techmavie.digital/white-paper-journey-planning.html, and as a PDF
Live arrival times and punctuality (white paper, PDF)	malaysiatransit.techmavie.digital/downloads/malaysia-transit-arrivals-and-punctuality.pdf
How arrival times are worked out	malaysiatransit.techmavie.digital/arrival-times.html
Trip history, and how punctuality is measured	malaysiatransit.techmavie.digital/trip-history.html
Weekly reports (PDF, each area, 13 languages)	From the Trip history page, every Monday
Actual timetables (PDF, each route)	Under each route's timetable on Departures
How to use (with clips)	malaysiatransit.techmavie.digital/how-to.html
Frequently asked questions	malaysiatransit.techmavie.digital/faq.html
Changelog	malaysiatransit.techmavie.digital/changelog.html · sgjbtransit.techmavie.digital/changelog.html
Privacy policies	malaysiatransit.techmavie.digital/app-privacy.html, and in each app
Developer API	developers.malaysiatransit.techmavie.digital

B Glossary

GTFS	General Transit Feed Specification: the standard file format for timetables, routes and stops.
GTFS Realtime	The live companion to GTFS: where each vehicle is, updated every few seconds.
MOTIS	An open-source journey planner, run on our own server.
GrabMaps	Grab's maps and place data for South-East Asia, offered through Amazon Location Service.
OpenStreetMap	The free, open map of the world, made by volunteers.
ODbL	Open Database Licence: OpenStreetMap's licence. Its data, and data built from it, may be used by anyone, with credit, under the same licence.
pfaedle	An open-source tool from the University of Freiburg that matches timetables to OpenStreetMap's roads and railways, to draw route lines.
Map matching	Finding the path along a map's roads or railways that best fits a set of positions, such as a route's stops.
OTA update	An over-the-air update: new app code delivered without a new store release.
MCP	Model Context Protocol: a standard way for AI assistants to use tools such as transit data.
Not departed yet	A live bus still at its trip's first stop: its time counts from its departure, not from now.

C Sources and credits

Live and timetable data: data.gov.my (Ministry of Transport and the operators, CC BY 4.0); LTA DataMall (Land Transport Authority, Singapore Open Data Licence); KTMB, Causeway Link, Perbadanan Pengangkutan Awam Johor (Bas Muafakat Johor), Penang Port and the State Railway of Thailand's published timetables and fares. Maps and streets: © OpenStreetMap contributors (ODbL), drawn from Protomaps' builds. Place search: GrabMaps through Amazon Location Service. Journey planning: MOTIS (motis-project, MIT licence). Historical positions: Khazanah Research Institute's 2025 archive. Figures on live times and records: *Live arrival times and punctuality*, version 1.1, 23 November 2026.

Malaysia Transit and SG-JB Transit are independent apps, not government apps. They do not represent, and are not affiliated with or endorsed by, any government entity or transit operator.

APPENDIX D · TECHNICAL WHITE PAPER

Enhanced route lines from OpenStreetMap

A route line is what the map draws for a route between its stops. Since 26 November 2026, Malaysia Transit and SG-JB Transit draw their Enhanced route lines from OpenStreetMap, the open map of the world, instead of Google Directions. Buses are matched to the roads with pfaedle, an open-source tool from the University of Freiburg made for exactly this job, and trains follow the railway track by a method of our own that also finds stations a timetable puts in the wrong place.

1,337
route patterns drawn: 1,210 bus patterns by pfaedle, 127 train patterns along the track

802
Singapore bus service directions, which LTA publishes with no lines at all

6–11 m
from the stops to the new lines, on average, across the eight BAS.MY timetables tested

23
KTM stations found off the railway or out of order in the timetable, reported back

In four points

- **Lines that follow the route's own roads.** pfaedle works out which roads a bus takes through all its stops, in order, preferring main roads and the bus routes mapped in OpenStreetMap, so a line no longer swerves onto another road to reach a stop set back from the kerb.
- **Ours to show, keep and share.** The lines are OpenStreetMap data, under the Open Database Licence: they may be shown on any map, kept for good and shared, with the credit "© OpenStreetMap contributors". Google's terms allowed none of that.
- **Checked line by line.** Every line passes a quality check before it is kept. One that fails falls back to the timetable's own line, so Enhanced is never worse than Basic.
- **Cheap to keep up.** All the lines are rebuilt in about 20 minutes on the server the apps already run on, into about 2 MB of files. Nothing is paid per line shown.

Contents

D1 What a route line is
D2 Where the lines came from
D3 Why Google's lines had to go
D4 The options
D5 OpenStreetMap, the map underneath
D6 pfaedle, in brief
D7 How pfaedle matches a route
D8 Our build, step by step
D9 Trains, along the track
D10 Routes no timetable draws
D11 The trial
D12 What is built today
D13 Against Google's lines
D14 What the build found
D15 How the apps use the lines
D16 Rebuilding
D17 Licence and credit
D18 Limits and next steps
D19 Sources

APPENDIX D · BACKGROUND

Why route lines needed a new source

Riders read a route from its line. Most of the timetables we show don't draw one that follows the roads, and the service that used to draw them for us came with terms our maps can't meet.

D1 What a route line is

A route line is the path the map draws for a bus or train route between its stops. Riders use it to see which roads a bus takes, where it turns and where to wait for it, and the apps draw each ride of a planned journey along it. Both products offer two styles, switched on the map under Route Style:

Basic

The stops joined by straight lines, or the operator's own line where its timetable has one. Always available, and honest about what the timetable says.

Enhanced

The route along the roads it really takes, and trains along their track. Labelled "✓ Enhanced along OpenStreetMap" where the line comes from this work.

Timetables in the GTFS format may carry each route's path (the optional `shapes.txt` file), but most of the ones we show don't carry one that follows the roads:

- **BAS.MY's feeds** on data.gov.my for Alor Setar, Ipoh, Kangar, Kota Bharu, Kuala Terengganu, Kuching and Seremban (two) have one point per stop, so their own line is just the stops joined up.
- **KTMB's live feed** has no lines at all.
- **LTA DataMall** gives Singapore's bus routes as lists of stops, with no lines.
- **Our own timetables** for Causeway Link, City Public Link S19, KLIA Ekspres and SRT's shuttle to Hat Yai had lines made with Google Directions (section D2).

Prasarana's feeds (Rapid KL's buses and trains, the MRT feeders and Rapid Penang), BAS.MY's for Johor Bahru and Melaka (5 to 20 points per stop) and Rapid Kuantan's already have good lines of their own, and keep them. The server uses an Enhanced line where a timetable's own is too sparse to follow the roads: fewer than 1.5 points per stop, no line at all, or a KTM train.

D2 Where the lines came from

Until 26 November 2026, Enhanced lines came from Google Directions, in three ways:

- **On request.** Malaysia Transit's server asked Google for directions through a route's stops when a rider opened it, and kept the answer. KTM's lines came the same way.
- **Saved into our timetables.** Four build scripts had fetched Google's directions once and saved them as lines: Causeway Link's CW2 and parts of CW4S and CW6 (also copied into SG-JB Transit), City Public Link S19, KLIA Ekspres and SRT's shuttle. Some station positions had been copied from Google Maps too.
- **Kept for good.** SG-JB Transit's server kept its Google lines in a permanent cache file.

D3 Why Google's lines had to go

Not allowed on our maps

Google's Service Specific Terms say Directions results "must not" be used "in conjunction with a non-Google map" (section 4.2). Our websites draw with Leaflet on an OpenStreetMap map, and the apps with MapLibre: neither is Google's.

Not allowed to keep

Only latitudes and longitudes may be cached, for up to 30 days (section 4.3), and the general terms forbid storing Google's content or making new content from it (section 3.2.3). Lines saved into timetables, or cached for good, did both.

Not the bus's roads

A directions service finds its own best way between each pair of stops: it doesn't know which roads the bus takes. Where a stop sat a little off the road, Google's line sometimes swerved onto another road to reach it.

A bill that grows

Every line asked for is a billed request (US$5.00 per 1,000 Directions calls after 10,000 free a month), and the risk was larger than the bill: breaking the terms lets Google suspend the account's Maps services, all at once.

D4 The options

On 26 November 2026 the first plan was to fall back to Basic lines everywhere, until we asked whether Enhanced lines could come from somewhere other than Google. These were weighed:

OPTION	HOW IT WORKS	VERDICT
Basic lines only	The stops joined up, or the operator's line	Allowed and free, but gives up the road-following lines riders had
pfaedle	Matches whole timetables to OpenStreetMap's roads and railways ahead of time	**Chosen** Made for exactly this, open source, offline, about a minute per timetable
MOTIS's route shapes	The journey planner can work out lines for trips without one from its own street routing (its `route_shapes` setting)	Not yet running when the lines were needed, and it would tie the route views to the planner. The planner now draws its rides along pfaedle's lines instead
Valhalla	An open-source router with a bus profile, which can snap points to the roads when a line is asked for	One more service to run and call while riders wait, as Google was. Building lines ahead of time is simpler, and each can be checked before anyone sees it
Google Directions	Directions through the stops	Not allowed on our maps or to keep (section D3)

We trialled pfaedle on the server first (section D11). Its first lines looked better than Google's had, and they became the new Enhanced the same day.

APPENDIX D · METHOD

How the lines are made

Buses and trains are drawn by two methods, on the same OpenStreetMap data, into the same kind of file. Both run ahead of time, so riders never wait on them.

