

TECHNICAL REFERENCE

Autonomous vehicles

– Part 1 : Basic behaviour



Published by

Enterprise
Singapore

TR 68 : Part 1 : 2019
(ICS 03.100.70; 43.020)

TECHNICAL REFERENCE

Autonomous vehicles

– Part 1 : Basic behaviour

All rights reserved. Unless otherwise specified, no part of this Technical Reference may be reproduced or utilised in any form or by any means, electronic or mechanical, including photocopying and microfilming, without permission in writing from Enterprise Singapore. Request for permission can be sent to: standards@enterprisesg.gov.sg.

ISBN 978-981-48-3558-9

This Technical Reference was approved on 8 January 2019 by the Manufacturing Standards Committee under the purview of the Singapore Standards Council.

First published, 2019

The Manufacturing Standards Committee, appointed by the Standards Council, consists of the following members:

	Name	Capacity
Chairman	: Dr John Yong	<i>Individual Capacity</i>
Deputy Chairman	: Mr Brandon Lee	<i>Individual Capacity</i>
Secretary	: Mr Kwok Wing Kit	<i>Singapore Manufacturing Federation – Standards Development Organisation</i>
Members	: Ms Fong Pin Fen	<i>Economic Development Board</i>
	Mr Goh Wee Hong	<i>TÜV SÜD PSB Pte Ltd</i>
	Mr Ho Chi Bao	<i>Enterprise Singapore</i>
	Mr Steven Koh	<i>Singapore Precision Engineering Technology Association</i>
	Ms Lee Wan Sie	<i>Info-communications Media Development Authority</i>
	Dr Jim Li Hui Hong	<i>Individual Capacity</i>
	Dr Lim Ee Meng	<i>A*STAR National Metrology Centre</i>
	Mr Loh Wai Mun	<i>A*STAR Science Engineering Research Council</i>
	Er. Prof Ramakrishan Seeram	<i>The Institution of Engineers, Singapore</i>

The Technical Committee on Automotive, appointed by the Manufacturing Standards Committee and responsible for the preparation of this standard, consists of representatives from the following organisations:

	Name	Capacity
Co-Chairmen	: Mr Lam Wee Shann	<i>Individual Capacity</i>
	Assoc Prof Marcelo H Ang Jr	<i>Individual Capacity</i>
Secretary	: Mr Kwok Wing Kit	<i>Singapore Manufacturing Federation – Standards Development Organisation</i>
Members	: Mr Chandrasekar s/o Palanisamy	<i>Land Transport Authority</i>
	Mr Alvin Chia	<i>Land Transport Authority</i>
	Dr Chin Kian Keong	<i>Land Transport Authority</i>
	Mr Niels de Boer	<i>Centre of Excellence for Testing & Research of AVs – NTU</i>
	Dr Jaya Shankar s/o Pathmasuntharam	<i>A*STAR Institute for Infocomm Research</i>
	Mr Lim Soon Chia	<i>Cyber Security Agency of Singapore</i>
	Mr Mahesh Tanwani	<i>Aptiv PLC</i>
	Mr Peter Quek	<i>Land Transport Authority</i>

Members : Mr Tan Nai Kwan *ST Engineering Land Systems Ltd*
Dr Vrizlynn Thing *A*STAR Institute for Infocomm Research*
Mr Daryl Yeo *Ministry of Transport*

The Working Group on Basic Behaviour, appointed by the Technical Committee to assist in the preparation of this standard, comprises the following experts who contribute in their *individual capacity*:

Name

Co-Convenors : Mr Chandrasekar s/o Palanisamy
SAC Gerald Lim

Secretary : Mr Kwok Wing Kit

Members : Mr Ken Chan
Mr Chua Eng Hock
Dr Henriette Cornet
Mr Niels de Boer
Mr Erwin de Gelder
Dr James Fu
Mr S Ganesan
Mr Charles Han
Ms Bernadette Lee
Dr Graham Leedham
Mr Charlie Lim
Mr Ng Kok Cheong
Dr Scott Pendleton
Dr Kostyantyn Slutskyy
Dr Song Zhi Wei
Ms Andrea Teo
Mr Tham Kwang Sheun
Mr Thomas Webster
Assoc Prof Wong Yiik Diew
DSP Zeya Lwin Tun

The organisations in which the experts of the Working Group are involved are:

3M Singapore
Aptiv PLC
Centre of Excellence for Testing & Research of AVs – NTU
Firemark Labs Singapore, Insurance Australia Group
HERE Technologies
Land Transport Authority
Nova Systems Pte Ltd
nuTonomy
Singapore Road Safety Council
Singapore Traffic Police
SingPilot Pte Ltd
ST Engineering Land Systems Ltd

*The Netherlands Organisation for Applied Scientific Research
Transport Research Centre @ NTU
TUMCREATE Ltd*

Contents

	Page
Foreword _____	6
0 Introduction _____	7
1 Scope _____	7
2 Normative references _____	8
3 Terms and definitions _____	8
4 Assumptions _____	10
5 Driving policy for AV behaviour _____	11
6 Safe distances _____	18
7 Manoeuvres _____	21
8 AV's conduct of driving task _____	26

Annexes

A List of applicable rules for AVs _____	28
--	----

Figures

1 Process flow of dynamic driving task _____	9
2 Filtering rules applicable to AV behaviour _____	12
3 Dynamic driving tasks (DDT) _____	13
4 Crossing a double white line in order to overtake an illegally parked car _____	15
5 Minimum lateral clearance for car to proceed to allow free movement of traffic _____	16
6 Car unable to proceed when the minimum lateral distance is not met _____	16
7 Refinement of rulebook and scenario database _____	17
8 Roundabouts _____	24

Foreword

This Technical Reference (TR) was prepared by the Working Group on Basic Behaviour appointed by the Technical Committee on Automotive under the direction of the Manufacturing Standards Committee.

