MARECO algorithm

How to drive a train
using the least amount of energy

Alex ROLLAND

FOSDEM Feb 3rd 2024

MARECO algorithm

How to drive a train
a bus
using the least amount of energy

Alex ROLLAND

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MARECO algorithm

How to drive a train
a bus
any public transport vehicle with wheels
using the least amount of energy

Alex ROLLAND

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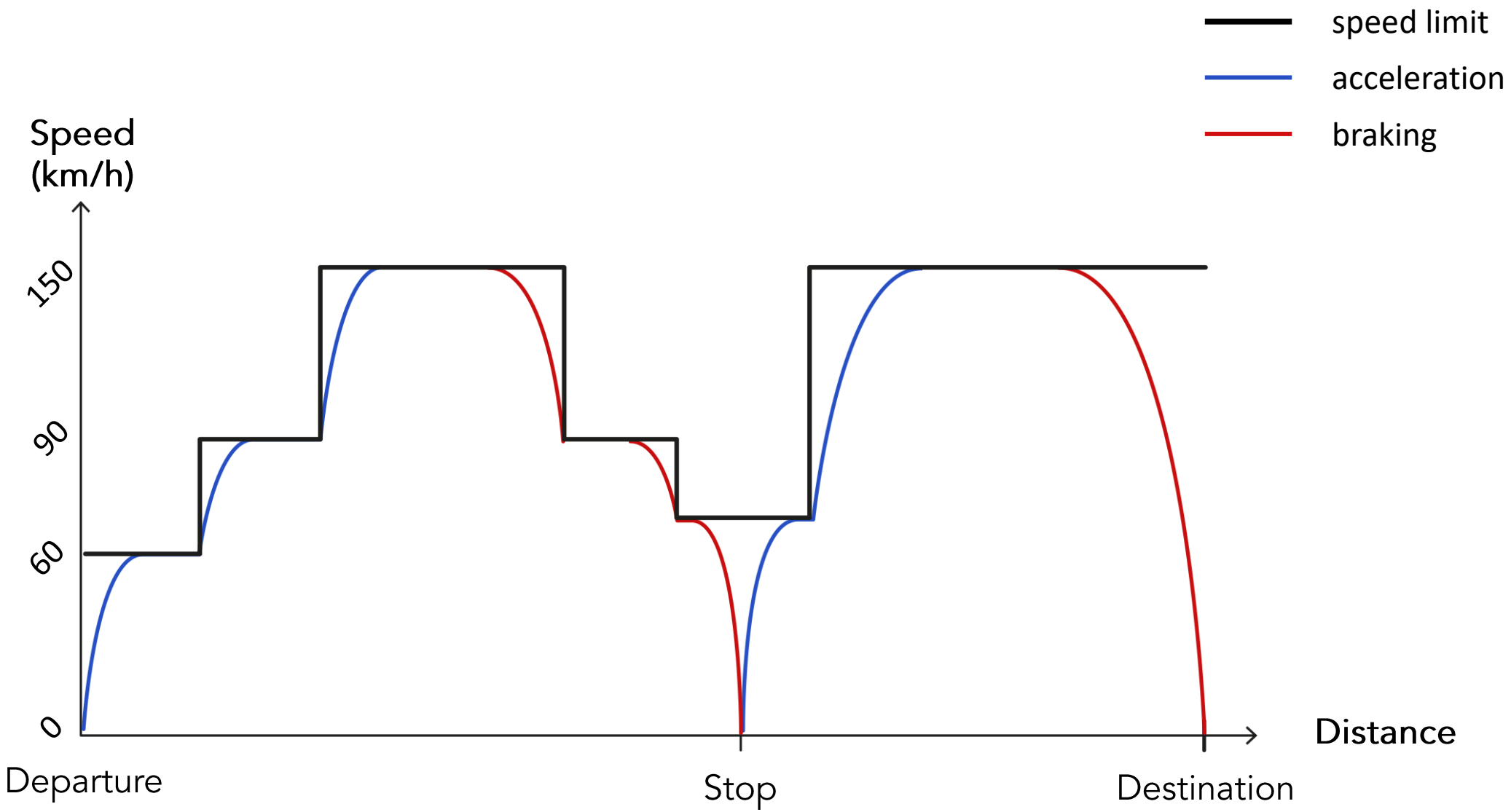
MARECO algorithm

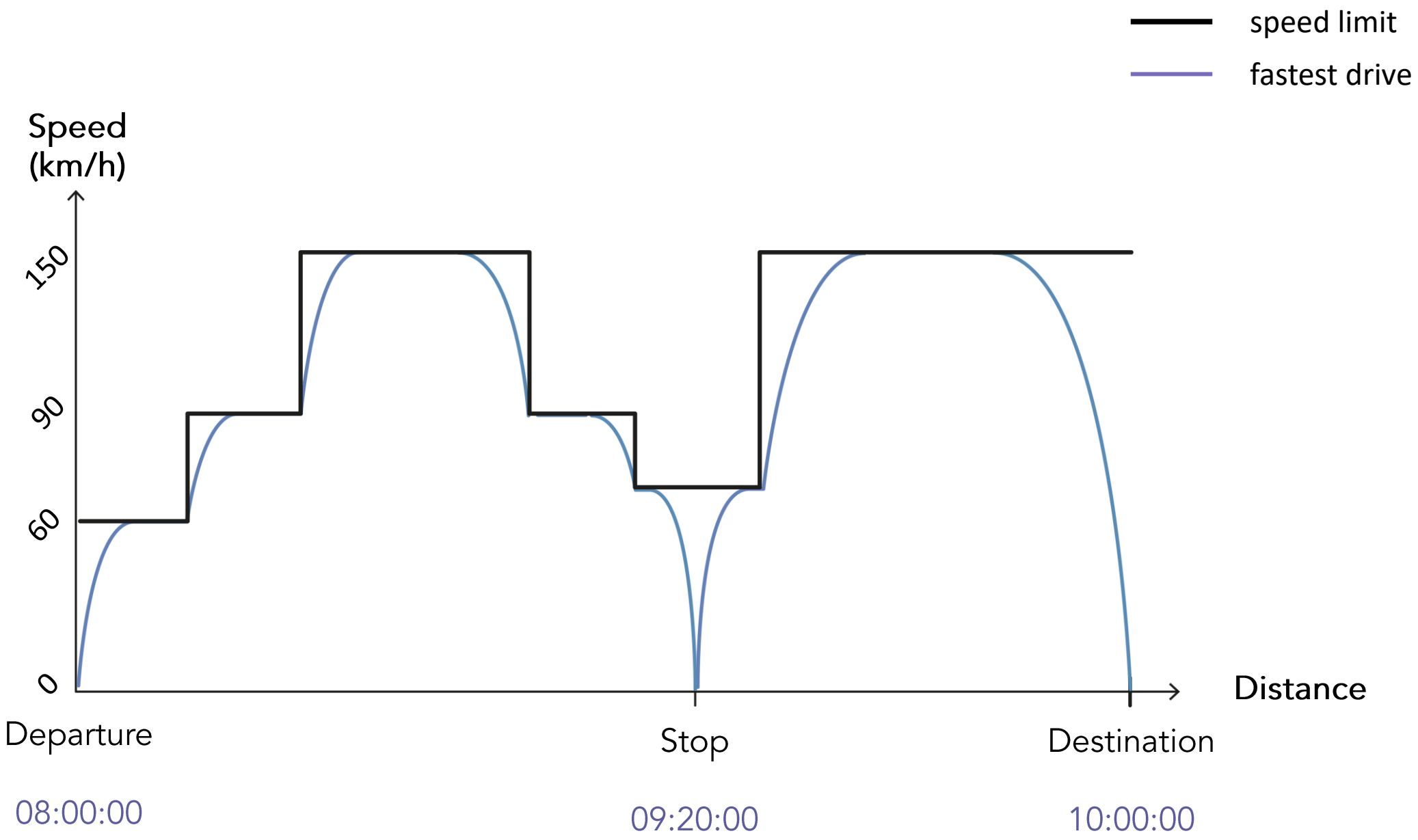
How to drive a train
a bus
any public transport vehicle with wheels
bikes
using the least amount of energy

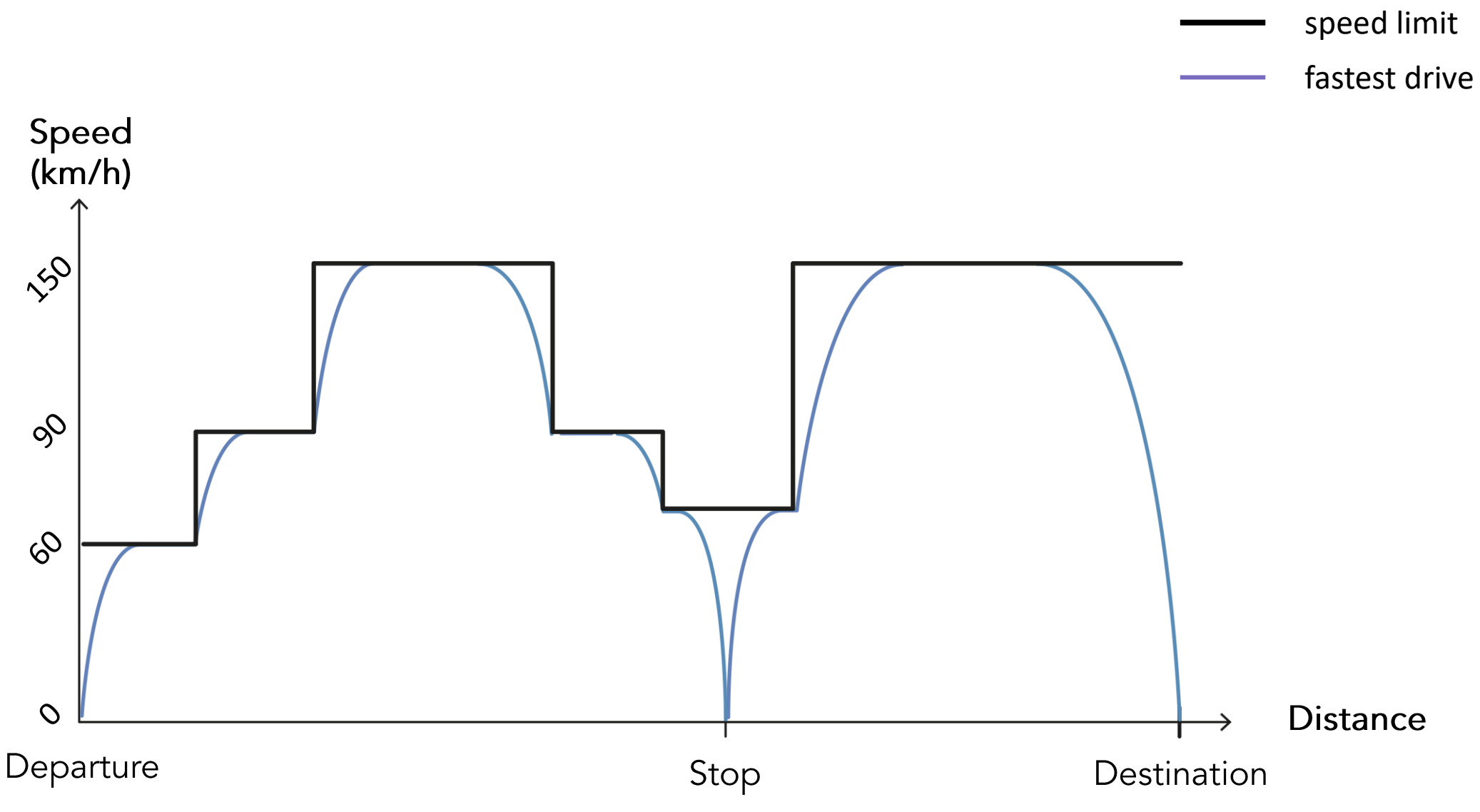
Alex ROLLAND

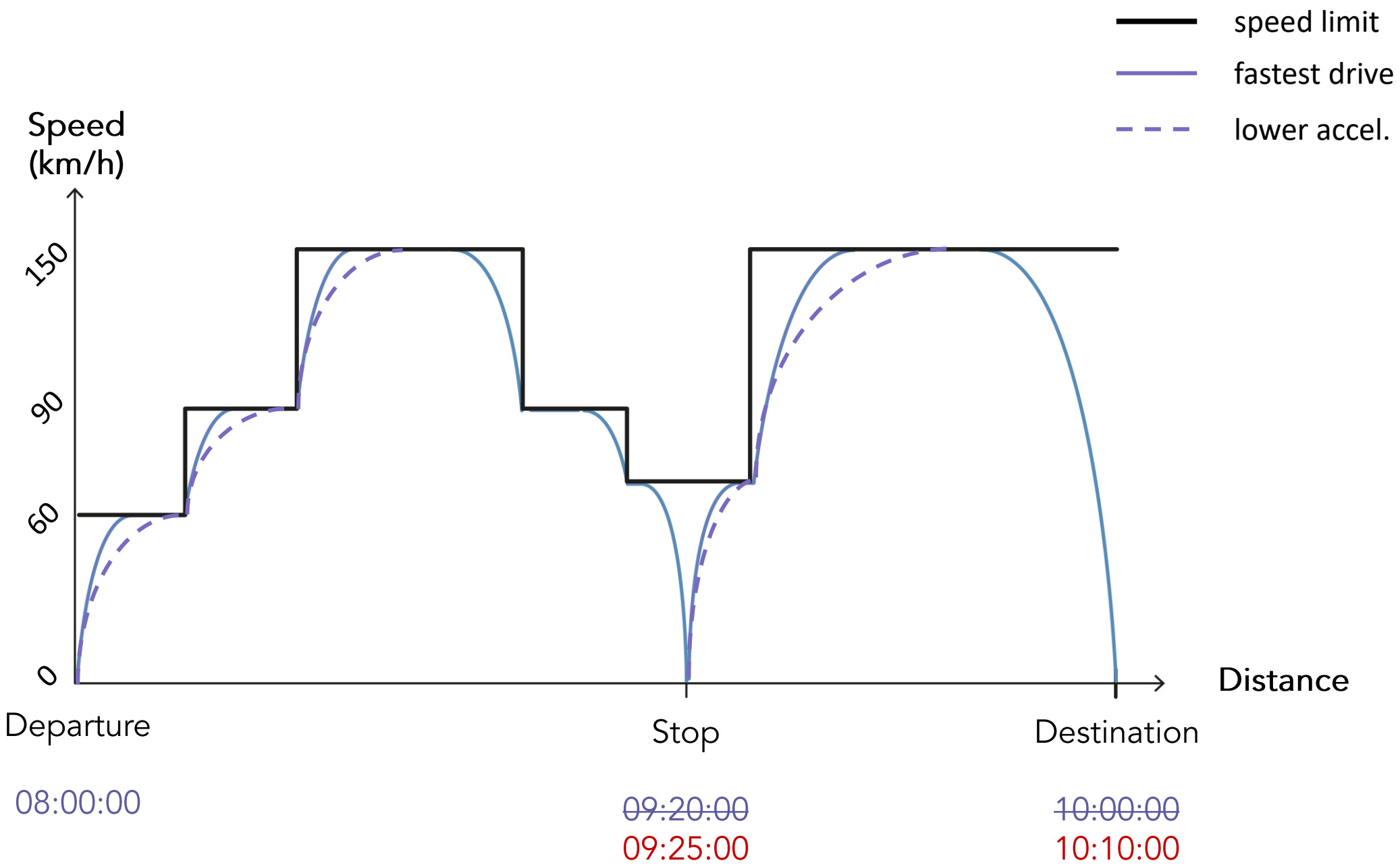
OSRD

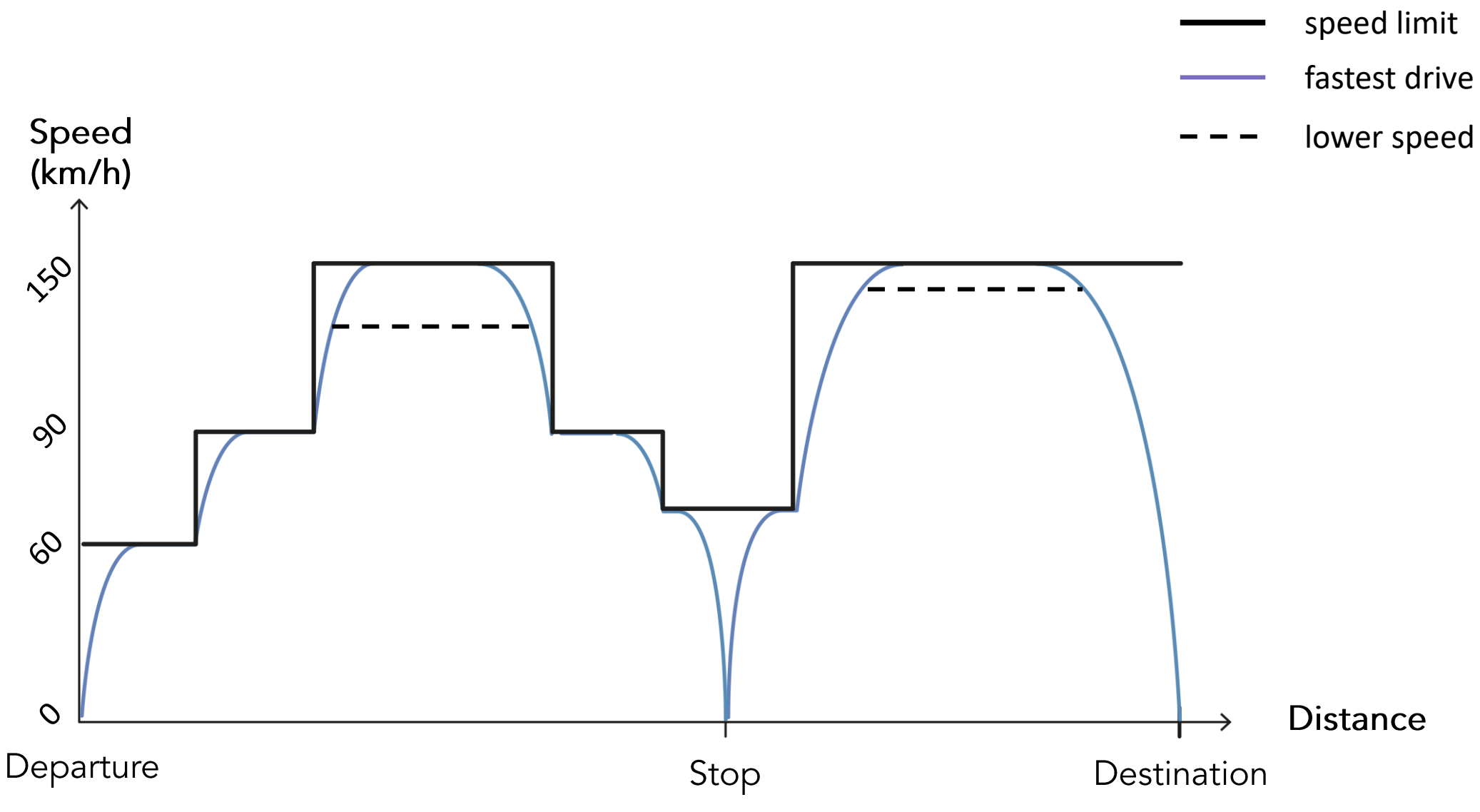
https://github.com/osrd-project/osrd

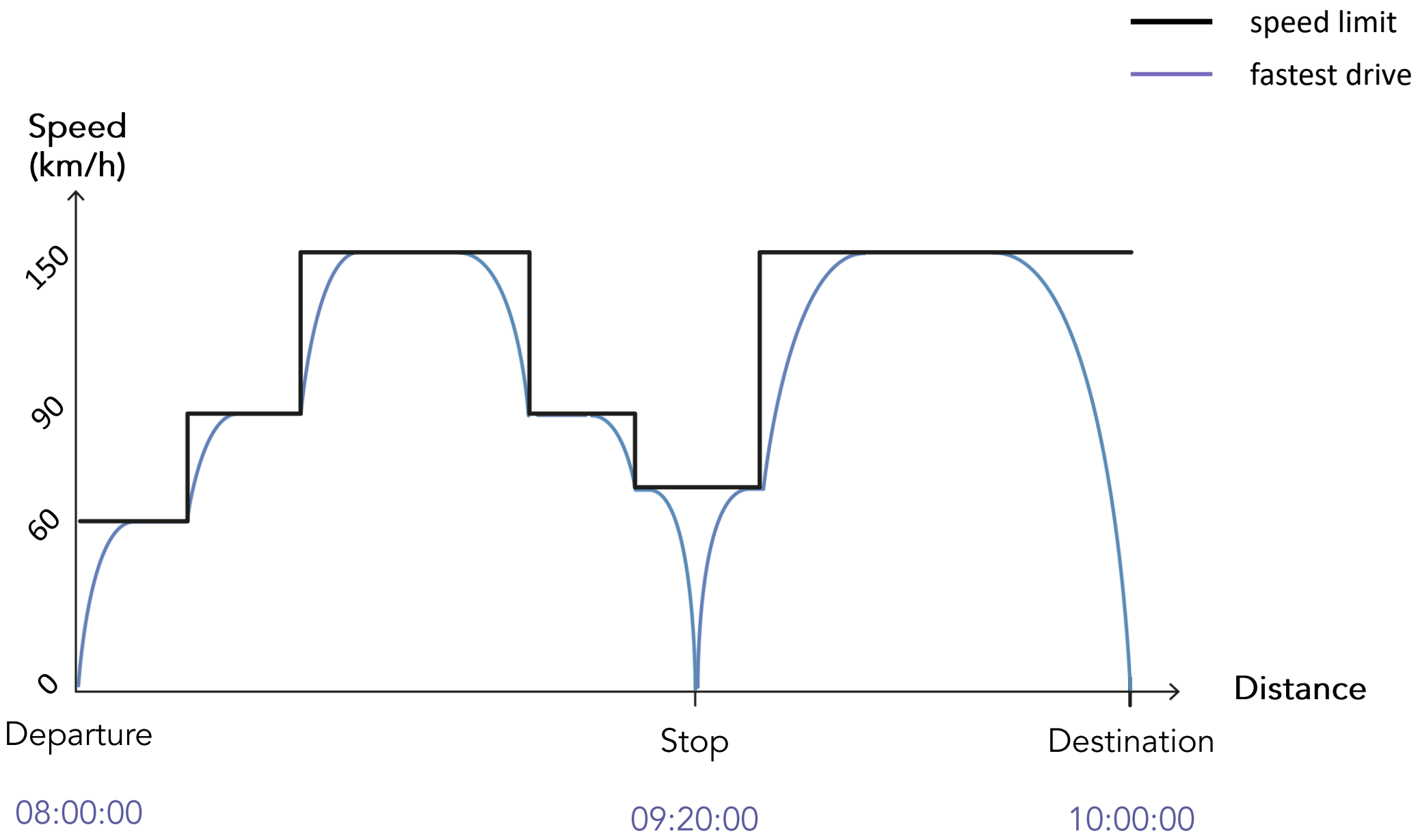

speed limit
acceleration
braking
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination

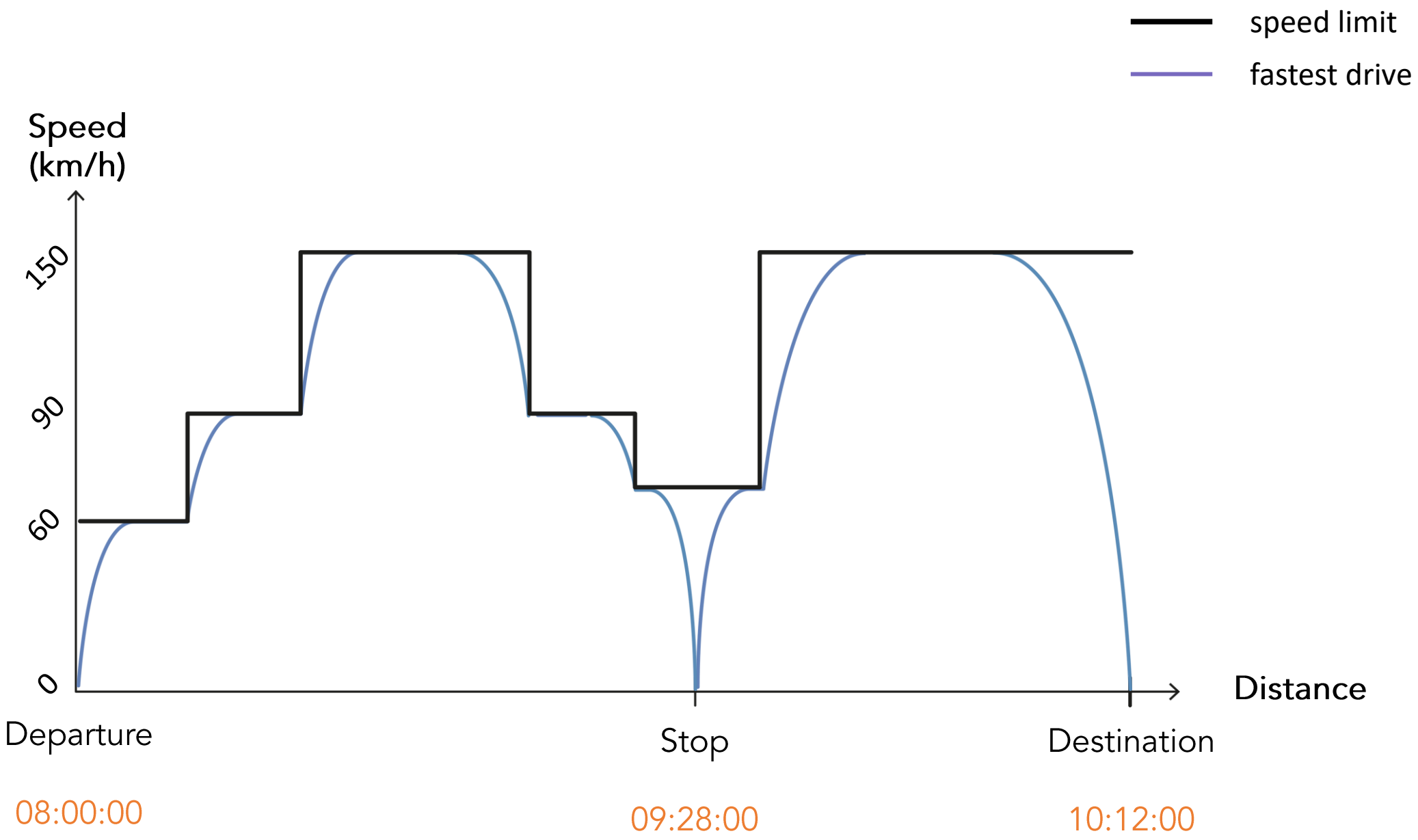

speed limit
fastest drive
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:20:00
10:00:00


speed limit
fastest drive
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
08:05:00
09:20:00
09:25:00
10:00:00
10:05:00


speed limit
fastest drive
lower accel.
Speed (km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:20:00
09:25:00
10:00:00
10:10:00


speed limit
fastest drive
lower speed
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:20:00
09:25:00
10:00:00
10:10:00


speed limit
fastest drive
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:20:00
10:00:00


speed limit
fastest drive
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:28:00
10:12:00

MARECO algorithm – How to drive a train using the least amount of energy ?

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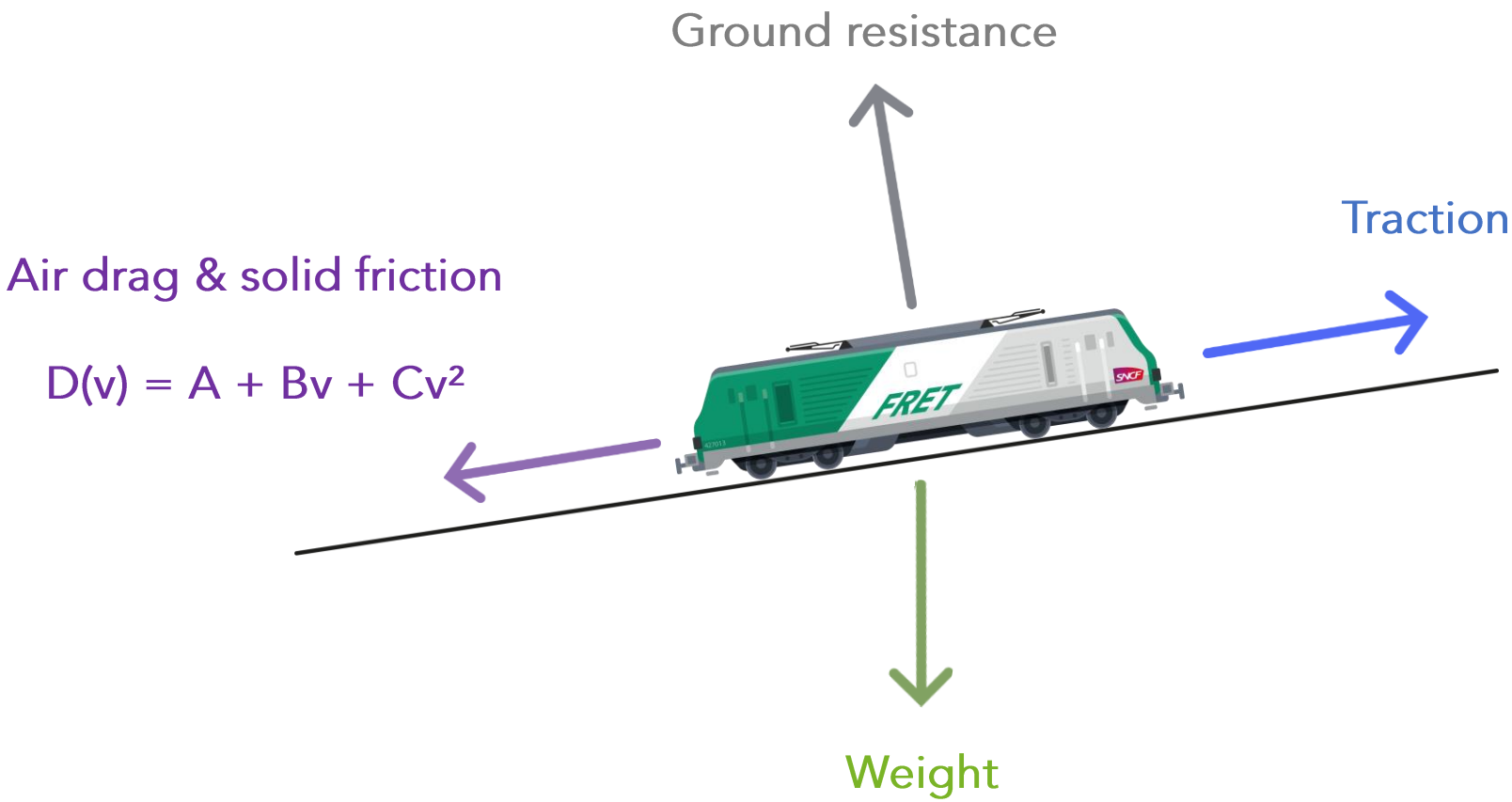
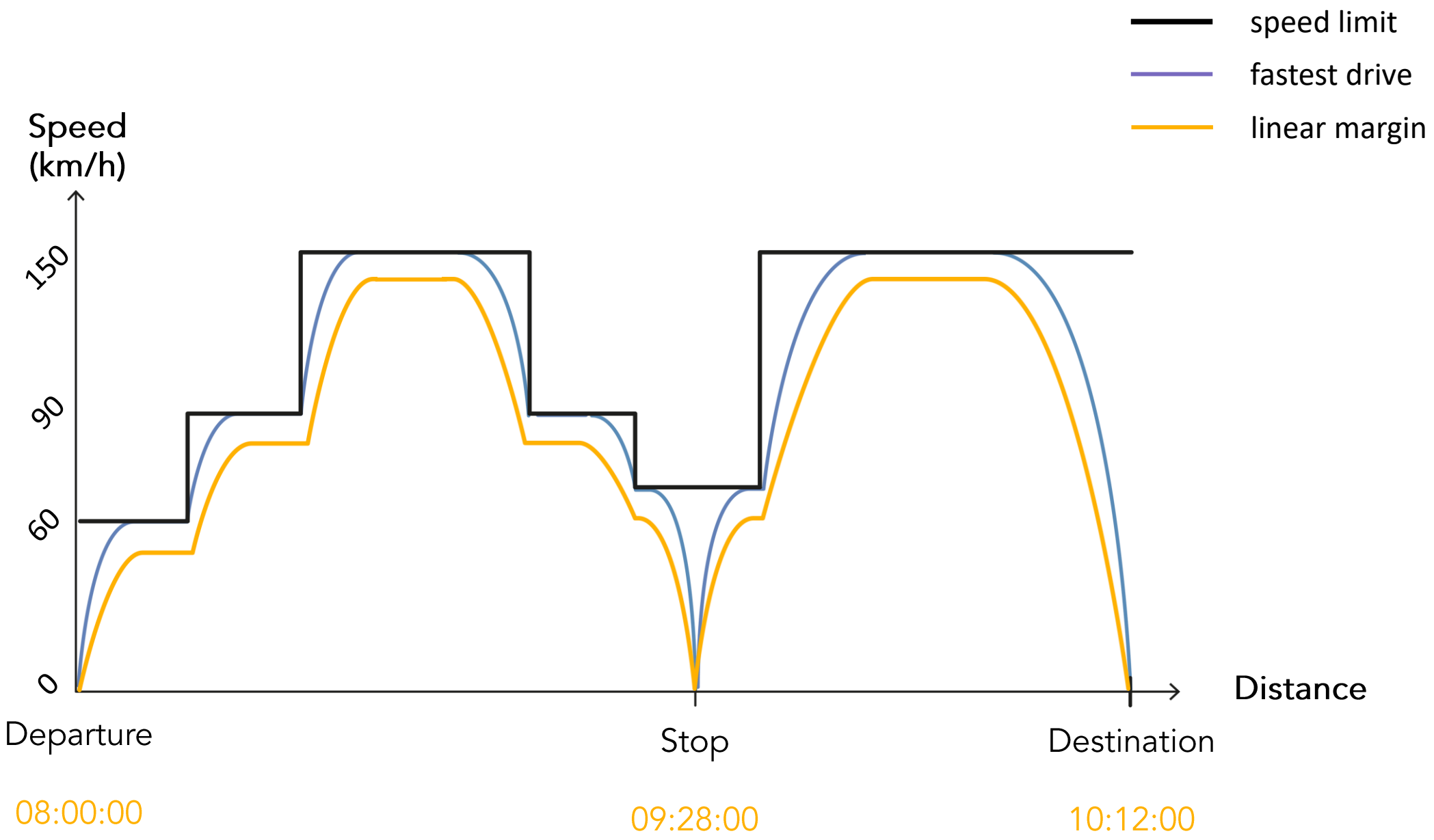
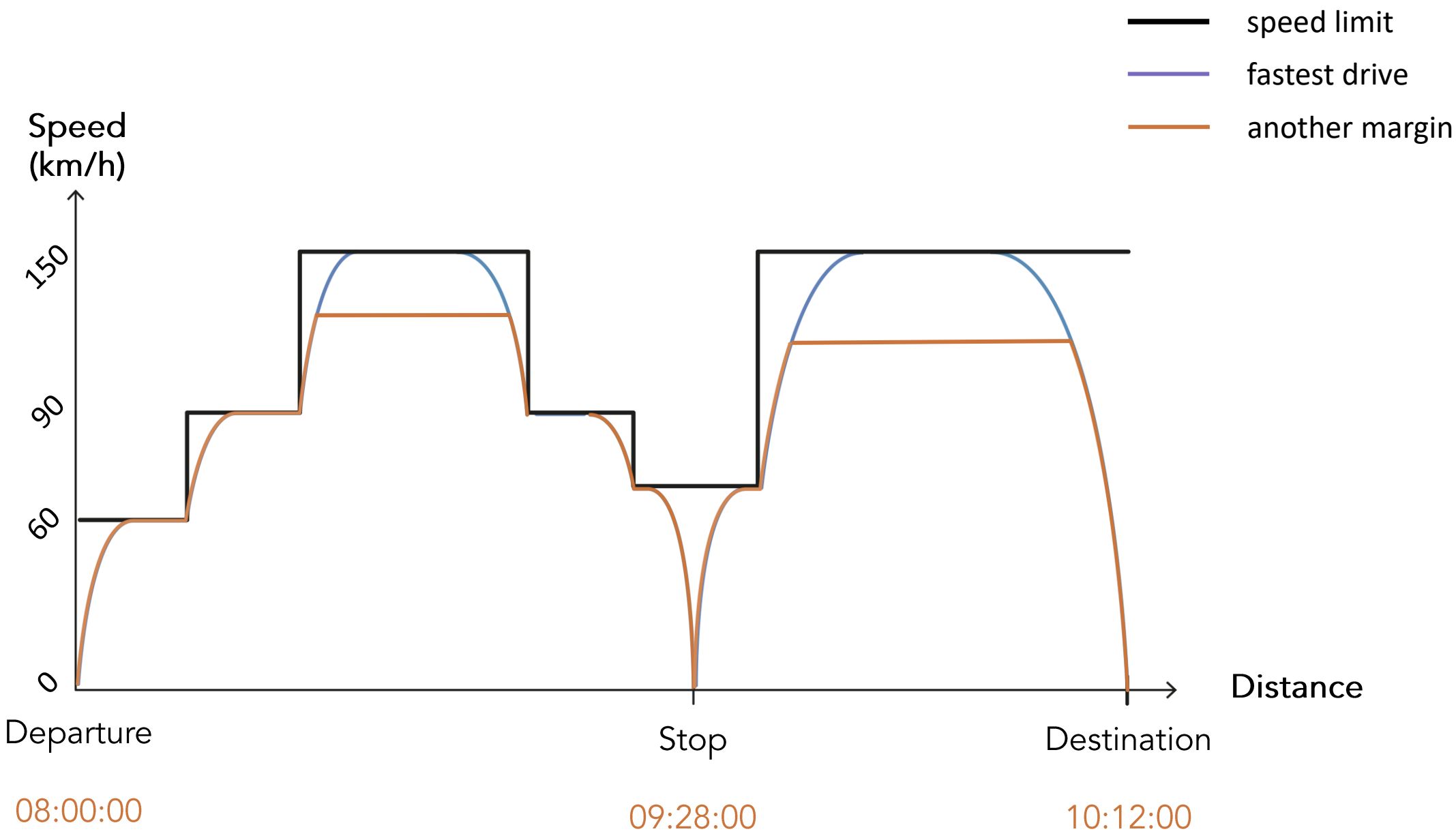
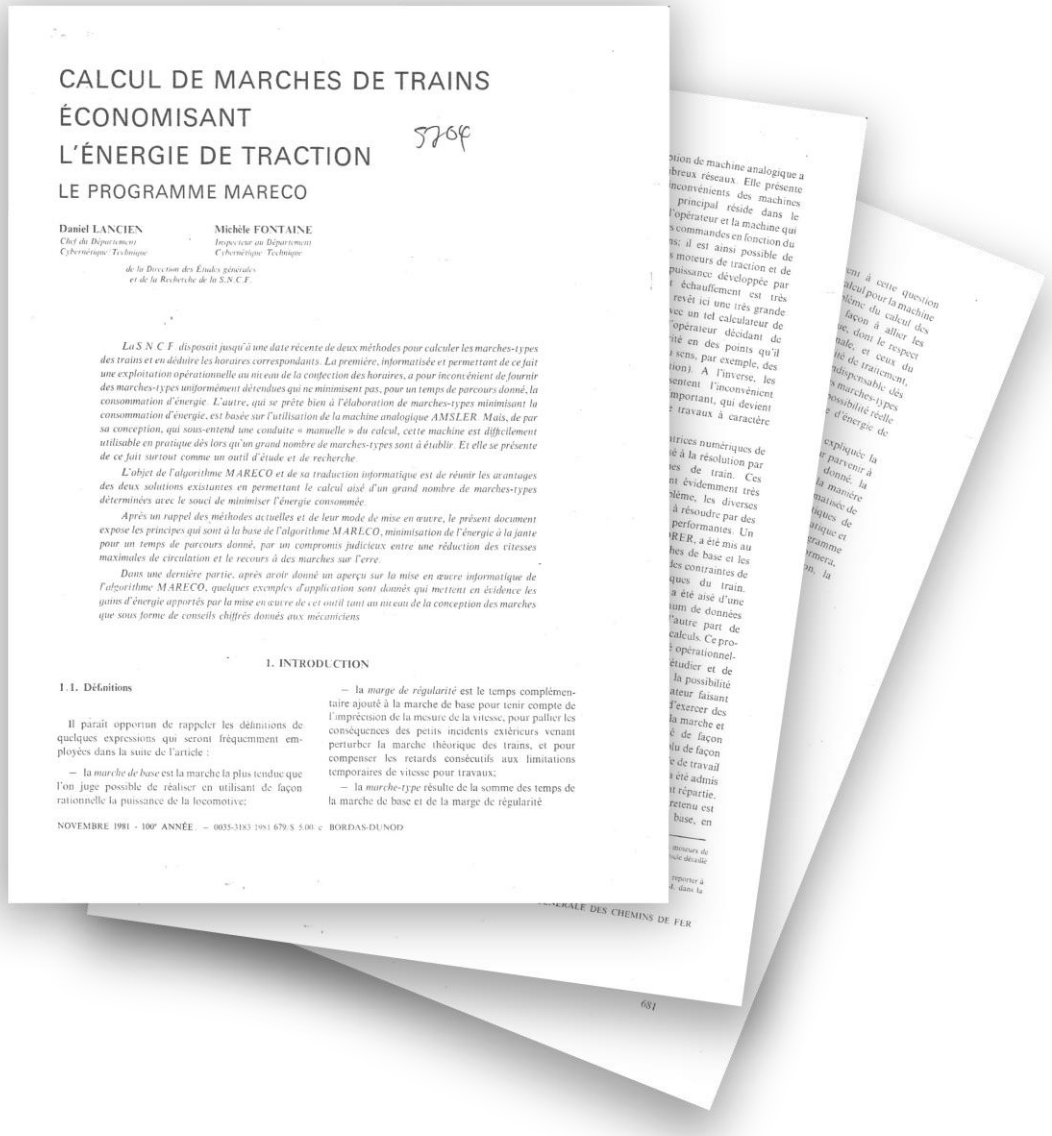

Ground resistance
Traction
Air drag & solid friction
D(v) = A + Bv + Cv²
FRET
SNCF
Weight


speed limit
fastest drive
linear margin
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:28:00
10:12:00


speed limit
fastest drive
another margin
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:28:00
10:12:00

MARECO algorithm – How to drive a train using the least amount of energy ?



CALCUL DE MARCHES DE TRAINS
ÉCONOMISANT
L'ÉNERGIE DE TRACTION

LE PROGRAMME MARECO

Daniel LANCIEN
Chef du Département Cybernétique Technique

Michèle FONTAINE
Inspecteur au Département Cybernétique Technique

de la Direction des Études générales et de la Recherche de la S.N.C.F.

La S N C F disposait jusqu'à une date récente de deux méthodes pour calculer les marches-types des trains et en déduire les horaires correspondants. La première, informatisée et permettant de ce fait une exploitation opérationnelle au niveau de la confection des horaires, a pour inconvénient de fournir des marches-types uniformément détendues qui ne minimisent pas, pour un temps de parcours donné, la consommation d'énergie. L'autre, qui se prête bien à l'élaboration de marches-types minimisant la consommation d'énergie, est basée sur l'utilisation de la machine analogique AMSLER. Mais, de par sa conception, qui sous-entend une conduite « manuelle » du calcul, cette machine est difficilement utilisable en pratique dès lors qu'un grand nombre de marches-types sont à établir. Et elle se présente de ce fait surtout comme un outil d'étude et de recherche.

L'objet de l'algorithme MARECO et de sa traduction informatique est de réunir les avantages des deux solutions existantes en permettant le calcul aisé d'un grand nombre de marches-types déterminées avec le souci de minimiser l'énergie consommée.

Après un rappel des méthodes actuelles et de leur mode de mise en œuvre, le présent document expose les principes qui sont à la base de l'algorithme MARECO, minimisation de l'énergie à la jante pour un temps de parcours donné, par un compromis judicieux entre une réduction des vitesses maximales de circulation et le recours à des marches sur l'erre.

Dans une dernière partie, après avoir donné un aperçu sur la mise en œuvre informatique de l'algorithme MARECO, quelques exemples d'application sont donnés qui mettent en évidence les gains d'énergie apportés par la mise en œuvre de cet outil tant au niveau de la conception des marches que sous forme de conseils chiffrés donnés aux mécaniciens

1. INTRODUCTION

1.1. Définitions

Il paraît opportun de rappeler les définitions de quelques expressions qui seront fréquemment employées dans la suite de l'article :

– la *marche de base* est la marche la plus tendue que l'on juge possible de réaliser en utilisant de façon rationnelle la puissance de la locomotive;

– la *marge de régularité* est le temps complémentaire ajouté à la marche de base pour tenir compte de l'imprécision de la mesure de la vitesse, pour pallier les conséquences des petits incidents extérieurs venant perturber la marche théorique des trains, et pour compenser les retards consécutifs aux limitations temporaires de vitesse pour travaux;

– la *marche-type* résulte de la somme des temps de la marche de base et de la marge de régularité

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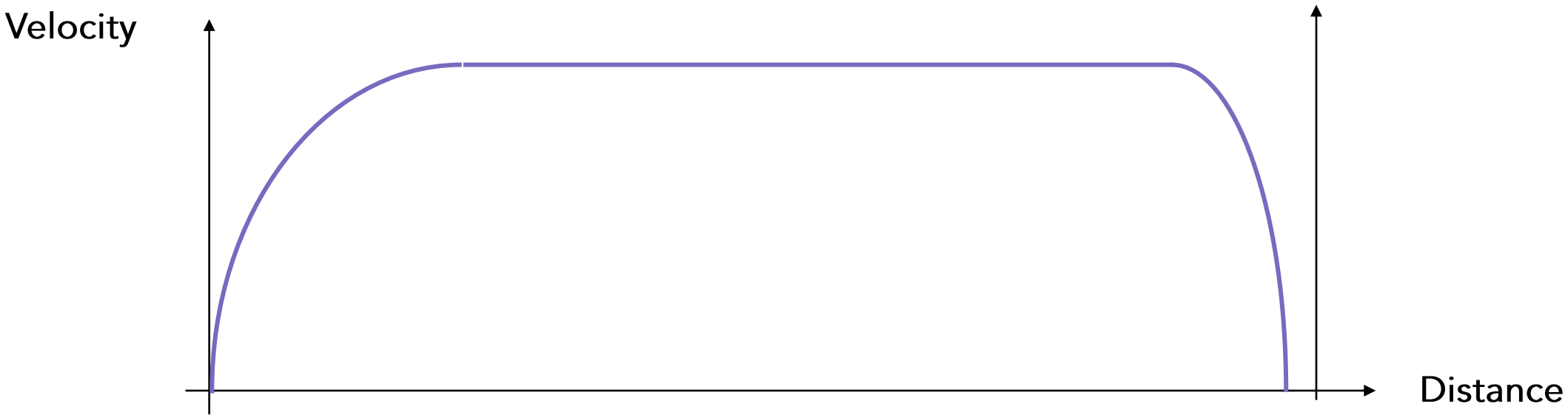
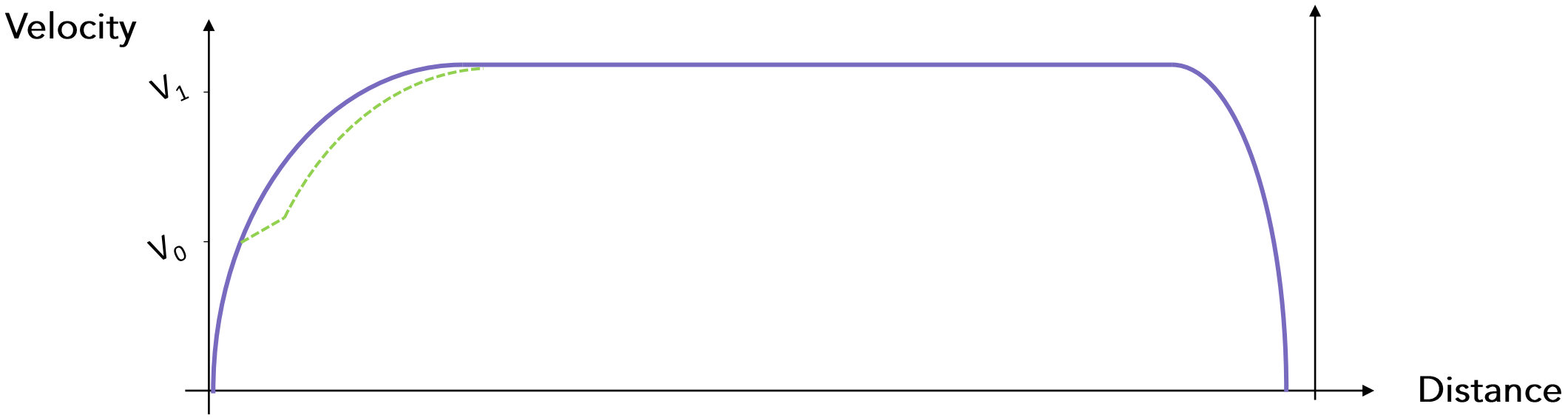
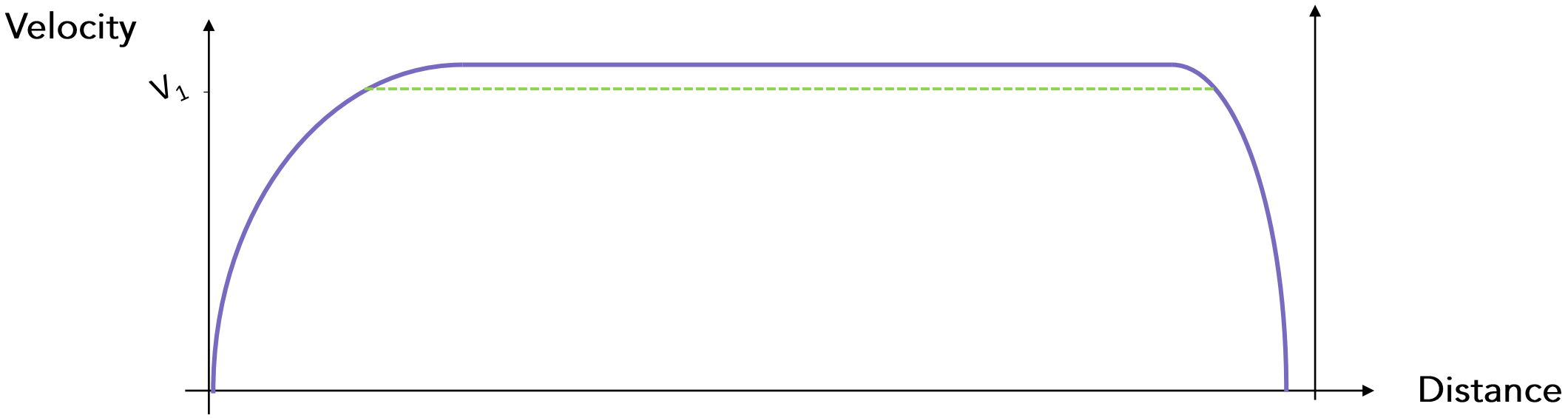
Action	Accelerating	Maintaining speed	Coasting	Braking
Parameters				
Energy saving per unit of added time				



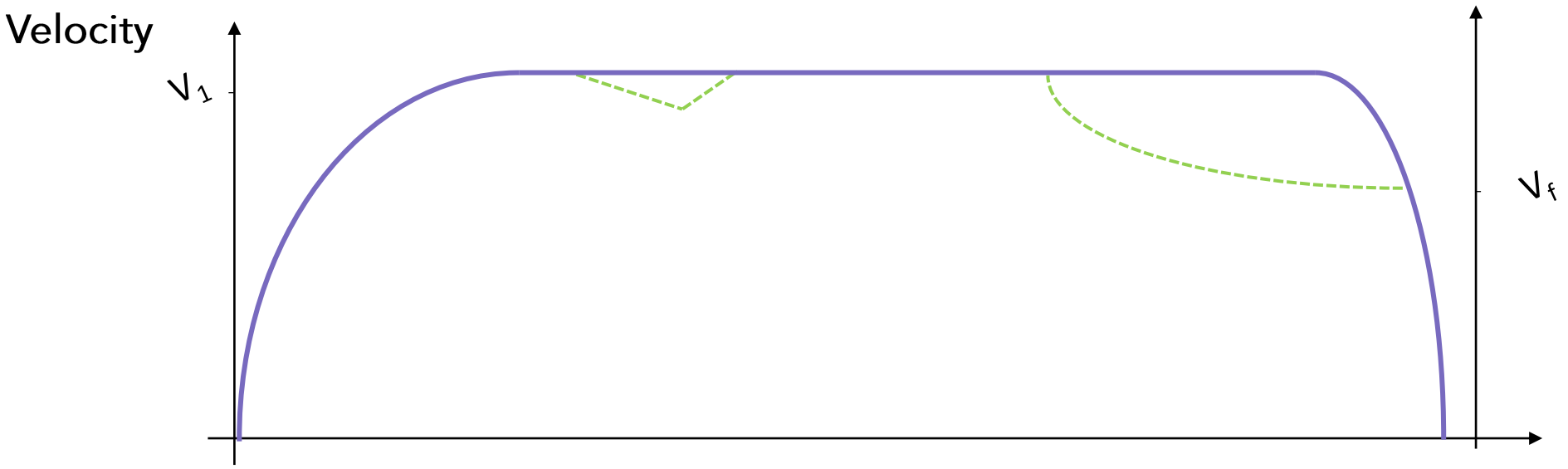
Action	Accelerating	Maintaining speed	Coasting	Braking
Parameters	V_0 , V_1			
Energy saving per unit of added time	+			



