



Universidade do Minho
Escola de Engenharia

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Modelling of existing railway tunnels: a case study focused on IFC interoperability

BIM A+ European Master in
Building Information Modelling

Modelling of existing railway tunnels: a case study focused on IFC interoperability

Fernanda Benezra Maia



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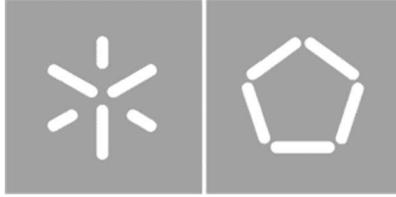
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European Master in
Building Information Modelling

Master Dissertation
European Master in Building Information Modelling

Work conducted under supervision of:
Miguel Ângelo Dias Azenha



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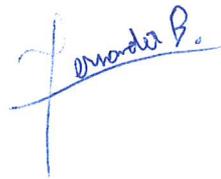
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I dedicate this dissertation to my two nephews, Pedro and Martin, whose giggles made me stronger and life a bit lighter.

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.



RESUMO

Esta dissertação tem como principal objetivo o desenvolvimento de um fluxo de trabalho para a modelação das condições de túneis ferroviários, com enfoque na interoperabilidade de dados. O fluxo de trabalho proposto é aplicado a um caso de estudo real e estruturado com base na utilização do IFC 4.3 e no conceito de Nível de Necessidade de Informação (Level of Information Need). Para apoiar a definição das propriedades dos objetos, são comparadas e analisadas três referências de dados: o Crossrail Asset Data Dictionary, o Catálogo Técnico de Dados da SBB (Caminhos-de-Ferro Federais Suíços) e as Industry Foundation Classes (IFC). Com base nesta comparação, são selecionados três objetos para a criação de Modelo de Dados de Produto (Product Data Templates - PDTs): um carril, um sinal ferroviário e um suporte para sistema rígido de catenária. Estes PDTs servem de base para a definição do Nível de Necessidade de Informação de cada objeto, de acordo com os casos de uso definidos para o estudo.

É realizado um levantamento com varrimento a laser (point cloud) do túnel, a partir do qual é desenvolvido o fluxo de trabalho de modelação. O processo envolve a utilização de dois tipos de software: uma ferramenta de modelação centrada em alinhamentos (Alignment-centered Modelling Tool – AMT) e uma ferramenta de autoria de modelos de edificações (Building Information Modelling Authoring Tool – BAT), que são comparadas quanto às suas capacidades e limitações. Por fim, a dissertação analisa os processos AS-IS e TO-BE para a interoperabilidade baseada em IFC, destacando os desafios atuais na implementação do esquema e nos softwares. Os resultados contribuem para os esforços em curso de normalização e melhoria das práticas digitais em projetos de infraestrutura ferroviária.

Palavras chave: modelação centrada em alinhamentos, BIM para infraestruturas, IFC 4.3, Nível de Necessidade de Informação, Modelo de Dados de Produto

ABSTRACT

This dissertation aims to develop a workflow for modelling the existing conditions of railway tunnels with a focus on data interoperability. The proposed workflow is applied to a real-world case study and structured around the use of IFC 4.3 and the concept of Level of Information Need. To support the definition of object properties, three data references are compared and analyzed: the Crossrail Asset Data Dictionary, the Technical Data Catalogue from SBB (Swiss Federal Railways), and the Industry Foundation Classes (IFC). Based on this comparison, three objects are selected for the creation of Product Data Templates (PDTs): a rail, a railway signal and a support for a rigid overhead contact line system. These PDTs serve as the basis for defining the Level of Information Need for each object according to the use cases defined for the case study.

A point cloud survey of the tunnel is conducted and the modelling workflow is developed. The process involves the use of two types of software tools: an Alignment-centered Modelling Tool (AMT) and a Building Information Modelling Authoring Tool (BAT), which are compared in terms of their capabilities and limitations. Finally, the dissertation analyses the AS-IS and TO-BE workflows for IFC-based interoperability, highlighting the current challenges in software implementation and schema navigation. The results contribute to the ongoing efforts to standardize and improve digital practices in railway infrastructure projects.

Keywords: Alignment-based modelling, BIM for infrastructure, IFC 4.3, Level of Information Need, Product Data Template

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LIST OF ACRONYMS AND ABBREVIATIONS

AD4s	Asset Data Dictionary Definition Documents
ADD	Asset Data Dictionary
AECO	Architecture, Engineering, Construction, and Operations
AIA	American Institute of Architects
AIM	Asset Information Model
AIMS	Asset Information Management System
AIR	Asset Information Requirements
AMT	Alignment-centered Modelling Tool
BAT	Building Information Modelling Authoring Tool
BIM	Building Information Modelling
bSI	buildingSMART International
bsDD	buildingSMART Data Dictionary
CAD	Computer Aided Design
COBie	Construction Operations Building Information Exchange
CRBIM	China Railway BIM Alliance
DB	Deutsche Bahn
EIR	Exchange Information Requirements
FDK	Technical Data Catalogue
FTIA	Finnish Transport Infrastructure Agency
FU	Functional Unit
IFC	Industry Foundation Classes
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LOD	Level of Development
LoD	Level of Detail
LOG	Level of Geometry
LOI	Level of Information
LOR	Level of Reliability
MINnD	Modélisation des INformations iNteropables pour les Infrastructures Durables
MVD	Model View Definition
N/A	Not Applicable
NATSPEC	National Building Specification in Australia
O&M	Operation and Maintenance
OCS	Overhead Contact Line System
OFT	<i>Office Fédéral des Transports</i>
OIR	Organizational Information Requirements
PDT	Product Data Template
PFU	Primary Functional Unit
PIM	Project Information Model
PIR	Project Information Requirements

Pset	Property Set
RGB	Red, Green, Blue
SBB	Swiss Federal Railways
SIA	Swiss Society of Engineers and Architects
UC	Use Case
UML	Unified Modeling Language

1. INTRODUCTION

In recent years, Building Information Modelling (BIM) has become mandatory in many countries, especially for publicly funded projects. Since most infrastructure projects fall into this category, the demand for BIM in infrastructure is increasing (*Railway Information Modeling RIM: The Track to Rail Modernization*, n.d.). However, there is still a noticeable gap between how BIM is applied in the architectural sector and how it is used in linear infrastructure projects (Shin et al., 2024). Some authors and researchers even estimate that this gap could be as much as 10 years (*Railway Information Modeling RIM: The Track to Rail Modernization*, n.d.).

BIM for architectural design is already well established, with mature tools, standardized workflows and a strong culture of collaboration. In contrast, infrastructure projects, particularly linear ones like tunnels and railways, face different challenges. These projects are geographically extensive, often involve complex geometries tied to an alignment and require coordination across many disciplines and phases (*Railway Information Modeling RIM: The Track to Rail Modernization*, n.d.). The tools and workflows developed for buildings do not always translate well to this context.

At the same time, much of the infrastructure is already built, these are, in fact, refurbishment projects. That means modelling existing conditions becomes essential. Surveying existing conditions using point clouds, with sufficient precision and a focus on relevant features to support future design phases, is an important part of making BIM truly useful in infrastructure (Cicccone et al., 2022) (Kwon et al., 2020) (Cheng et al., 2019).

To support this shift, countries are beginning to define their own BIM regulatory frameworks and standards for infrastructure, particularly regarding metadata (Mitera-Kielbasa and Zima, 2024). On the international level, the publication of ISO 16739-1:2024 is a major step forward. For the first time, the schema includes the Rail Domain, offering new possibilities for representing railway assets and their relationships in an interoperable way.

1.1. Objectives

Taking into consideration the challenges and the context presented, the main goal of this dissertation is to address the problem of the digitalization of existing railway and tunneling infrastructures in preparation for refurbishment or restoration. This challenge takes into consideration the new data structure of IFC 4.3, which includes entities for railway and infrastructure assets in general. Moreover, the definition of the Level of Information Need is used to define how this model should be developed from the existing conditions survey using point clouds and to determine which information is relevant for the model to include at the start of a refurbishment phase.

The main objectives of this dissertation can be subdivided into a list:

- Comparison of three different data references;
- Development of three simplified Product Data Templates for three selected objects;

- Description of the Level of Information Need regarding alphanumerical and geometrical information for the case study selected objects within the context of railway projects in Switzerland and the new IFC 4.3 schema;
- Comparison of different software tools, especially for alignment-based modelling;
- Development of a modelling workflow for the case study from a point cloud survey following the Level of Information Need defined;
- Critical analysis of the IFC translation of the tunnel railway model.

1.2. Structure of the Dissertation

After the introduction made in the present chapter, this dissertation continues with a literature review on Chapter 2. This literature review starts by giving the context of railway projects and initiatives in Europe regarding BIM. Two of these initiatives are presented and briefly described to show the possibilities of BIM related to infrastructure, especially in the railway sector. The description of the BIM@SBB initiative goes deeper and elaborates on how BIM is being driven in Switzerland. Then, Chapter 2 continues the literature review by assessing the state of the art of information structure, definition and exchange. This is done by developing the concepts and standards of Product Data Template and Level of Information Need. Afterwards the chapter explains three references used for defining the alphanumerical properties of the case study. Finally, the literature review on point cloud survey and infrastructure modelling is made.

Chapter 3 consists of a more detailed description of the case study and the selection of the objects found in the case study. Afterwards, a comparison of the three data references is made. Then, a basic data mining is done based on three sources of information: the IFC 4.3, the Crossrail Asset Data Dictionary and the FDK (Technical Data Catalogue from the Swiss Federal Railway Company SBB). This is followed by the development of the Level of Information Need for the chosen objects, which describes the alphanumerical and geometrical information required for the model.

Chapter 4 focuses on the modelling definitions and workflow used for the case study. This includes showing plans and a point cloud survey made using a terrestrial laser scanner. Then, the software tools are compared and chosen for the modelling workflow. Moreover, the workflow for inserting alphanumerical information from the Level of Information Need is shown. Finally, a critical comparison of the AS-IS translation of the IFC workflow and the TO-BE translation is made.

2. BIM STANDARDS AND PRACTICES IN RAILWAY INFRASTRUCTURE

2.1. Infrastructure projects and BIM

As infrastructure projects grow in complexity and involve an increasing number of stakeholders, governments worldwide are seeking strategies to improve project efficiency, cost control, and asset management. In response, many countries have begun mandating the use of Building Information Modeling (BIM) in public construction projects, with implementation timelines defined in national regulations (*Railway Information Modeling RIM: The Track to Rail Modernization*, n.d.).

Between 2010 and 2020, countries such as the United Kingdom, China, Germany, Brazil, and Switzerland introduced regulatory frameworks requiring BIM adoption through progressive implementation levels (Mitera-Kiełbasa and Zima, 2024). These frameworks often include roadmaps and mandates tailored to national infrastructure priorities. For instance, the UK was among the first to enforce BIM requirements in public projects (Mitera-Kiełbasa and Zima, 2024), while Germany's Federal Ministry of Transport and Digital Infrastructure published its BIM roadmap in 2015 to guide adoption in governmental infrastructure initiatives (Federal Ministry of Transport and Digital Infrastructure, 2015)

In parallel with these governmental mandates, national infrastructure organizations and operators have developed BIM standards and guidelines to support consistent implementation. These initiatives often address sector-specific needs, including those of the railway industry. The following sections highlight notable examples of such efforts, with a particular focus on the UK's Crossrail project and Switzerland's BIM@SBB program, both of which are examined in greater detail later in this dissertation.

2.1.1. The Crossrail project in the UK

The Crossrail project was selected as a key reference for this dissertation due to its pioneering approach to BIM implementation and the extensive public documentation available through the Crossrail Learning Legacy. Launched in mid-2015, the Learning Legacy serves as a platform to disseminate information, lessons learned, best practices, and innovations related to the Crossrail Management System.

Crossrail is a major rail infrastructure project in London and the southeast of England (Dentten, 2018). The line was opened by the end of 2022 and it's now called *The Elizabeth line*, being considered as the most significant addition to London's transport network in a generation ("History of the Elizabeth line - Crossrail," 2022). The line spans 100 km long and includes 41 stations along its route.

A defining feature of the Crossrail project is its focus on the entire lifecycle of the infrastructure. Beyond delivering a reliable railway system, the project emphasizes long-term operational efficiency and maintainability. Achieving this requires robust asset management practices that support risk assessment and informed decision-making throughout the asset's life.

To manage information for over 500,000 assets, Crossrail developed the Crossrail Asset Information Management System (AIMS). This system encompasses a wide range of assets, including concrete structures, railway signalling, and ventilation systems (Dentten, 2018).

Traditionally, asset information in engineering projects is compiled at the end of the project, often in a rushed and fragmented manner, leading to issues with data quality, traceability, and cost. In contrast, Crossrail adopted a progressive and structured approach to asset information management. Data was collected and enriched continuously throughout the project lifecycle, increasing in volume and detail in parallel with project development (Dentten, 2018).

The completeness of the Crossrail Learning Legacy, its focus on railway infrastructure, and its coverage of all project phases made it a valuable reference and one of the key data sources for this dissertation. The Crossrail Data Dictionary is a result of this initiative, and it's further explained in Chapter 2.2.6.

2.1.2. BIM@SBB in Switzerland

In the Swiss context, the Swiss Federal Railways (SBB) has been leading the implementation of BIM in railway infrastructure projects. While SBB had already adopted BIM for its real estate developments, typically commercial or residential buildings located on railway-owned land near stations, the application of BIM to railway infrastructure began with pilot projects launched in 2021.

As part of its BIM implementation roadmap, SBB initiated broader preparations in 2024, including the integration of BIM requirements into tendering processes. From 2025 onward, all new infrastructure projects are required to be conceived using the BIM methodology. These projects will enter the planning phase in 2025, with construction expected to begin in 2027. By 2029, passengers using Swiss railways are anticipated to benefit from facilities that were first developed in a fully digital environment. The overall timeline, which includes both major and minor milestones aligned with the project phases defined by the Swiss Society of Engineers and Architects (SIA), is illustrated in Figure 1.

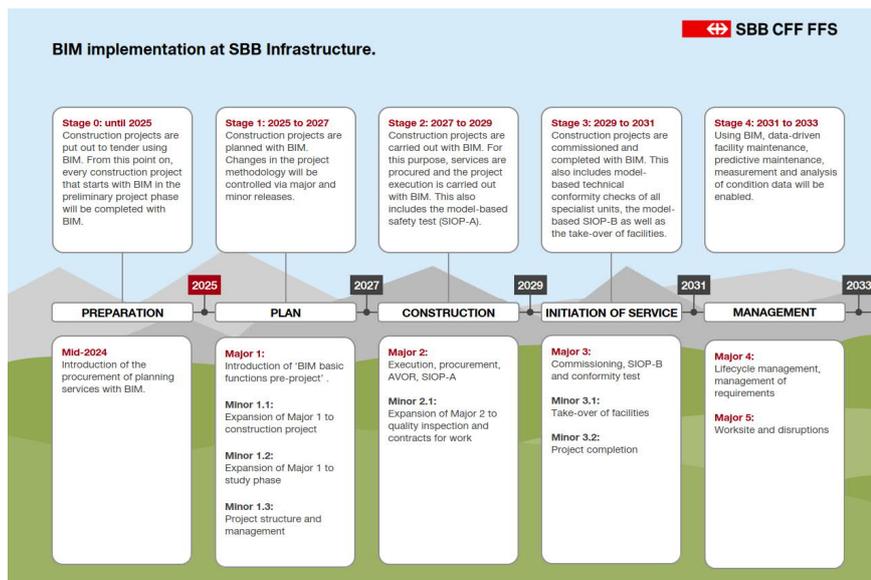


Figure 1 - BIM@SBB timeline for implementation of BIM in their railway projects. (“BIM implementation schedule and ongoing BIM projects | SBB,” n.d.)

To support this transition, SBB has established an internal learning center dedicated to BIM. Its mission is to train technicians, engineers, and project managers in BIM methodologies, while also developing internal standards, tools, and best practices. With the support of this center, SBB has already launched 48 pilot projects across Switzerland, as shown in Figure 2, being 34 infrastructure projects and 14 real estate projects.

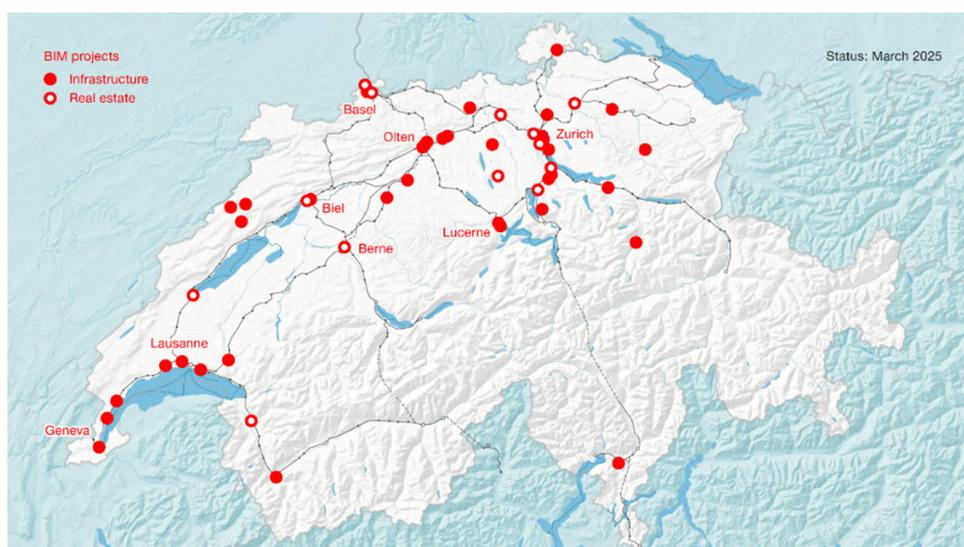


Figure 2 - 34 Projects currently being developed by SBB using the BIM method across Switzerland. (“BIM implementation schedule and ongoing BIM projects | SBB,” n.d.)

A central component of the BIM@SBB initiative is the development and continuous refinement of the *Fachdatenkatalog* (FDK), or “technical data catalogue.” The FDK serves as a comprehensive compilation of data requirements for SBB’s infrastructure projects. It forms part of the company’s Exchange Information Requirements (EIR) and is used as a mandatory data template that defines the set of properties required for any BIM model developed for SBB. A more detailed explanation of the FDK and its role in the case study will be provided in Chapter 2.2.7. Moreover, since the case study is in Switzerland, the FDK implementation and study is essential.

2.1.3. Other international initiatives for BIM and infrastructure

Several other countries and international initiatives have also been progressing in the use of BIM in construction projects. Since infrastructure projects are largely funded through public investment, governments tend to regulate them in order to ensure transparency and cost efficiency. This is largely shown in the work of (Mitera-Kiełbasa and Zima, 2024), which shows that in most countries, BIM implementation is tied to the creation of national policies for infrastructure and transportation projects, including, but not limited to, railway systems.

In Germany, the Federal Ministry for Digital and Transport published a roadmap in 2015 to guide the implementation of BIM in public infrastructure projects (Federal Ministry of Transport and Digital Infrastructure, 2015). The aim of the *BIM4INFRA2020* roadmap is to make BIM mandatory for federal funded infrastructure projects starting in 2020 (Borrmann et al., 2021). The practical application of this roadmap in the railway sector is being carried out by Deutsche Bahn (DB), which has been integrating

BIM into its planning and construction processes, which began integrating BIM into its planning and construction processes with the publication of its first implementation guide in 2019 (Deutsche-Bahn, 2019), later updated in 2022 (Deutsche Bahn AG, 2022).

The Rail Baltica project is another relevant example. It is a transnational railway infrastructure project connecting Estonia, Latvia, and Lithuania to the European rail network. BIM is being used throughout the project lifecycle, with a strong emphasis on data consistency, digital collaboration, and the use of open formats to support cross-border coordination.

In France, the MINnD (Modélisation des INformations iNteropables pour les Infrastructures Durables) project in France. It brings together public and private sectors to the development of BIM for infrastructure. The project focuses on how data should be structured in order to be exchanged during the whole life cycle of a project (“Qu’est-ce que MINnD ?,” n.d.). Its concrete outcomes include two key documents: *Le guide de mise en place du BIM* and *Le guide d’application du BIM* (“Livrables saison 1 Projet MINnD,” n.d.).

In Finland, the Finnish Transport Infrastructure Agency FTIA Väylävirasto (formerly Liikennevirasto) has been promoting the use of open BIM in infrastructure projects. FTIA has developed its own model requirements and classification systems and mandates the use of open standards in its projects to ensure consistency and data quality throughout the asset lifecycle.

Other countries such as China, Brazil, Norway, and South Korea have also launched national BIM strategies or pilot programs. In Brazil, for example, the BIM BR Strategy was launched in 2018 and includes a phased plan for mandatory BIM use in public works. In China, BIM is being applied in large-scale infrastructure projects and counts with the China Railway BIM Alliance (CRBIM) which played an important role in the creation of the IFC Rail (“IFC Rail Project Context & Approach,” 2019).

2.2. Data structure for railway projects

As seen in Chapter 2.1, BIM adoption for railway projects depends strongly on governmental policies and the creation of implementation roadmaps, mandates and standards. BIM relies on digital models not only for geometric representation but also for structuring information that is consistent, machine-readable and usable across the entire asset lifecycle. One of the key challenges addressed by the initiatives mentioned earlier is the structuring of metadata.

The main goal of Chapter 2.2 is to briefly explain key concepts in light of important BIM standards, with the objective of producing an existing conditions model of a railway tunnel for a refurbishment project using properly structured metadata. These standards include the use of Product Data Templates (PDTs) to define object properties, the specification of metadata and geometric information through the application of the Level of Information Need for the project’s specific use cases, and the adoption of standards to ensure consistency and collaboration such as the ISO 22014:2024 and the ISO 19650 series (“ISO 19650-1:2018,” 2018). In addition, this chapter highlights key points of the IFC 4.3 developed to support infrastructure and linear assets. Finally, it introduces two data structures that are particularly relevant to this dissertation’s case study: the Crossrail Asset Data Dictionary and the Technical Data Catalogue (FDK) from BIM@SBB.

2.2.1. Product Data Template (PDT)

Different countries and initiatives have created and will continue to create distinct data dictionaries according to local regulations and culture. These data dictionaries need to be interoperable across tools and applications to support international projects. To assure this interoperability, data dictionaries need to speak the “same language” by connecting attributes with equivalent meanings for the same object type. This is essential to map and harmonize properties in different dictionaries. This result can only be achieved if the data follows a common structure for all dictionaries. Following the same structure enables the dictionaries to keep being governed in a local manner, while exchanging attributes with other independently governed dictionaries (“ISO 23386:2020,” 2020).

According to ISO 23387:2020, a Data Template is defined is used to describe the characteristics objects. The ISO 23387:2020 describes how the data templates should be structured for any construction object. By object the standard means product, system, assembly, space, building etc (“ISO 23387:2020,” 2020). In this context, a Product Data Template can be described as a data structure that aims to anticipate the information needed for an element type during the whole lifecycle of the asset (CT197 BIM, n.d.). Nevertheless, a data template is an objects’ set of attributes and associations from a data dictionary that can be linked to a network of data dictionaries and lead to an equal object in meaning and with attributes that can also be related between dictionaries.

Data Templates have several characteristics that improve information exchange through an asset life cycle. They enable the use of a common data structure, terminology and globally unique identifiers for machine readable data (“ISO 23387:2020,” 2020). Also, in a world where infrastructure projects are developed as an international effort, data templates provide a common language for exchanging information. Moreover, to support interoperability and open BIM processes, they need to be in accordance with the Industry Foundation Classes (IFC) standards defined by ISO 16739-1. IFC is a machine readable, conceptual data schema and exchange file format used for BIM (“ISO 23387:2020,” 2020). It enables the description of any object type for any information need by linking the IFC schema to structured data dictionaries or data templates.

For a PDT to be linked to the IFC schema, it needs to have a proper structure divided into Entity/Entity Type, Property/quantity and MeasureWithUnit. The elements in the data template need to have associations among them defined by the ISO 12006-3:2022 to create relationships between the construction object and the IFC entity, as shown in Table 1 and Figure 3. The term “xtdRelAssocitates” is used to declare that there is an association within the elements like in a relational database.

Table 1 - IFC classes link to data template concepts. (“ISO 23387:2020,” 2020)

IFC class	ISO 12006-3 relationship	Data template concept
Entity/Entity Type	xtdRelAssociates	Construction object
Property/quantity	xtdRelAssociates	Property/Specific property
MeasureWithUnit	xtdRelAssociates	Quantity

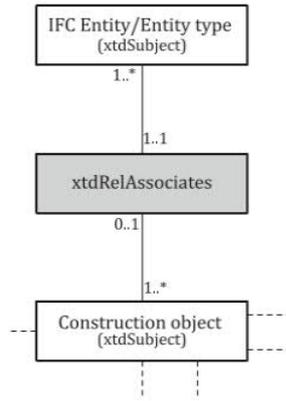


Figure 3 - Making a relationship between construction object and IFC Entity/Entity type. (“ISO 23387:2020,” 2020)

Another prerequisite for linking data templates with the IFC schema is having a classification system based on the ISO 12006-3:2022. This basically means having classification levels for the data template itself, the construction objects, and the properties as shown on Table 2.

Table 2 - Classification levels linked to Data template concepts. (“ISO 23387:2020,” 2020)

Classification	ISO 12006-3 relationship	Data template concept
Classification level	xtdRelClassifies	Data template
Classification level	xtdRelClassifies	Construction object
Classification level	xtdRelClassifies	Property

Moreover, to be machine-readable and human-understandable, properties shall be defined by a set of attributes. The attributes defining a property in a proper data dictionary need to have a code, a name, a data type, a description, and an example. If the attribute is an enumerated type, a list of possible values for the attribute must also be provided (“ISO 23386:2020,” 2020).

The article published by Sibaii et al. (2022) proposes a clear methodology for the creation of Product Data Templates. The process begins with the acquisition of parameters from various sources, followed by the normalization and categorization of the identified properties. Subsequently, the methodology incorporates the implementation of ISO 23387:2020 and ISO 23386:2020 standards to ensure consistency and interoperability. As a final step, the authors recommend gathering feedback from industry professionals to validate and refine the proposed templates. The workflow is summarized on Figure 4.

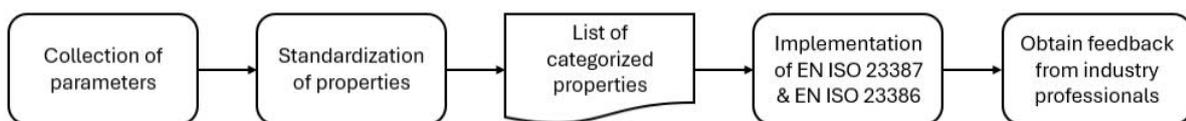


Figure 4 - Methodology for the creation of a Product Data Template. (Sibaii et al., 2022)

A relevant example is shown on the work of El Sibai et al., (2024), which proposes PDTs specifically related to railway tunnel projects. This work uses methodology of Sibai et al. (2022).

EN13674-1	IFC	Entrevista c/ Especialistas	Propriedade (Inglês)	Propriedade (Português)
	PositionInTrack		PositionInTrack	PosicaoNaVia
	TechnicalStandard		TechnicalStandard	PadraoTecnico
	RailDeliveryState		RailDeliveryState	EstadoDeEntregaDe-Carril
	RailCondition		RailCondition	CondicaoDoCarril
		Rail Length Description	Rail Length Description	- -
hydrogen content		Levels of hydrogen	HydrogenContent	ConteudoHidrogenio
Total oxygen		Levels of oxygen	TotalOxygen	OxigenioTotal
Decarburisation		Decarburiza- tion	Decarburisation	Descarburacao
Hardness (HBW)		Hardness	Hardness	Dureza
Tensile strength		Tensile resistance	TensileStrength	ForcaDeTracao
Section modulus - Head			SectionModulusHead	ModuloSeccaoCabeca
Section modulus - Base			SectionModulusBase	ModuloSeccaoBase
Moment of inertia y-y axis			MomentOfIner- tiaYYAxis	MomentoDeInerciaEi- xoYY
Section modulus y-y axis			SectionModu- lusYYAxis	ModuloSeccaoEixoYY

Figure 5 - Part of the matrix used to standardize the properties of the Rail object. (Sibai et al., 2024)

An initiative in Portugal aims to develop Product Data Templates based on regulations, standards, IFC property sets, COBie, Declarations of Performance, Environmental Product Regulations, etc. This initiative is a current project at the Universidade do Minho and can be accessed by the webpage pdts.pt (CT197 BIM, n.d.). A few railway-specific Product Data Templates are already available on the platform developed following the methodology proposed by Sibai et al. (2024).

Ideally, a Product Data Template (PDT) should be applicable for any phase, stakeholder, use case or software. In this sense, a complete list of attributes for a uniform description of a PDT is almost impossible. So, comparing product descriptions schemas takes meta-considerations instead of task-driven requirements. (Wagner et al., 2022)

So, to compare data schemas, an option is using the method created by Wagner et al. by the means of meta-considerations. Wagner et al. compare nine meta-considerations to evaluate if a data schema can continuously change or extend technical information:

- Open: capability of the schema to be interoperable and integrable by any stakeholder or software application
- Queryable: capability of enabling users to search for suitable properties

- Machine-readable: capability of automating data processing and integration by importing data into any software application without the need of special software requirements
- Filterable: capability of filtering information to reduce the amount of data to be dealt with in respect of the stakeholder and use case in question. Information overhead needs to be avoided
- Flexible: capability of addressing any use cases, including, when possible, the manufacturer's and the possibility of adding more properties
- Exhaustive: capability of integrating as much data as possible even if it's impossible to be complete so it can be used for any BIM model and use case
- Modular: capability of including or excluding new perspectives or domains of the product
- Multi-lingual: capability of describing information multi-lingually in order to exchange data internationally
- Domain-independent: capability of serving any domain and complying with their individual guidelines.

Since PDTs aim to anticipate the need for information, they are a great source of alphanumerical properties for the Level of Information Need. Level of Information Need

2.2.2. Level of Information Need

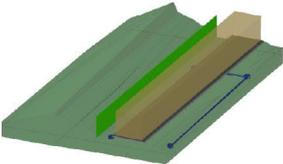
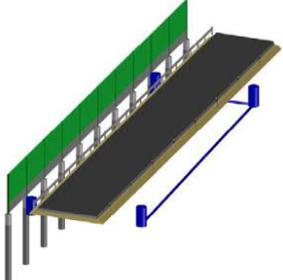
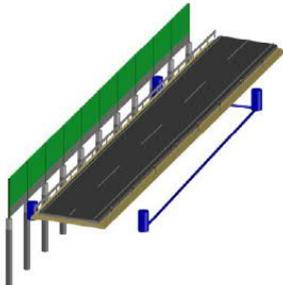
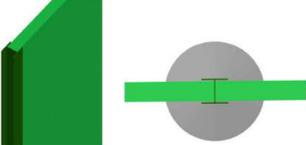
For over a decade, the Level of Development (LOD) was the concept most used in the AECO industry to describe the minimum amount of information required in a model element to fulfill a purpose (Pham et al., 2021). Similar concepts appear in different standards worldwide like Level of Detail, Level of Definition, Level of Accuracy, Level of Reliability and Level of Information Need, etc (Pham et al., 2021). Several initiatives have also emerged to define the maturity of information across different phases of the design process, like the NATSPEC and the Level of Development Specification by the BIMForum (Abualdenien and Borrmann, 2022).

Despite being similar at first glance, they may vary in their fundamentals. Level of Detail (LoD) was the first created, in 2005, and concerned only geometric information. Later, the LoD was refined by the American Institute of Architects (AIA) to include both semantic and geometric information (Pham et al., 2021). Since then, LOD has become an important part of the definitions for a BIM project and it appears in many contracts, being, in that sense, legally binding. The BIMForum publishes annual updates of their *Level of Development Specification* ranging in a scale from LOD 100 to LOD 500. (Abualdenien and Borrmann, 2022).

In 2015 Switzerland published its own guidelines entitled *Building Information Modeling (BIM): Basic principles of an open BIM methodology for Switzerland* based on the LOD definition developed by the BIMForum and the AIA. These guidelines also aligned project life-cycle phases according to the SIA 102 regulations to the elements described (Maier, 2015). In September 2018 buildingSMART Switzerland published the *Swiss definition BIM LOIN-LOD* describing the principles and basis for describing BIM elements according to the Level of Geometry (LOG) and Level of Information (LOI) separately. According to this guideline, the LOI and LOG levels must be defined separately for each project phase and the classification still follows a scale ranging from 100 to 500, consistent with the BIMForum. Unlike the BIMForum specification, which defines LOD at the object level, the Swiss approach focuses more on domains or systems (Bâtir digital Suisse, 2018).

Speaking specifically about information definitions for infrastructure, Germany has made significant progress in developing LOD for the field. This change was driven by an announcement from the Federal Ministry of Transport and Digital Infrastructure making BIM for federal infrastructure projects mandatory (Bundesministerium für Verkehr und digitale Infrastruktur, 2015). Making BIM mandatory triggered leading companies and institutions to develop their own guidelines to fulfill the Ministry's decree. Among these institutions is Deutsche-Bahn, who published their guidelines for defining LOD as part of the documentation mentioned in Chapter 2.1.3 (Deutsche Bahn AG, 2022). Finally, the Federal Ministry of Transport and Digital Infrastructure of Germany established the BIM4INFRA2020 project. One of the handouts of this project was the first definition of LOD aiming infrastructure projects, adopting it as a sum of LOG and LOI. (BIM4INFRA2020, 2019). Table 3 summarizes the LOD definitions according to the BIM4INFRA2020 initiative.

Table 3 - Description of LOD according to the BIM4INFRA2020 initiative. (BIM4INFRA2020, 2019)

LOD	Description	Illustration
LOD 100	The model is created as a simple model with essential rough building parameters such as area, length, width, height, location and position and does not necessarily have to contain individual model elements. It serves to develop a solution concept for the linear structure, including the engineering structure, the urban planning classification and communication with the client. The respective technical models are also called preliminary design models.	
LOD 200	The essential elements are modeled according to types as components or component groups with information on dimensions, shape, position, geographic reference and quantities as well as the required alphanumeric information. 2D plans can be derived from the model. Models or model elements with a LOD 200 are used in construction phases.	
LOD 300	The elements are modeled according to type and ready for execution as components or component groups with precise information about dimensions, shape, location, geographic reference and quantities. More alphanumeric information is added to the model elements. The quantities and other information are derived from the model for bills of quantities. Models or model elements with a LOD 300 are used in work phases.	
LOD 350	The elements are modeled according to type and ready for execution as components or component groups with precise information about dimensions, shape, location, geographic reference and quantities and alphanumeric information. The	

	LOD can be supplemented by detailed drawings, such as embankment protection, railings or curb details.	
LOD 400	The model elements are modeled in the model as type-appropriate and ready-to-execute components or component groups with precise information about dimensions, shape, location, geographic reference and quantities as well as assembly and installation details. Additional alphanumeric information such as fabrication and installation details and manufacturer information is added to the model elements. Models or model elements with a LOD 400 are used in service phase.	
LOD 500	The model elements are a verified representation of the installed components in terms of dimension, shape, location, geographic reference, quantities and all required alphanumeric information. Models or model elements with a LOD 500 include the "as built" model. Based on the "as built" model, the operating model for the operation and maintenance of the structure is created. Operational alphanumeric information is added, complex geometry and planning information is removed or simplified.	

When focusing specifically on LOD definitions for railway infrastructure, Gigante-Barrera et al. developed LOD levels aimed at risk mitigation for turnout systems in 2017 and Pham et al developed a LOD framework for railway infrastructure in Vietnam in 2021. However, neither of these works incorporates the Level of Information Need as defined in EN 17412-1:2020. Gigante-Barrera's work predates the EN 17412-1:2020 and Pham's work was developed outside the scope of European regulations.

Table 4 and Figure 6 summarize Gigante-Barrera et al.'s findings for a rail element within a turnout system. Table 5, on the other hand, presents the LOD developed by Pham et al for a tunnel element based on his definition of LOD as the sum of LOG (Level of Graphic), LOI (Level of Information) and LOR (Level of Reliability).

Table 4 - Rail turnout LOD attributes, units and description for risk mitigation. (Gigante-Barrera et al., 2017)

LOD	Attributes	Units	Description
100/200	Rail-Wheel material type Tensile strength Toughness	Material Type Mpa Pa.m	First, the designer should generate an approximate design.
300	Rail profile Rail size	Profile Type Kg/m	Later, the designer should consider producing scaled models with consistent dimensions. Thus, using interoperable

			dimensions for product manufacturing comparison and selection.
350	Track alignment	mm	At this stage, the rail clearance should be inferred from the model, i.e. this can be useful to set the minimum railheads distance in a switch heel, which will be a function of the wheel flange thickness. Other relationships between parallel rails can be inferred, for example track alignment.
400	Cant Curvature Rail welding	cm m Weld Type	Finally, installation and construction requirements can be inferred from the model and weld type and position can be precisely indicated.

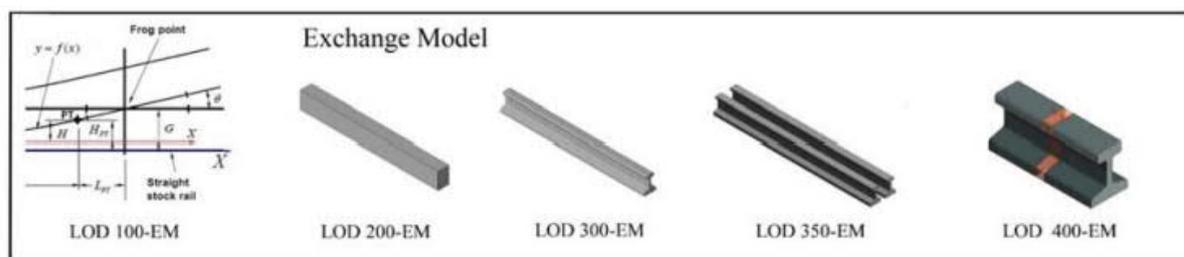
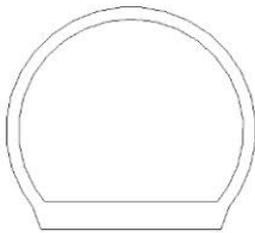


Figure 6 - Illustration of the LOD created for railway turnout risk mitigation. (Gigante-Barrera et al., 2017)

Table 5 - LOD specification for a tunnel. (Pham et al., 2021)

Level	LOG	Image sample	LOI	LOR
100	Typical section or standard symbol		- Type, name	Not specified
200	Overall shape - Alignment, location, size and shape		- Type, name - Locations - Material type -Grade/ strength of material	<i>Assumed</i> Tunnels are specified on an assumed level for geometry, location and associated properties

<p>300</p>	<p><i>Specific elements</i> The LOG 200 model is further developed to include: - Roof and base slab, lining, ventilation duct, etc.) that varies continuously along the alignment - Cross-fall and longitudinal fall of the element component</p>		<p>The LOI 200 model is further developed to include: - Classification title/ codes - Design codes to be adopted</p>	<p><i>Defined</i> - Tunnels are specified on a defined level for geometry, location and associated properties</p>
<p>400</p>	<p><i>Specific elements</i> The LOG 300 model is further developed to include: - Locations and sizes of the panel walls and the waterproof membrane - Locations of Construction joints; - Locations of Box-out Openings - Location and size of reinforcements - Supplementary components required for fabrication and field installation</p>		<p>The LOI 300 model is further developed to include: - Manufacturer's equipment information and parameters of the objects</p>	<p><i>Final</i> - Tunnels are specified on a final level for geometry, location and associated properties</p>

As discussed before, Switzerland alongside other countries have several guidelines, standards and definitions for LOD. The concept of Level of Information Need emerged from the necessity to describe information in a common and comparable way for procurement all over Europe, as different LOD specifications are inconsistent between each other. Moreover, the Level of Information Need differs from traditional LOD specifications in how information is structured and described (Abualdenien and Borrmann, 2022).

The term “Level of Information Need” was first standardized as a part of the ISO 19650 series in 2018, but it was only in 2020 that it received its own European standard, the EN 17412-1:2020 and later, in 2024, its international standard, as part of a series, the ISO 7817:2024. The Level of Information Need structures the information delivery as a part of the Exchange Information Requirements defined by the Appointing Party. The purpose of the EN 17412-1:2020 and the ISO 7817:2024 standard is to provide

methods for describing the information required. How this information is exchanged and related topics is explained in the context of the ISO 19650 (“ISO 19650-1:2018,” 2018).

According to the EN 17412-1:2020, Level of Information Need is directly related to the purpose and timing of information exchange within BIM processes. Different levels of granularity of information can be seen in different phases of a project’s lifecycle and clearly defining the information needed helps avoid both over-delivery and under-delivery of data (“EN 17412-1:2020,” 2020) (“ISO 7817-1:2024,” 2024).

In this sense, the foundations of the Level of Information Need differ significantly from those of LOD. While LOD, as the one described by the BIMForum, ranges in a fixed scale, the Level of Information Need was not created to be limited to a scale, as the geometric and semantic information requirements are too vast to be limited to levels. Also, while the LOD focuses on the refinement of objects in an incremental way following the design process, the Level of Information Need is use-case centered and does not need to be an increment on element created for the previous phase of the design process. Figure 7 summarizes the main differences between the structure of LOD and Level of Information Need (Abualdenien and Borrmann, 2022).

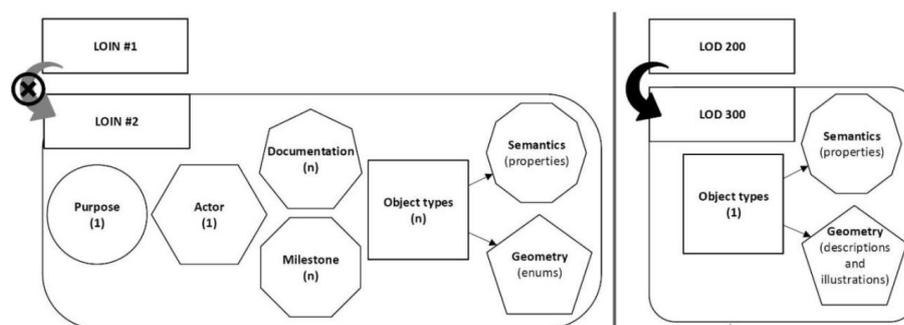


Figure 7 - Comparison between the structure of the Level of Information Need and LOD concepts. (Abualdenien and Borrmann, 2022)

To determine the level of information need, the standards advise to consider prerequisites that may not appear in the description of the information needed:

- Purposes for the use of the information to be delivered to clarify **why** there is a need for such information. The purpose can be extracted from the OIR (Organizational Information Requirements), PIR (Project Information Requirements) and AIR (Asset Information Requirements);
- Information delivery milestones to clarify **when** the information should be delivered;
- Actors **who** are going to request and actors who are going to deliver the information;
- Objects organized in one or more breakdown structures. This defines **what** objects are needed within a structure, identifying the semantic, functional and/or decomposition of the project into objects. This includes spaces, construction complexes/systems, construction entities and construction elements. (“ISO 7817-1:2024,” 2024)

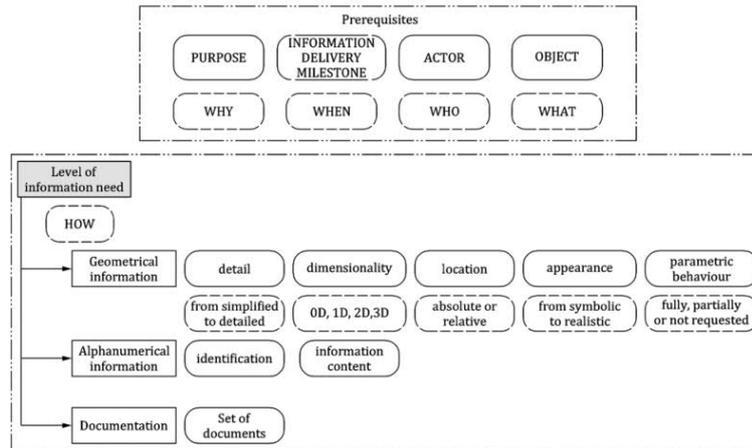


Figure 8 - Relationship diagram on level of information need. (“EN 17412-1:2020,” 2020; “ISO 7817-1:2024,” 2024)

The information is divided into geometrical, alphanumerical and documentation as shown in the Figure 8.

Geometrical information

The geometrical information described by the ISO 7417-1:2024 contains aspects such as detail, location, appearance, parametric behaviour etc. For the geometrical information of an object or system, the previous independent aspects should be specified, if not relevant to the elements, “not applicable” should be used.

Location, according to the standard, can be absolute or relative. Absolute location concerns a reference point attached to a coordination system and relative concerns another object (“ISO 7817-1:2024,” 2024), like the alignment for linear infrastructure projects.

Alphanumerical information

Alphanumerical information should be linked directly to a data template according to the EN ISO 23387:2020 for the data structure and to the EN ISO 23386:2020 for the properties. The identification is used to place the element according to a breakdown structure. The alphanumerical information can be divided into identification and information content. Examples of identification are name, type name, classification, codification, etc. The information content is the alphanumerical data used to populate objects in order to fulfil a purpose defined by the EIR (Exchange Information Requirements).

Documentation

The documentation defines the set of documents to be delivered according to the object type. Possible types of documents may include reports, specifications, manuals, photographs, signed documents, etc. Documentation can also be assigned as “not applicable” according to the milestone or the purpose of the Level of Information Need.

2.2.3. Library of objects

The ISO 22014:2024 standard was developed to describe the best practices for the creation of library objects. These libraries are essential for BIM workflows and organizations, as they enable the reuse of objects across teams and projects. Reusing objects enriched with structured metadata, parametric behavior, and graphical symbols helps save valuable resources and enhances productivity among project stakeholders (“ISO 22014:2024,” 2024).

In Switzerland, for example, the *Office Fédéral des Transports* (OFT), the authority responsible for approving railway projects, does not yet operate with a BIM-based process. As a result, symbolic representations of the railway projects using 2D computer aided design (CAD) are required to support their construction approval procedures. Generating these symbolic representations from BIM models is only possible with a well-structured and vast library of objects.

Despite their relevance, the symbolic representation of objects as presented by the ISO 7519-1:2025 standard and national guidelines falls outside the scope of this dissertation.

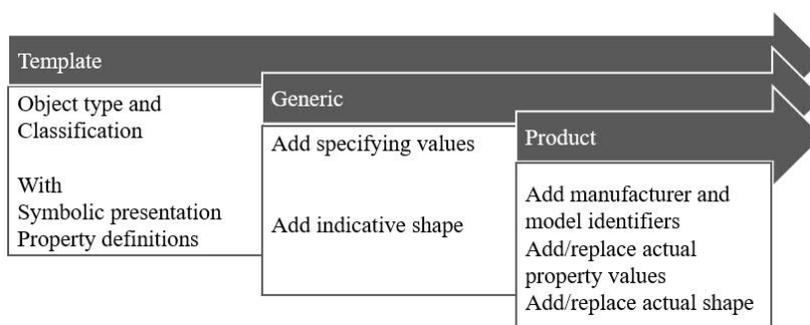


Figure 9 - Example of upgrading a library object. (“ISO 22014:2024,” 2024)

Figure 9 summarizes the differences between template, generic and product library objects according to the ISO 22014:2024. For the purposes of this dissertation, the focus is placed on generic library objects considering the refurbishment purpose of the case study. According to the ISO 22014:2024, when possible, objects need to be classified according to the IFC schema.

Several public libraries of objects, without evaluating if they serve all the purposes described by the ISO 22014:2024, are available for open use and download. Unfortunately, these libraries concern mostly real estate projects, not infrastructure projects (Seo and Lee, 2020). Moreover, the parametric templates used for modeling linear objects in the context of railway and tunnel projects are not openly available and are not specifically mentioned in ISO 22014:2024. As described by Seo and Lee, (2020), these templates need to be based on 2D cross-sections, which change in accordance with the alignment they are based on. The 3D object created is a result of the 2D template following the alignment and the information contained in it, like the cant, for railway projects.

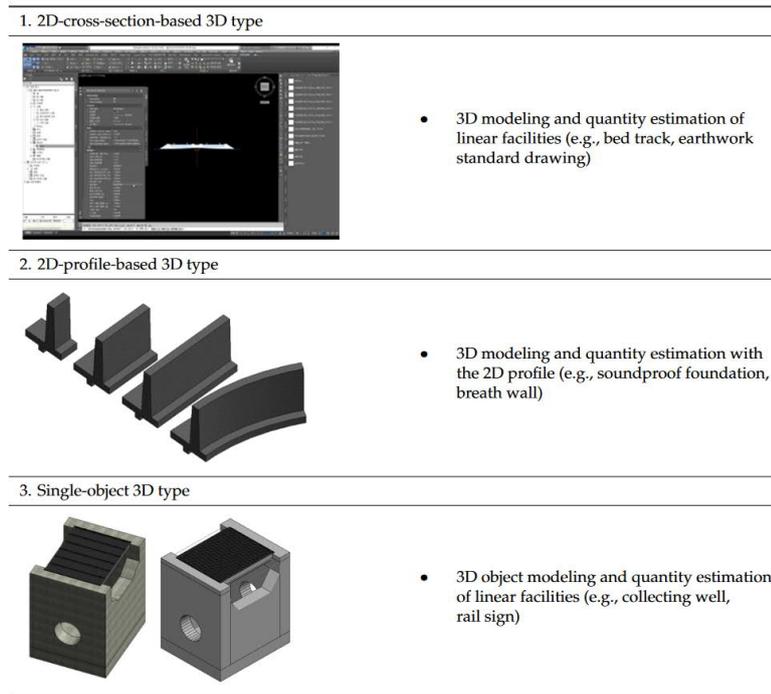


Figure 10 - Types of libraries for infrastructure projects. (Seo and Lee, 2020)

2.2.4. Existing conditions modelling in the framework of ISO 19650

In light of the ISO 19650-1:2018, the Level of Information Need, alongside process maps and interaction/transaction maps describes exchange information requirements. Geometrical information, alphanumerical information and documentation are considered information containers used in exchange transactions, which ultimately result in information deliverables in the form of a Project Information Model (PIM) or an Asset Information Model (AIM).

A model or dataset is referred as Project Information Model (PIM) during the briefing phase till construction phase. After handover, it becomes the Asset Information Model (AIM), which supports the operation and maintenance phase. The Asset Information Model represents a single source of approved and validated information. It can be created by surveying the existing conditions of the asset using methods such as laser scanning or photogrammetry and compiling this geometrical data with corresponding alphanumerical information.

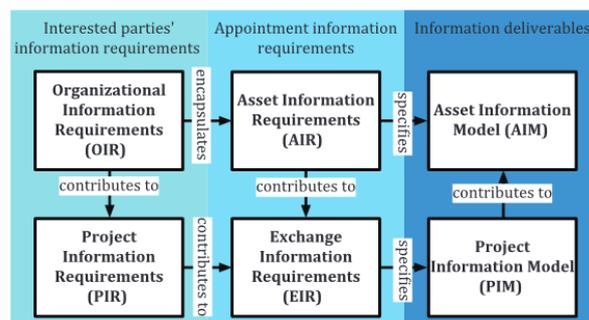


Figure 11 - Hierarchy of information requirements. (“ISO 19650-1:2018,” 2018)

In the case of existing railway assets without existing AIMs used for their operation and maintenance, the existing conditions model occupies an intermediate position between the AIM and the PIM. Its purpose is to support integration into a new system while being based on the current state of the asset.

Figure 12 presents a diagram illustrating the relationship between the standards mentioned in the previous chapters and the concepts of EIR, Level of Information Need, PIM and AIM through the eyes of the ISO 19650 series.

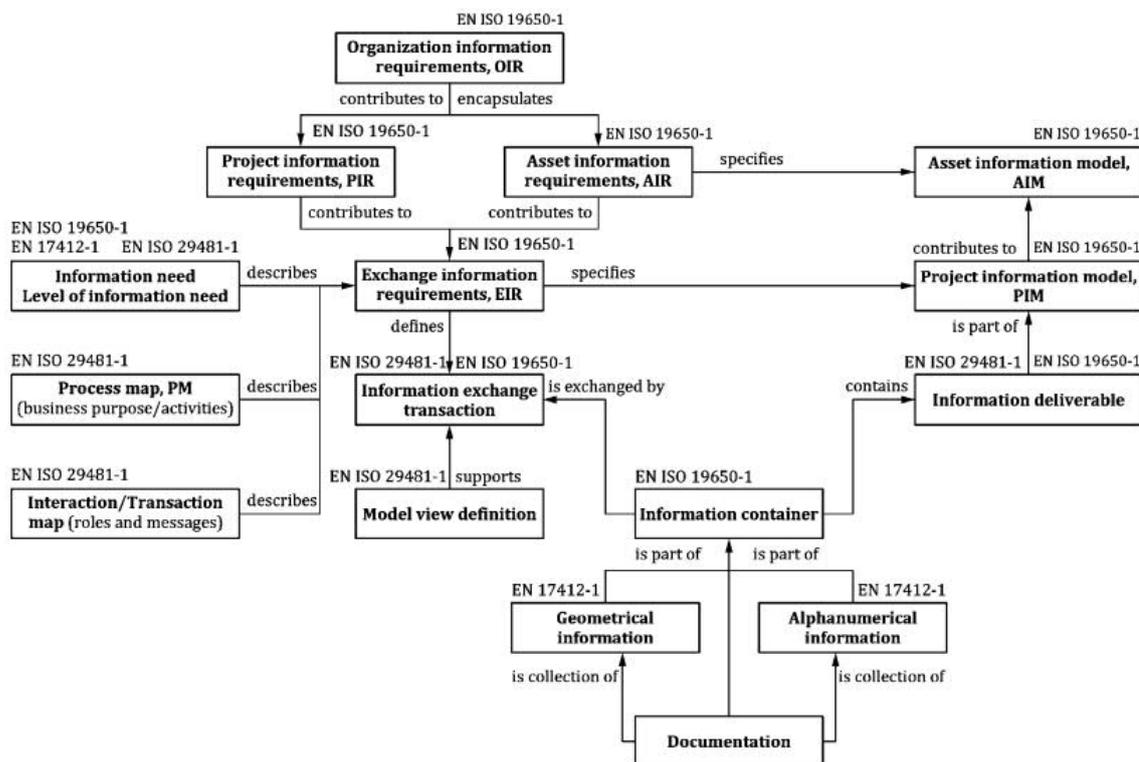


Figure 12 - Conceptual relationships between the EN 17412-1:2020 and the ISO 19650-1. (“EN 17412-1:2020,” 2020)

2.2.5. IFC 4.3

After a robust development process, bSI (buildingSMART International) has published the IFC 4.3 as an international standard in March 2024, the ISO 16739-1:2024. This means it is ready for users to use and for vendors to implement. The IFC 4.3 is the first to include linear assets, such as roads, railways, and other infrastructure domains.

The preparation for the addition of the railway domain started in 2015 by the China Railway BIM Alliance publicly released the first IFC Rail Specification standard for the railway industry at buildingSMART. These became the foundation of the IFC Rail project proposal and the IFC Rail consortium (“IFC Rail Project Context & Approach,” 2019). The stakeholders of the IFC Rail Project included software vendors as well as national railway operators. Among them was SBB, representing Switzerland.

IFC as a source of data

The IFC schema is set in a way to organize data through classes, describe alphanumerical and geometrical information efficiently. The IFC appears as the most popular data dictionary on the buildingSMART Data Dictionary page (“buildingSMART Data Dictionary - buildingSMART International,” 2024). It can be used as a data dictionary and data template, considering it decomposes complex data using a breaking down structure and has a list of properties grouped in Pset according to use cases for determined object types and classes. Every property has a data type, units and a semantic definition.

These properties appear in the Resource Layer of the IFC architecture overview as seen in Figure 13. The resource layer is the lowest in the IFC architecture, this layer contains resource definitions that cannot be used independently of an entity at a higher level. These are the IFC entities that appear in the bsDD.

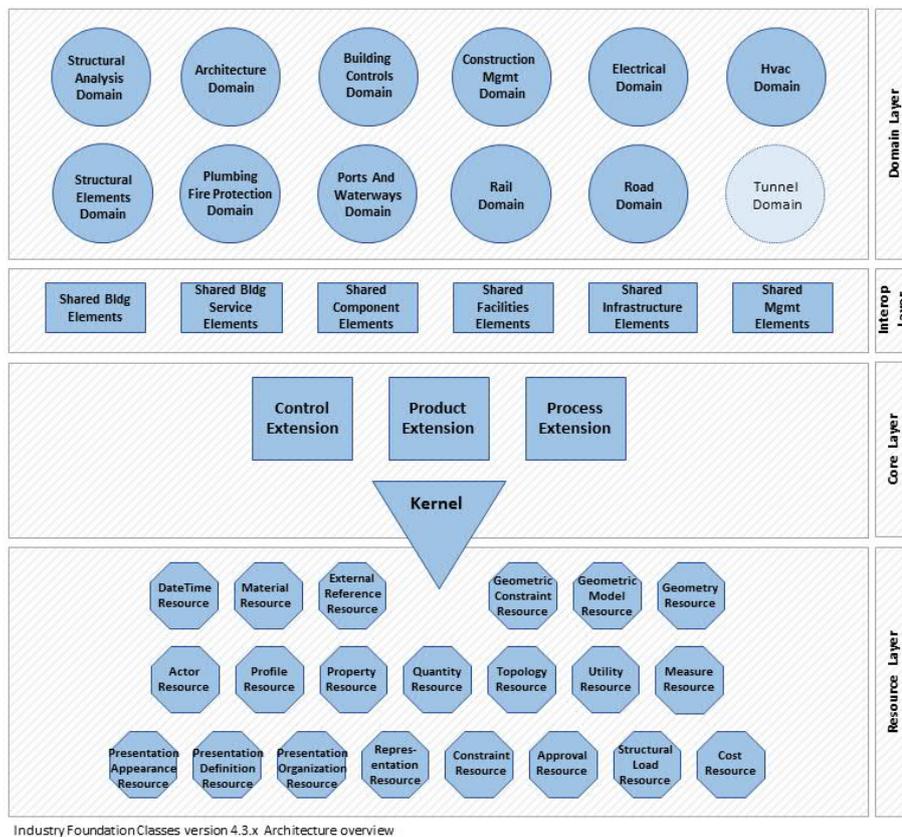


Figure 13 - Industry Foundation Classes version 4.3.x Architecture overview. (“Introduction - IFC4.3.2.0 Documentation,” n.d.)

IFC for linear infrastructure

In that context, the *IfcObjectPlacement* establishes how the object is placed in space. This placement can be absolute according to a world coordinate system, relative to another object or constrained by grid axes (virtual intersection and reference direction given by two axes) or to a linear placement using distances along a curve and possible offsets (“8.7.3.15 IfcObjectPlacement - IFC4.3.0.1

Documentation,” n.d.). This entity is mandatory if the object is represented in the model. Its representation type, absolute, relative or constrained is determined by the subtypes of *IfcObjectPlacement*.

While previous versions of the IFC schema proposed that objects would be placed in a coordinate-based cartesian approach (XYZ), from version 4x1, IFC proposes an alignment-based approach. This new way of placing and describing geometry is more efficient for linear infrastructure models (Jaud et al., 2021). What makes the IFC schema remarkable is the addition and consideration of the entity *IfcAlignment*.

The IFC 4.3 official documentation describes three model view definitions (MVDs): Reference View, Alignment Based Reference View and Design Transfer View. In theory these three MVDs should represent increasing levels of implementation (“Introduction - IFC4.3.2.0 Documentation,” n.d.). Specifically, the Alignment Based Reference View would be critical for the placement of objects in linear BIM models, allowing their location to be specified according to stations or mileage in an alignment entity, as shown on Figure 14.

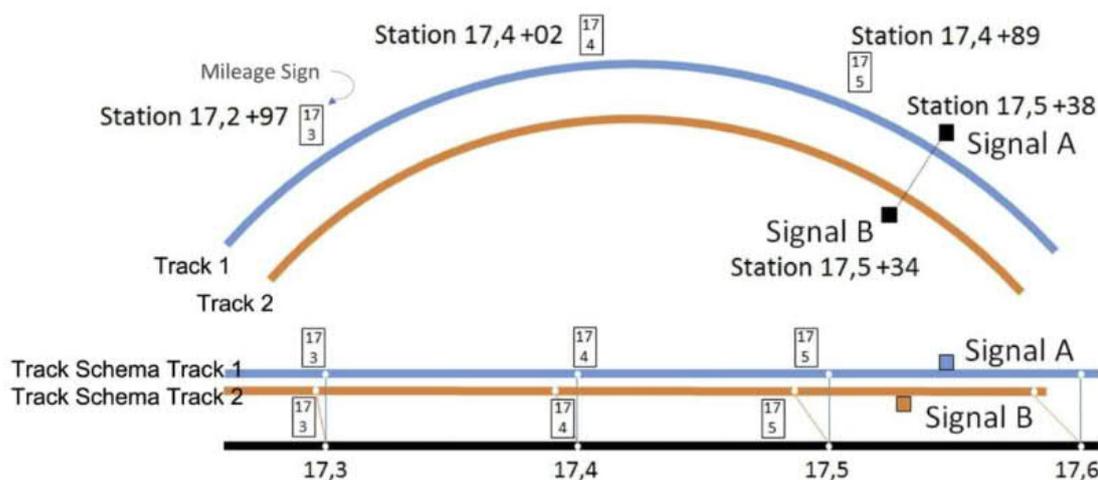


Figure 14 - Stationing on Alignment. (“Applying IFC 4.3 for Rail Project - buildingSMART International,” 2022)

The IFC 4.3 also defines a vertical and longitudinal separation for railway parts. It is similar to what the entity *IfcBuildingStorey* is for real estate projects: it creates a spatial structured container for the objects. An example of vertical organization is seen in Figure 15 and an example of longitudinal organization is shown in Figure 16.

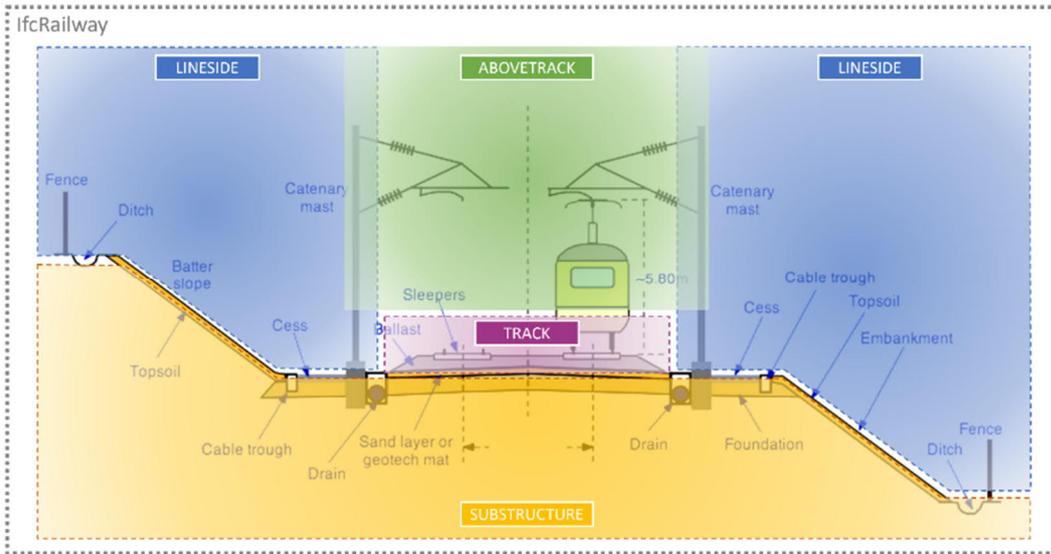


Figure 15 - Example of usage of *IfcRailwayPart* to organise elements vertically. (“7.8.2.2 *IfcRailwayPartTypeEnum* - IFC 4.3.2 Documentation,” n.d.)

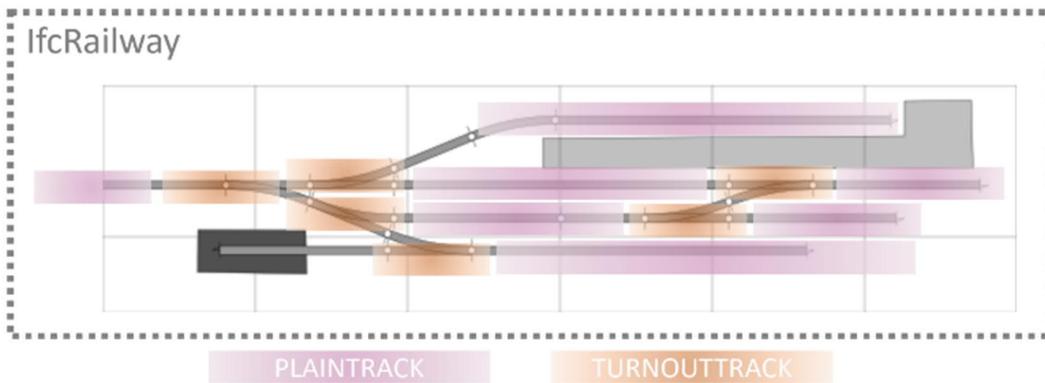


Figure 16 - Example of longitudinal organization for the *IfcRailwayPart*. (“7.8.2.2 *IfcRailwayPartTypeEnum* - IFC 4.3.2 Documentation,” n.d.)

During the writing stage of this dissertation, the IFC for Tunnel was still not a part of the published IFC schema and ISO. The IFC Tunnel Project continue to work on it as a part of bSI’s Infrastructure Domain. Figure 17 shows an example of how the *IfcAlignment* entity interacts with the *IfcTunnelPart* and how the vertical organization of the elements would be done according to different level of detail.

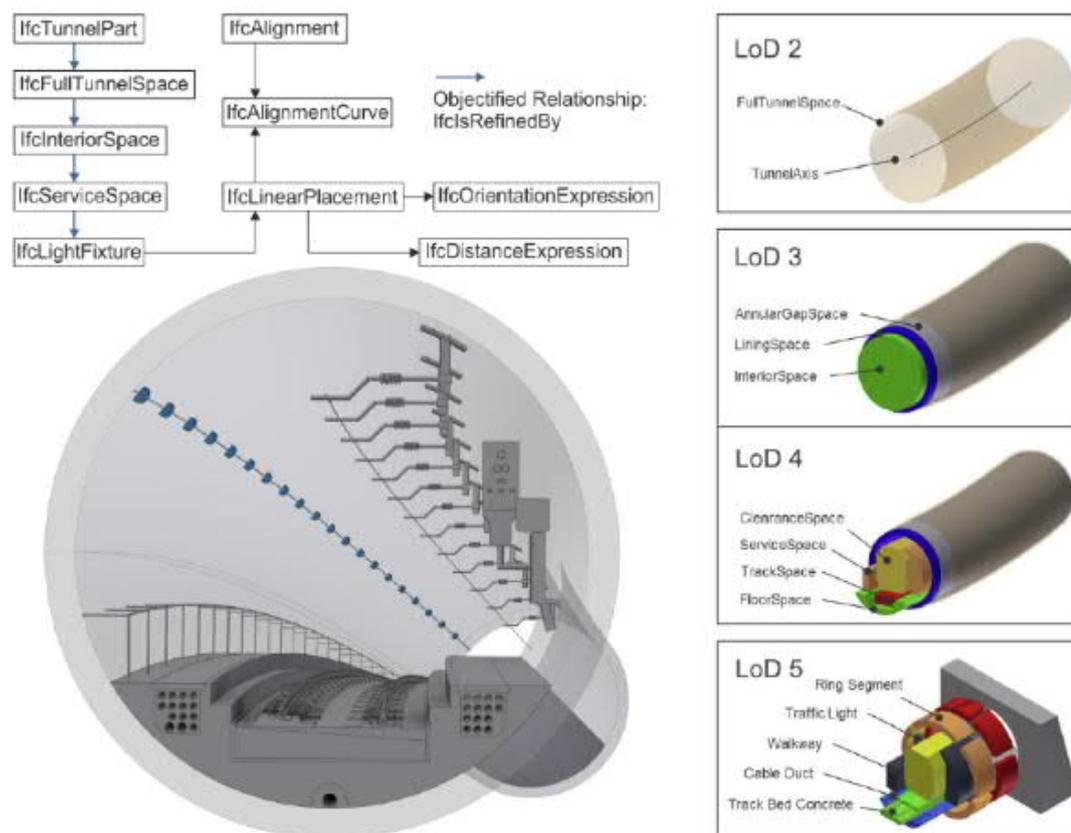


Figure 17 - Placement of lighting objects in the visualization of an IFC tunnel model described in the IFC Tunnel proposal. (“Linking BIM and GIS Models in Infrastructure by Example of IFC and CityGML,” 2017)

2.2.6. Crossrail Asset Data Dictionary

The Crossrail Asset Data Dictionary was developed to fulfill their needs for structured data. Crossrail has over 400 different classes of assets regarding tunnels, railway systems etc which makes it a good reference for railway projects in general. It defines Facility, System and Asset classes. The last one represents physical items according to their class/type. It also creates a relationship between assets, systems and facilities. Moreover, the Asset Data Dictionary (ADD) relates specific attributes to classes' specific information requirements (“Crossrail Asset Data Dictionary,” n.d.). Each class is supported by the Asset Data Dictionary Definition Documents (AD4s). AD4s are provided to ensure consistent interpretation of data (“Crossrail Asset Data Dictionary,” n.d.).

In order to organize the information, Crossrail created an Asset Breakdown Structure (ABS). This ABS is used to classify data in the Crossrail Asset Data Dictionary. The structure is made of:

1. Facilities;
2. Primary Functional Units (PFUs);
3. Functional Units (FUs). (“12C-06_Crossrail-OM-Information-Guide-LL.pdf,” n.d.)

Facilities mean station, track, platform and etc; a PFU is the system and the FU a sub-system. One example is a rail weld. The facility is “Track Facility”, the PFU is “Track System Plain Line” and the FU is “Slab/Ballasted Track”.

2.2.7. FDK - Technical Data Catalogue from SBB

The FDK is one of the main outcomes of the BIM@SBB initiative described in Chapter 2.1.2. Each object type contains attributes defined by groups of data specialists inside SBB’s departments, like track, traction current, railway and so on. The company’s idea is to keep improving the data catalogue while receiving feedback from the pilot projects and gaining more experience with infrastructure projects using the BIM methodology. That’s also why the catalogue is hosted on a webpage in order to be updated constantly. A consolidated version is published regularly and attached to the documents for procurements. An interesting characteristic of the FDK is inherited by its country of origin, every object has its object name property translated to four languages: German, French, Italian and English.

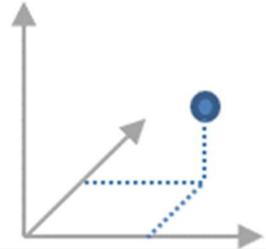
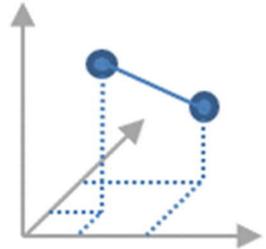
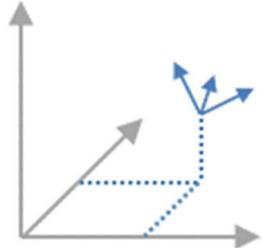
Moreover, the FDK was not developed to focus only on the Project Information Model, but also to contain properties used for the Asset Information Model during O&M phase which makes a data source for the whole life cycle of the asset. The FDK is structured by dividing the objects into systems. This separation into systems was made to include not only railway projects but also mixed projects between real estate and infrastructure. The catalogue can be consulted according to “departments” or “disciplines”: alignment, railway, cable carrier segment, energy, telecommunications, cable systems, bridges, tunnels, signaling, geotechnics and buildings.

For now, the FDK focus on alphanumerical properties and does not define geometrical properties, only placements, or levels of geometric information (“FDK - Objekttypen,” n.d.). The properties applied are grouped into property sets. Each element contains at least an Object ID, Object Name, Functional description, Spatial localization and IFC Class according to different IFC versions. Moreover, attributes are also classified by property ID, property name, functional description, format/data type, unit and example.

FDK has an interesting way of defining the location of objects regarding an alignment, which is not found in other data catalogues and complies with the new IFC 4.3 strategy. The property group *L* refers to the type of spatial reference used for the object or localization system. This classification is not used for building construction, only for linear infrastructure projects and the reference options can be seen on the Table 6.

Table 6 - Spatial references for objects according to the FDK. (“FDK - Deckenstromschiene (DSS),” n.d.)

<p>linear, point</p>	<p>The object type is located in a linear reference system, ie has a reference to a "reference axis" (route reference, track edge reference) with a distance specification and optionally a transverse position and a height to the reference axis.</p>	
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linear, line	Object type is located linearly in a linear reference system, ie has a start and end reference on a "reference axis" (route reference, track edge reference) each with a distance specification and optionally a transverse position and a height to the reference axis.	
planar, point	The object type is located in a point in a Cartesian coordinate system, ie it has x, y and z coordinates	
planar, line	Object type is located linearly in a Cartesian coordinate system, ie has start and end x, y and z coordinates	
Planar, surface	The object type is spatially located in a Cartesian coordinate system, ie it has a polygon with support points that each have x, y and z coordinates	
Topological	Object type is "located" indirectly through a relationship to another object type. At the beginning of a topological relationship chain, there must be an object that has one of the above references.	

Taking the example of the object *Rail joint welded* from the FDK website, it is possible to see that each object has an object ID, a picture, and a description to make the identification of the objects easier. Figure 18 shows a screenshot from the FDK website containing the elements mentioned above.

Rail joint welded

Subject: road
ID: OBJ_FB_14



description

- Seamless transition between two adjacent rails
- Electrically connected
- Special quality requirements to ensure the continuous load-bearing capacity of the running rail (particularly temperature fluctuations in the seamlessly welded track)
- Radius dependent

Figure 18 – FDK catalogue showing the description of the Rail joint welded object according to the FDK. (“FDK - welded rail joint,” n.d.)

Also, every object in the FDK catalogue has an IFC mapping according to the IFC version. It clearly shows the transformation in the class structure from IFC 2x3 to IFC 4. IFC 2x3 had the rail weld classified as a generic object called *IfcBuildingElementProxy* and IFC 4 classifies it as *IfcFastener* with a specific predefined type of *WELD* as seen in Figure 19.

IFC mapping

version	class	Type	predefined type
IFC 2x3	IfcBuildingElementProxy	IfcBuildingElementProxyType	CUSTOMIZED
IFC 4 ADD2 TC1	IfcFastener	IfcFastenerType	WELD
IFC 4.3 RC4	IfcFastener	IfcFastenerType	WELD

Figure 19 - FDK's IFC mapping for the Rail joint welded object. (“FDK - welded rail joint,” n.d.)

The FDK also has a suggestion of the phase that the element should be modelled/showed in the project (Figure 20). The phases are shown according to the service phases of SIA 112 (The Swiss Society of Engineers and Architects).

Project phase

Use in the following project phases planned (dark background):



Figure 20 - FDK's project phases' use for a Rail joint welded object. (“FDK - welded rail joint,” n.d.)

Another interesting feature of the FDK is that it shows the other types of elements that may contain the object. For instance, a rail weld can be used in a “track grid”, “points grid”, “expansion grate” and “track cutting grid”. This section of the page contains links to the FDK page of the objects mentioned, creating a relation between them. Moreover, one of the alphanumeric attributes is to define if the weld belongs to the track grid or to the switch grid.

2.3. Modelling for infrastructure

Building Information Modeling, as the name says, was originally developed for buildings, which are circumscribed geographically, not linear infrastructure. As infrastructure projects in general and more specifically railway projects evolve in complexity and number of actors, BIM appears as a resource to enhance project efficiency and management. Nevertheless, there is an important gap between the level of application of BIM for buildings and its application for infrastructure projects (Šarkiene, 2020).

Another challenge in the railway domain is the age of existing infrastructure. Considering this, many assets are in need of refurbishment and to be more efficient and comply with the BIM policies being adopted worldwide these projects need to be developed using the BIM methodology. This fact implies the application of existing conditions modelling, which allows to plan the intervention and correctly integrate the new system into the existing one.

2.3.1. Point cloud survey methods for tunnels and railways

There are different ways of surveying an existing railway. One of them is using a train-borne lidar system. This method was used for the High Speed Two (HS2) project in the UK (“Using Train-Borne Lidar to improve design confidence in railway electrification,” n.d.) and by Ciccone et al. (2022) in Italy. It consists of equipping the front of a train with cameras and laser scanners. The resulting data can be used for signal sighting, for overhead contact line design and even for marketing. One of the advantages of this system is running it without the need of blocking the track and disrupting service (“Using Train-Borne Lidar to improve design confidence in railway electrification,” n.d., p. 2). Another method used for surveying railway assets without disrupting service is the photogrammetry by drone (Ciccone et al., 2022). The last one cannot be used inside tunnels, so it was not further studied.



Figure 21 - For railway lines outside tunnels, the methods used are (a) drones and (b) autonomous railway vehicle. (Ciccone et al., 2022)

Another survey method that may apply inside railway tunnels is the use of a terrestrial laser scanner. This method is only advised for short distances since it requires technicians to move the equipment after

each measurement. Given this limitation, the autonomous railway vehicle is the most efficient method for surveying long railway tunnels without interrupting service.

After a survey is concluded, the point cloud data needs to be processed. The method proposed by Cheng et al., 2019 (Cheng et al., 2019) for modelling parametric elements inside a railway tunnel consists of classifying the point cloud into several categories to facilitate the modelling process. This type of classification is called “semantic”. In their case study, they segmented the model into five types of tunnel components, namely rails, cross-sections, pipes, catenary equipment and refuges.

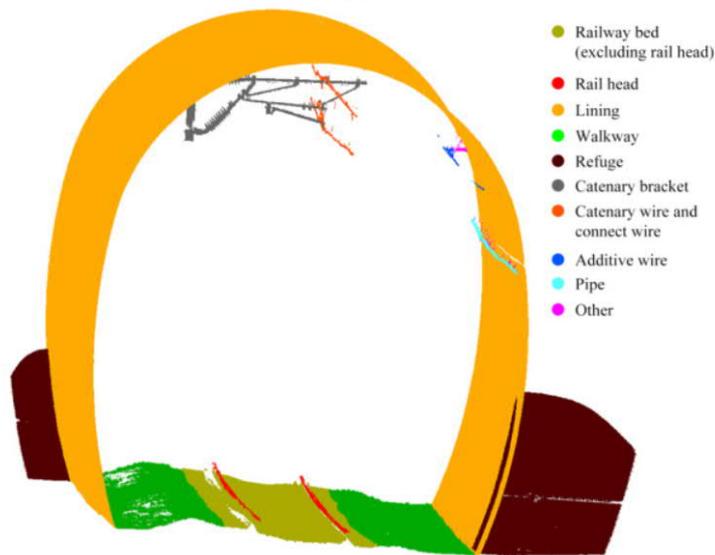


Figure 22 - Colored point cloud representing the segmenting technique proposed by Cheng et al., 2019.

Another example of the use of semantic classification is shown by Soilán et al. (2021). In his case study, the signal elements were also classified as shown on Figure 23. In both case studies the alignment was generated using the segmented rails from the point cloud data.

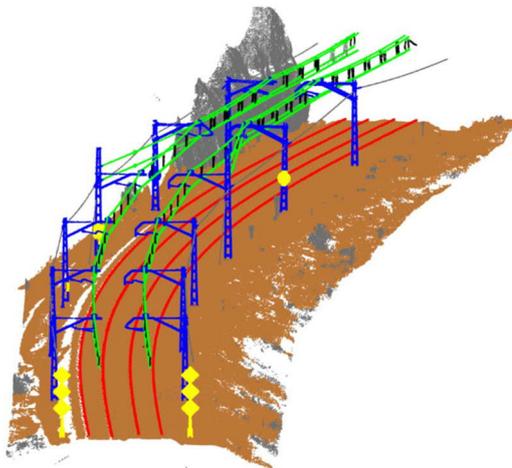


Figure 23 - Semantic segmentation of a railway section. Rails (red), masts (blue), droppers (black), wiring (green) and signs (yellow). (Soilán et al., 2021)

Figure 24 summarizes the workflow for creating an existing conditions model from survey data. Further explanations on modelling linear infrastructure are provided in Chapter 2.3.2.

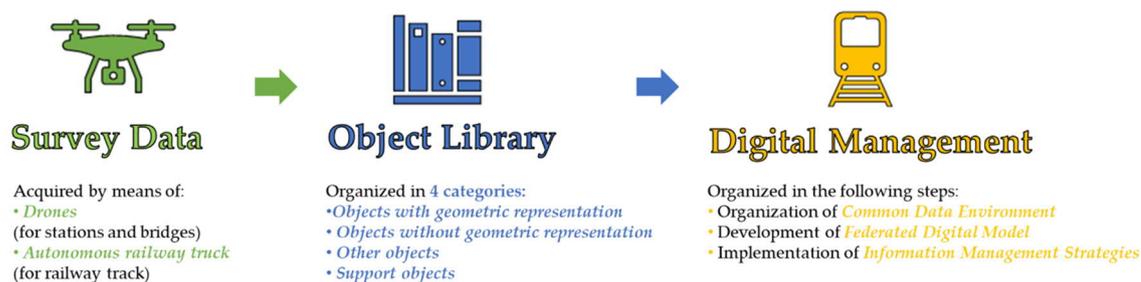


Figure 24 - Definition of a digitalization strategy for existing railway infrastructure. (Ciccone et al., 2022)

2.3.2. Differences between modelling buildings and linear infrastructures

When modelling infrastructure, two types of assets can be found: point assets and linear assets. Point assets are found in one location and can normally be determined by a single point representing its geometrical center. Examples of point assets are cabinets, doors, luminaires, signals, catenary supports and etc. Linear assets have the start and end in different locations, like rails and ballast. Examples of linear assets are cables, pipes, ducts and rails. (“12C-004-01_Asset-Tag-and-Equipment-Label-Guidance-7.0_Redacted.pdf,” n.d.). Table 6 shows different ways an object can be referenced in space. Table 6 - Spatial references for objects according to the FDK. (“FDK - Deckenstromschiene (DSS),” n.d.)

To develop BIM models, several software vendors have created BIM authoring tools. However, implementing these tools to represent information models dependent on alignment is still a major challenge (Kwon et al., 2020). While most BIM modelling platforms focus on buildings, other platforms focus exclusively on alignment-based modelling, considering a cross-section that follows an alignment to create a 3D object. Despite being capable of modelling a few of the elements of railway tunnel projects, these software struggle to model discontinuous structures, such as sleepers (Kwon et al., 2020).

To produce a linear infrastructure model, the objects composing it need to come from a software capable of considering 2D cross-sections and alignments when modelling; and an object-based software capable of creating 3D objects (Seo and Lee, 2020).

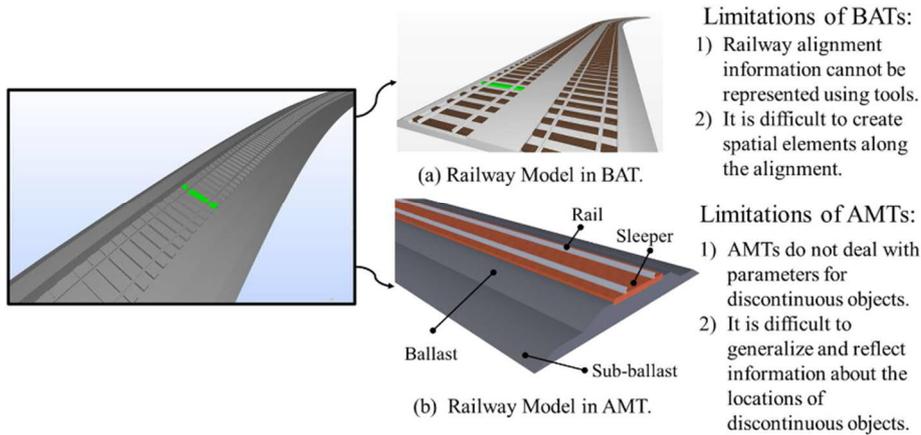


Figure 25 - Software representation of railway track: (a) A railway model based on building information modeling authoring tools (BATs); (b) a railway model based on alignment-centered modeling tools (AMTs). (Kwon et al., 2020)

Studies on the application of the IFC for linear infrastructure projects started as early as the development of the *IfcAlignment* entity for the IFC 4x1. An example is the work done by Kwon et al. (2020). A few works show the implementation of the IFC for modelling existing railway assets. Ciccone et al. (2022) used the IFC 4x2 as an open exchange information format for the Canello-Benevento Railway Line. For brand new projects, the Copenhagen Metro team presented their IFC 4.3 based workflow in Autodesk’s Rail Summit 2024 (“Update on IFC 4.3 for Rail and Infrastructure,” 2025).

3. USE CASES DEFINITION AND CORRESPONDING LEVEL OF INFORMATION NEED APPLIED TO THE CASE STUDY

3.1. Description of the case study and use cases

The case study is situated in Switzerland. The total length of the line is 23 km, of which approximately 500 m were in a tunnel passing underneath a busy city. At the exit of the tunnel, in the city center, the train ran in a shared space with road traffic. As a result, speed had to be decreased, and operation resembled that of a tram, relying on the conductor's ability to detect possible collisions.

Considering the increasing demand for public transportation in the region and the need to assure better safety, the operator decided to increase the frequency of trains operating on the line and extend the length of the existing tunnel. The added tunnel is 1600 m long, placing the line underground beneath an avenue between two existing stations. The resulting underground structure measures 2200 m and includes two underground stations, an intermediate ventilation shaft, and two underground emergency exits. These works help reduce the risks associated with mixed rail-road traffic and address the increase in service frequency. This tunnel is the focus of this dissertation work.

GESTE Engineering SA, the company where this dissertation was developed, specializes in mobility and safety, with a particular emphasis on rail, urban and road transport engineering (GESTE Engineering SA, 2025). Together with its partners, GESTE was responsible for the general project management for the construction of the new tunnel and the integration with the existing infrastructure.

Among all the technical domains involved in the project, GESTE was responsible for all the railway equipment, including rails, turnouts, the catenary system, the signaling system, cables, ventilation systems and more. GESTE oversaw these activities from preliminary studies to commissioning (SIA phases 21 to 53) and participated in managing the interfaces with the requirements of the project manager, the operator, and other contractors, particularly civil engineering. Figure 26 shows the train during testing, in which GESTE Engineering SA played a key role in ensuring safety prior to its opening to the general public on 15 May 2022.



Figure 26 - Train during testing inside the finished tunnel.

For the purpose of this case study, 240 meters of the tunnel, including its railway system were analyzed. The selected section does not include any turnouts. Turnouts are complex assemblies of components used to deviate rolling stock from a track onto another one next to it (Gigante-Barrera et al., 2017) and are usually more complex to model. They represent a discontinuity within the track grid making modelling them more challenging. In order to model this type of element a point cloud may not be enough, detailed plans or manual measurements using specialized equipment are often required. When modelling existing conditions the turnouts are usually not modelled with a major level of geometrical detail to avoid onerous work.

The case study comprises of an electrified railway system. Specifically, the case study uses a Rigid Catenary System consisting of an extruded aluminium profile clamping the contact wire that sends energy to the pantograph of the rolling stock. The aluminium profile is held in place by catenary supports attached to the tunnel's vault. This system is often used in tunnels with smaller sections because it involves fewer components than conventional catenary, thus taking less space. Moreover, the modeled zone is composed of a ballastless slab track, more often used nowadays due to maintenance. The track width is 1.0 m. Figure 27 shows the studied zone of the tunnel right before handing over to the operators, at the time the point cloud was done.

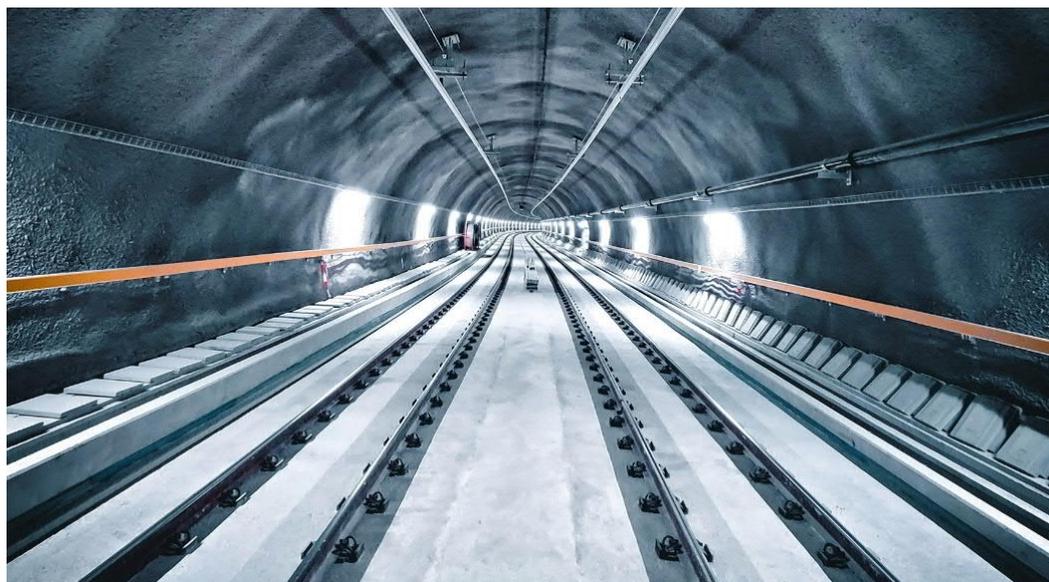


Figure 27 - Photo taken before handover of the tunnel. (GESTE Engineering SA, 2022)

When looking at the ISO 19650 series, the case study is positioned between an Asset Information Model (AIM) and a Project Information Model (PIM) as seen in Chapter 2.2.4, Figure 11. The project was developed using the traditional delivery method rather than BIM, so there was no model that could be used as a basis to develop an AIM. Moreover, the line operator is currently working on its processes to use models for Operations and Maintenance (O&M), but this is not yet the case.

Finally, the existing conditions model created as part of this dissertation serves the same purpose as most infrastructure existing conditions models: refurbishment. Since this model would be used at the beginning of a new project to integrate the built systems with new ones, it is considered as a PIM for the purpose of this study. The use cases (UCs) applied are an extract of the BIM@SBB standards (“Documents, media and contacts BIM @SBB | SBB,” n.d.), more specifically, the “*Catalogue des prestations BIM*”, or “*BIM Services catalog*” in free translation:

- UC-24 : Provide existing conditions models for project studies: existing conditions models are created and made available. The foundational data is collected or aggregated from inventory systems and third-party sources, and prepared as discipline-specific digital models.
 - UC 24-3: Survey for discipline-specific digital models of existing conditions according to specifications, and creation of the point cloud model.
 - UC 24-4: Model and review discipline-specific digital models until the requirements are met.
- UC-25 : Make digital models available during planning and construction: discipline-specific models are created using the appropriate BIM authoring tools, in the required quality, and in accordance with the EIR specifications.

3.2. Selection of objects

The non-exhaustive list of objects identified within the tunnel can be found in Appendix 1. It represents the main objects found in the tunnel and it does not go into further detail about their types and/or

components. Also, the list does not include electrical elements such as cables, which may range from low to high voltage, as well as optical fiber cables used for communication systems.

Three objects were chosen from the list in Appendix 1: the rail, the catenary support and a signal. All three objects are classified and have entities according to the IFC 4x3 schema, allowing this dissertation to compare the data that could be exported. More details are given in sections 3.2.1, 3.2.2 and 3.2.3. Other objects were also modeled within the tunnel, but their PDTs and Level of Information Need were not studied in detail due to time constraints. Therefore, these additional objects are not included in the discussion of Chapter 3.

3.2.1. Rail

Among the most important elements in a railway system is the rail grid itself. The alignment is the basis and the reference for every element inside a railway tunnel. Moreover, it is one of the elements that most needs to be inspected, renewed and whose presence, by definition, is a constant in any railway project.

Rail degradation may cause derailment, which is the most critical type of accident in railway operations. Therefore, choosing these elements properly during design phase and maintaining them during O&M phase is highly important for assuring passengers' safety. Some of the objects were chosen because they may represent a risk for derailment, as seen on Figure 28. Among these objects is the rail itself. Gigante-Barrera described these elements for risk mitigation using the LOD concept in 2017, before the publishing of the Level of Information Need standard as seen in Section 2.2.2.

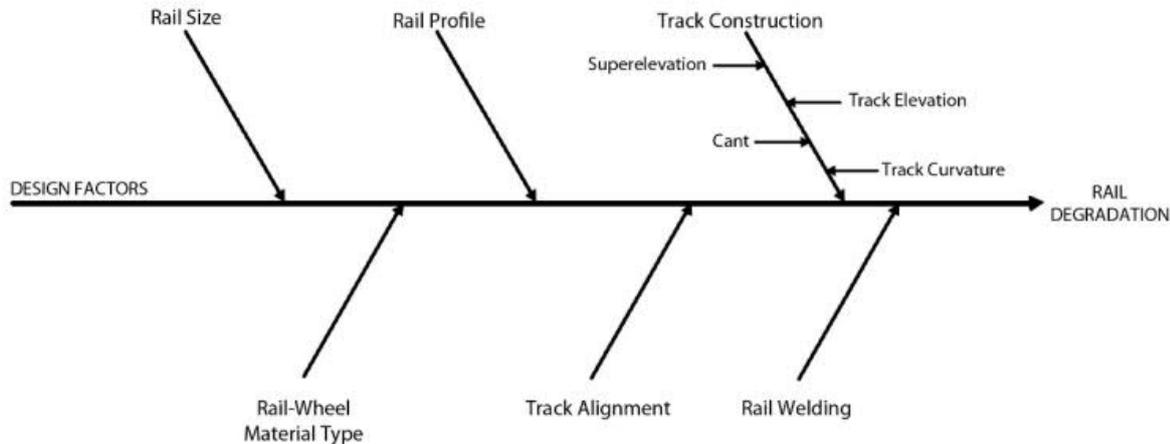


Figure 28 - Cause effect diagram on design factors causing rail degradation. (Gigante-Barrera et al., 2017)

Due to the way a railway track is calculated and designed, modelling it requires specific knowledge and specialized software. The rail is a linear object that depends strictly on the alignment to be modelled and exported to IFC. According to the work of Seo and Lee, 2020, the rail could be classified as a “2D-profile-based 3D type” in a library of objects. This means the object is built from the extrusion of a profile. In the case of rails, it uses standardized rail profiles that need to be reconstructed in softwares. This extrusion follows the railway alignment, which contains information specific for it since it is not a simple extrusion along a 3D line. More about railway alignments is explained in Section 4.2.3.



Figure 29 - Rails in the tunnel of the case study. Picture taken by the author.

3.2.2. Catenary support

Another system for which assessment is crucial in the refurbishment of the railway is the power supply. Along with the rails and the signaling system, it is an essential part of the railway, without it the line cannot be operated. Its nature differs significantly from that of the rail. While the rail is mainly characterized by its profile and mechanical properties, the catenary system is primarily defined by its electrical properties, providing an interesting set of data to analyze.

As explained in Section 3.1, the case study uses a rigid catenary support system. In this context, the object chosen is the catenary support attached directly to the tunnel's vault by metal rods. The metal rods were attached to the vault's structure before the sprayed concrete layer. Then, after spraying the concrete, the prefabricated catenary supports were attached to the rods. Considering the irregularity of the sprayed concrete, it's relevant for the operator to know the placement of these supports since they may affect the contact wire that sends energy to the rolling stock.

Moreover, a catenary support is a repetitive element even if it's punctually placed. When modelling linear infrastructures, it is important to automate processes when possible, making modeling affordable since often repetitive. According to Seo and Lee, 2020, these elements may be considered as "Single-object 3D types" since they are not created from a profile or a cross-section. It is an object that fits the framework of ISO 22014:2024 discussed in Section 2.2.3, it is a library object that can be used for different purposes across companies and projects, it was not specifically created for the project.



Figure 30 - Catenary support in the tunnel of the case study. Picture taken by the author.

3.2.3. Signal

Finally, the last object selected is a railway signal. Signals play a critical role in ensuring operational safety and must be regularly inspected and maintained. Across Europe, signaling systems are undergoing significant changes, transitioning from fully visual systems to technologies that transmit signals directly to the rolling stock. GESTE Engineering SA is involved in several projects led by railway operators, focused specifically on the refurbishment of these systems.

Moreover, signaling systems vary in type and function across countries, so analyzing how the IFC 4x3 property sets and structure may adapt to the needs of a specific region is relevant to this dissertation. For this kind of object, the properties associated with its type are important, along with the properties related to the light bulbs that generate the visual instructions for the conductor.

Signaling elements are punctual, non-repetitive, and manually positioned in a model. The geometry of the signal in Figure 31 is unique and was developed specifically for the shape and constraints of the case study tunnel. Respecting its geometry and correct placement when modelling the existing conditions in the tunnel is a must since it is a visual element for the train conductor. Therefore, if the rolling stock is upgraded or additional elements are introduced into the tunnel, the visualization of this element needs to be verified during the refurbishment design phase.



Figure 31 – Railway signal in the tunnel of the case study. Picture taken by the author.

3.3. Comparing data references

For this case study and dissertation work, three data references were chosen to be mined and contribute to the data template: the Crossrail Asset Data Dictionary, the FDK – Technical data catalogue from SBB and the IFC 4.3. The Crossrail Asset Data Dictionary was chosen because it serves the purpose of a data template for railway and tunnel elements. The FDK was selected as a direct reference to the Swiss Federal Railways, developed by local experts in the domain of railway systems and tunneling. It has become the data dictionary used for every railway infrastructure project by SBB in Switzerland since 2025. Finally, the IFC 4.3 version was chosen because it includes entities related to railway and infrastructure and associated property sets. The three references are further explained in the literature review, Section 2.2.

As explained in Section 2.2.1, Wagner et al. (2022) created a method based on meta-considerations to compare data schemas. Data schemas in Wagner's work are considered from a broader perspective than Product Data Templates, having product information sheets included in the scope of the research. In this case, the methodology for comparing product descriptions can also be applied to Product Data Templates. The 9 meta-considerations proposed by Wagner et al. are evaluated next. The result of the evaluation is summarized in Table 8.

- Open: all three data references used in this dissertation are publicly available and documented. Their structures are accessible and can be interpreted by any stakeholder with the help of the available documentation. IFC's property sets are available on buildingSMART's technical website. The FDK can be accessed online via the BIM@SBB webpage and downloaded as a spreadsheet. The Crossrail Asset Data Dictionary is also available in spreadsheet format. This openness is particularly relevant for the case study in this dissertation, where interoperability and data exchange between different platforms and stakeholders are key concerns. Having access to well-documented, open data references supports the development of the Level of Information Need in the context of this case study.

- Queryable: among the three references, only the IFC 4.3 allows for property queries to a certain extent. As a data schema, IFC has a broader and more complex structure than a data dictionary, which enables querying of properties directly with some limitations. The other two references, the FDK and the Crossrail Asset Data Dictionary, do not support property queries as proposed by Wagner et al., mainly because their data structure is not as complex.

According to ISO 23386:2020, for a data template to be considered a data dictionary, its properties must include attributes defined by a code, a name, a description, an example, a type and a list of possible values. Although the FDK is presented as a catalogue, it could be considered a data dictionary due to its structured format and potential to be linked to a network of data dictionaries. However, for the time being, it is not interconnected with other dictionaries, thus not being part of a network and not being capable of exchanges between experts, users and requests.

In the case of the Crossrail Asset Data Dictionary, objects are classified according to an Asset Breakdown Structure (ABS). While this classification organizes physical objects, the attributes listed in the AIMS table are not structured hierarchically or grouped. All attributes are at the same level, with only specifications such as type and quantity per object. This limits its ability to support property queries as defined by Wagner et al.

- Machine-readable: both IFC 4.3 and the FDK follow naming standards for their attributes. IFC uses CamelCase for naming, while the FDK assigns a unique code to each attribute, which also allows the name to be translated into other languages. The Crossrail Asset Data Dictionary does not include a global unique identifier for its attributes, and its structure presents limitations for use in certain software tools, such as the presence of spaces or special characters in attribute names.

According to ISO 23387:2020, a Product Data Template should be linkable to the IFC schema to be considered machine-readable. This is not the case for the Crossrail Asset Data Dictionary, which does not present a direct connection to IFC. The FDK, on the other hand, relates its objects to IFC entities across different versions, allowing project teams to adapt the classification depending on the version used. However, properties and quantities are not yet directly linked to IFC, as shown in Table 1.

Both IFC and the FDK include a description, data type, unit, unique ID or name and example for each attribute. This means both could be considered data dictionaries according to ISO 23386:2020. More importantly, the IFC is used to define the structure of the data template developed in this dissertation (Section 3.4), as also recommended by ISO 23387:2020 to ensure interoperability.

- Filterable: filterability refers to the ability to isolate only the use cases needed for a specific project. IFC 4.3 supports this through Model View Definitions (MVDs) and by organizing properties into distinct groups called property sets (Psets). These Psets allow for quicker integration of the use cases defined for the project. For example, the entity *IfcRailType* includes a long list of Psets as seen on Table 7, but it is possible to identify and select the relevant ones according to the project's needs, enabling effective filtering. Moreover, the Psets include a

description, allowing for the user to choose multiple attributes at once using the Pset's description.

In the case of the FDK, properties are separated into six groups: SBB-CFF-FFS, SBB-CFF-FFS_LO, SBB-CFF-FFS_PO, SBB-CFF-FFS_SPEZ, SBB-CFF-FFS_Punktuale_GLT, and SBB-CFF-FFS_Lineare_GLT as shown in Figure 32. These groups relate to project status, object placement (linear or punctual), and some aspects of the Asset Breakdown Structure and O&M. However, the connection between these groups and specific use cases is not clearly defined.

