SPECIFICATION

Workstation Worker Matching Data

Version 1-0

2023-12-11

Submodel Template of the Asset Adminstration Shell

Imprint

Publisher

Steinbeis Innovation gGmbH
Adornostr. 8
70599 Stuttgart
Germany

Source for Specification Document

Plattform Industrie 4.0
Bertolt-Brecht-Platz 3
10117 Berlin
Germany

Version history

2023-12-11	Version 1-0	Release of the Submodel template

Authors

Ronald Hall, Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA)
Sebastian Häberer, Fraunhofer-Institut für Fabrikbetrieb und -automatisierung IFF
Bernd Höpfner, INFORM GmbH
Karsten Jänsch, Datalyze Solutions GmbH
Ronald Orth, Fraunhofer-Institut für Produktionsanlagen und Konstruktionstechnik (IPK)
Rico Schady, FoP Consult GmbH (Method Consultant, Use Case Provider)
Georg Schnauffer, ARENA 2036 e.V.

Contents

Figures

Tables

1 General

1.1 About this document

This document is a part of a specification series. Each part specifies the contents of a Submodel template for the Asset Administration Shell (AAS). The AAS is described in [1], [2], [3] and [6]. First exemplary Submodel contents were described in [4], while the actual format of this document was derived by the "Administration Shell in Practice" [5]. The format aims to be very concise, giving only minimal necessary information for applying a Submodel template, while leaving deeper descriptions and specification of concepts, structures and mapping to the respective documents [1] to [6].

The target group of the specification are developers and editors of technical documentation and manufacturer information, which are describing assets in smart manufacturing by means of the Asset Administration Shell (AAS) and therefore need to create a Submodel instance with a hierarchy of SubmodelElements. This document especially details on the question, which SubmodelElements with which semantic identification shall be used for this purpose.

1.2 Motivation and Scope of the Submodel

The focus of the Submodel “Workstation Worker Matching Planning” is on the employee scheduling and operational deployment of employees who carry out manual activities in production. The activities performed can include, for example, the processing of products, their assembly, the operation of machines and systems, as well as their loading and set-up, transportation, quality inspections, maintenance, servicing and much more. With the high level of automation and increasing digitalization and autonomation of production the requirements for the planning and management of employees are changing. In future, employees will have to be deployed in a more situational and targeted manner according to their qualifications and skills. The fixed assignment of an employee to a workstation for an entire shift, in which the employee covers all the skills potentially required at the workstation, will no longer be the norm.

In an Industry 4.0 production environment, different requirements are placed on employee scheduling than in a traditional production system, in which employees are manually assigned, usually by the group leader. In Industry 4.0 production, employees and the (autonomous) automation system will have to work together synergistically and employees with the appropriate qualifications or skills will have to be scheduled and managed according to the situation. When qualified personnel resources are scarce, the optimal allocation of qualifications and skills is particularly important.

The current approach of employee scheduling (shift planning) and operative employee deployment by the group leader will reach its limits in future Industry 4.0 production. The classic qualification matrix for planning the necessary qualifications and skills will also no longer be sufficient. The manual creation and maintenance of the matrix will get at its limits and is not interoperable.

The "Workstation Worker Matching Data" Submodel is used to map the general-, ad hoc- and order-dependent demand of a workstation for qualifications and skills. In addition, further information will be provided by the Submodel that are relevant for operative worker deployment and employee scheduling.

With this Submodel the **demand of qualifications and skills** of a production workstation has been modeled. Together with a potential future Submodel specification for employees that covers also the **supply of qualifications and skills** an automated matching between workstations and workers and thereby an automated employee scheduling and deployment can be realized.

1.3 Relevant standards

One important standard for competence management that is also relevant in production is ISO 27001:2022 clause 7.2 competence. To meet the requirements of this clause in production companies often a competence matrix is implemented.

Further standards (classifications) are of special interest for the Submodel:

- ESCO (European Skills, Competences, Qualifications and Occupations)
- O*NET OnLine (to ESCO comparable classification for US)
- European Qualification Framework (EQF) with its levels
- IEC 62264-1:2013 - Enterprise-control system integration, Part 1: Models and terminology

As public classification of skills in the Submodel the ESCO classification can be used. The latest ESCO dataset has the version v1.1.1. The classification can be found at the ESCO-website: https://esco.ec.europa.eu/en.
The classification ID (URI) is http://data.europa.eu/esco/skill/335228d2-297d-4e0e-a6ee-bc6a8dc110d9. An example of an ESCO class can be found in the appendix A.

As public classification for competence (skill) levels of the European Qualification Framework (EQF) can be referred to. The description of the eight EQF levels can be found at the europass-Website: https://europa.eu/europass/en/description-eight-eqf-levels and within this document in the appendix A.

Some relevant publications for this Submodel template specification can be found in the Bibliography under [7], [8] und [9].

2 Approach of the Submodel

2.1 Use cases and requirements

The use cases of this Submodel template are employee (worker) scheduling and deployment in production for workstations as defined as “work unit” in IEC 62264-1. However, the Submodel can be applied to other kind of workplaces as for example mobile workplaces as well.

Following main requirements arise out of these use cases:

- Mapping of a time-based target profile (demand) of qualifications and skills for a workstation. In combination with a Submodel for the supply side (qualification and skills for employees), this should enable automated employee scheduling and deployment in the future.
- Digitalization of the qualification matrix as used to fulfill the requirements of ISO 27001:2022 for example.
- Creation of a prerequisite for realistic detailed production planning and control (APS), taking into account the "qualifications and skills" bottleneck.
- Creation of the prerequisites for real-time employee deployment in an Industry 4.0 production system and leveraging of optimization potentials, like best fit of the deployed competence levels, avoidance of workstation changes and long walking times or consideration of preferences of workers.
- Insights on mid- and long term qualification and skill demand based on data analytics in order to understand the future demand structure and plan appropriate qualification and training measures.

With this Submodel, the demand side for qualifications and skills of a workstation is mapped. In Figure 1, the Submodel is exemplarily integrated into an overall IT infrastructure of a production company with an ERP (order management and production planning), APS (advanced planning and scheduling systems) and MES (manufacturing execution system) or a shift planning system.

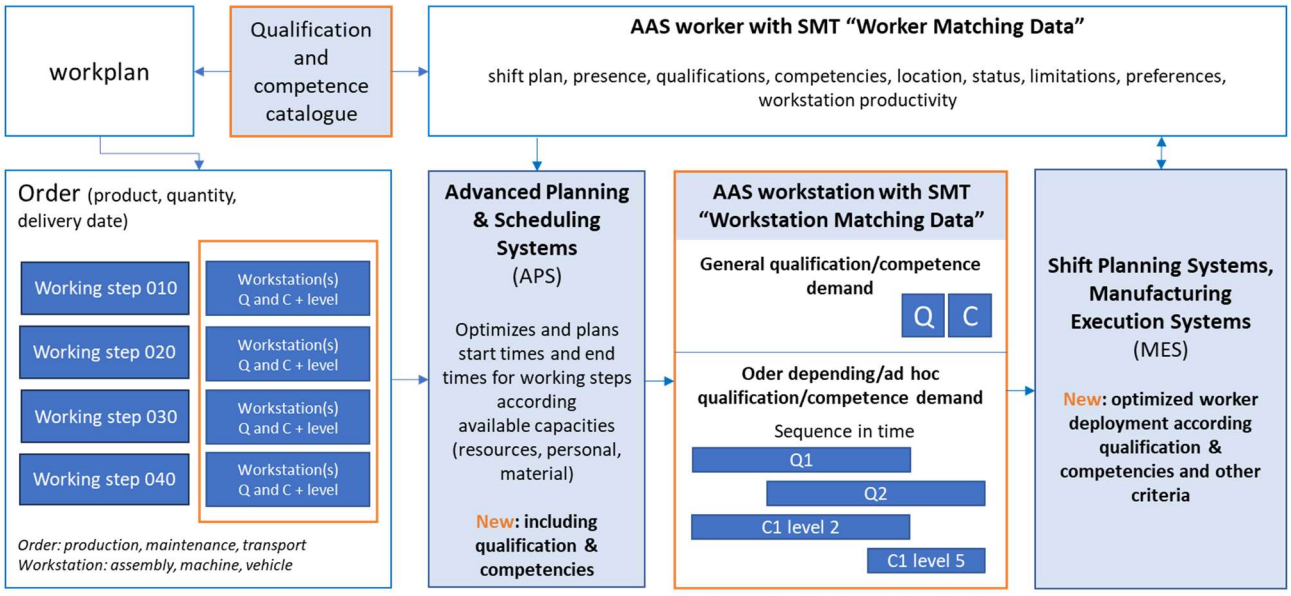

Figure 1: Potential implementation of an AAS with Submodel “Workstation Matching Data”

Based on a qualification and competence catalogue the ERP/MES will add information about the qualification and competence as information to the single working steps of a work plan. The APS is generating the time-based demand structure under consideration of the supply information that can be

obtained from the AAS of the workers. The MES/shift planning system is performing the operative deployment and controlling of the workers.

Within the Submodel three kinds of scheduled (planned) demands on qualification and skills are differentiated:

- general: Demand that is required when working at the workstation in general
- ad-hoc: Demand that arises sporadically based on certain events, like an unplanned repair task that has to be scheduled at a workstation
- orderDependending: Demand that is generated due to a specific production order (ordinary production order, maintenance order, transportation order, etc.). For example, a certain product has a workplan that requires a specific qualification to perform a work step. This qualification would have to be scheduled together with the general qualification demand and potential ad-hoc demand for the workstation.

2.2 Structure and design decisions

The structure of the Submodel “WorkstationWorkerMatchingData” is shown in Figure 2. The Submodel has been divided into the two SubmodelElementCollections “GeneralWorkstationData”, “ErgonomicWorkstationProfile” and the three SubmodelElementLists “WorkstationConfigurationRecords”, “PlannedQualificationDemand” and “PlannedSkillDemand”.

The SubmodelElementCollection “GeneralWorkstationData” contains the SubmodelElementCollection “WorkstationInformation” that could be moved to a future separate SMT for workstations where all general workstation information is embraced. All other SubmodelElements are related to the use cases as described in section 2.1.

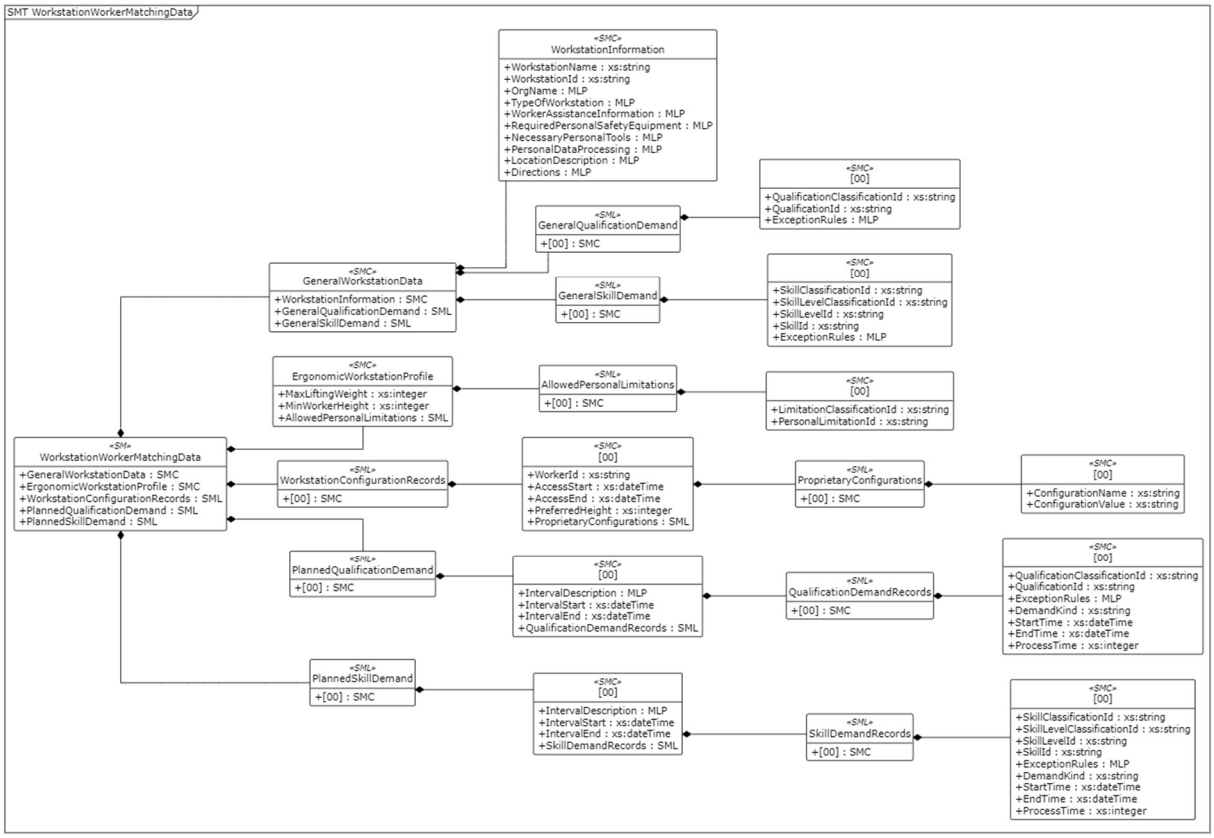

Figure 2: Information structuring of the Submodel template “WorkstationWorkerMatchingData”

The SubmodelElementCollection “GeneralWorkstationData” contains the SubmodelElementLists “GeneralQualificationDemand” and “GeneralSkillDemand”. These are demands that are always existing, when this workstation is in use. Tools can retrieve this data from the asset shell as information but should not interpret the records as concrete demand of production, due to the fact that the workstation will be in use only in certain timeslots. To retrieve the actual demand the SubmodelElementLists “PlannedQualificationDemand” and “PlannedSkillDemand” have to be used, where the planning results of planning tools, like APS, are stored.

3 Submodel and SubmodelElements

3.1 SubmodelElements of the Submodel template “WorkstationWorkerMatchingData”

Table 1: Submodel elements of “WorkstationWorkerMatchingData”

idShort:	WorkstationWorkerMatchingData		
Class:	Submodel		
semanticId:	https://admin-shell.io/idta/sm/workstationworkermatchingdata		
Parent:	Asset Administration Shell with asset, which is a workstation		
Explanation:	Submodel containing workstation data in order to match and deploy workers to workstations		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] GeneralWorkstationData	[IRI] https://admin-shell.io/idta/smc/generalworkstationdata General workstation data, which are relevant for worker deployment control and deployment planning	n/a	[1]
[SMC] ErgonomicWorkstationProfile	[IRI] https://admin-shell.io/idta/smc/ergonomicworkstationprofile Ergonomic characteristics of the workstation which might influence the worker deployment	n/a	[0..1]
[SMC] WorkstationConfigurationRecords	[IRI] https://admin-shell.io/idta/sml/workstationconfigurationrecords List with worker specific configuration options of a workstation	n/a	[0..1]
[SMC] PlannedQualificationDemand	[IRI] https://admin-shell.io/idta/sml/plannedqualificationdemand Production plan depending planned qualification demand at a workstation	n/a	[0..1]

[SMC] PlannedSkillDemand	[IRI] https://admin-shell.io/idta/sml/plannedskilldemand Production plan depending planned skill demand at a workstation	n/a	[0..1]