TR 68 is intended to support the development of AV technology and deployments and consists of the following parts under the generic title “Autonomous vehicles”:

Part 1 – Basic behaviour

Sets out fundamental behaviours AVs should exhibit while driving on public roads in order to co-exist safely with entities on the roads such as other vehicles, cyclists, and pedestrians.

Part 2 – Safety

Sets out the safe design and continuing safety management process requirements, supported by competent personnel and organisational quality certifications that organisations should have in place so that the AVs driving on public roads are inherently safe and behave in the manner that they are designed to.

Part 3 – Cybersecurity principles and assessment framework

Sets out principles and assessment framework for organisations to support development and management of AVs. The assessment framework is intended to provide a cybersecurity safeguard for AVs to satisfy prior to on-road deployment.

Part 4 – Vehicular data types and formats

Sets out what data, resolution, capture frequency and the format in which they should be transmitted so that there is seamless communication between sending party and receiving party.

This TR is a provisional standard made available for application over a period of three years. The aim is to use the experience gained to update the TR so that it can be adopted as a Singapore Standard. Users of the TR are invited to provide feedback on its technical content, clarity and ease of use. Feedback can be submitted using the form provided in the TR. At the end of the three years, the TR will be reviewed, taking into account any feedback or other considerations, to further its development into a Singapore Standard if found suitable.

Acknowledgement is made to the following organisations for their kind permission to reproduce their materials into this TR:

- Singapore Police Force [Basic Theory of Driving (Tenth Edition) and Final Theory of Driving (Ninth Edition)];
- nuTonomy [Figure 7 of this TR].

Attention is drawn to the possibility that some of the elements of this Technical Reference may be the subject of patent rights. Enterprise Singapore shall not be held responsible for identifying any or all of such patent rights.

NOTE

1. *Singapore Standards (SSs) and Technical References (TRs) are reviewed periodically to keep abreast of technical changes, technological developments and industry practices. The changes are documented through the issue of either amendments or revisions.*
2. *An SS or TR is voluntary in nature except when it is made mandatory by a regulatory authority. It can also be cited in contracts making its application a business necessity. Users are advised to assess and determine whether the SS or TR is suitable for their intended use or purpose. If required, they should refer to the relevant professionals or experts for advice on the use of the document. Enterprise Singapore shall not be liable for any damages whether directly or indirectly suffered by anyone or any organisation as a result of the use of any SS or TR.*
3. *Compliance with a SS or TR does not exempt users from any legal obligations.*

Technical Reference for autonomous vehicles

Part 1: Basic behaviour

0 Introduction

This TR discusses basic driving behaviour for autonomous vehicles (AVs), where the AV is operated by a level 4/5 automated driving system (ADS) as defined in SAE J3016_2018.

AVs are one of the many types of vehicles that are on the roads today. For the purpose of this TR, it is assumed that the regulations in place at the time of its writing that apply to traffic rules have not been changed to accommodate AVs. Based on our current knowledge of how AVs are designed, Annex A of this TR seeks to list traffic rules published in the *Basic Theory of Driving* (Tenth Edition) and *Final Theory of Driving* (Ninth Edition) that may be applicable to AVs.

By listing the basic interactions anticipated in the context of Singapore's public roads, this TR gives provisions on an AV's longitudinal and lateral movements, as well as relevant vehicle controls so that it can co-exist with other road users harmoniously. As older AVs may have some technological limitations, Clause 5 gives provisions on the management of capability limitations.

The meanings of automation driving levels, automated driving system (ADS), operational design domain (ODD), dynamic driving task (DDT) are as defined in SAE J3016_2018.

This TR is applicable to the following:

- AV developers / operators;
- Suppliers and manufacturers;
- Government agencies / local authorities;
- Testing, inspection and certification bodies;
- Private service and data providers;
- Insurance companies.

1 Scope

This TR gives the provisions relating to the dynamic driving task (DDT) and behaviour controlled by an AV's automated driving system (ADS). The scope is as follows:

- a) Conduct of autonomous driving, including but not limited to vehicle-to-vehicle interactions;
- b) Interpretation of road signs, markings and traffic signals; and
- c) Management of non-transferable rules.

This TR covers the key directives, providing safety and maintaining traffic movement, for automated driving and provides a hierarchy of directives and rules to overcome potential conflicts between rules. It introduces a framework for the application of rules as part of a driving policy. The TR also discusses the current capability limitations of AVs and accounts for a continual process of improvement, which includes the refinement of the rulebook and scenario database.

The following are not covered in this TR and may be considered in future revisions:

- a) The interface between an AV and any occupants including the human safety driver;
- b) Rules relating to non-driving tasks and longer term tactical cognitive functions such as route planning; and
- c) Communication or signalling between the AV and external stakeholders including but not limited to pedestrians and other drivers, which extends beyond use of standard vehicle equipment, including lighting and horn, as described in existing driving rules.

There are substantial references to Singapore's *Basic Theory of Driving* (BTD) and *Final Theory of Driving* (FTD) throughout this TR. Where applicable the relevant items of the BTD/FTD are linked in brackets. For example "(BTD 1)" refers to item number 1 of the BTD.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BTD	<i>Basic Theory of Driving</i> (Tenth Edition), Singapore Traffic Police, 15 February 2018.
FTD	<i>Final Theory of Driving</i> (Ninth Edition), Singapore Traffic Police, 1 July 2017.
ECE/TRANS/WP.29/GRRF/85	Report of the working party on brakes and running gear on its eighty-fifth session
SAE J3016_2018	Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles