

## TECHNICAL REFERENCE Safe use of autonomous mobile robots (AMRs) in warehouses





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#### Foreword

This Technical Reference (TR) was prepared by the Working Group on the Safe Use of Autonomous Mobile Robots (AMRs) in Warehouses set up by the Technical Committee on Logistics under the purview of the Trade and Connectivity Standards Committee.

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 materials from their documents into this standard (refer to the footnotes in the standard):

- 1. A3 Association for Advancing Automation
  - ANSI/RIA R15.08-1 For industrial mobile robots Safety requirements Part 1: Requirements for the industrial mobile robot
- 2. International Organization for Standardization
  - ISO 3691-4:2020 Industrial trucks Safety requirements and verification Part 4: Driverless industrial trucks and their systems;
  - ISO 15638-17:2014 Intelligent transport systems Framework for cooperative telematics applications for regulated vehicles (TARV) – Part 17: Consignment and location monitoring;
  - ISO 12100:2010 Safety of machinery General principles for design Risk assessment and risk reduction

ISO standards can be purchased from Enterprise Singapore.

Acknowledgement is made for the use of information from the above publications.

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

#### NOTE

- 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. Where SSs are deemed to be stable, i.e. no foreseeable changes in them, they will be classified as "mature standards". Mature standards will not be subject to further review unless there are requests to review such standards.
- 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 and the Singapore Standards Council 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. Although care has been taken to draft this standard, users are also advised to ensure that they apply the information after due diligence.
- 3. Compliance with a SS or TR does not exempt users from any legal obligations.

## Safe use of autonomous mobile robots (AMRs) in warehouses

## 0 Introduction

Warehouse operators want a high degree of control over logistics as it is an extremely vital part of their business, both from a cost and a customer experience standpoint. With high labour costs and in the relentless pursuit for profit, logistics companies have begun to explore the use of varied technologies to improve productivity, e.g., by increasing the rate of product movement through warehouse, reducing picking errors, minimising walking time and developing labour cost reduction strategies through the adoption of AMRs.

AMRs have begun assisting the pickers, where both man and machine work together as a unit to complete their intended tasks. The dynamism and unstructured nature of warehouse environments are a result of the presence of varied AMRs which traverse the facility at high speeds across very-narrow-aisles. During peak seasons, the increase in contractual labour who are unfamiliar with the working environment pose challenges to the safe use of AMRs. Hence, it is important that AMRs need to be configured in a way such that they can respond in a safe and measured manner and react responsibly to safety hazards.

Some of the safety hazards associated with/to AMRs are, but not limited to, as follows:

- a) Colliding with humans/structures;
- b) Inability to identify broken/malfunctioned pallets;
- c) Toppling of goods due to instability when elevated to a certain height; and/or
- d) Fire (e.g., overheating, poor contact with charging point).

## 1 Scope

This TR defines the safety requirements relating to the elements of operation, navigation and control of powered AMRs and the system of which the vehicles are a part of, operating in a warehouse. Only the use in warehouses and the maintenance part of the system life cycle of an AMR is within the scope of this TR (see Figure 1). It also applies to mobile robots originally designed to operate exclusively in a manned mode, but which are subsequently modified to operate in an unmanned, automatic mode or in a semi-automatic mode, manual, or maintenance mode. This TR includes automated guided vehicles (AGV)s which have equipment or software added to or updated to convert their navigation capabilities from guided to autonomous.

The aspects of AMRs that impact the performance of AMRs not related to safety, such as mapping, remapping, including any physical preparation of the warehouse/operating area, are excluded from this standard. The robotics middle framework (RMF) is not covered in this TR as it is still under development. This TR covers only non-hazardous, non-dangerous goods in warehouses. The TR does not include operations in extreme temperatures.



Figure 1 – Scope of this TR

## 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.

ANSI B11.19	Performance requirements for risk reduction measures: Safeguarding and other means of reducing risk
ANSI/ITSDF B56.5	Safety standard for driverless, automatic guided industrial vehicles and automated functions of manned industrial vehicles
ANSI/RIA R15.08-1	For industrial mobile robots – Safety requirements – Part 1: Requirements for the industrial mobile robot
IEC 60204-1	Safety of machinery – Electrical equipment of machines – Part 1: General requirements
IEC 61496-1	Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests
IEC 61496-2	Safety of machinery – Electro-sensitive protective equipment – Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)
IEC 61496-3	Safety of machinery – Electro-sensitive protective equipment – Part 3: Particular requirements for active opto-electronic protective devices responsive to diffuse Reflection (AOPDDR)
IEC 61496-4-2	Safety of machinery – Electro-sensitive protective equipment – Part 4-2: Particular requirements for equipment using vision based protective devices (VBPD) – Additional requirements when using reference pattern techniques (VBPDPP)

IEC 61496-4-3	Safety of machinery – Electro-sensitive protective equipment – Part 4-3: Particular requirements for equipment using vision based protective devices (VBPD) – Additional requirements when using stereo vision techniques (VBPDST)
IEC 61980-1	Electric vehicle wireless power transfer (WPT) systems – Part 1: General requirements
IEC 62046	Safety of machinery – Application of protective equipment to detect the presence of persons
IEC 62311	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz $-$ 300 GHz)
IEC TS 62998-1	Safety of machinery – Safety-related sensors used for the protection of persons
IEC TR 62998-2	Safety of machinery – Part 2: Examples of application
ISO 13850	Safety of machinery – Emergency stop function – Principles for design
ISO 13855	Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body
ISO 13856-1	Safety of machinery – Pressure-sensitive protective devices – Part 1: General principles for design and testing of pressure-sensitive mats and pressure-sensitive floors
ISO 13856-2	Safety of machinery – Pressure-sensitive protective devices – Part 2: General principles for design and testing of pressure-sensitive edges and pressure-sensitive bars
ISO 13856-3	Safety of machinery – Pressure-sensitive protective devices – Part 3: General principles for design and testing of pressure-sensitive bumpers, plates, wires and similar devices
ISO 3691-4	Industrial trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems
NFPA 79	Electrical standard for industrial machinery
TR 25-1	Electric vehicles charging system – Part 1: Electrical safety and general requirements
TR 25-2	Electric vehicles charging system – Part 2: Low power charging
TR 25-3	Electric vehicles charging system – Part 3: High power charging
TR 25-4	Electric vehicles charging system – Part 4: Battery swapping