



IEC TR 63319

Edition 1.0 2025-06

TECHNICAL REPORT

Corrected version
2025-06

A meta-modelling analysis approach to smart manufacturing reference models



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2025 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search -

webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	10
INTRODUCTION.....	12
1 Scope.....	13
2 Normative references.....	13
3 Terms and definitions, abbreviated terms, acronyms and conventions.....	13
3.1 Terms and definitions.....	13
3.2 Convention used for term and definition selection.....	15
3.3 Abbreviations and acronyms.....	16
3.4 Conventions used for selected references.....	17
4 Smart manufacturing (SM).....	18
4.1 Introduction to and vision of SM.....	18
4.2 SM characteristics and differences from conventional manufacturing.....	18
4.3 Essential concepts and enabling technologies for SM.....	19
4.3.1 SM categories.....	19
4.3.2 Generic methods.....	19
4.3.3 Applications in the manufacturing domain.....	20
4.3.4 Information and communication technologies.....	20
5 Smart manufacturing reference model (SMRM).....	21
5.1 Need for a SMRM.....	21
5.2 Objectives in more detail.....	21
5.3 SMRM focus.....	22
5.4 Reference modelling.....	22
5.5 Usage of a reference model: the OSI model.....	22
5.6 SMRM harmonization needs.....	22
5.7 SMRM abstraction stack.....	23
6 SMRM meta-modelling approach.....	23
6.1 General.....	23
6.2 Objectives.....	24
6.3 Assumptions, constraints and guidance.....	24
6.3.1 Assumptions.....	24
6.3.2 Constraints.....	24
6.3.3 Guidance.....	24
6.4 Concepts.....	25
6.4.1 General.....	25
6.4.2 Concepts of the meta-model.....	25
6.4.3 Proposition of the meta-model for SMRM.....	27
6.5 Meta-model for SMRM visualization.....	29
6.6 <i>*Facet_composition_rules</i> and <i>*aspect_collection_coherence_rules</i>	29
6.7 Utilizing the meta-model concept of use case.....	30
6.7.1 General.....	30
6.7.2 <i>*Use_cases</i> for articulating concerns.....	31
6.7.3 <i>*Viewpoints</i> capture concerns and specify views.....	32
6.7.4 Examples of <i>*model_content_purpose</i>	33
7 Mapping of the contributions for SMRMs to the SMRM meta-model.....	34
7.1 General.....	34
7.2 Mapping for Scandinavian smart manufacturing model.....	35

7.2.1	Graphical depiction of SSIF mapping	35
7.2.2	SSIF <i>*facet_composition_rule</i>	35
7.2.3	Business dimension <i>*aspect_collection</i>	36
7.2.4	Product dimension <i>*aspect_collection</i>	36
7.2.5	Production dimension <i>*aspect_collection</i>	37
7.2.6	Space Time dimension (Life cycle) <i>*aspect_collection</i>	37
7.3	Mapping for RAMI 4.0.....	38
7.3.1	Graphical depiction of RAMI 4.0 mapping	38
7.3.2	RAMI 4.0 – <i>*facet_composition_rule</i>	40
7.3.3	Service oriented architecture as a universal technical approach	40
7.3.4	Layers <i>*aspect_collection_coherence_rule</i>	41
7.3.5	Hierarchy Levels <i>*aspect_collection_coherence_rule</i>	42
7.3.6	Life cycle <i>*aspect_collection_coherence_rule</i>	42
7.4	Mapping for IMSA	43
7.4.1	Graphical depiction of IMSA mapping	43
7.4.2	System Hierarchy <i>*aspect_collection_coherence_rule</i>	44
7.4.3	Life Cycle <i>*aspect_collection_coherence_rule</i>	45
7.4.4	Intelligent Function <i>*aspect_collection_coherence_rule</i>	45
7.5	Mapping for ISO 15704:2019, Annex B – GERAM	46
7.5.1	Graphical depiction of ISO 15704:2019, Annex B – GERAM.....	46
7.5.2	GERAM <i>*facet_composition_rules</i>	46
7.5.3	Life cycle phases <i>*aspect_collection_coherence_rule</i>	47
7.5.4	Modelling viewpoints <i>*aspect_collection_coherence_rule</i>	47
7.5.5	Instantiation <i>*aspect_collection_coherence_rule</i>	48
7.5.6	Manifestation <i>*aspect_collection_coherence_rule</i>	48
7.5.7	Purpose <i>*aspect_collection_coherence_rule</i>	48
7.5.8	Implementation <i>*aspect_collection_coherence_rule</i>	49
7.6	Mapping for NIST Smart Manufacturing Standards Landscape	50
7.6.1	Graphical depiction of NIST Smart Manufacturing Standards Landscape mapping.....	50
7.6.2	NIST <i>*facet_composition_rules</i>	50
7.6.3	Business life cycle <i>*aspect_collection_coherence_rule</i>	51
7.6.4	Product life cycle <i>*aspect_collection_coherence_rule</i>	52
7.6.5	Production life cycle <i>*aspect_collection_coherence_rule</i>	52
7.6.6	Manufacturing pyramid <i>*aspect_collection_coherence_rule</i>	53
7.7	Mapping for KSTEP cube framework.....	54
7.7.1	Graphical depiction of KSTEP cube framework mapping	54
7.7.2	Space axis 1 <i>*aspect_collection_coherence_rule</i>	54
7.7.3	Space axis 2 <i>*aspect_collection_coherence_rule</i>	54
7.7.4	Time axis t <i>*aspect_collection_coherence_rule</i>	54
7.8	Mapping for IVRA Next.....	55
7.8.1	Graphical depiction of IVRA Next mapping.....	55
7.8.2	Three axes of SM facet and SMU facet composition rules	55
7.8.3	Product axis (thing) <i>*aspect_collection_coherence_rule</i>	56
7.8.4	Service axis (occurrence) <i>*aspect_collection_coherence_rule</i>	56
7.8.5	Knowledge axis <i>*aspect_collection_coherence_rule</i>	56
7.8.6	Asset view <i>*aspect_collection_coherence_rule</i>	57
7.8.7	Management view <i>*aspect_collection_coherence_rule</i>	57
7.8.8	Activity view <i>*aspect_collection_coherence_rule</i>	58

7.9	Mapping for IIC Industrial Internet Reference Architecture.....	59
7.9.1	Graphical depiction of IIC IIRA mapping	59
7.10	Mapping for Smart Manufacturing Standards Map (SM2).....	60
7.10.1	Graphical depiction of Smart Manufacturing Standards Map (SM2).....	60
7.10.2	SM2 <i>*facet_composition_rules</i>	62
7.11	Mapping for URM-MM	62
7.11.1	Graphical depiction of URM-MM	62
7.11.2	URM-MM <i>*facet_composition_rules</i>	63
7.11.3	Model/Organization <i>*aspect_collection_coherence_rule</i>	63
7.11.4	URM-MM <i>*aspect_collection_coherence_rule</i>	64
8	Analysis of particular collections of aspects.....	64
8.1	Identification of a set of common <i>*aspects_collections</i>	64
8.2	Life cycle	65
8.2.1	General	65
8.2.2	Overview on contributions for SMRMs	65
8.2.3	Particularities of contributions for SMRMs with respect to life cycle	67
8.2.4	Fundamental questions concerning life cycle aspects of a SMRM.....	70
8.2.5	Observed consequences to the life cycle questions.....	70
8.2.6	Outlook.....	72
8.3	Hierarchy	72
8.3.1	General	72
8.3.2	Overview on contributions for SMRMs with respect to hierarchy	72
8.3.3	Particularities of contributions for SMRMs with respect to hierarchy	73
8.3.4	Fundamental questions concerning hierarchy aspects of a SMRM.....	78
8.3.5	Observed consequences to the hierarchy questions.....	78
8.3.6	Outlook.....	79
8.4	Layer	79
8.4.1	General	79
8.4.2	Overview on contributions for SMRMs	80
8.4.3	Particularities of contributions for SMRMs with respect to layer	81
8.4.4	Fundamental questions concerning layer aspects of a SMRM.....	82
8.4.5	Observed consequences to the layer questions	82
8.4.6	Outlook.....	83
8.5	Additional aspects.....	85
8.5.1	General	85
8.5.2	Fundamental questions concerning additional <i>*aspect_collections</i> of a SMRM	85
8.5.3	Observed consequences to the additional <i>*aspect_collections</i> questions.....	85
9	Toward a family of SMRM representations	88
9.1	Expectations for a unifying SMRM	88
9.2	Identification of generic (timeless) principles for SMRM.....	89
9.3	Structurally addressing the missing smart technologies.....	90
9.4	Observations from mapping and analysis.....	91
9.5	Candidate <i>*aspect_collection_coherence_rules</i> and <i>*facet_composition_rules</i>	92
9.6	The family of SMRM representations	93
9.7	The case for <i>*use_case</i>	94
9.8	Approaching creation of the SMRM.....	95
Annex A	(informative) Objectives and terms of reference for JWG 21	97

A.1	Objectives.....	97
A.2	Terms of reference.....	97
Annex B (informative) Contributions for SMRMs		98
B.1	RAMI	98
B.1.1	General	98
B.1.2	Layer axis.....	99
B.1.3	Life cycle axis in RAMI 4.0	101
B.2	IMSA	105
B.2.1	Intelligent manufacturing system framework.....	105
B.2.2	Life cycle	105
B.2.3	System hierarchy	106
B.2.4	Intelligence characteristics	106
B.2.5	Structural diagram of intelligent manufacturing standard system	107
B.3	GERAM	109
B.3.1	Rationale for enterprise-reference architecture and methodologies.....	109
B.3.2	Generalized enterprise-reference architecture and methodologies.....	109
B.3.3	Framework for enterprise architecture and enterprise integration	111
B.4	NIST Smart Manufacturing EcoSystem and Standards Landscape.....	115
B.5	KSTEP cube framework for standards.....	117
B.5.1	Skeleton meta-model	117
B.5.2	KSTEP cube framework	119
B.6	IVRA Next.....	121
B.6.1	General	121
B.6.2	Overview	121
B.6.3	Evolutional Model in Manufacturing	125
B.7	ISO/TC 184 Automation systems and integration – the Big Picture of standards (ISO TR 23087:2018 [40])	130
B.7.1	History.....	130
B.7.2	Purpose.....	131
B.7.3	Summary of axis and facets of the ISO/TC 184 Big picture of standards diagram and matrix	133
B.8	AIF framework and reference model for SM Standard Landscape (France)	134
B.8.1	History.....	134
B.8.2	Purpose.....	134
B.8.3	Summary of facets and blocks of the AIF RM for SM Standard Landscape.....	136
B.9	ISO-IEC Smart Manufacturing Standards Landscape (SM2)	138
B.9.1	History.....	138
B.9.2	Terms of reference.....	139
B.9.3	SM2 framework.....	139
B.9.4	SM2 vocabulary	142
B.10	URM-MM	144
B.10.1	Background	144
B.10.2	Overview	144
B.10.3	Usage.....	145
B.10.4	Practical use-case.....	145
B.10.5	Illustration of Relevant International Standards Mapping	149
B.11	Scandinavian model	151
B.11.1	Scandinavian Semantic Model Design Principles	151

B.11.2	Domain Semantic Model exemplified by Product Dimension	153
B.12	UK Model	155
Annex C (informative)	Definition of smart manufacturing, and interpretations	157
Annex D (informative)	Concepts of Meta-modelling	158
Bibliography	160
Figure 1	– Example of transition from centralized to distributed system paradigm	18
Figure 2	– SMRM abstraction stack	23
Figure 3	– Meta-model for SMRM	29
Figure 4	– Segments of the SMRM meta-model	31
Figure 5	– Relation between typical concerns and use-cases on SM	32
Figure 6	– Example of an implementation model for <i>*use-case #1</i>	32
Figure 7	– Illustration about relation between a SMRM and a <i>*stakeholder</i>	33
Figure 8	– Mapping for Scandinavian smart manufacturing model	35
Figure 9	– Mapping for RAMI 4.0	38
Figure 10	– Mapping for IMSA	44
Figure 11	– Mapping for ISO 15704:2019 – GERAM Annex	46
Figure 12	– Mapping for NIST Smart Manufacturing Standards Landscape	50
Figure 13	– NIST SMS Ecosystem – Integrated Smart Manufacturing	51
Figure 14	– Mapping for KSTEP cube framework	54
Figure 15	– IVRA Next: Mapping to Three Axes of SM and SMU	55
Figure 16	– Mapping for IIC IIRA	59
Figure 17	– System representation # 1	61
Figure 18	– System representation # 2	62
Figure 19	– Mapping for URM-MM	63
Figure 20	– The validity of individual exemplary life cycles on elements over time	65
Figure 21	– Graphical overview on different contributions for SMRMs	66
Figure 22	– Graphical overview on different contributions for SMRMs with respect to Hierarchy	73
Figure 23	– Graphical overview on different contributions for SMRMs	81
Figure 24	– N^2 <i>*aspect_collection</i> of semantic coherence	93
Figure 25	– Basic structure for a family of SMRM with alternative 3D representations	94
Figure 26	– Basic structural representation for several of the contributions – SSIF, RAMI 4.0, IMSA, and IVRA Next	94
Figure B.1	– The viewpoint of the RAMI 4.0 model	98
Figure B.2	– Linking of life cycles	103
Figure B.3	– Factory reference architecture model as of IEC 62264-1 and IEC 61512-1, with Industrie 4.0 enhancements	104
Figure B.4	– Intelligent Manufacturing System Framework	105
Figure B.5	– Structural diagram of intelligent manufacturing standard system	107
Figure B.6	– Mapping between IMSA and standard system structure	108
Figure B.7	– GERAM-ISO (Generalized Enterprise Reference Architecture and Methodology – ISO) framework components	112
Figure B.8	– GERA Modelling Framework representation with Modelling Views	113
Figure B.9	– Smart Manufacturing Ecosystem	116

Figure B.10 – Smart Manufacturing Standards Landscape	117
Figure B.11 – Skeleton of the NIST framework	118
Figure B.12 – Skeleton of the RAMI 4.0 framework and the KSTEP framework.....	118
Figure B.13 – Three axes of the KSTEP cube framework	119
Figure B.14 – KSTEP cube framework.....	120
Figure B.15 – Digital twin of the KSTEP cube framework	121
Figure B.16 – Three layers of manufacturing	123
Figure B.17 – Three axes of SM.....	124
Figure B.18 – Four cycles of SM	125
Figure B.19 – EROR cycle for evolution.....	126
Figure B.20 – Icons of scenario defining elements	128
Figure B.21 – Cyber and physical connection	129
Figure B.22 – Cross border management by PLU	130
Figure B.23 – Example of a Big Picture matrix.....	132
Figure B.24 – Graph-Nodes filtered building	132
Figure B.25 – Tree map sector barrier.....	133
Figure B.26 – Example: business, operate and ship.....	133
Figure B.27 – Standards landscape.....	135
Figure B.28 – Principles of the AIF framework for the SM standards landscape	136
Figure B.29 – Relation between standards map projects.....	139
Figure B.30 – Example mapping of product catalogue data standards	140
Figure B.31 – Example mapping structure for production system standards.....	141
Figure B.32 – Unified Reference Model – Map and Methodology (URM-MM)	144
Figure B.33 – Diagram of Canvas on an example of a production system having dynamic optimization	146
Figure B.34 – Diagram of Use-case on an example of a production system having dynamic optimization	146
Figure B.35 – Diagram of Function on an example of a production system having dynamic optimization	147
Figure B.36 – Diagram of Data (1 of 2) on an example of a production system having dynamic optimization	148
Figure B.37 – Diagram of Data (2 of 2) on an example of a production system having dynamic optimization	149
Figure B.38 – Example of Mapping of Relevant International Standards at "Canvas"	150
Figure B.39 – Example of Mapping of Relevant International Standards at "Data".....	151
Figure B.40 – Scandinavian Smart Industry Framework Semantic Cube	152
Figure B.41 – Basic principles for the Semantic Space	152
Figure B.42 – Domain Semantic Model exemplified by Product Dimension	153
Figure B.43 – Separation of model content and Presentation	154
Figure B.44 – Semantic model Architecture	155
Figure B.45 – Dependencies between different aspects in Smart Products Through-Life.....	156
Figure D.1 – Meta-abstraction stack.....	158
Table 1 – SSIF business dimension <i>*Aspect</i> and <i>*Viewpoint</i> according to <i>*Perspective</i>	36
Table 2 – SSIF product dimension <i>*Aspect</i> and <i>*Viewpoint</i> according to <i>*Perspective</i>	36