D5 OpenStreetMap, the map underneath

OpenStreetMap is the free, editable map of the world, made by volunteers and published under the Open Database Licence. Besides drawing the base map of both products, it describes everything a route line needs:

WHAT	HOW OPENSTREETMAP RECORDS IT	USED FOR
Roads	`highway=*` ways, from motorways to service roads, with `oneway` and access tags	Bus lines
Turn rules	`type=restriction` relations (no right turn, only straight on…)	Bus lines
Railway track	`railway=rail` ways, with `service=siding`, `yard`, `crossover` or `spur` for side track	Train lines
Stops and stations	Bus stops, platforms, stop positions and stations, with their names	Placing stops; station positions

- **The extract:** Geofabrik's Malaysia–Singapore–Brunei file (about 250 MB, OpenStreetMap data until 17 November 2026 for today's lines).
- **Southern Thailand:** SRT's railway from Padang Besar to Hat Yai lies outside that extract, so a small extract of just that railway is taken from an Overpass API server (section D10).
- **The same roads as the map.** Both products' base maps are drawn from OpenStreetMap too, so a line follows exactly the roads the map shows under it. Google's lines were drawn from Google's own road geometry over our OpenStreetMap map.

D6 pfaedle, in brief

pfaedle is a free, open-source tool that gives a GTFS timetable its route lines by matching every trip to OpenStreetMap. It comes from the Chair of Algorithms and Data Structures at the University of Freiburg in Germany (Professor Hannah Bast's group), where Patrick Brosi wrote it and still develops it. It first appeared in 2018, with the paper "Sparse Map-Matching in Public Transit Networks with Turn Restrictions" (Bast and Brosi, ACM SIGSPATIAL 2018), and its method is the first part of Brosi's doctoral thesis, *Automated Generation of Transit Maps* (2022). It is written in C++ and published under the GNU General Public Licence, version 3.

Made for timetables

It reads a whole GTFS feed and works from what a timetable already has: each trip's stops in order, their positions and names, and their times.

Each mode on its own ways

Its settings cover buses and coaches, trams and subways, trains, ferries, gondolas and funiculars, each matched only to the kind of way it runs on.

Run ahead of time

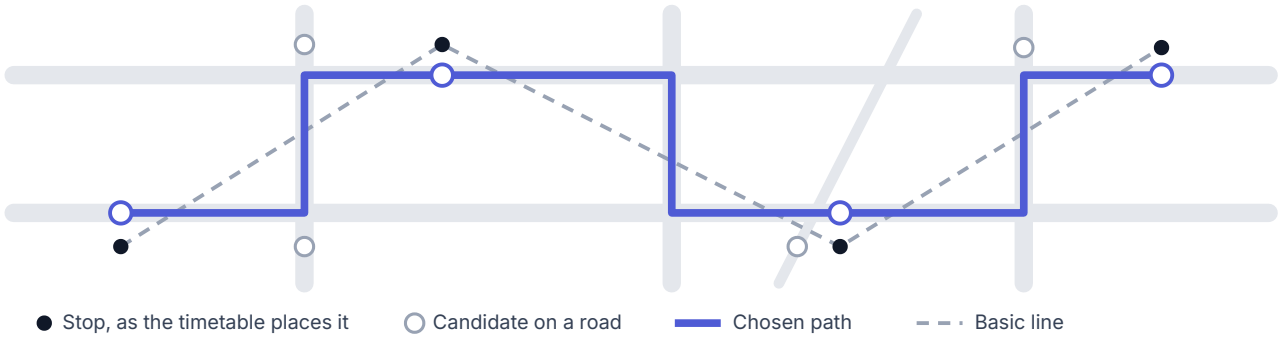
It writes the lines into the timetable's `shapes.txt`. Nothing is asked of any service while riders use the apps.

Fast, and tested

In the thesis it matched every trip in Germany in 8.5 minutes (not counting reading the map), and got 90% of trips right on at least nine hops in ten, against 84% for the usual distance-based method, with lines 6.9 m from the true path on average.

D7 How pfaedle matches a route to the roads

Map matching usually starts from a GPS trace: a position every second or so, close together. A timetable gives far less: only the stops, often hundreds of metres apart. Between two stops many paths are possible, and the job is to pick the one the bus really takes. pfaedle treats this as a hidden Markov model, the standard tool for map matching: the stops are what is observed, and where each stop really sits on the network is hidden. With the settings it ships with, it works like this:



Each stop gets candidate positions on the roads nearby (two shown per stop here). pfaedle chooses one per stop, and the roads between them, so that the whole trip costs least; the Basic line just joins the stops.

1. **A network for each mode.** From the extract it builds a graph of the ways a mode may use, sorted into eight levels by their tags, each with an average speed. For buses, trunk and primary roads are level 1, secondary roads level 2, residential streets level 4 and service roads level 5, with speeds from 85 km/h on the fastest level down to 5 km/h on the slowest. OpenStreetMap's mapped bus routes are read too.
2. **Candidates for each stop.** For each stop it gathers the places where the stop could be: stops and stations mapped in OpenStreetMap within 200 m, scored by how alike their names are to the timetable's, weighed with distance; the nearest points on roads within 100 m, down to service roads; and, as a last resort, the stop's own position. A candidate costs a little more the further it is from the stop, and a little more again if it isn't a mapped stop, or its name doesn't match.
3. **Hops between candidates.** For each pair of candidates at consecutive stops, it finds the quickest path along the network, at each level's speed. Driving against a one-way street costs five times the time plus 5 minutes, and a banned turn 5 minutes: heavy penalties rather than outright bans. A U-turn costs 2 minutes, and stretches away from the line's own mapped bus route take a fifth longer.
4. **The timetable's times as a limit.** Each hop's search stops at three times the time the timetable allows for it (at least a minute), and is widened up to three times if nothing is found. If no path fits even then, pfaedle reports "No viable hop found" and draws that hop straight.
5. **The best path overall.** The candidates form one layer per stop, joined by the hops. The trip's line is the cheapest path through all the layers, one candidate per stop: a shortest-path search through the layers, which is how a hidden Markov model's most likely sequence (the Viterbi path) is found.

6. **Shared work.** Trips of the same line with the same stops are merged into a tree of stop sequences and matched once, so a timetable of thousands of trips takes about a second.

D8 Our build, step by step

One script, `scripts/osm-lines/build.mjs`, builds every line. It runs on the server beside the live apps, so it is careful with memory.

STEP	WHAT HAPPENS
1. Pick the timetables	From the service areas the apps serve: every BAS.MY city but Kuantan, Bas Muafakat Johor, Causeway Link, City Public Link S19, the Singapore cross-border buses and, given LTA DataMall's routes, every Singapore bus service; for trains, KTMB, KLIA Ekspres and SRT's shuttle. A new BAS.MY city is picked up at the next build.
2. Find the trip patterns	A pattern is one distinct sequence of stops: a route, a direction, a variant. Every trip with that sequence shares its line, so 1,338 patterns stand for all the trips. The stops are the ones the server lists, after it merges a timetable's stops into places, so the line's stop ids are the ones the apps receive.
3. Write a small timetable	One trip per pattern, with its stops and times, as a GTFS folder for pfaedle.
4. Run pfaedle	In a container from an image pinned to one exact build, matching buses only and every trip afresh. Each run is capped at 3 GB of memory and 2 CPUs at low priority, one at a time; none starts with less than 3.5 GB free, and a run is stopped after 45 minutes.
5. Check each line	The quality gate below. A line that fails is not kept, and the server goes on showing the timetable's own line for that pattern.
6. Pin the stops	Each stop is pinned to its point on the line, in the stops' order. A stop's choices are its nearest points on up to 8 pieces of the line and the nearest point of every pass the line makes within 250 m of it: a loop that starts and ends at its terminal passes it twice, and the first stop belongs on the first pass even where the nearest pieces all lie on the last. A line that can't pass its stops in order isn't kept. The server can then cut the line between any two stops.
7. Simplify and store	Points closer than 2 m (buses) or 4 m (trains) to the simplified line are dropped, as the eye can't see them; stop points are always kept. Each line is stored as an encoded polyline (to about a metre), in one JSON file per timetable with its build time, the map data's date, the credit and the licence.
8. Report	Each timetable's patterns kept and not kept, and why; lines with a straight piece over 1.5 km (a road pfaedle couldn't follow there); and the stations left out of train lines.

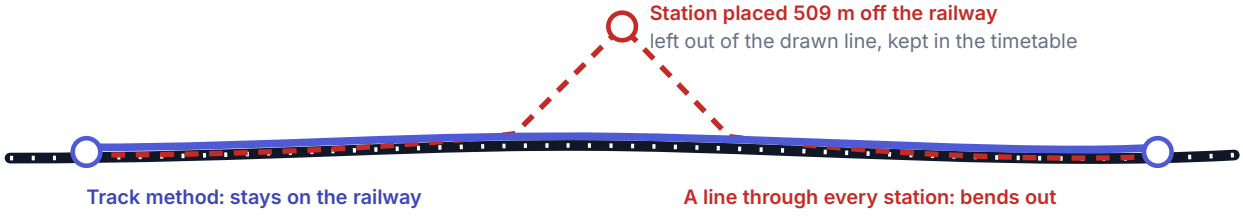
The quality gate for bus lines

A line is kept only if it **passes its stops in order**, **every stop is within 200 m of it**, and, for patterns longer than 300 m, it is **between 0.7 and 3 times as long as its stops joined up**. The trial's worst kept cases were a stop 115 m from its line (a pole recorded well off the road) and a two-stop route 2.5 times its straight length, because its road really goes round. A line that is too short has cut a corner; one that is far too long has wandered.