3.2 SubmodelElements of the SMC “GeneralWorkstationData”

Table 2: Submodel elements of “GeneralWorkstationData”

idShort:	GeneralWorkstationData		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/smc/generalworkstationdata		
Parent:	WorkstationWorkerMatchingData		
Explanation:	General workstation data, which are relevant for worker deployment control and deployment planning		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] WorkstationInformation	[IRI] https://admin-shell.io/idta/smc/workstationinformation General information about the workstation in respect of worker deployment	n/a	[1]
[SML] GeneralQualificationDemand	[IRI] https://admin-shell.io/idta/sml/generalqualificationdemand Ergonomic characteristics of the workstation which might influence the worker deployment	n/a	[0..1]
[SML] GeneralSkillDemand	[IRI] https://admin-shell.io/idta/sml/generalskilldemand Worker skills that are required in order to work at the workstation	n/a	[0..1]

3.3 SubmodelElements of the SMC “WorkstationInformation”

Table 3: Submodel elements of “WorkstationInformation”

idShort:	WorkstationInformation
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/smc/workstationinformation
Parent:	GeneralWorkstationData
Explanation:	General information about the workstation in respect of worker deployment

[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Prop] WorkstationName	[IRI] https://admin-shell.io/idta/prop/workstationname Name of a workstation according to IEC 62264 defined "work unit"	[String] milling machine	[0..1]
[Prop] WorkstationId	[IRI] https://admin-shell.io/idta/prop/workstationid Identification of the workstation	[String] mil0123	[1]
[MLP] OrgName	[IRI] https://admin-shell.io/idta/mlp/orgname Organizational name	[langString] mechanical workshop@en Mechanische Werkstatt@de	[0..1]
[MLP] TypeOfWorkstation	[IRI] https://admin-shell.io/idta/mlp/typeofworkstation Type of the workstation, e.g, cable assembly station	[langString] testing station@en	[0..1]
[MLP] WorkerAssistanceInformation	[IRI] https://admin-shell.io/idta/mlp/workerassistanceeinformation Information about the kind and degree of implemented worker assistance at the workstation	[langString] digital step-by-step instructions with final visual quality control, that is supported by computer vision@en	[0..1]
[MLP] RequiredPersonalSafetyEquipment	[IRI] https://admin-shell.io/idta/mlp/requiredpersonalsafetyequipment Required or recommended personal safety equipment and gear at a workstation, e.g., noise protection	[langString] Safety helmet@en	[0..1]

[MLP] NecessaryPersonalTools	[IRI] https://admin-https://admin-shell.io/idta/mlp/necessarypersonaltools Necessary personal tools to be brought with by the worker to the workstation	[langString] caliper gauge@en	[0..1]
[MLP] PersonalDataProcessing	[IRI] https://admin-shell.io/idta/mlp/personaldataprocessing Description how personal data are captured and processed at the workstation	[langString] employee ID is recorded when starting a work order@en	[0..1]
[MLP] LocationDescription	[IRI] https://admin-shell.io/idta/mlp/locationdescription Description of the location of the workstation	[langString] Hall A, Bay 1@en	[0..1]
[MLP] Directions	[IRI] https://admin-shell.io/idta/mlp/directions Descriptions how to get from certain locations to a workstation	[langString] From the entry move straight forward 100m@en	[0..1]

3.4 SubmodelElements of the SML “GeneralQualificationDemand”

Table 4: Submodel elements of “GeneralQualificationDemand”

idShort:	GeneralQualificationDemand		
Class:	SubmodelElementList		
semanticId:	https://admin-shell.io/idta/sml/generalqualificationdemand		
Parent:	GeneralWorkstationData		
Explanation:	Worker qualifications that are required in order to work at the workstation		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/generalqualificationdemandrecord The SMC contains: [Prop] QualificationClassificationId with IRI: https://admin-	n/a [String]	[0..*] [1]

	shell.io/idta/prop/qualificationclassificationid and definition: Identification of the classification system where the qualification is classified [Prop] QualificationId with IRI: https://admin-shell.io/idta/prop/qualificationid and definition: Indentification of the qualification [MLP] ExceptionRules with IRI: https://admin-shell.io/idta/mlp/exceptionrules and definition: Exceptions rules that define possible deviations when the required qualification or skill is not available	[String] [langString]	[1] [0..1]

3.5 SubmodelElements of the SML “GeneralSkillDemand”

Table 5: Submodel elements of “GeneralSkillDemand”

idShort:	GeneralSkillDemand		
Class:	SubmodelElementList		
semanticId:	https://admin-shell.io/idta/sml/generalskilldemand		
Parent:	GeneralWorkstationData		
Explanation:	Worker skills that are required in order to work at the workstation		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/generalskilldemandrecord The SMC contains: [Prop] SkillClassificationId with IRI: https://admin-shell.io/idta/prop/skillclassificationid and definition: Identification of the classification system where the skill is classified [Prop] SkillLevelClassificationId with IRI: https://admin-shell.io/idta/prop/skilllevelclassificationid and definition: Identification of the classification system	n/a [String] [String]	[0..*] [1] [1]

	where the skill level is classified, e.g., EQR level 1-8 [Prop] SkillLevelId with IRI: https://admin-shell.io/idta/prop/skilllevelid and definition: Identification of the skill level for a worker [Prop] SkillId with IRI: https://admin-shell.io/idta/prop/skillid and definition: Identification of the skill for a worker [MLP] ExceptionRules with IRI: https://admin-shell.io/idta/mlp/exceptionrules and definition: Exceptions rules that define possible deviations when the required qualification or skill is not available	[String] [String] [langString]	[1] [1] [0..1]

3.6 SubmodelElements of the SMC “ErgonomicWorkstationProfile”

Table 6: Submodel elements of “ErgonomicWorkstationProfile”

idShort:	ErgonomicWorkstationProfile		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/smc/ergonomicworkstationprofile		
Parent:	WorkstationWorkerMatchingData		
Explanation:	Ergonomic characteristics of the workstation which might influence the worker deployment		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Prop] MaxLiftingWeight	[IRI] https://admin-shell.io/idta/prop/maxliftingweight Maximum weight the worker has to lift at the workstation	[Integer] 16 kg	[0..1]
[Prop] MinWorkerHeight	[IRI] https://admin-shell.io/idta/prop/minworkerheight Minimal height of the worker to perform all operations at the workstation	[Integer] 170 cm	[0..1]

[SML] AllowedPersonalLimitations	[IRI] https://admin-shell.io/idta/sml/allowedpersonallimitations List of all personal limitations that are accepted for working at the workstation, e.g., special measures have been implemented	n/a	[0..1]

3.7 SubmodelElements of the SML “AllowedPersonalLimitations”

Table 7: Submodel elements of “AllowedPersonalLimitations”

idShort:	AllowedPersonalLimitations		
Class:	SubmodelElementList		
semanticId:	https://admin-shell.io/idta/sml/allowedpersonallimitations		
Parent:	ErgonomicWorkstationProfile		
Explanation:	List of all personal limitations that are accepted for working at the workstation, e.g., special measures have been implemented		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/allowedpersonallimitationsrecord The SMC contains:	n/a	[0..*]
	[Prop] LimitationClassificationId with IRI: https://admin-shell.io/idta/prop/limitationclassificationid and definition: Identification of a classification system for worker limitations	[String]	[1]
	[Prop] PersonalLimitationId with IRI: https://admin-shell.io/idta/prop/personallimitationid and definition: Identification of a personal limitation an employee has	[String]	[1]

3.8 SubmodelElements of the SML “WorkstationConfigurationRecords”

Table 8: Submodel elements of “WorkstationConfigurationRecords”

idShort:	WorkstationConfigurationRecords		
Class:	SubmodelElementList		
semanticId:	https://admin-shell.io/idta/sml/workstationconfigurationrecords		
Parent:	GeneralWorkstationData		
Explanation:	List with worker specific configuration options of a workstation		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/workstationconfigurationrecord The SMC contains: [Prop] WorkerId with IRI: https://admin-shell.io/idta/prop/workerid and definition: Identification of a worker (employee) [Prop] AccessStart with IRI: https://admin-shell.io/idta/prop/accessstart and definition: Start (date and time) from when a worker is allowed to be deployed at a workstation [Prop] AccessEnd with IRI: https://admin-shell.io/idta/prop/accessend and definition: End (date and time) until when a worker is allowed to be deployed at a workstation [Prop] PreferredHeight with IRI: https://admin-shell.io/idta/prop/preferredhight and definition: Preferred height of the working table of a workstation measured from floor level, where the worker stands [SML] ProprietaryConfigurations with IRI: https://admin-shell.io/idta/sml/proprietaryconfigurations and definition: A list to that proprietary worker-depending configurations can be added	n/a [String] [dateTime] [dateTime] [Integer] 190 mm n/a	[0..*] [1] [0..1] [0..1] [0..1] [0..1]

3.9 SubmodelElements of the SML “ProprietaryConfigurations”

Table 9: Submodel elements of “ProprietaryConfigurations”

idShort:	ProprietaryConfigurations
Class:	SubmodelElementList
semanticId:	https://admin-shell.io/idta/sml/proprietaryconfigurations
Parent:	WorkstationConfigurationRecords
Explanation:	A list to that proprietary worker-depending configurations can be added

[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/proprietaryconfigurationrecord The SMC contains: [Prop] ConfigurationName with IRI: https://admin-shell.io/idta/prop/configurationname and definition: Name of a worker-dependend configuration of a workstation [Prop] ConfigurationValue with IRI: https://admin-shell.io/idta/prop/configurationvalue and definition: Configuration value for a worker-depending workstation configuration	n/a [String] DashboardDesign [String] Classic	[0..*] [1] [1]

3.10 SubmodelElements of the SML “PlannedQualificationDemand”

Table 10: Submodel elements of “PlannedQualificationDemand”

idShort:	PlannedQualificationDemand

Class:	SubmodelElementList
semanticId:	https://admin-shell.io/idta/sml/plannedqualificationdemand
Parent:	WorkstationWorkerMatchingData
Explanation:	Production plan depending planned qualification demand at a workstation

[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/plannedqualificationdemandrecord The SMC contains:	n/a	[0..*]
	[MLP] IntervalDescription with IRI: https://admin-shell.io/idta/mlp/intervaldescription and definition: Description of a production planning interval and planning granularity (hour, day, ...), e.g., defined in an APS software	[langString]	[0..1]
	[Prop] IntervalStart with IRI: https://admin-shell.io/idta/prop/intervalstart and definition: Begin (timestamp) of a planning interval for qualification demand depending on the planning horizon	[dateTime]	[0..1]
	[Prop] IntervalEnd with IRI: https://admin-shell.io/idta/prop/intervalend and definition: End (timestamp) of a planning interval for qualification demand depending on the planning horizon	[dateTime]	[0..1]
	[SML] QualificationDemandRecords with IRI: https://admin-shell.io/idta/sml/qualificationdemandrecords and definition: Worker qualifications that are required in order to work at the workstation	[n/a]	[0..1]

3.11 SubmodelElements of the SML “QualificationDemandRecords”

Table 11: Submodel elements of “QualificationDemandRecords”

idShort:	QualificationDemandRecords

Class:	SubmodelElementList
semanticId:	https://admin-shell.io/idta/sml/qualificationdemandrecords
Parent:	PlannedQualificationDemand
Explanation:	Worker qualifications that are required in order to work at the workstation

[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/qualificationdemandrecord The SMC contains:	n/a	[0..*]
	[Prop] QualificationClassificationId with IRI: https://admin-shell.io/idta/prop/qualificationclassificationid and definition: Identification of the classification system where the qualification is classified	[String]	[1]
	[Prop] QualificationId with IRI: https://admin-shell.io/idta/prop/qualificationid and definition: Indentification of the qualification	[String]	[1]
	[MLP] ExceptionRules with IRI: https://admin-shell.io/idta/mlp/exceptionrules and definition: Exceptions rules that define possible deviations when the required qualification or skill is not available	[langString] [String]	[0..1] [0..1]
	[Prop] DemandKind with IRI: https://admin-shell.io/idta/prop/demandkind and definition: Kind of the demand, defined by the enumeration: ad-hoc, general, orderDepending	ad-hoc, general, orderDepending [dateTime]	 [1]
	[Prop] StartTime with IRI: https://admin-shell.io/idta/prop/starttime and definition: Point in time where a process with a certain resource demand starts	[dateTime]	[1]
	[Prop] EndTime with IRI: https://admin-shell.io/idta/prop/endtime definition: Point in time where a process with a certain resource demand ends	[Integer] 120 min	[1]
	[Prop] ProcessTime with IRI: https://admin-shell.io/idta/prop/processtime and		

	definition: Manual work time that is planned for a production process		

3.12 SubmodelElements of the SML “PlannedSkillDemand”

Table 12: Submodel elements of “PlannedSkillDemand”

idShort:	PlannedSkillDemand
Class:	SubmodelElementList
semanticId:	https://admin-shell.io/idta/sml/plannedskilldemand
Parent:	WorkstationWorkerMatchingData
Explanation:	Production plan depending planned skill demand at a workstation

[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/plannedskilldemandrecord The SMC contains: [MLP] IntervalDescription with IRI: https://admin-shell.io/idta/mlp/intervaldescription and definition: Description of a production planning interval and planning granularity (hour, day, ...), e.g., defined in an APS software [Prop] IntervalStart with IRI: https://admin-shell.io/idta/prop/intervalstart and definition: Begin (timestamp) of a planning interval for qualification demand depending on the planning horizon [Prop] IntervalEnd with IRI: https://admin-shell.io/idta/prop/intervalend and definition: End (timestamp) of a planning interval	n/a [langString] [dateTime] [dateTime]	[0..*] [0..1] [0..1] [0..1]

	for qualification demand depending on the planning horizon [SML] SkillDemandRecords with IRI: https://admin-shell.io/idta/sml/skilldemandrecords and definition: Worker skills that are required in order to work at the workstation	[n/a]	[0..1]

3.13 SubmodelElements of the SML “SkillDemandRecords”

Table 13: Submodel elements of “SkillDemandRecords”

idShort:	SkillDemandRecords		
Class:	SubmodelElementList		
semanticId:	https://admin-shell.io/idta/sml/skilldemandrecords		
Parent:	PlannedSkillDemand		
Explanation:	Worker skills that are required in order to work at the workstation		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] n/a	[IRI] https://admin-shell.io/idta/smc/skilldemandrecord The SMC contains: [Prop] SkillClassificationId with IRI: https://admin-shell.io/idta/prop/skillclassificationid and definition: Identification of the classification system where the skill is classified [Prop] SkillLevelClassificationId with IRI: https://admin-shell.io/idta/prop/skilllevelclassificationid and definition: Identification of the classification system where the skill level is classified, e.g., EQR level 1-8 [Prop] SkillLevelId with IRI: https://admin-shell.io/idta/prop/skilllevelid and	n/a [String] [String] [String]	[0..*] [1] [0..1] [0..1]

	definition: Identification of the skill level for a worker	[String]	[1]
	[Prop] SkillId with IRI: https://admin-shell.io/idta/prop/skillid and definition: Identification of the skill for a worker	[langString]	[0..1]
	[MLP] ExceptionRules with IRI: https://admin-shell.io/idta/mlp/exceptionrules and definition: Exceptions rules that define possible deviations when the required qualification or skill is not available	[String] ad-hoc, general, orderDepending	[0..1]
	[Prop] DemandKind with IRI: https://admin-shell.io/idta/prop/demandkind and definition: Kind of the demand, defined by the enumeration: ad-hoc, general, orderDepending	[dateTime]	[1]
	[Prop] StartTime with IRI: https://admin-shell.io/idta/prop/starttime and definition: Point in time where a process with a certain resource demand starts	[dateTime]	[1]
	[Prop] EndTime with IRI: https://admin-shell.io/idta/prop/endtime definition: Point in time where a process with a certain resource demand ends	[Integer] 120 min	[1]
	[Prop] ProcessTime with IRI: https://admin-shell.io/idta/prop/processtime and definition: Manual work time that is planned for a production process		

Annex A. Additional information

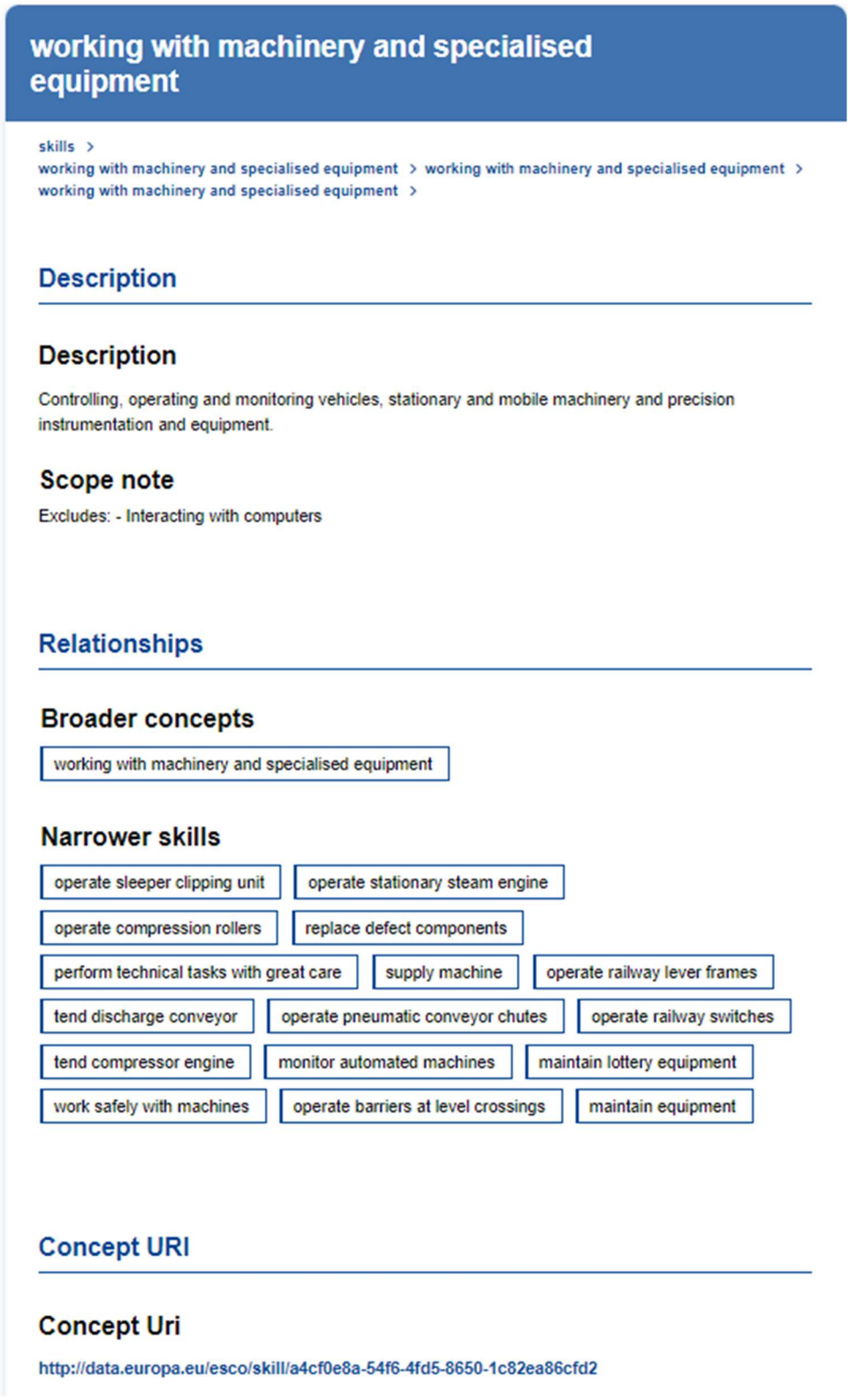

Figure 3: Example of a class within the ECSO classification

— Level 1 - learning outcomes

Knowledge	Skills	Responsibility and autonomy
Basic general knowledge	Basic skills required to carry out simple tasks	Work or study under direct supervision in a structured context

— Level 2 - learning outcomes

Knowledge	Skills	Responsibility and autonomy
Basic factual knowledge of a field of work or study	Basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	Work or study under supervision with some autonomy

— Level 3 - learning outcome

Knowledge	Skills	Responsibility and autonomy
Knowledge of facts, principles, processes and general concepts, in a field of work or study	A range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	Take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problems

— Level 4 - learning outcomes

Knowledge	Skills	Responsibility and autonomy
Factual and theoretical knowledge in broad contexts within a field of work or study	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities

— Level 5 - learning outcomes

Knowledge	Skills	Responsibility and autonomy
Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others

— Level 6 - learning outcomes

Knowledge	Skills	Responsibility and autonomy
Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups

— Level 7 - learning outcomes

Knowledge	Skills	Responsibility and autonomy
Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research Critical awareness of knowledge issues in a field and at the interface between different fields	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams

— Level 8 - learning outcomes

Knowledge	Skills	Responsibility and autonomy
Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

Figure 4: Description of the eight EQF levels

Annex B. Explanations on used table formats

1. General

The used tables in this document try to outline information as concise as possible. They do not convey all information on Submodels and SubmodelElements. For this purpose, the definitive definitions are given by a separate file in form of an AASX file of the Submodel template and its elements.

2. Tables on Submodels and SubmodelElements

For clarity and brevity, a set of rules is used for the tables for describing Submodels and SubmodelElements.

- The tables follow in principle the same conventions as in [5].
- The table heads abbreviate 'cardinality' with 'card'.
- The tables often place two informations in different rows of the same table cell. In this case, the first information is marked out by sharp brackets [] form the second information. A special case are the semanticIds, which are marked out by the format: (type)(local)[idType]value.
- The types of SubmodelElements are abbreviated:

SME type	SubmodelElement type
Property	Property
MLP	MultiLanguageProperty
Range	Range
File	File
Blob	Blob
Ref	ReferenceElement
Rel	RelationshipElement
SMC	SubmodelElementCollection

- If an idShort ends with '{00}', this indicates a suffix of the respective length (here: 2) of decimal digits, in order to make the idShort unique. A different idShort might be choosen, as long as it is unique in the parent’s context.
- The Keys of semanticId in the main section feature only idType and value, such as: [IRI]https://admin-shell.io/vdi/2770/1/0/DocumentId/Id. The attributes "type" and "local" (typically "ConceptDescription" and "(local)" or "GlobalReference" and (no-local)") need to be set accordingly; see [6].
- If a table does not contain a column with "parent" heading, all represented attributes share the same parent. This parent is denoted in the head of the table.
- Multi-language strings are represented by the text value, followed by '@'-character and the ISO 639 language code: example@EN.
- The [valueType] is only given for Properties.

Annex C. Bibliography

[1] “Recommendations for implementing the strategic initiative INDUSTRIE 4.0”, acatech, April 2013. [Online]. Available https://www.acatech.de/Publikation/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-final-report-of-the-industrie-4-0-working-group/

[2] “Implementation Strategy Industrie 4.0: Report on the results of the Industrie 4.0 Platform”; BITKOM e.V. / VDMA e.V., /ZVEI e.V., April 2015. [Online]. Available: https://www.bitkom.org/noindex/Publikationen/2016/Sonstiges/Implementation-Strategy-Industrie-40/2016-01-Implementation-Strategy-Industrie40.pdf

[3] “The Structure of the Administration Shell: TRILATERAL PERSPECTIVES from France, Italy and Germany”, March 2018, [Online]. Available: https://www.plattform-i40.de/I40/Redaktion/EN/Downloads/Publikation/hm-2018-trilaterale-coop.html

[4] “Beispiele zur Verwaltungsschale der Industrie 4.0-Komponente – Basisteil (German)”; ZVEI e.V., Whitepaper, November 2016. [Online]. Available: https://www.zvei.org/presse-medien/publikationen/beispiele-zur-verwaltungsschale-der-industrie-40-komponente-basisteil/

[5] “Verwaltungsschale in der Praxis. Wie definiere ich Teilmodelle, beispielhafte Teilmodelle und Interaktion zwischen Verwaltungsschalen (in German)”, Version 1.0, April 2019, Plattform Industrie 4.0 in Kooperation mit VDE GMA Fachausschuss 7.20, Federal Ministry for Economic Affairs and Energy (BMWi), Available: https://www.plattform-i40.de/PI40/Redaktion/DE/Downloads/Publikation/2019-verwaltungsschale-in-der-praxis.html

[6] “Details of the Asset Administration Shell; Part 1 - The exchange of information between partners in the value chain of Industrie 4.0 (Version 3.0RC01)”, November 2020, [Online]. Available: https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/Details-of-the-Asset-Administration-Shell-Part1.html

[7] “User-friendly, requirement-based assistance for production workforce using an asset administration shell design”, Preprint 2020. [Online]. Available: https://elib.uni-stuttgart.de/handle/11682/10957

[8] “Erstellung prozessbezogener Kompetenzmatrizen in produzierenden KMU“, Handreichungen für die betriebliche Praxis, Aachen 2023.

[9] „Der Digitale Zwilling des Mitarbeiters auf Basis der Verwaltungsschale - Impulspapier der Gesellschaft für Wissensmanagement e.V.“, Research Proposal, January 2020. Available: https://www.researchgate.net/publication/341441428_Der_Digitale_Zwilling_des_Mitarbeiters_auf_Basis_der_Verwaltungsschale_-_Impulspapier_der_Gesellschaft_fur_Wissensmanagement_eV