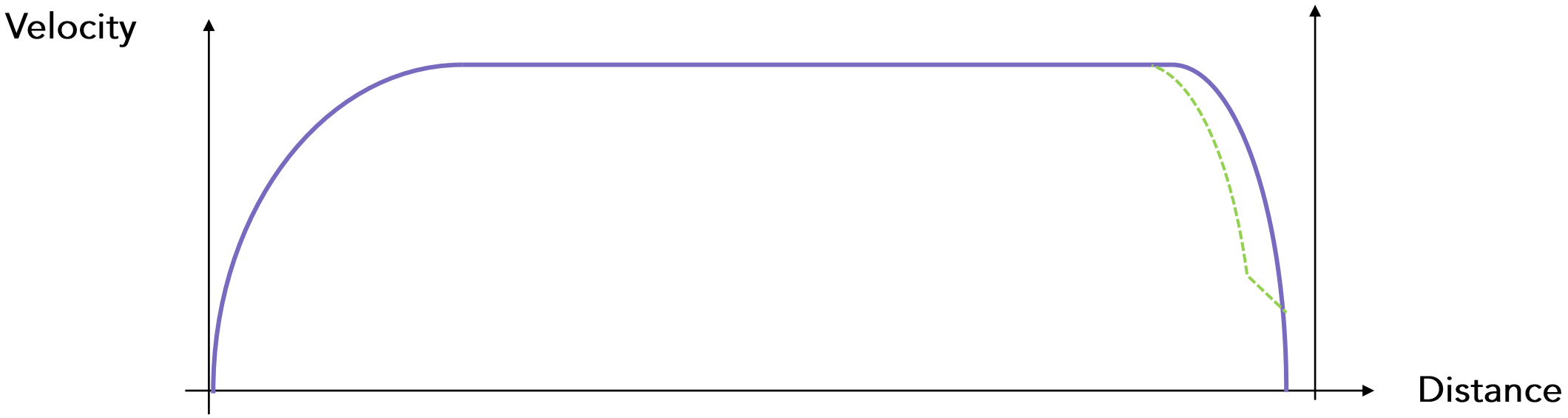
Action	Accelerating	Maintaining speed	Coasting	Braking
Parameters	V_0 , V_1	V_1		
Energy saving per unit of added time	+	+ + +		



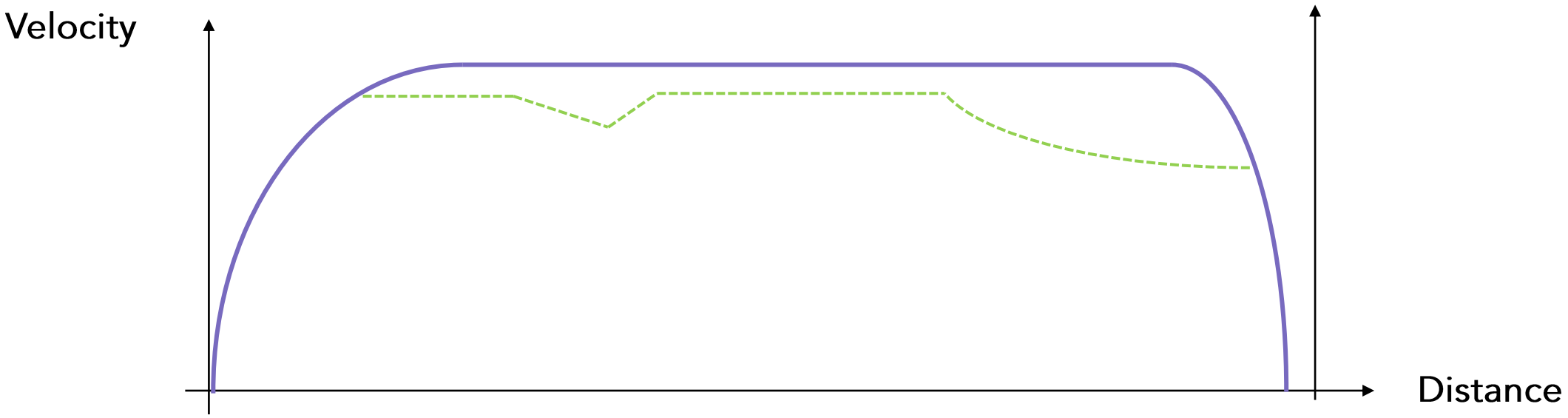
Action	Accelerating	Maintaining speed	Coasting	Braking
Parameters	V_0 , V_1	V_1	V_1 , V_f	
Energy saving per unit of added time	+	+ + +	+ + +	



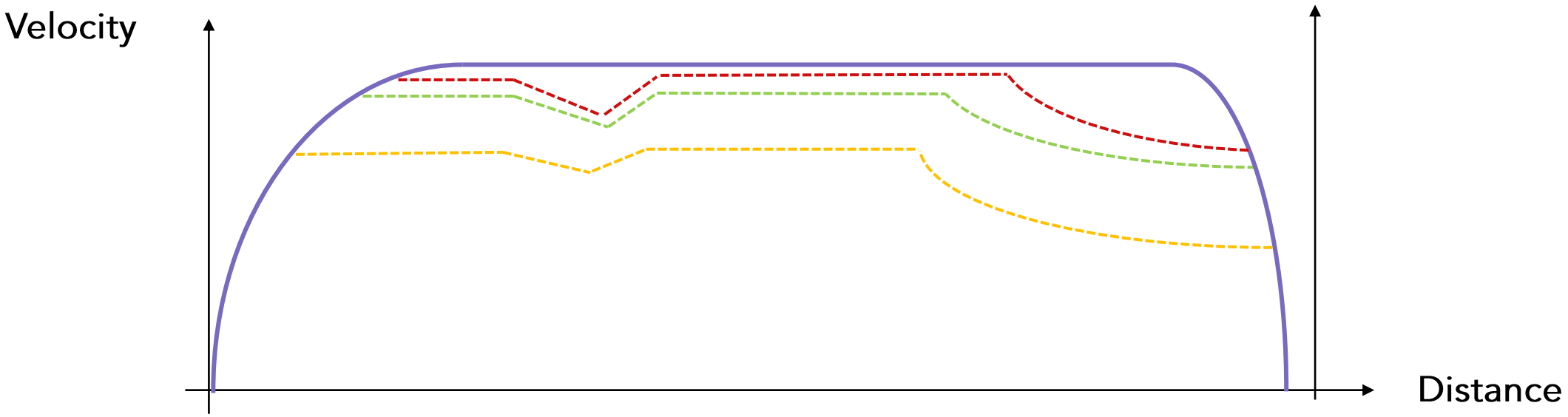
Action	Accelerating	Maintaining speed	Coasting	Braking
Parameters	V_0 , V_1	V_1	V_1 , V_f	None
Energy saving per unit of added time	+	+ + +	+ + +	0

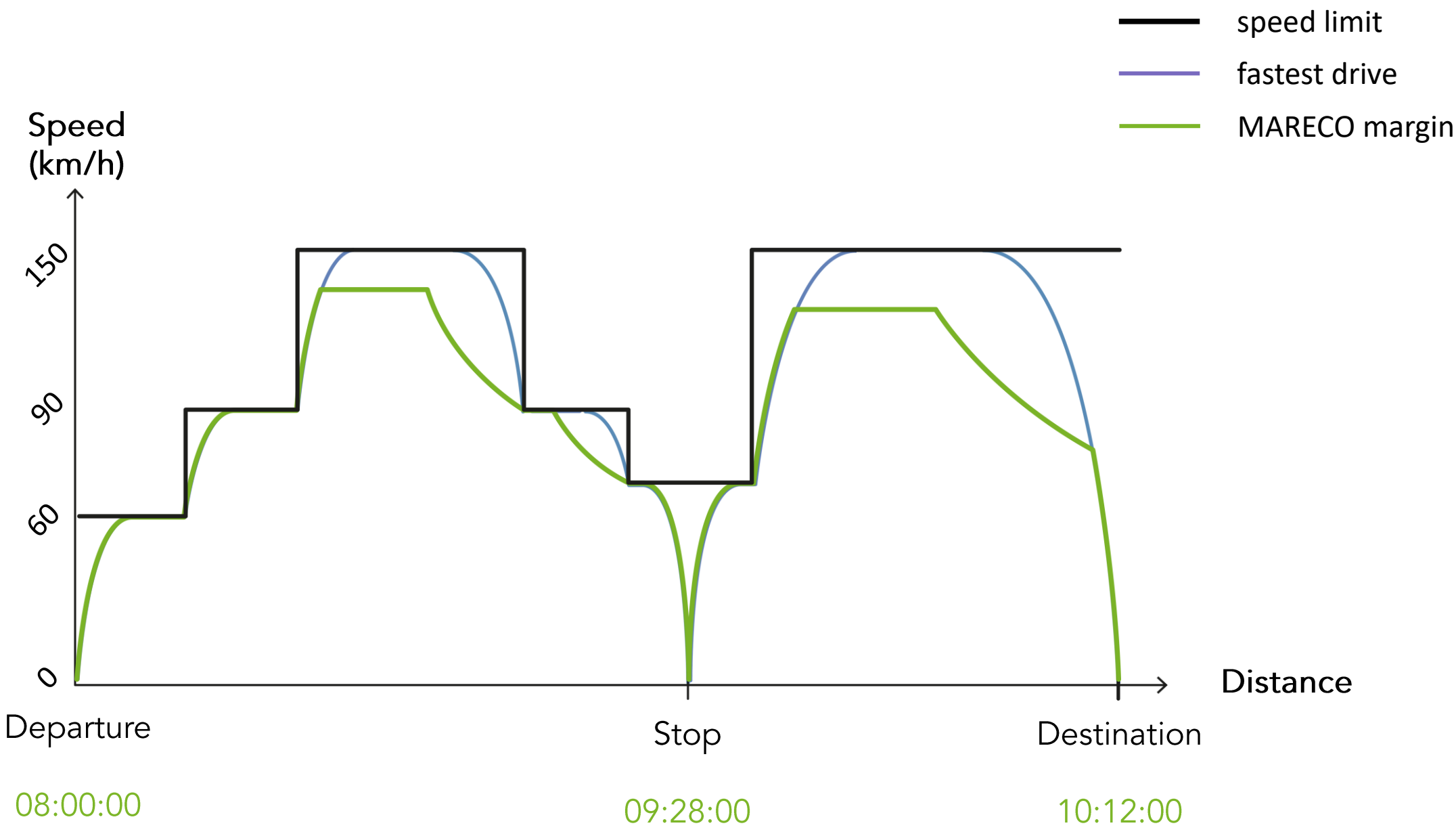


Action	Accelerating	Maintaining speed	Coasting	Braking
Parameters	V_0 , V_1	V_1	V_1 , V_f	None
Energy saving per unit of added time	+	+ + +	+ + +	0



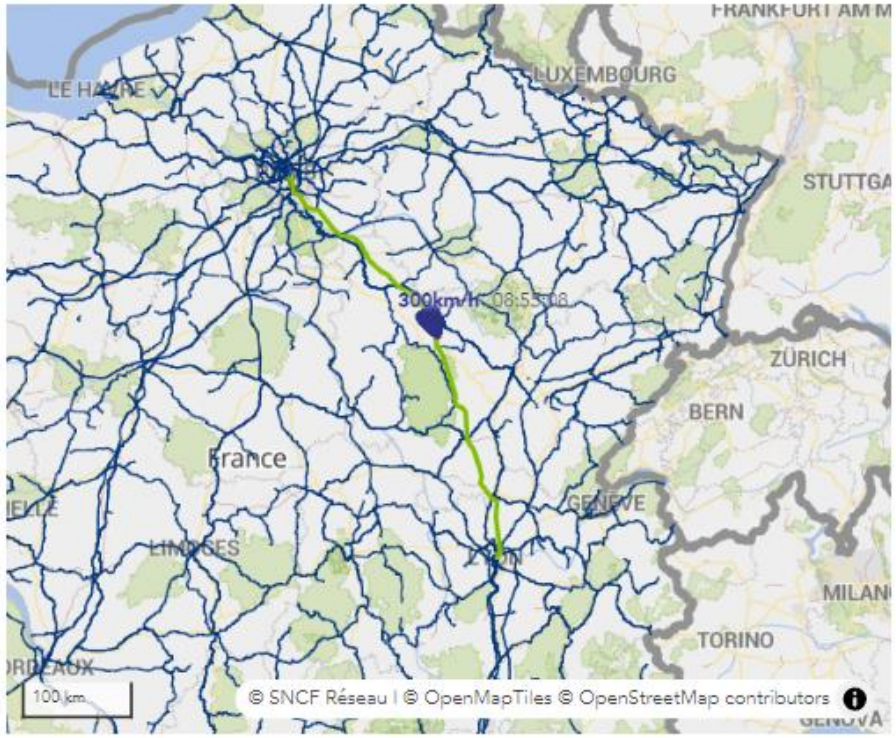
Binary search iterations

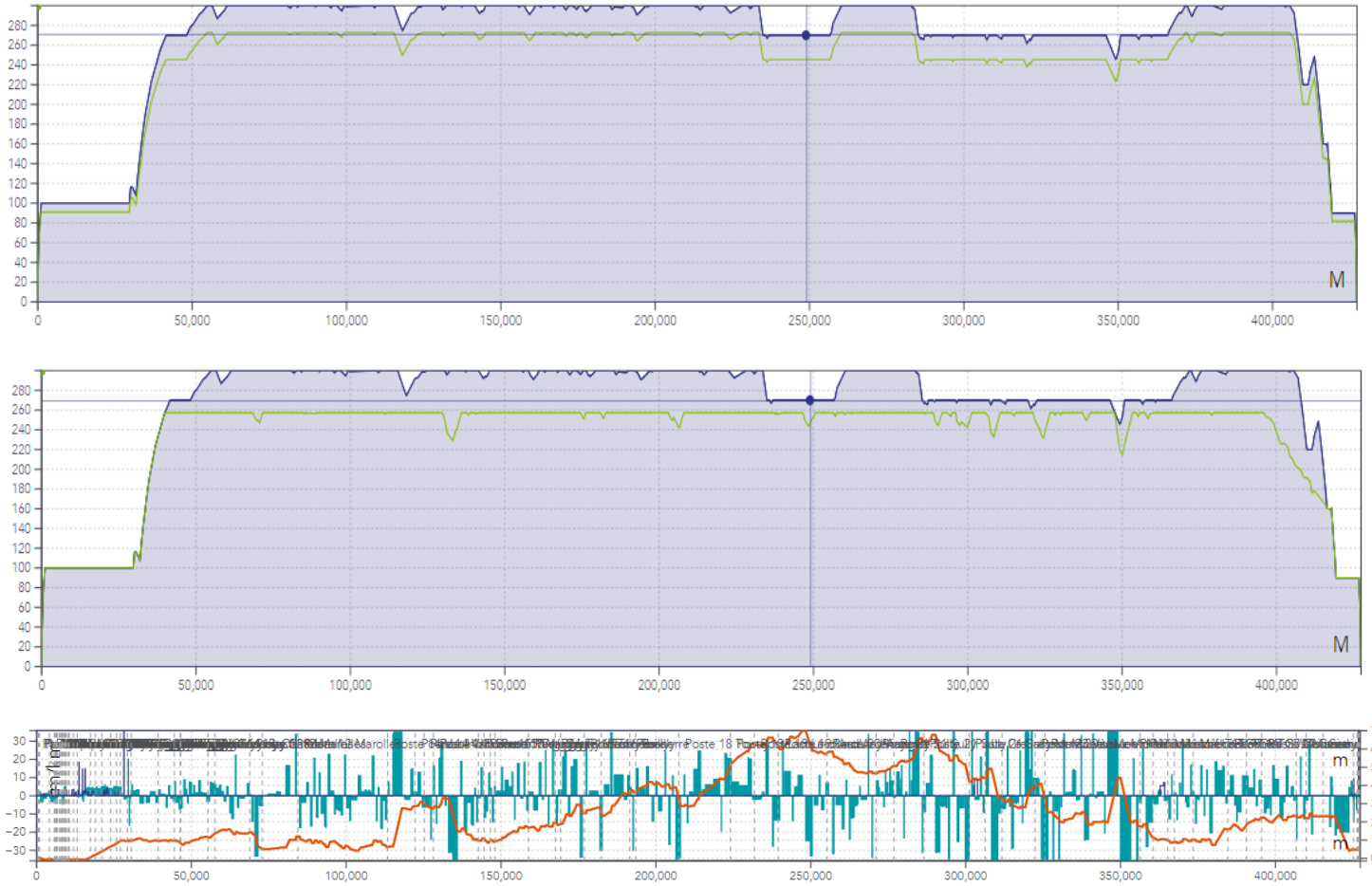



speed limit
fastest drive
MARECO margin
Speed
(km/h)
150
90
60
0
Distance
Departure
Stop
Destination
08:00:00
09:28:00
10:12:00

Paris – Lyon

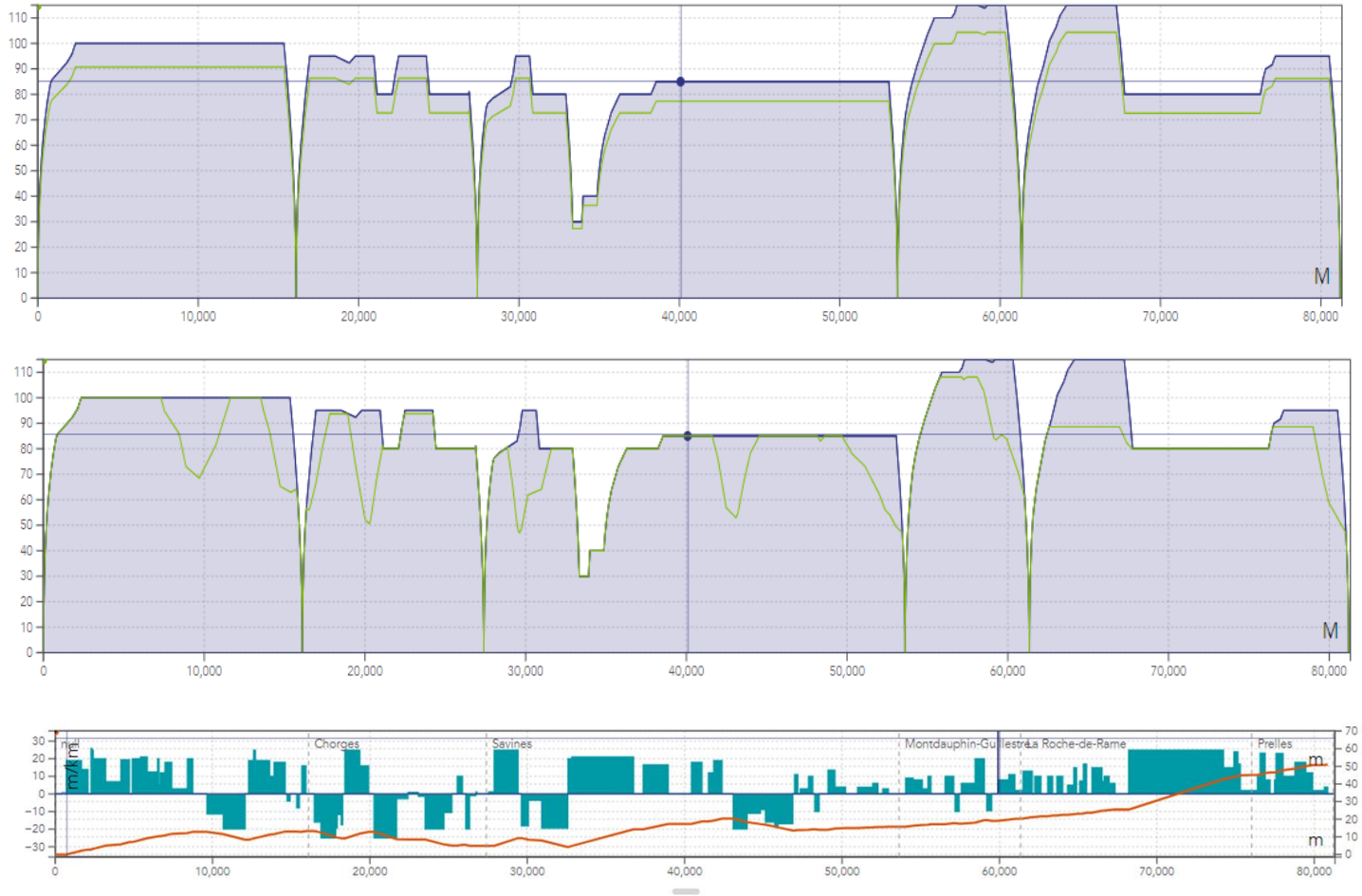
12%





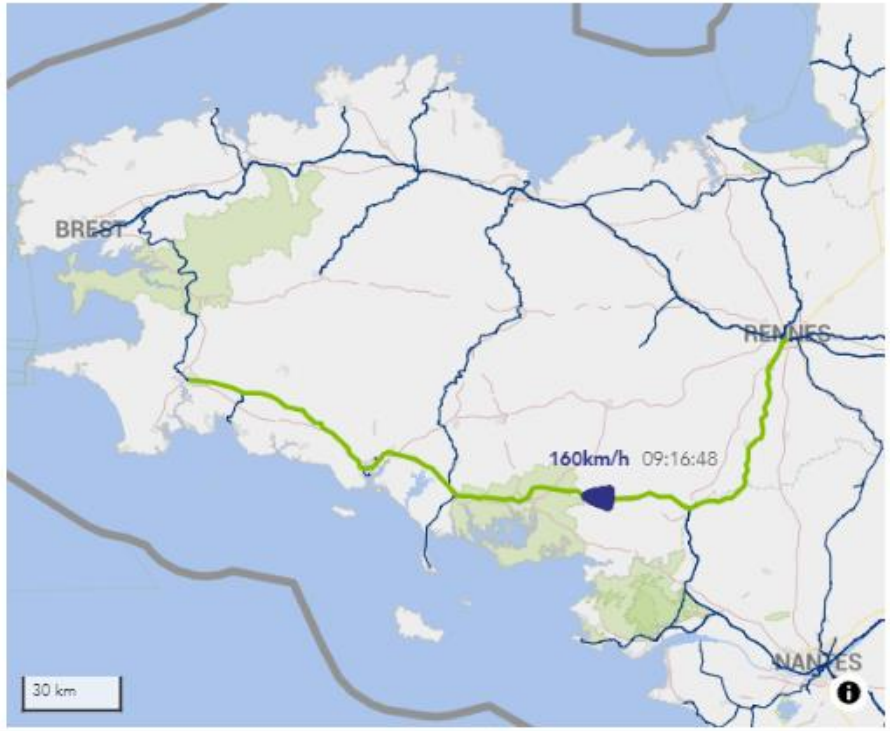
Gap - Briançon

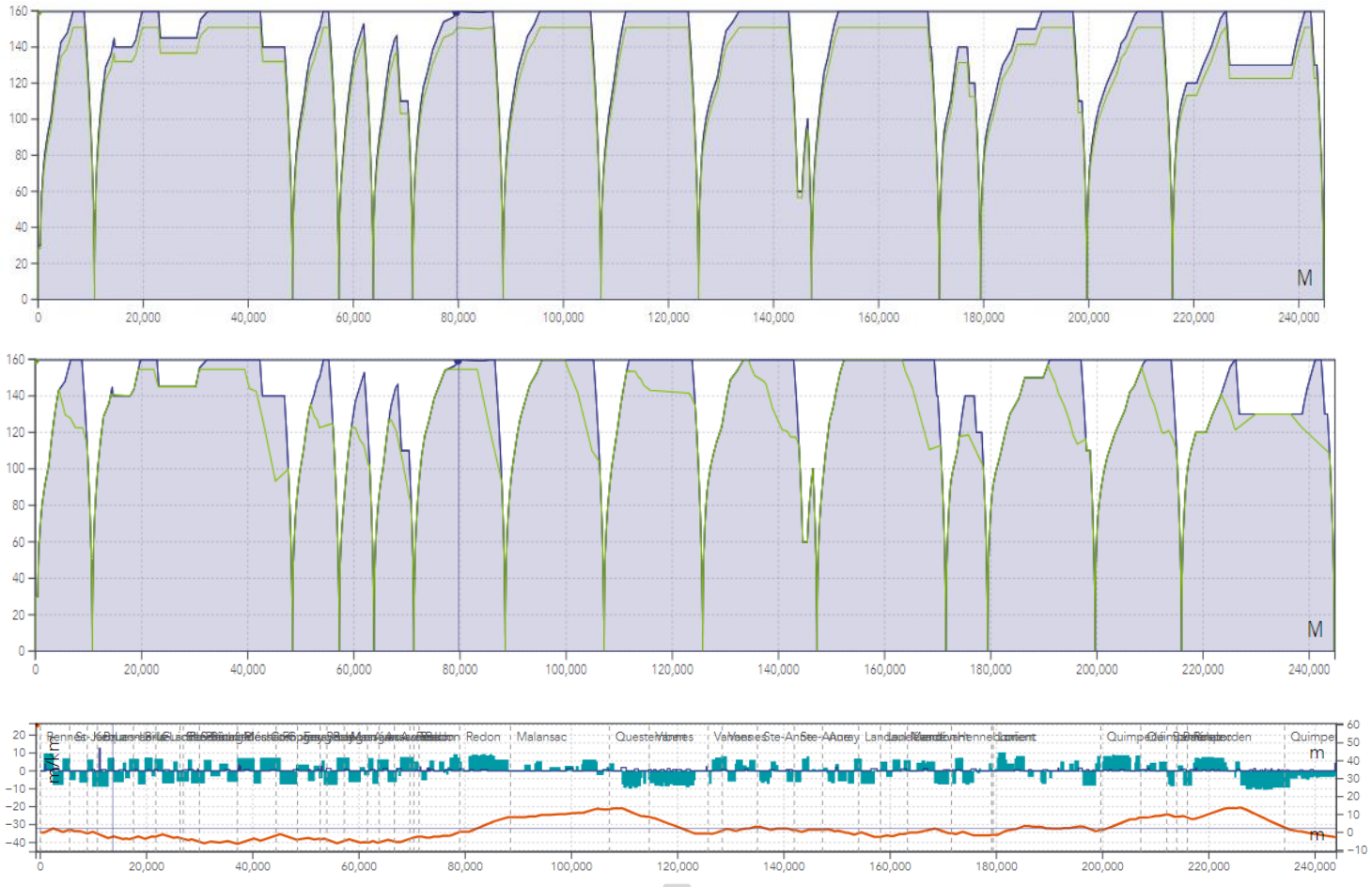
13%



Rennes – Quimper

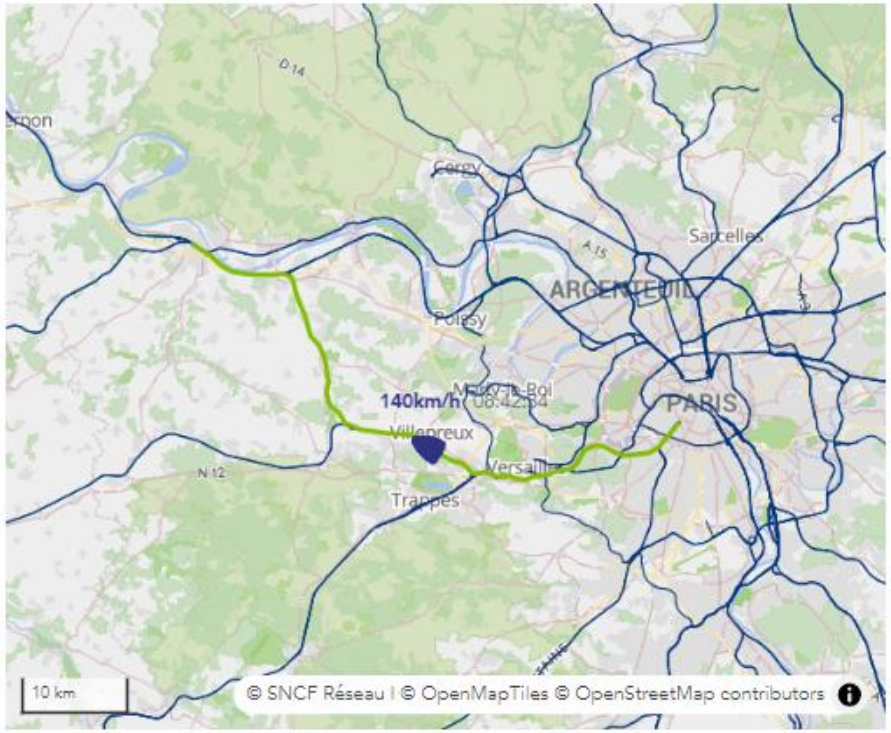
20%

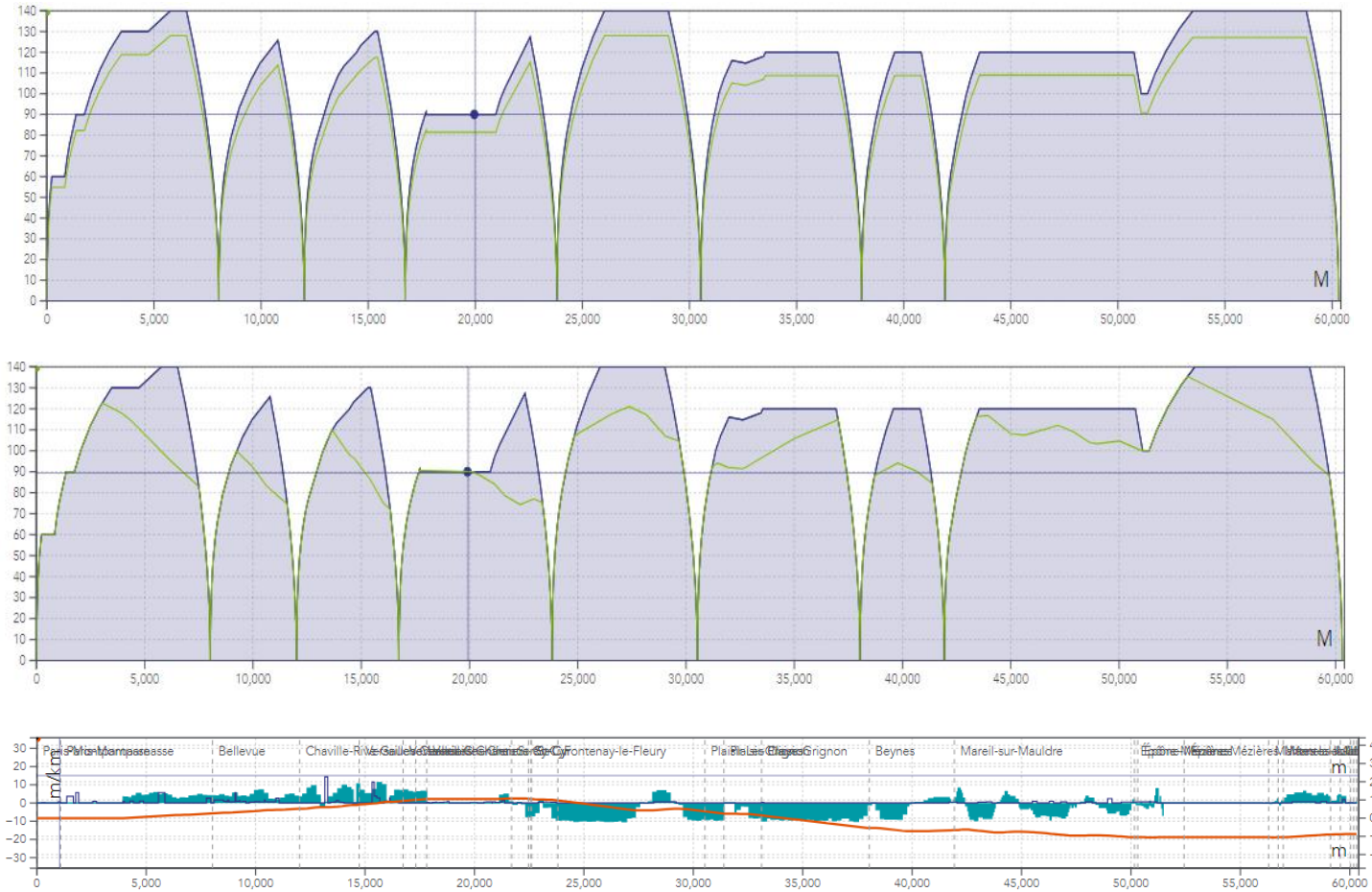




Paris – Mantes-la-Jolie

32% !!!





Impacts of MARECO in train planning and operation

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- - -

- Most of the margin ends up towards the braking phases
  - Needs to be used carefully for long distances
  - Can detorierate the headaway on some zones

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Impacts of MARECO in train planning and operation

- - -	+++

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Impacts of MARECO in train planning and operation

- - -	+++

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	- Coasting before braking on dense lines brings drivers to reach stations at lower speeds, hence adapt braking better

Thank you!

https://github.com/osrd-project/osrd

Exemples with energy consumption comparison

Trip	Linear vs Fastest	MARECO vs Fastest	MARECO vs Linear
Paris-Lyon (10% margin)	14%	24%	12%
Gap – Briancon (10% margin)	7%	19%	13%
Rennes – Brest (6% margin)	9%	27%	20%
Paris – Mantes-la-Jolie (10% margin)	16%	43%	32%