D9 Trains, along the track

pfaedle draws a train's line through every station, as it should. But KTMB's timetable places some stations well away from the railway, and a station in the wrong place pulls the line off the track: out to Sedenak, 509 m from the railway between Layang-Layang and Kulai; out to Kalumpang, placed about 7 km from the real station; and zigzagging to East Coast halts several kilometres off the line. So trains are drawn by a method of our own (`scripts/osm-lines/railPaths.mjs`), on the railway track pfaedle extracts from the map:

1. **Track.** Only ways tagged `railway=rail`, the track KTM trains run on. Light rail, monorail, funicular, tram, disused and unbuilt track are left out. Sidings, yards, crossovers and spurs may be used but count three times their length, so the main line wins.
2. **Stations meet the track.** Each station is matched to the nearest point on up to 8 nearby tracks, measured to the track itself, not to its mapped points: straight track can have points kilometres apart. KL Sentral has six tracks within 40 m, and the KLIA Ekspres line must find its own among them.
3. **Off the railway.** A station with no track within 300 m is out of place, and left out of the line.
4. **The shortest way along the track.** The line joins the stations in order by the shortest route along the track. A hop may be up to 3 times the straight distance, or 5 km more; a station the line can't reach in order within that is left out too.
5. **Doubling back.** KTM trains don't reverse on the way, so a station that makes the line run past it and come back (by over 30% of the direct way, and over 1 km) is in the wrong place or the wrong order, and left out, the worst first. At most three stations in a row are left out.
6. **Close to the station.** Where a station has several tracks nearby, the line uses the one that keeps it closest to the station: each metre between station and track counts like 5 m of track.



What happened at Sedenak, between Layang-Layang and Kulai. The black and white line is the track.

Left-out stations stay in the timetable and on the map; only the drawn line doesn't bend to them, and the server lists them with the line (`skippedStops`). Where stations are placed correctly, this method and pfaedle give the same line: on Komuter Utara both sit on the railway, and the track method places stations a few metres closer (17 m and 28 m on average, against 22 to 32 m). Long hops are real track, not errors: Ipoh to Kuala Kangsar is 51.7 km by rail for 25.3 km in a straight line, and Dabong to Kuala Krai 55.0 km for 27.3 km. Two settings were tuned on such cases: at 2 times the straight distance the method wrongly dropped Ipoh and Kuala Krai, and without the 5-to-1 weight lines started 261 m from Dabong and 198 m from Gua Musang, joined through a short station siding.

D10 Routes no timetable draws

- **Singapore's buses.** LTA DataMall lists each service's stops in order, with distances, but no line. Given a copy of the server's LTA data, the build turns all 802 service directions into patterns and matches them in about 3 minutes. SG-JB Transit uses the same file.

- **Causeway Link AA1**, the only bus to Senai Airport, is in no timetable feed. Its two lines are built the same way, by the Lot 10 stop as the bus goes.
- **SRT's shuttle to Hat Yai.** Its track is in Thailand, outside the main extract, so the build reads a small extract of the railway between Padang Besar and Hat Yai from an Overpass API server, and draws it by the track method. Its four stations' positions now come from the same data (KTM's stop positions at Padang Besar, averaged, and the Thai stations' nodes).
- **Kuching's Q11 to Q16.** data.gov.my's feed gives every stop on these routes the same time, so all 6,026 stop-to-stop hops last minus 10 seconds, and pfaedle, which uses the time between stops to limit each hop's search, reported "No viable hop found" and drew them straight. Stand-in times worked out from distance (20 km/h between stops, plus 15 seconds at each) are used for drawing only, never shown as a timetable. With them, all 22 Kuching patterns matched, stops 6.6 m from the line on average.
- **The border checkpoints.** At Woodlands, the stop "Woodland Checkpoint Out" sits on a one-way carriageway that OpenStreetMap doesn't let a bus reach from the south, so CW2 and CW5 towards Johor drew straight lines of 18.7 km and 17.0 km in the first round; a few shorter stretches at the Second Link did the same. Such a stretch is now drawn straight, as Basic draws it, and the report counts it. At JB Checkpoint, the 160, the 950 and the 170X go out to JB Sentral and back between the checkpoint's two bays, but pfaedle turned them round on the checkpoint's own bus lanes, so JB Sentral and the bay to Singapore shared one point, 158 m and 84 m off. They're now drawn through a point on each carriageway of Jalan Ismail Sultan, round the loop OpenStreetMap maps for the 170X, and both stops sit within 22 m of their lines.
- **Station positions.** Positions copied from Google Maps were replaced with OpenStreetMap's: KLIA Ekspres's and KLIA Transit's six stations (each station's stop positions in the two routes' relations, averaged) moved 15 to 60 m, and Tebedu's stop, now the immigration complex's bus station, about 70 m.

APPENDIX D · RESULTS

The lines in numbers

pfaedle was tried in three rounds on 26 November 2026 before anything went live, on the same server and with the same caps as the build uses today.

D11 The trial

Round 1: four timetables

TIMETABLE	TIME	PEAK MEMORY	TRIPS MATCHED	STOP TO LINE
Singapore cross-border buses	73 s	437 MB	1,565 of 1,565	11.4 m
Causeway Link	73 s	446 MB	1,015 of 1,015	9.6 m
BAS.MY Kangar	48 s	353 MB	344 of 344	6.5 m
KTMB (rail)	36 s	131 MB	265 of 265	20.1 m

Stop to line: the median, over a timetable's patterns, of the average distance from each stop to the line. Most of each run (about 65 seconds) is spent reading the map file; the matching itself takes about a second per timetable.

- **Against the operator's own lines** (28 Causeway Link patterns): pfaedle's lines stay within **5.5 m** of them on average, with 95% of points within 15.8 m.
- **Against Google's old line** for CW2, from Larkin to Queen Street, along the expressway and across the Causeway: **2.5 m** on average, 6.2 m at the 95th percentile.
- **Most "stop off the line" flags were cosmetic:** single stops set back from the road or inside an interchange or terminal (Jurong Town Hall, Queen Street, Larkin, Woodlands), and some Kangar poles recorded 50 to 96 m off the road. The lines themselves followed the roads.

Round 2: six more BAS.MY cities, and Komuter Utara

TIMETABLE	TIME	PEAK MEMORY	PATTERNS	STOP TO LINE
Alor Setar	61 s	498 MB	26	6.7 m
Kota Bharu	55 s	397 MB	32	8.4 m
Kuala Terengganu	49 s	282 MB	17	8.1 m
Kuching (with stand-in times)	48 s	293 MB	22	6.6 m
Ipoh	55 s	328 MB	29	11.2 m
Seremban A	61 s	489 MB	19	8.0 m
Seremban B	73 s	562 MB	22	8.1 m

Ipoh's figure is the highest because its feed lists a separate pole for every route at shared stops. Komuter Utara's lines were good too: all 40 straight pieces over 2.5 km stay within 6 m of the real track, half within 1 m, because pfaedle draws straight track with few points.

Round 3: trains along the track

KTMB TIMETABLE	TIME	STATIONS	LINES	STATIONS LEFT OUT	STRAIGHT GAPS
Malaysia Transit's copy	17 s	184	45	23	0
data.gov.my's live feed	54 s	156	86	14	0

Every train line followed the railway with no straight gaps; each straight piece over 2.5 km is a single piece of mapped straight track (the longest, 5.8 km, crosses the Perlis and Kedah paddy belt). Kept stations sit within 150 m of their line, except two whose recorded positions are that far from the track.

D12 What is built today

TIMETABLE	METHOD	PATTERNS KEPT	FILE
Singapore's buses (LTA DataMall)	pfaedle	802 of 802	943 KB
KTMB (every KTM service)	Track	121 of 121	417 KB
BAS.MY Melaka	pfaedle	66 of 66	113 KB
Bas Muafakat Johor	pfaedle	57 of 57	51 KB
BAS.MY Johor Bahru	pfaedle	45 of 45	66 KB
Causeway Link	pfaedle	36 of 36	38 KB
BAS.MY Kota Bharu	pfaedle	32 of 32	70 KB
BAS.MY Ipoh	pfaedle	30 of 30	50 KB
BAS.MY Alor Setar	pfaedle	27 of 27	33 KB
BAS.MY Kangar	pfaedle	23 of 23	40 KB
BAS.MY Kuching	pfaedle	23 of 23	31 KB
BAS.MY Seremban B	pfaedle	22 of 22	53 KB
BAS.MY Seremban A	pfaedle	18 of 19	33 KB
BAS.MY Kuala Terengganu	pfaedle	19 of 19	32 KB
Singapore cross-border buses	pfaedle	6 of 6	10 KB
KLIA Ekspres and KLIA Transit	Track	4 of 4	5 KB
Causeway Link AA1	pfaedle	2 of 2	2 KB
City Public Link S19	pfaedle	2 of 2	3 KB
SRT Padang Besar–Hat Yai	Track	2 of 2	2 KB
19 timetables	**1,211 pfaedle, 127 track**	**1,337 of 1,338**	**1.94 MB**

Built on 26 November 2026 from OpenStreetMap data until 17 November 2026 (SRT's railway: an extract of 28 July 2026); on 27 November the bus lines' stops were pinned again, as step 6 of section D8 describes, the cross-border buses' lines built again on LTA DataMall's stop positions, and those and Singapore's built again with the 160, the 950 and the 170X drawn out to JB Sentral and back (section D10). One line doesn't pass its stops in order and isn't kept: Seremban A's Desa Rhu loop. KTMB's file serves all 11 KTM services in the apps, from Komuter Klang Valley to Shuttle Tebrau and the Intercity trains to Kota Bharu. BAS.MY Johor Bahru's and Melaka's own lines already follow the roads, so their route views keep them.

D13 Against Google's lines

	GOOGLE DIRECTIONS (BEFORE)	OPENSTREETMAP (NOW)
On our own maps	Not allowed (section 4.2)	Allowed, with the credit
Keeping them	Coordinates only, for 30 days	Ours to keep, and to share under the same licence
Which roads	Google's own best way between each pair of stops	The quickest way through all the stops in order, weighing each stop's distance, road class, turns and mapped bus routes
A stop set back from the road	Could swerve onto another road to reach it	Pinned to the road beside it; a line too far from any stop isn't kept
Trains	Through every station, even one placed off the line	Along the track, leaving out stations placed off it, and reporting them
Fit with the map	Google's road geometry over an OpenStreetMap map	The same roads the map draws
Cost	US$5.00 per 1,000 requests after 10,000 free a month	Nothing per line; about 20 minutes of our server per rebuild
Fresh roads	Google's current map	As fresh as the extract: rebuilt every month or two
If it fails	No line, or a line that bends wrong	The quality gate falls back to the timetable's own line

On ordinary roads the two are very close: CW2's new line is 2.5 m from Google's on average. The difference shows where it matters to riders: at stops set back from the road, at terminals and interchanges, and on trains whose timetable puts a station in the wrong place.

D14 What the build found

Drawing lines carefully is also a close check of the timetables. These findings are worth sending to KTMB and data.gov.my, and are listed with every build:

KTM stations off the railway. More than 5 km off: Mela, Sg Mengkuang Baru, Kuala Gris, Kemubu, Sri Mahligai, Kalumpang (placed near Lembah Beringin), Tembeling and Padang Piol. Closer in: Sri Bintang 4.5 km, Pahi 4.4 km, To' Uban 2.9 km, Aur Gading 1.6 km, Sri Jaya 1.4 km, Kg Berkam 1.1 km, Bertam 666 m, Sedenak 509 m, Dura 412 m, Sungai Temau 341 m and Holiday Plaza 307 m.

In the wrong place or order. "Mengkuang" is timetabled between Triang and Kemayan in Pahang but placed south of Kuala Krai in Kelantan, about 330 km up the line. Kubang Rusa and Teluk Gunong are listed in swapped order, and so are Kg Telang and Pdg Tungku.

Other timetable issues. On Kuching's Q11 to Q16 every stop has the same time (section D10). KTMB's live feed has no route lines at all, and codes its five Komuter services, Shuttle Selatan among them, as trams. The KTMB copy used in the trial had 8 stop times pointing at a station (37200) missing from its stop list, and 39 Komuter trips with no stops. BAS.MY's feeds, all but Johor Bahru's and Melaka's, have one line point per stop, and some poles recorded 40 to 115 m off the road. (Hat Yai is left out of KTM's lines only because the main extract stops at the border: not a timetable error.)

APPENDIX D · IN USE

Serving, upkeep and licence

The lines are plain files in the server's code. The server reads them when it starts, and riders get them with no outside service in the way.

D15 How the apps use the lines

- **Route views.** `GET /api/routes/:routeId/geometry/enhanced` gives a trip its OpenStreetMap line where the timetable's own is too sparse (section D1). The answer says `source: openstreetmap`, carries the credit, and lists the stations the line leaves out.
- **Trips that changed since the build.** A trip whose stops run in a row inside a longer pattern gets that stretch of its line; a trip unlike any pattern gets the timetable's own line until the next build.
- **Journey plans.** Each ride in a planned journey is drawn along the same line, cut between the stops where the rider boards and leaves, so a journey looks exactly like the route view. Where that piece of line ends a little off those stops, up to 400 m away (a terminal inside a building, say), it is joined to them with a short straight piece; a line that ends farther away isn't used for the ride.
- **Shared timetables.** A file serves every service that shares its timetable, including ones added after the build: KTM Shuttle Selatan, added to the Rest of Johor on 26 November 2026, had lines from KTMB's file at once.
- **SG-JB Transit** keeps its own copies of four files and serves them the same way: the Singapore buses' and AA1's, for its route views and journeys, and the cross-border buses' and KTMB's, for its journeys across the Causeway.

D16 Rebuilding

Lines are rebuilt when a timetable's trips change a lot, and every month or two for newer map data. The whole build takes about 20 minutes on the server:

1. Download a fresh Geofabrik extract (about 250 MB).
2. In a scratch copy of the code, never the copy the live server runs from, run the builder with the extract, LTA DataMall's cached bus routes and SRT's railway extract.
3. Read the report: patterns kept and not kept, straight pieces, stations left out.
4. Look over each area's new lines against Basic on an internal review page.
5. Commit the files; the server reads them on its next start. Copy the Singapore, cross-border, AA1 and KTMB files to SG-JB Transit.

Per timetable a run takes about a minute and under 0.5 GB of memory; extracting the railway for the train method takes 43 seconds at a 139 MB peak, and the track method itself seconds.

D17 Licence and credit

- **OpenStreetMap's data** is © OpenStreetMap contributors, under the Open Database Licence (ODbL) 1.0. The lines are built from it, so they are under the ODbL too.
- **Credit:** wherever a line shows, "© OpenStreetMap contributors". Both products' maps already credit OpenStreetMap, and every API answer with one of these lines carries the credit.

- **Sharing:** anyone may use the line files under the same licence, which makes them something we can offer partners and other developers, as Google's lines never were.
- **pfaedle** is free software under the GNU General Public Licence, version 3, run unchanged as a separate tool in a container. The lines it writes are OpenStreetMap data, and pfaedle's own documentation asks that a timetable carrying them credit OpenStreetMap under the ODbL when it is shared.

D18 Limits and next steps

- **Only as good as the map.** A missing road, a wrong one-way or a missing link bends a line or leaves a straight piece. The fix is to correct OpenStreetMap itself, which helps everyone who uses it; the Woodlands checkpoint lanes are the first candidate.
- **Only as good as the stops.** A stop recorded far from its road, or a station in the wrong place, is reported rather than drawn to. Fixing the timetables at the source (section D14) fixes the lines too.
- **New routes wait for the next build.** Until then they show the timetable's own line. A scheduled monthly rebuild, like the journey planner's nightly refresh, is a natural next step.
- **One more region.** If the main extract gains southern Thailand, as the journey planner's street map already has, SRT's line can come from the main build.

D19 Sources

pfaedle: github.com/ad-freiburg/pfaedle (code, default settings and README, read 27 November 2026); H. Bast and P. Brosi, "Sparse Map-Matching in Public Transit Networks with Turn Restrictions", Proceedings of ACM SIGSPATIAL 2018, pp. 480–483, doi:10.1145/3274895.3274957; P. Brosi, *Automated Generation of Transit Maps*, doctoral thesis, University of Freiburg, 2022, chapter 2, "Map-Matching Schedule Data", doi:10.6094/UNIFR/228990.

OpenStreetMap: openstreetmap.org/copyright (credit and licence); the Open Database Licence 1.0, opendatacommons.org/licenses/odbl/1-0; Geofabrik's Malaysia, Singapore and Brunei extract, download.geofabrik.de/asia/malaysia-singapore-brunei.html; the Overpass API, overpass-api.de.

Timetables: data.gov.my's GTFS feeds (CC BY 4.0); LTA DataMall's bus routes and stops (Singapore Open Data Licence); the GTFS reference for `shapes.txt`, gtfs.org.

Google Maps Platform: Service Specific Terms (version of 24 November 2026), cloud.google.com/maps-platform/terms/maps-service-terms; Terms of Service, cloud.google.com/maps-platform/terms; pricing, developers.google.com/maps/billing-and-pricing/pricing (read 27 November 2026).

Malaysia Transit's own records: how the lines are built (`docs/osm-route-lines.md`), the builder (`scripts/osm-lines/`), the line files (`data/osm-lines/`, built 26 November 2026, the bus lines' stops pinned again on 27 November), and the pfaedle trial report of 26 November 2026, with its three rounds.

APPENDIX E · TECHNICAL WHITE PAPER

Journey planning with MOTIS and GrabMaps

Since 27 November 2026, every journey on Malaysia Transit's and SG-JB Transit's websites and apps is planned by MOTIS, an open-source journey planner we run on our own server, and every place search is answered by GrabMaps, through Amazon Location Service. Together they replaced Google Maps Platform, whose terms don't allow its results on our own maps, and whose bill grows with every rider.

27
timetables MOTIS plans on: 15 from data.gov.my, 10 of our own, Singapore's buses and trains

25
test journeys against Google: MOTIS quicker on 15, one of them a trip Google couldn't plan, and level on 1

35 s
to load the night's fresh timetables, checked with a test journey before use

US$70
for 100,000 place searches a month, against about US$990 with Google's Places UI Kit

In five points

- **Allowed on our maps.** MOTIS is ours to run (MIT licence), and Amazon's terms allow GrabMaps' results on any map. Google's terms don't allow its results on a map that isn't Google's.
- **Plans on our own data.** Every timetable the apps show, including the ones we put together: Causeway Link's AA1, S19, SRT's shuttle to Hat Yai, KLIA Ekspres, the Penang ferry, and Singapore's buses, MRT and LRT.
- **Small and fast.** One program capped at 1.5 GB of memory, answering in 9 to 110 milliseconds. OpenTripPlanner keeps everything in memory, and would have strained our server.
- **At least as good.** As quick as or quicker than Google's on 16 of 25 test journeys, including Seremban to KL Sentral, which Google couldn't plan.
- **A fraction of the cost.** Nothing per journey; US$0.20 per 1,000 place suggestions and US$0.50 per 1,000 lookups, against US$2.83 to US$20 per 1,000 for Google's.

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APPENDIX E · BACKGROUND

Why we left Google Maps Platform

Google planned our journeys and found our places for years. Its terms never fitted products with their own maps, and its bill was set to grow with every free rider.

E1 What Google did for us

FEATURE	GOOGLE SERVICE	USED BY
Planning a journey	Directions API: a transit search with alternatives, walking legs, and extra searches to piece together the S19, SRT and Causeway Link corridors by hand	Both websites and both apps
Search as you type	Places Autocomplete	Both websites and both apps
The chosen place's position	Place Details	Both websites and both apps
Naming a point on the map	Reverse geocoding and Place Details	Both websites and both apps
A typed address to a position	Geocoding API	The developer API and the chatbot
Route lines along the roads	Directions API (replaced first: Appendix D)	Both live maps

The apps never called Google themselves: they draw with MapLibre and ask only our servers. So everything could be replaced on the two servers, and the websites and apps kept working unchanged.

E2 The terms

On 26 November 2026 we read Google Maps Platform's terms as they stood (the Service Specific Terms of 24 November 2026) against how both products used Google. For every service we used, the terms say Google's content "must not" be used "in conjunction with a non-Google map". Our websites draw with Leaflet on an OpenStreetMap map, and the apps with MapLibre.

SERVICE	NOT WITH A NON-GOOGLE MAP	WHAT MAY BE CACHED
Directions	Section 4.2	Latitudes and longitudes only, for 30 days (4.3)
Places	Section 14.2	Latitudes and longitudes only, for 30 days (14.3)
Geocoding	Section 6.2	30 days; longer only per end user (6.3)
Places UI Kit	Allowed "with or without any map" (15.1)	We would answer for not exporting its content or making content from it (15.3)

The review found five problems, the most serious first:

1. **Google's results drawn on non-Google maps**, on both websites and in both apps.
2. **Google-made route lines kept for good** in four of our timetables, and in a permanent cache on SG-JB Transit's server. The general terms forbid storing Google's content or building new content from it (section 3.2.3).

3. **Passing Google's results on.** Malaysia Transit's public tools for AI assistants offered journey planning and place search to any client.
4. **Keeping results too long:** plans cached for up to 10 minutes as whole answers, journey legs for 30 minutes, and share links for 7 days.
5. **No Google credit** where its results showed.

Breaking the terms lets Google suspend access. If it did, everything Google-backed would stop at once: the journey planner, place search, geocoding and the AI tools, and possibly other projects on the same Google account. And a business partner can't take Google-derived routes or data from us, which closes off working with others on the planner's results.

E3 The bill

Google gives each paid service a free monthly allowance, then charges for every 1,000 calls:

FOR	GOOGLE ITEM	FREE EACH MONTH	THEN, PER 1,000
Journey planner	Directions (Essentials)	10,000	US$5.00
	Directions Advanced (Pro)	5,000	US$10.00
Suggestions as you type	Autocomplete requests	10,000	US$2.83
The chosen place	Place Details: Essentials, Pro, Enterprise	10,000 / 5,000 / 1,000	US$5 / 17 / 20
Address to position	Geocoding	10,000	US$5.00
Places UI Kit	Autocomplete, per session; Query	10,000 each	US$10.00; US$1.00

Google Maps Platform's pricing list, read on 27 November 2026: the first paid tier after the free allowance.

At today's traffic the bill was small. But one journey search made several Directions calls (the main transit search, the walking legs, and the corridor searches), and both products are free for riders: a cost per search grows with every new rider and earns nothing back. The RTS Link between Johor Bahru and Singapore would bring far more people to the planner.

E4 What we needed

- **For journeys:** allowed with our own maps, with results we may keep and share; plans on every timetable the apps show, our own included, across Malaysia, Singapore and Hat Yai; door to door, walking along real streets; fast enough for a phone; free for commercial use, maintained, with a documented API.
- **For the server:** fits beside the live apps on one netcup VPS (8 CPUs and 15 GB of memory, about 6 GB of it free on 26 November 2026, with swap already in use), so 1 to 3 GB at most, and refreshes its data without taking the apps down.
- **For places:** good on Malaysian and Singaporean places (shops, malls, condominiums, offices, bus terminals), in several languages; allowed with our maps; cheap per search; answered through our server as before, so the websites and apps need no change.
- **For riders:** nothing to notice but better answers: the same journey cards, fares, ways to pay and live times, in 13 languages.

APPENDIX E · THE PLANNER

MOTIS: the journey planner

MOTIS is an open-source journey planner from the research world, built to plan across whole countries on modest hardware. It reads the same open timetables and map the apps already use.

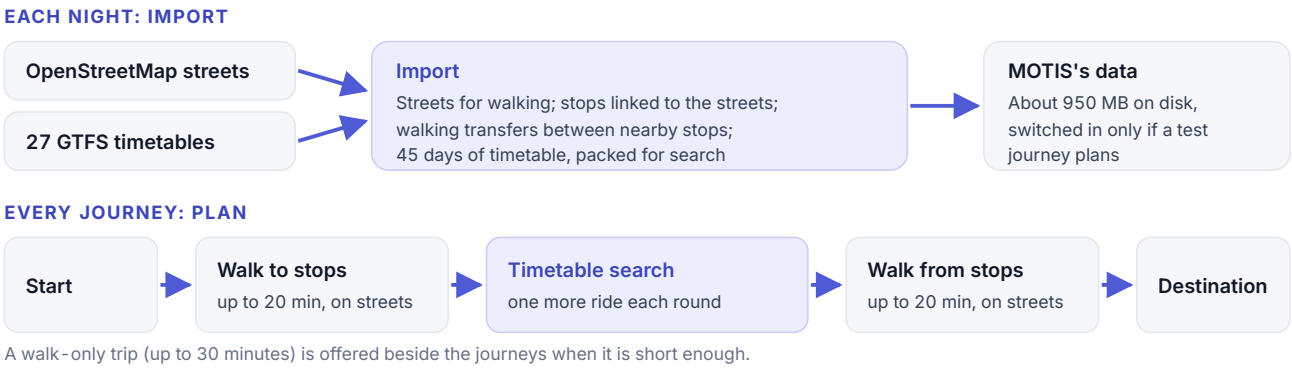
E5 MOTIS, in brief

MOTIS began at the Technical University of Darmstadt in Germany, in Professor Karsten Weihe's algorithms group, as a research journey planner developed with Deutsche Bahn and the consultancy datagon. Its name first stood for "Multi Objective Travel Information System"; its own documentation now calls it the "Modular Open Transportation Information System". It became open source in 2020, and was rewritten from 2023 as MOTIS 2 (version 2.0 in December 2024), led by Felix Gündling of TU Darmstadt, whose company triptix offers support and hosting for it. It is written in C++ and published under the MIT licence. The version we run, 2.11.4 of 21 October 2026, was the newest release when this paper was written.

PART	WHAT IT DOES	LICENCE
nigiri	The timetable and the transit search	MIT
osr	Routing on OpenStreetMap's streets: walking, wheelchair, bike and car, with indoor levels and lifts	MIT
cista	Storing all of it as compact binary data the server reads straight from disk	MIT
adr	Place search and naming points (switched off in our setup)	AGPL 3.0
tiles	Map tiles from OpenStreetMap (not used: our maps have their own)	MIT

Proven at scale. MOTIS powers Transitous, a free, community-run journey planning service started at the FOSDEM conference in 2024. By early 2025 it covered 94 regions with 1,417 timetables and 167 live feeds, and apps such as GNOME Maps, KDE Itinerary and Träwelling plan with it. Its public service is for open-source, non-commercial apps only, which is why we run our own copy (section E7).

E6 How MOTIS plans a journey



A walk-only trip (up to 30 minutes) is offered beside the journeys when it is short enough.

MOTIS's two halves: an import that packs streets and timetables into its own data, and a search that answers each journey from that data in milliseconds.

The **import** reads the OpenStreetMap extract and every timetable, and builds MOTIS's own data: the street network for walking, each stop matched to the streets beside it, walking transfers between nearby stops routed along the streets, and the timetable for the days asked for. Each trip's running days are kept as a row

of bits, so a year of timetable costs little more memory than a month. The data is written as binary images the server reads straight from disk, partly through memory-mapped files, without unpacking them first. That is why the server runs in a few hundred megabytes.

The **search** answers each journey from that data:

1. **First and last mile.** From the start, it walks along the streets to every stop within the time allowed (20 minutes in our setup), and does the same backwards from the destination. A walk-only trip is offered too, when it is short enough.
2. **Round by round.** The timetable search comes from the RAPTOR family (round-based public transit routing, Delling, Pajor and Werneck, 2012). Round one finds the earliest arrival at every stop with one ride; each further round adds one more ride, scanning only the routes through stops that improved in the round before, then the walking transfers from them. A journey is kept only if no other beats it on both arrival time and number of changes, so the answer is a short list of real choices: the quickest, and those with fewer changes.
3. **Across the whole hour.** The search runs over the search window (an hour in our setup), so a rider is offered the good departures in that hour, not just one.
4. **Legs, with their lines.** Each journey comes back as walks along the streets and rides with their route, stops, times and line.