Table 3 – SSIF production dimension <i>*Aspect</i> and <i>*Viewpoint</i> according to <i>*Perspective</i>	37
Table 4 – SSIF Space Time dimension <i>*Aspect</i> and <i>*Viewpoint</i> according to the <i>*Perspective</i>	37
Table 5 – RAMI 4.0 <i>*aspect_collections</i> and bifurcations	39
Table 6 – <i>*Aspect</i> and <i>*Viewpoint</i> for RAMI 4.0 Layers	41
Table 7 – <i>*Aspect</i> and <i>*Viewpoint</i> for RAMI 4.0 Hierarchy Levels	42
Table 8 – <i>*Aspect</i> and <i>*Viewpoint</i> for the RAMI 4.0 Life cycle	43
Table 9 – <i>*Aspect</i> and <i>*Viewpoint</i> for the IMSA System Hierarchy	44
Table 10 – <i>*Aspect</i> and <i>*Viewpoint</i> for IMSA Life Cycle	45
Table 11 – <i>*Aspects</i> possible values and explanation for the IMSA Intelligent Functions	45
Table 12 – <i>*Aspects</i> and <i>*viewpoints</i> for GERAM life cycle	47
Table 13 – <i>*Aspects</i> and <i>*viewpoints</i> for GERAM modelling viewpoints	48
Table 14 – <i>*Aspects</i> and <i>*viewpoints</i> of GERAM Instantiation <i>*aspect_collection</i>	48
Table 15 – Representation of the physical manifestation of the enterprise-entity	48
Table 16 – Representation of the model contents according to the purpose of the enterprise entity	49
Table 17 – Representation of the implementation of the enterprise-entity	49
Table 18 – <i>*Aspects</i> for the Business life cycle	52
Table 19 – <i>*Aspects of the product life cycle</i>	52
Table 20 – <i>*Aspects of the production life cycle</i>	52
Table 21 – <i>*Aspects of the Manufacturing Pyramid</i>	53
Table 22 – Product axis (thing) <i>*aspects</i> and <i>*viewpoints</i>	56
Table 23 – Service axis (occurrence) <i>*aspects</i> and <i>*viewpoints</i>	56
Table 24 – Knowledge axis <i>*aspects</i> and <i>*viewpoints</i>	56
Table 25 – Asset view <i>*aspects</i> and <i>*viewpoints</i>	57
Table 26 – Management view <i>*aspects</i> and <i>*viewpoints</i>	57
Table 27 – Activity view <i>*aspects</i> and <i>*viewpoints</i>	58
Table 28 – Correspondence between SM2 concepts and SMRM meta-model concepts	60
Table 29 – Examples of representations	60
Table 30 – Mapping for System representation # 1	61
Table 31 – Mapping for System representation # 2	62
Table 32 – <i>*Aspect</i> and <i>*Viewpoint</i> for Model/Organization in URM-MM	63
Table 33 – <i>*Aspect</i> and <i>*Viewpoint</i> for the horizontal column in URM-MM	64
Table 34 – Particularities on life cycle on different contributors' perspective	67
Table 35 – IMSA Hierarchy levels	74
Table 36 – RAMI 4.0 Hierarchy related functionalities	74
Table 37 – IVRA Hierarchical levels	75
Table 38 – Big Picture Hierarchical levels	76
Table 39 – Standards Landscape Hierarchical levels	77
Table 40 – Particularities on layer on different contributors' models	82
Table 41 – Aspects along the dimension of layers/Intelligent functions	83
Table 42 – Grouping (and sub-grouping) of additional aspects	86
Table 43 – Proposed assignment of the additional <i>*aspect_collections</i> groups	87

Table B.1 – RAMI 4.0 Layers99

Table B.2 – RAMI 4.0 generalized life cycle phases 102

Table B.3 – RAMI 4.0 Hierarchy Levels 104

Table B.4 – Block "Identification"..... 136

Table B.5 – Block "Object of standard" 137

Table B.6 – Block "Hierarchy" 137

Table B.7 – Block "Life cycle"..... 137

Table B.8 – Block "Relevance" 138

Table B.9 – Block "Interoperability" 138

Table B.10 – Block "Priority" 138

Table B.11 – Block "Validation" 138

Table B.12 – Relevant blocks, sub-blocks and characteristics of SM2 142

INTERNATIONAL ELECTROTECHNICAL COMMISSION

A META-MODELLING ANALYSIS APPROACH TO SMART MANUFACTURING REFERENCE MODELS

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a Technical Report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 63319 has been prepared by IEC technical committee 65: Industrial-process measurement, control and automation in cooperation with ISO technical committee 184: Automation systems and integration. It is a Technical Report.

It is published as a dual logo standard.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
65/812/DTR	65/846/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

In this document, meta-model concepts are described in Clause 6 and are identified as **italic*, that is, starting with an asterisk followed by the concept name in italic.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

This corrected version of IEC TR 63319:2025 incorporates the following correction:

- update to points 1 to 9 of the foreword.

INTRODUCTION

The term "manufacturing" refers to a range of human activities, from handicraft to high tech, and is commonly applied to industrial production, in which raw materials and parts are transformed into products on small to large scale by a series of interconnected processes. In today's manufacturing landscape, manufacturing is no longer characterized as a set of serial processes, but instead as a highly complex set of processes interacting on different time scales, coordinated by a set of supervisory processes to dynamically respond to changing conditions in demands, supply, environment, energy, and other human caused or natural disruptive events.

The purpose of smart manufacturing is to accommodate those disruptive events, while supporting the introduction of new technologies and methods in a coordinated manner across a varied set of customers, suppliers and stakeholders at various stages in the value chain.

Both the IEC SMB and ISO TMB recognized the changing dynamics of manufacturing and the potential opportunities and benefits of developing a reference model for smart manufacturing for both the developers and the users of standards.

The objective of Smart Manufacturing Reference Model(s) (SMRMs) is the development of one or more than one unifying reference model of smart manufacturing to harmonize existing reference models for smart manufacturing. Objective details are described in Annex A.

The plan is to deliver the following outputs:

- 1) TR (Technical Report) A meta-modelling analysis approach to smart manufacturing reference models (this document);
- 2) IS (International Standard) Unified reference model for smart manufacturing (URMSM). (IEC 63339:2024, "*Unified reference model for smart manufacturing*" was developed concurrently; it was published on 2024-10-10).

A META-MODELLING ANALYSIS APPROACH TO SMART MANUFACTURING REFERENCE MODELS

1 Scope

This document uses a meta-modelling approach to identify commonalities among ten smart manufacturing reference models. Each reference model is placed into the context of the meta-model to facilitate analysis of both common and distinct features. Major smart manufacturing reference model topics are identified, and the reference models compared within each topic.

As part of the meta-modelling approach development, a collection of models differing in extent of abstraction characterizes the evolution of a particular smart manufacturing system from the meta-model through a unifying smart manufacturing reference model and successively less abstract domain models to a model for system implementation.

This document presents a range of issues and challenges for further work to specify a high-level smart manufacturing reference model that unifies the concepts and practices identified using the meta-model approach analysis of the smart manufacturing reference models.

2 Normative references

There are no normative references in this document.