MOTIS also reads timetables in NeTEx, live updates (GTFS Realtime, SIRI and others) and bike and scooter sharing (GBFS). Our setup needs none of these today.

E7 MOTIS against the alternatives

OpenTripPlanner, the best-known open-source planner, was the first idea. On 26 November 2026 it was compared with everything else on offer, on licence and cost, memory, features, whether it would fit our server, and the work involved:

OPTION	LICENCE AND COST	MEMORY AND SERVER	VERDICT
MOTIS 2, self-hosted	MIT: free, commercial use allowed; credit OpenStreetMap	Measured: import 1 min 16 s at a 2.7 GB peak, then about 365 MB to run	Chosen
OpenTripPlanner 2, self-hosted	LGPL: free	Keeps all its data in memory: its documentation puts all of Finland at a little over 10 GB	Too heavy for our server
Transitous (hosted MOTIS)	Free, but only for open-source, non-commercial apps, and it may stop serving any app	Nothing to run	Ruled out by its usage policy
Valhalla, GraphHopper	Open source	—	Strong for walking and driving, weaker for timetabled transit: walking routers only

OPTION	LICENCE AND COST	MEMORY AND SERVER	VERDICT
Our own planner engine	Ours	—	Possible (there was one before Google), but it would rebuild what MOTIS does
Paid routing services	Per request	Nothing to run	The same per-request bill and terms questions as Google
Keep Google Directions	US$5.00 per 1,000 after 10,000 free	Nothing to run	Not allowed with our maps

Why not OpenTripPlanner

OpenTripPlanner is the best-known open-source planner. It was started in 2009 with funding from Portland's transit agency, TriMet, is written in Java and published under the LGPL, and runs national journey planners for Entur in Norway and Digitransit in Finland. Its second version (2020), led by Entur, brought a RAPTOR-based transit search. It is mature and well documented. But it keeps all its data in memory, and its own documentation puts all of Finland at a little over 10 GB, and Germany at 95 GB: more than our server could spare beside the live apps. MOTIS imported our whole region at a 2.7 GB peak and serves it in a few hundred megabytes.

Two comparisons published elsewhere point the same way:

- **Switzerland (SKI+, for the Federal Office of Transport, November 2025).** Of nine open-source routers, MOTIS and OpenTripPlanner were tested in depth on 124 Swiss use cases. MOTIS fully supported 81% of them, against OpenTripPlanner's 62% (91% against 76% on average fulfilment), and answered them faster on average (317 against 402 ms). The study found both suitable, with no clear speed winner on comparable hardware: OpenTripPlanner more mature, MOTIS more adaptable.
- **Great Britain (TransCAPI, October 2026; a company's own report).** Moving from OpenTripPlanner 2.9 to MOTIS 2.11 took serving memory from about 26 GB to about 2.4 GB (plus memory-mapped files), the build from about 37 GB to a 9.5 GB peak in about 7 minutes, and the median search from 5.5 to 0.7 seconds. MOTIS gave the better journey in 243 of 400 test journeys, OpenTripPlanner in 42, though the author notes OpenTripPlanner was short of memory there.

Where OpenTripPlanner is ahead: a longer record as a national planner, a larger community and more documentation. For one small server, MOTIS's memory use decided it.

The others

- **Navitia** (Hove, France): its maker announced in 2023 that it would limit access to the source code of new versions.
- **R5** (Conveyal): built for accessibility analysis and scenario planning, not for riders' journeys.
- **Valhalla and GraphHopper:** excellent street routers with limited timetable support (Valhalla's transit mode can't plan "arrive by"); the Swiss study dropped GraphHopper after its first phase.

E8 Our MOTIS setup

- **Where:** the netcup VPS that runs both products, in a container named `motis` running MOTIS 2.11.4 from its official 69 MB image, pinned to one exact build. It is capped at 1.5 GB of memory and 2 CPUs, restarts by itself, and is reachable only from the apps' private network on the server, never from the internet.

- **Streets:** Geofabrik's Malaysia–Singapore–Brunei OpenStreetMap extract with Songkhla province merged in (section E9): 261 MB.
- **Data on disk:** about 950 MB, with the previous day's copy kept beside it.

The 27 timetables

FROM	TIMETABLES
data.gov.my (15)	KTMB; BAS.MY in Alor Setar, Ipoh, Johor Bahru, Kangar, Kota Bharu, Kuala Terengganu, Kuching, Melaka and Seremban (two); Prasarana's Rapid KL buses, Rapid KL trains, MRT feeder buses and Rapid Penang
Ours (10)	Causeway Link, and its AA1 airport bus (the only bus to Senai Airport); the Singapore cross-border buses; City Public Link S19; SRT's Padang Besar–Hat Yai shuttle; KLIA Ekspres and KLIA Transit; the Penang ferry; BAS.MY Kuantan; Bas Muafakat Johor, in Johor Bahru and the rest of Johor
Built from LTA DataMall and OpenStreetMap (2)	Singapore's buses, and Singapore's MRT and LRT (section E9)

Readying the timetables

MOTIS reads timetables strictly, and plans only on dates a timetable's calendar covers. A preparation step repairs what it can before every import, and prints what it changed:

- **Calendars run on for 60 days.** Several feeds end within days or weeks: Ipoh's and Seremban's on data.gov.my give a calendar for today only.
- **Intercity rail left out** (KTMB's ETS, Ekspres Rakyat Timuran and Intercity shuttles): the planner offers commuter journeys, with fares it knows.
- **Route numbers:** Ipoh's and Seremban's feeds put a description where the route number goes, and the number in the route's id.
- **Strict-reader repairs:** service names matched to the calendar whatever their case, stations used as stops made stops, and times that run backwards reported.

The settings that matter

SETTING	OURS	WHAT IT MEANS
Days loaded	45, from today	Journeys can be planned up to six weeks ahead
Walking transfers	Along the streets, up to 15 minutes	Changing between nearby stops follows real footpaths, not straight lines
Least time to change	2 minutes	Where a timetable doesn't say
Walking links between stops	Within 100 m	Stops this close are joined by a walking transfer
Stops matched to streets	Within 25 m (250 m worked out ahead)	How far a stop may be from the street it is matched to for walking
Route shapes	Kept	A timetable's own lines are kept for each ride
Place search, live updates	Off	GrabMaps finds places; data.gov.my publishes no delay predictions to feed in

The nightly refresh

Every night at 04:15 Malaysia time (03:15 in Europe's summer), a script fetches data.gov.my's feeds (keeping the last good copy of any that fails), takes our own timetables from the running Malaysia Transit server and Singapore's data from SG-JB Transit's, rebuilds Singapore's two timetables, readies them all and imports them into a copy of MOTIS's data. MOTIS switches to the new data only if the import worked, and switches back if it then can't plan a test journey from KL Sentral to KLCC. An import of new timetables alone takes about 35 seconds at a 1.2 GB peak; with new streets, about 1½ minutes at a 2.7 GB peak. No import starts with less than 3.5 GB of memory free.

E9 Singapore and southern Thailand

Neither place had what MOTIS needs out of the box, so we built it.

Singapore's buses

LTA DataMall publishes each service's stops, its first and last buses, and how often it runs in four parts of the day, but no timetable. So trips run from the first bus to the last, at the middle of LTA's range for that part of the day ("09–16" minutes becomes every 12½); AM peak 06:30–08:59, AM off-peak 09:00–16:59, PM peak 17:00–19:29, and PM off-peak the rest. Times along the route come from LTA's distances at 25 km/h, at least a minute a stop. Weekdays, Saturdays and Sundays run apart, and public holidays on Sunday times. Result: **584 services and 152,170 trips**. Services 160, 170, 170X and 950 come from our cross-border timetable instead.

Singapore's MRT and LRT

LTA publishes station codes and order, but no timetables or positions. So each line's stations, in order, and their positions come from OpenStreetMap's route relations, and trains run at the usual headways: every 3 minutes in weekday peaks (07:00–09:00, 17:00–20:00), 5 otherwise and 6 after 20:00; LRT every 4, 6 and 8; the Changi Airport branch every 7. First trains 05:30 (06:00 on Sundays and holidays), last 23:45 from each end; 45 km/h between stations (LRT 30), plus half a minute at each. Result: **9 lines and 434 platforms**, each drawn along its track. The Jurong Region Line joins when it opens.

- **These are typical services, not real timetables.** A planned Singapore journey is right on route and roughly right on time. The live bus arrivals shown with it come from LTA's own predictions.
- **Hat Yai.** Thailand's streets weren't in our map, so a trip could reach Hat Yai's station but not a point in town. Songkhla province (Hat Yai and Songkhla) is cut from Geofabrik's Thailand extract and merged into ours, so Kangar to Hat Yai town now plans door to door, by bus R11 and SRT's shuttle.
- **The border.** SG-JB Transit's server adds the time to clear immigration at the Causeway and the Second Link to every journey that crosses.

E10 How our server uses MOTIS

The websites and apps never talk to MOTIS. They ask our servers, which ask MOTIS and turn its answer into the journeys riders see.

STEP	WHAT THE SERVER DOES
Ask	One plan request (`/api/v6/plan`) from the start to the destination, leaving at or arriving by the time asked, over a one-hour search window, with up to 20 minutes' walk at each end and up to 30 minutes for a walk-only trip.

STEP	WHAT THE SERVER DOES
Choose	MOTIS gives every good journey in the hour searched: 28 for Tampines to HarbourFront at 08:30, with a train every few minutes. The server keeps those arriving soonest (leaving latest, for "arrive by"), at most two of each combination of routes so other ways still show, and drops any journey more than twice as long as the shortest, or more than 30 minutes longer, whichever allows more. (With AA1 hourly, Senai Airport to Eco Galleria once also offered a 763-minute overnight trip through Singapore beside a 155-minute one.)
Hard-to-place points	A point MOTIS can't place on its street map, such as a footway inside a mall that doesn't join the streets, is planned from the nearest stop within 700 m, with a straight walk to it.
Same shape as before	The answer is turned into the shape Google's answers had (walking and transit steps), so the planner's route matching, stops, fares, filters and sorting stay exactly as they were, and the websites and apps needed no change.
Draw	Each ride is drawn along its route's Enhanced line from OpenStreetMap (Appendix D), as the route views draw it.
Add	Fares in ringgit and Singapore dollars (with Causeway Link's free-transfer rule), how to pay on each operator, live times and approaching buses on top of the plan, share links, and the hand-off between the two apps.

The switch is a setting on each server. Until Google's code is deleted, removing one setting brings Google back with a redeploy, as a way back if anything goes badly wrong.

E11 Results

The trial (26 November 2026)

MOTIS 2.11.4 on the VPS, capped at 3 GB and 2 CPUs at low priority, with the Malaysia–Singapore–Brunei map and 23 timetables. The import took **1 minute 16 seconds** at a 2.7 GB peak and 918 MB on disk; the server then used about **365 MB** and answered each journey in **9 to 110 milliseconds**. It was as good as or better than the Google-based planner on most of 22 test journeys, and planned directly on our own timetables, the ferry, S19, Causeway Link and SRT's shuttle among them. What it got wrong at first came from our data, not from MOTIS:

IN THE TRIAL	CAUSE	FIX
KLIA T1 to KL Sentral offered the next day's 05:00 train	Our KLIA timetable held one sample train per direction	All 305 trains (118 KLIA Ekspres, 187 KLIA Transit): 08:39 by KLIA Ekspres, 30 minutes
No Penang ferry trips	Service names in two cases; a calendar that ended on 31 December 2025; terminals marked as stations	Rebuilt from the ferry's schedule with all three fixed
Komtar to Penang Airport by bus 302 (117 minutes)	The test's airport point was off the terminal	At the terminal MOTIS offers 401E and 102
No trip to a point in Hat Yai	Thailand's streets weren't in the map	Songkhla merged in: Kangar to Hat Yai town plans door to door
No trip from a point inside Ipoh Parade	The point couldn't be placed on the street map	Planned from the nearest stop within 700 m

IN THE TRIAL	CAUSE	FIX
Calendars ending too soon	Today-only calendars; KTMB's ending 10 December, Rapid Penang's 20 December	Calendars run on for 60 days before each import
Causeway Link trips after midnight ran backwards	Times written 00:xx instead of 24:xx	Fixed in the build script (28 trips)

Fixing our timetables for a strict planner also fixed the live sites' departure pages, which read the same files.

Against Google (Friday 27 November 2026, from 08:30)

JOURNEY	MOTIS	GOOGLE	ROUTES
KL Sentral → Suria KLCC	**19**	30	Kelana Jaya line (both)
Bangsar South → Mid Valley	**25**	37	
SS2 Petaling Jaya → Bukit Bintang	**52**	55	T816, Kajang line (both)
KLIA T1 → KL Sentral	**30**	35	KLIA Ekspres (both)
Shah Alam Seksyen 7 → KL Sentral	**75**	106	753, 750; Google: LRT
Kajang → Putrajaya Sentral	**63**	76	
Seremban → KL Sentral	**122**	error	N50, N57, KLIA Ekspres
Komtar → Penang Airport	67	**50**	401E (102 also offered, 52); Google: 102
Penang Sentral → Weld Quay	**19**	39	Ferry (both)
Batu Ferringhi → Komtar	**43**	45	102 (both)
Bukit Mertajam → Penang Sentral	56	**45**	701; Google: CT14, KTM
JB Sentral → Larkin Sentral	29	**22**	CW2 (both)
JB Sentral → Kranji MRT	**21**	26	160; Google: 170X
Taman Universiti → JB Sentral	64	**53**	J31, J30; Google: P211, J30
Kulai → JB Sentral	**64**	99	J30; Google: P411, J30
Kuching Waterfront → Kuching Sentral	**14**	36	Q15; Google: Q14
Serian → Tebedu	62	**60**	S19 (both)
Ipoh station → Ipoh Parade	**10**	12	A33B (both)
Melaka Sentral → Jonker Street	22	22	M22; Google: M13
Kangar → Hat Yai town	187	**176**	R11, SRT shuttle; Google adds R105
Kangar → Hat Yai Junction	179	**169**	The same
KB Mall → Kota Bharu bus terminal	29	**27**	D50 (both)
Pasar Payang → UMT Kuala Terengganu	**60**	66	T10 (both)
Kuantan Sentral → East Coast Mall	41	**26**	C30, C50; Google: C33
Alor Setar station → Aman Central	**12**	18	K50; Google: K30

Minutes door to door; the quicker in bold. MOTIS was quicker on 15, level on 1, and Google quicker on 9, by 2 to 17 minutes.

- **Seremban to KL Sentral** isn't a fault. While the line is upgraded, KTMB's own timetable runs Seremban Line trains through Seremban only at peak times (5 each way on weekdays, northbound 05:56–07:21,

and 2 at weekends). MOTIS takes them when they run, and otherwise a bus and KLIA Ekspres. Google returned an error.

- **To Penang airport**, MOTIS also offers the 102 (52 minutes) but lists the 401E first, because it arrives earlier.
- **In Kuantan**, Google's C33 runs past Stadium Darul Makmur, while in the Kuantan timetable our maps show, the C33 from that stop heads into town, so MOTIS doesn't offer it.
- **Where Google is quicker elsewhere**, it mostly takes another route (CT14 and KTM from Bukit Mertajam, P211 from Taman Universiti, R105 towards Hat Yai), or a timetable's stop positions slow the trip, as P101's do at JB Sentral. Those are now ours to look into and improve, which Google's data never was.

APPENDIX E · PLACE SEARCH

GrabMaps: finding the places

A journey starts with a place a rider types: a mall, a condominium, a clinic, an address. GrabMaps knows South-East Asia's places, and its terms let us show them on our own maps.

E12 GrabMaps, in brief

GrabMaps is the map of Grab, South-East Asia's ride-hailing and delivery company. Grab began building it in 2017, launched it as a service for businesses in June 2022, and runs its own apps on it. Its data comes from Grab's own community: millions of rides and deliveries a day, its driver and delivery partners (some paid to collect places, street names and street-level imagery with Grab's own cameras), merchants and customers, on OpenStreetMap as the base layer. Amazon says a local team of more than 1,000 people maintains it.

Amazon Location Service has offered GrabMaps since January 2023, and since March 2026 through its newer Places operations, with nothing to set up beyond a key, in two regions: Asia Pacific (Singapore) and Asia Pacific (Malaysia), which we use. It covers eight countries and over 500 cities: Malaysia, Singapore, Thailand, Indonesia, the Philippines, Vietnam, Myanmar and Cambodia. Brunei is not among them.

E13 How place search works

Our servers call four of Amazon Location Service's Places operations, in its Asia Pacific (Malaysia) region, where they answer with GrabMaps' data:

OPERATION	USED FOR	PRICE BUCKET
Suggest	The search box: suggestions as the rider types (GrabMaps has no Autocomplete)	Label: US$0.20 per 1,000
GetPlace	The position and address of the suggestion picked	Core: US$0.50 per 1,000
ReverseGeocode	A name for a point picked on the map, and "where am I"	Core: US$0.50 per 1,000
SearchText	A typed address or place name to one position, for the developer API	Core: US$0.50 per 1,000

- **What the server asks for:** up to 20 suggestions, near the rider (or the area on screen), in Malaysia, Singapore and Thailand for Malaysia Transit (Thailand for Hat Yai), and Singapore and Malaysia for SG-JB Transit, in the rider's language where GrabMaps has it (English, Malay, Chinese, Thai, Indonesian, Vietnamese and five more); other languages get English.
- **Its own ordering, at no extra cost.** GrabMaps barely weighs where the rider is: "Komtar" typed in Penang put a Johor Bahru food court first, and "Hat Yai" put Singapore shops called Hatyai first. So the server reorders: names that start with what was typed, or places in the town it names, come first; within that, places in the rider's own country.
- **Tidied answers.** In Malaysia and Thailand GrabMaps puts the state where the town would be, and writes some states in Malay; the server reads them right (Johor, Penang, Kuala Lumpur, Putrajaya, Songkhla), so the planner still tells Johor from the rest of Malaysia. A picked place's text starts with its name ("KOMTAR - Main Lobby, Lebuh Tek Soon, ..."), and a typed address takes the best of five answers.

- **Our own entries first.** Airports come from the planner's own list, ahead of GrabMaps' answers.
- **Nothing kept.** Answers are used for the request and not stored, as the terms ask; the key goes only to Amazon and is never logged; and both products' privacy policies say searches go to Amazon Location Service.

E14 GrabMaps against Google

Google's own answer to the terms problem is Places UI Kit, which may be shown on any map. It would have done, had it worked the way our search does. It doesn't, and the comparison on 26 November 2026 went like this:

	GOOGLE PLACES UI KIT	GRABMAPS THROUGH AMAZON	PHOTON (OPENSTREETMAP)
With our maps	Allowed (15.1)	Allowed: Amazon's terms (Service Terms, section 82) put no limit on showing GrabMaps' results on our maps	Allowed, with the credit
Places	Google's: the most complete	Grab's own, curated for South-East Asia	OpenStreetMap's: thinner for shops, condominiums and buildings
Works like our search	No: Google's own widget, not our list; no React Native version, so native work in both apps; a suggestion gives only an id, and its position needs a second, paid component	Yes: our server calls it and answers as before, so nothing else changes	Yes, self-hosted
Planning from the place	A grey area (15.3): would need Google's written OK	Fine: don't store results unless the request says so, keep Grab's credit, and don't merge Grab's places into OpenStreetMap data	Fine
At 100,000 searches a month	About US$990	About US$70	Free, on our server

GrabMaps was chosen, with self-hosted Photon recommended as a fallback (and for Brunei, which GrabMaps doesn't cover). MOTIS has an OpenStreetMap place search of its own, but OpenStreetMap has fewer of Malaysia's shops and condominiums than Google or Grab, so it is switched off and GrabMaps does the job.

Prices, side by side

AMAZON, ASIA PACIFIC (MALAYSIA)	PER 1,000
Suggest (Label, what we ask for)	**US$0.20**
Suggest with extra fields (Core)	US$0.50
GetPlace, ReverseGeocode, SearchText (Core)	**US$0.50**
With hours, contacts and similar (Advanced)	US$1.50
Marked for keeping (Stored)	US$4.00

SEARCHES A MONTH	GRABMAPS	PLACES UI KIT
10,000	US$7	Nothing (free allowance)
100,000	**US$70**	**US$990**

Amazon's price list for Asia Pacific (Malaysia), published 11 September 2026, and Google's pricing list, both read on 27 November 2026. One suggestion request and one lookup per search, after the free allowances; Amazon's free tier gives 10,000 suggestions and 20,000 lookups a month for the first three months. Suggestions go out as the rider types: a search with five suggestion requests costs about US$1.50 per 1,000 searches, still a fraction of Google's.

Quality, from the live test

- **Good:** malls, landmarks, stations and addresses across Malaysia and Singapore, in several languages, once reordered for the rider's town and country.
- **Weaker than Google on English descriptions:** "Kota Bharu bus terminal" finds only Thai bus terminals, while the Malay name, "Hentian Bas Kota Bharu", finds the right one.
- **Short names:** "City Square" typed in Johor Bahru brings up Singapore's mall; "JB City Square" works.
- **Names for map points** are sometimes odd (a point at Komtar came back as a rice mill), and one test lookup for "Stesen KTM Kulai" returned Kluang station.

APPENDIX E · TOGETHER

What the change adds up to

MOTIS and GrabMaps each do one job well. Together they cover everything Google did for our planner, on terms that fit our products.

E15 The pair against Google alone

	GOOGLE ALONE (BEFORE)	MOTIS AND GRABMAPS (NOW)
Allowed with our maps	No: Directions, Places and Geocoding results may not be shown on a non-Google map	Yes: MOTIS is ours (MIT licence, OpenStreetMap streets), and Amazon allows GrabMaps' results on our maps
Suspension risk	Planner, search and geocoding could all stop at once	No Google dependency left in the planner or search
Journey cost	US$5 per 1,000 Directions calls after 10,000 free, several calls per search	Nothing per journey, on the server already paid for
Search cost	US$2.83 to US$20 per 1,000 calls after the free allowance	US$0.20 per 1,000 suggestions, US$0.50 per 1,000 lookups
As riders grow	Grows with every free rider	Planner: only server capacity. Search: grows, slowly
Our own timetables	Google planned on its own data; our services needed hand-built workarounds (S19, SRT, Causeway Link)	Planned directly on our timetables, plus Singapore's
Trips Google failed on	Seremban to KL Sentral returned an error	Planned: peak Seremban Line trains when they run, otherwise a bus and KLIA Ekspres
Speed	A call out to Google for each search	9 to 110 ms per plan, inside our server
Keeping and sharing	Coordinates only, for 30 days; nothing passed on	Journey results are ours; GrabMaps' answers aren't kept
Working with partners	A partner can't take Google-derived routes or data	Routing and route lines are ours to offer, with the OpenStreetMap credit

US$0
for 100,000 journeys a month with MOTIS, against at least US$450 with Google Directions

US$70
for 100,000 place searches a month, against about US$990 with Places UI Kit

95%
less for the two together at that traffic: about US$70 against about US$1,440

€12.60
a month for the server that runs the planner, both products' servers and more

E16 Trade-offs and risks

Upkeep is ours

MOTIS is one more container to keep healthy on a server whose memory is tight. A failed nightly refresh keeps yesterday's data, so someone has to notice. New street maps are loaded by hand every month or two, and MOTIS's version is pinned, so upgrades are a deliberate job.

Only as good as the timetables

data.gov.my's feeds have quirks (today-only calendars, descriptions where route numbers go, stop positions that slow some trips), and the preparation step repairs what it can. Singapore's timetables are built from frequencies, not published.

No live delays in plans

data.gov.my publishes bus positions, not delay predictions, so plans follow the timetable. Our own live-arrival times are shown on top of each planned ride.

No second planner

With Google switched off, there is nothing to fall back to if MOTIS is down. Place search deliberately doesn't fall back to Google, since that is exactly what the terms forbid: a GrabMaps outage says suggestions are unavailable. Everything runs on one server.

GrabMaps' weak spots

English descriptions, short names and Brunei (section E14). The recommended Photon fallback isn't built yet.

Licences and terms to keep

Credit "© OpenStreetMap contributors" where its data shows. Don't store GrabMaps' answers, keep Grab's credit, and never merge Grab's places into OpenStreetMap-licensed data. MOTIS's own code is MIT, but its place-search library, adr, is under the AGPL, whose extra duties apply to changed copies offered over a network; we run the official image unchanged, with place search off.

E17 What comes next

- **A fallback for places:** self-hosted Photon on OpenStreetMap, for GrabMaps outages and for Brunei.
- **Live delays in plans:** MOTIS reads GTFS Realtime trip updates. If data.gov.my publishes delay predictions, plans can follow them with a setting.
- **Google removed for good:** its code and keys, once the switch has proved itself.
- **New services:** the RTS Link between Johor Bahru and Woodlands, the Jurong Region Line, and Kota Kinabalu, each a timetable added to the nightly refresh.
- **Upgrades:** newer MOTIS versions, tried on the server first, as this one was.

E18 Sources

MOTIS: github.com/motis-project/motis (README, setup guide, API specification, and release 2.11.4 of 21 October 2026); its libraries nigiri, osr and tiles (github.com/motis-project), cista (github.com/felixguendling/cista) and adr (github.com/triptix-tech/adr); the FOSDEM 2025 talk "GNOME Maps meets Transitous meets MOTIS". RAPTOR: D. Delling, T. Pajor and R. F. Werneck, "Round-Based Public Transit Routing", ALENEX 2012.

Transitous: transitous.org, and its usage policy, transitous.org/api.

OpenTripPlanner: docs.opentripplanner.org (history, version comparison, system requirements and deployments).

Comparisons: SKI+, "Open Source Routers – A comprehensive comparative market research", version 1.1, November 2025 (oev-info.ch); TransCAPI, "Replacing OpenTripPlanner with MOTIS for Great Britain", 16 October 2026 (transcapi.com).

Other planners: Navitia, github.com/hove-io/navitia; R5, github.com/conveyal/r5; Valhalla, github.com/valhalla/valhalla; GraphHopper, github.com/graphhopper/graphhopper.

GrabMaps' history: Grab's press release of 8 June 2022; Amazon's announcements of 10 January 2023 and 31 March 2026; Amazon's GrabMaps page (countries, regions and data).

Google Maps Platform: Service Specific Terms (version of 24 November 2026), cloud.google.com/maps-platform/terms/maps-service-terms; Terms of Service, cloud.google.com/maps-platform/terms; pricing, developers.google.com/maps/billing-and-pricing/pricing; Places UI Kit, developers.google.com/maps/documentation/javascript/places-ui-kit (all read 26–27 November 2026).

Amazon Location Service and GrabMaps: pricing and free tier, aws.amazon.com/location/pricing; AWS's price list for Asia Pacific (Malaysia), published 11 September 2026; Places price buckets, docs.aws.amazon.com/location/latest/developerguide/places-pricing.html; GrabMaps' countries and regions, docs.aws.amazon.com/location/latest/developerguide/GrabMaps.html; data attribution, docs.aws.amazon.com/location/latest/developerguide/data-attribution.html; AWS Service Terms, section 82, aws.amazon.com/service-terms (read 26–27 November 2026).

Place search fallback: Photon, github.com/komoot/photon.

Data: data.gov.my's GTFS feeds (CC BY 4.0); LTA DataMall (Singapore Open Data Licence); OpenStreetMap (© OpenStreetMap contributors, ODbL), through Geofabrik's extracts.

Malaysia Transit's own records: the plan, comparisons and trial results (`docs/google-maps-replacement-plan.md`), the server scripts and nightly refresh (`scripts/motis/`), the planner client (`lib/motisPlanner.js`) and the place search client (`lib/grabMapsPlaces.js`).