The Crossrail Asset Data Dictionary uses an Asset Breakdown Structure (ABS) composed of three levels: Facilities, Primary Functional Units (PFUs), and Functional Units (FUs). While this classification helps organize physical assets, the attributes themselves are not grouped or structured according to use cases. The data structure remains flat, and choosing attributes must be completely done manually, which limits its filterability according to Wagner et al.'s definition.

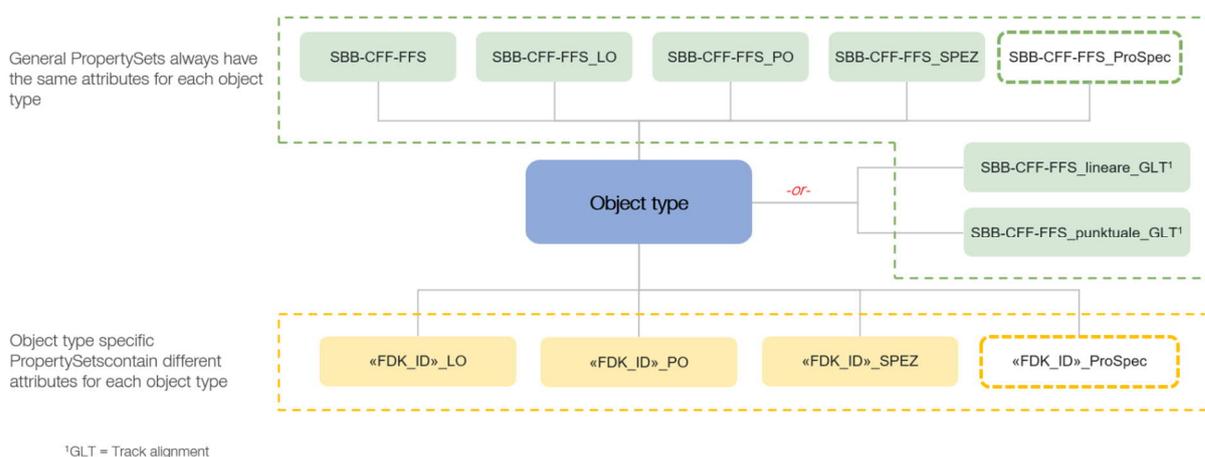


Figure 32 - Groups of properties according to the FDK. (“BIM Fachdatenkatlog,” n.d.)

Table 7 - Property sets for the entity *IfcRailType*. (“7.8.3.2 IfcRailType - IFC 4.3.2 Documentation,” n.d.)

Property set name	Description
Pset_Condition	Determines the state or condition of an element at a particular point in time.
Pset_ConstructionAdministration	Properties for Construction Administration. Often used for facility and asset management.
Pset_ElementKinematics	Information confirming that the element has cyclic and/or pathed kinematic behaviour. The resulting envelope may be available as a 'clearance' shape representation.
Pset_EnvironmentalCondition	Properties defining environment conditions required by the element.

Pset_EnvironmentalImpactIndicators	Environmental impact indicators are related to a given “functional unit” (ISO 14040 concept). Indicators values are valid for the whole life cycle or only a specific phase (see LifeCyclePhase property).
Pset_EnvironmentalImpactValues	The following properties capture environmental impact values of an element. They correspond to the indicators defined into Pset_EnvironmentalImpactIndicators.
Pset_MaintenanceStrategy	Property set for the association of a maintenance strategy to an element, asset of system.
Pset_MaintenanceTriggerCondition	Trigger levels for an asset that has an inspection-based maintenance strategy
Pset_MaintenanceTriggerDuration	Trigger levels for an asset that has an PPM based maintenance strategy.
Pset_MaintenanceTriggerPerformance	Properties for performance based maintenance policies
Pset_ManufacturerTypeInfo	Defines characteristics of types (ranges) of manufactured products that may be given by the manufacturer.
Pset_RailTypeBlade	Properties common to IfcRail types and occurrences with PredefinedType set to BLADE.
Pset_RailTypeCheckRail	Properties common to IfcRail types and occurrences with PredefinedType set to CHECKRAIL.
Pset_RailTypeGuardRail	Properties common to IfcRail types and occurrences with PredefinedType set to GUARDRAIL.
Pset_RailTypeRail	Properties common to IfcRail types and occurrences with PredefinedType set to RAIL.
Pset_RailTypeStockRail	Properties common to IfcRail types and occurrences with PredefinedType set to STOCKRAIL.
Pset_Risk	An indication of exposure to mischance, peril, menace, hazard or loss. Documentation of a potential hazard, likelihood and consequence which can be assigned to or associated with a product, activity and/or location.
Pset_ServiceLife	Captures the period of time that an artifact will last.
Pset_Tolerance	Properties expressing the tolerance relating to locating and shaping of an intended element or feature. Range diameters are non-negative describing a linear, rectangular or boxed region .
Pset_Uncertainty	Property set capturing the geometric uncertainty regarding measurements including how the way that uncertainty was assessed.
Pset_Warranty	An assurance given by the seller or provider of an artefact that the artefact is without defects and will operate as described for a defined period of time without failure and that if a defect does arise during that time, that it will be corrected by the seller or provider.
Qto_RailBaseQuantities	Base quantities that are common to the definition of all occurrences of rail.

- Flexible: flexibility is about how easily a data template can adapt to different use cases. In IFC 4.3, it's possible to add new entities using *IfcBuildingElementProxy* and create new property sets with attributes following the UpperCamelCase standard. But these additions often disconnect from the structure originally designed for the IFC, which affects the quality of the results. Also, adding new attributes or Psets officially is a long process. It needs to go through buildingSMART and sometimes ISO, which makes it more inflexible.

The FDK, on the other hand, is still being developed by BIM@SBB and new versions are released regularly. As shown in Figure 32, it allows adding property sets that apply to all objects (*SBB-CFF-FFS_ProSpec*) or specific ones (*FDK_ID_ProSpec*). Users can also suggest new attributes, and the process is explained on the BIM@SBB website. This makes it much more flexible in practice, since the users of the catalog can contribute directly to it with SBB's approval.

For the Crossrail Asset Data Dictionary, no information was found about adding new attributes. Since the initiative ended after the Purple Line handover, the dictionary isn't evolving anymore. That limits its flexibility and the ability to adapt to new systems and use cases.

- Exhaustive: exhaustiveness refers to how much relevant data a template can include, even if it's not possible to be fully complete. The IFC can be considered exhaustive, it was created based on the entire AEC industry. It has several groups of properties (Psets) that serve different purposes and domains and can use any Resource in the Resource Layer as shown on its architecture in Figure 13. For example, for the element Rail, it includes predefined types under the entity *IfcRailTypeEnum*, such as blade, checkrail, rackrail, rail, stockrail, userdefined and notdefined ("7.8.2.1 IfcRailTypeEnum - IFC4.3.0.1 Documentation," n.d.). Each of these types has its own Pset that extends the data template to reflect its specific characteristics. This structure allows the IFC to cover a wide range of infrastructure elements and use cases, even if not all attributes are always relevant or well-structured.

The FDK is also exhaustive, but within the Swiss railway context. It includes a large number of attributes and object types, and it's constantly being updated by BIM@SBB. This means it reflects the operational and technical needs of current projects in Switzerland. However, since it's based on national standards, it might not be suitable for projects outside the SBB framework or for international collaboration.

The Crossrail Asset Data Dictionary was developed for a specific project and includes detailed information for tunnel and railway elements. But its scope is limited to the needs of the Crossrail initiative, and it does not aim to cover other domains or future developments. So while it's exhaustive for its original purpose, it does not offer the same level of coverage or adaptability as IFC or the FDK.

- Modular: modularity refers to the capability of including or excluding entire domains or perspectives of a product from its data. The IFC schema is well separated into layers as shown in Figure 13. In practice, these layers are tightly interconnected. The structure is very complex, which makes it hard to modify the layers, they are very interconnected, and the attributes are very linked to the object type.

The FDK is more modular in practice. It is focused on railway infrastructure, but its structure allows for the addition of new perspectives. Property sets are grouped by object type and project context, and the catalogue is updated regularly.

The Crossrail Asset Data Dictionary is not modular. It does not include classification or groups of properties apart from the Asset Breakdown Structure so entire domains or perspectives cannot be included or excluded.

- Multi-lingual: multi-lingual capability refers to the ability of a data template to support translations and be used in different languages. The IFC schema is written in English. Entities such as classes, types, property sets, and attributes use English terms formatted in UpperCamelCase, creating in that sense a unique code. However, since each entity is defined by a unique code, the names and descriptions can be translated into other languages. This translation work is organized by buildingSMART with the collaboration of its community and made available through the buildingSMART Data Dictionary (bSDD), allowing users to better understand the schema in their native language.

The FDK also supports multi-lingual use. It assigns alphanumerical IDs to every object and attribute, which makes it possible to reference multiple translations for the same item. The catalogue includes names and descriptions in German, French, Italian and English. The first three being Switzerland's official languages. This makes the FDK fully multi-lingual for its intended context.

The Crossrail Asset Data Dictionary does not support multi-lingual use. Its attributes do not have unique identifiers, which makes referencing translations difficult or impossible. The structure is fixed and only available in English, limiting its usability in international or multi-lingual environments.

- Domain-independent: domain independence refers to the ability of a data template to serve different domains, such as buildings, railways, or waterways, and comply with their specific guidelines. The FDK is designed specifically for railway infrastructure. It makes distinctions between objects based on their system context. For example, it includes a handrail object for train stations and another for tunnels used in escape routes. However, since the catalogue is still under development, some properties are not yet uniform. Some attributes are missing examples, some are not grouped into property sets, and some translations are still incomplete. While the FDK is detailed and evolving, it is not domain-independent, it is tailored to Swiss railway and real estate projects. It presents other domains such as bridges, but in the context of being a part of the railway environment.

The IFC is broader and more domain independent. It includes entities and property sets that can be used across different domains. For example, while the FDK has a specific object for a rail weld, IFC treats welds as a generic type of fastener. To address this, IFC includes a property set called *Pset_FastenerRailWeld*. One of the strengths of IFC is that it considers the type of maintenance being performed and separates property sets accordingly. For instance, *Pset_MaintenanceTriggerDuration* can be added to a weld and is specifically used for Planned Preventive Maintenance (PPM). This flexibility makes IFC suitable for multiple domains, even if some definitions are generic and require adaptation.

The Crosrail Asset Data Dictionary is not domain independent. It was developed for a specific infrastructure project and focuses on tunnel and railway assets.

Table 8 - Comparison between three data templates.

	Crossrail Asset Data Dictionary	FDK – Technical Data Catalogue	IFC 4x3
<i>Open</i>	✓	✓	✓
<i>Queryable</i>	✗	✗	(✓)
<i>Machine-readable</i>	✗	(✓)	✓
<i>Filterable</i>	✗	(✓)	✓
<i>Flexible</i>	✗	✓	(✓)
<i>Exhaustive</i>	(✓)	(✓)	✓
<i>Modular</i>	✗	(✓)	(✓)
<i>Multi-lingual</i>	✗	✓	✓
<i>Domain-independent</i>	✗	✗	(✓)

3.4. Data templates for the selected objects

Based on the comparison of data references presented in the previous section, this chapter focuses on developing Product Data Templates (PDTs) for the three selected objects: rail, catenary support and signal. The method used to create the PDTs is adapted from the approach proposed by Sibaii et al. (2022), previously introduced in Section 2.2.1 and summarized in Figure 4. In this section, the adapted methodology is explained in the context of the case study and then applied to each object. Figure 33 summarizes the adapted methodology used.

The first step involves comparing the three data references to understand their structure and how information is presented. This step was already covered in Section 3.3. The development of the data templates is based on data mining from the three references selected, focusing on the alphanumeric properties published for railway elements.

The process includes listing all the attributes found in the three references and identifying which attributes appear in each source. Attributes are grouped by description using their names, allowing repetitive ones to be merged. Attributes found in more than one reference are considered highly relevant and are included in the final PDT. The others are included by choice and experience of the author. This

step is a long one, relying on the descriptions of the attributes when available and on the author's knowledge of the field. The partial outcome is a list of comparison of properties.

According to the ISO 19650-1:2018, information containers should be named according to a naming convention. In line with the standards for Product Data Template and the library of objects (Chapters 2.2.1 and 2.2.3), attribute names must be interchangeable and machine-readable. Based on these requirements, UpperCamelCase was used to name properties not already defined in the IFC. This naming convention also ensures uniformity, especially since the IFC structure and property names were retained whenever a property appeared in more than one reference.

Afterwards, the ISO 23387:2020 is applied to the list, linking each attribute to a data type, unit and possible value when available. The IFC, when considered as a data dictionary, includes properties related to documentation requirements and standards. The IFC is the only reference that presents documentation as a part of its list of properties. Since this dissertation focuses on alphanumerical and geometrical properties for defining the Level of Information Need, documentation-related properties were excluded from the final data templates. The "document" column only traces the attribute back to one of the three references used for the study.

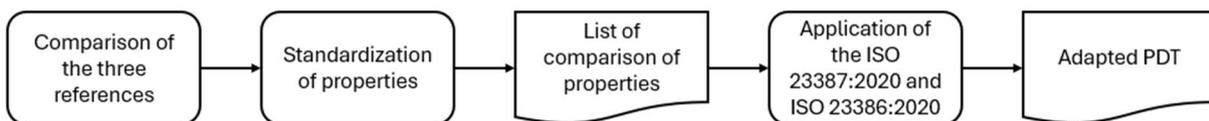


Figure 33 - Adapted methodology for the creation of PDTs.

The methodology described by Sibaii et al. (2022) includes a final step involving feedback from industry professionals. This step was not included in the adapted methodology used for this dissertation. Since the three references used were developed by domain experts, it was considered that an additional round of evaluation was not necessary.

3.4.1. Rail

The IFC 4.3 schema includes the entity *IfcRail*, which is further detailed through the predefined types listed under *IfcRailTypeEnum*. These types include: *blade*, *checkrail*, *guardrail*, *rackrail*, *rail*, *stockrail*, *userdefined* and *notdefined*. The first five types have specific property sets, as shown in Table 7. Considering that the rail in the case study corresponds to the type *rail*, the property sets *Pset_RailTypeBlade*, *Pset_RailTypeCheckRail*, *Pset_RailTypeGuardRail* and *Pset_RailTypeStockRail* were excluded from the analysis.

A total of 196 attributes were mined and compared, resulting in the first table of Appendix 2. The IFC contains 153 attributes, the FDK contains 24, and the Crossrail Asset Data Dictionary contains 19 properties. Only four attributes are shown in the three references: *PositionInTrack*, *RailElementaryLength*, *InstallationDate* and *TagNumber*.

The IFC has a property set called *Pset_ElementKinematics* that concerns the kinematic behaviour of the rails. In the FDK, for example, this behaviour does not appear as a part of the properties for the rail,

since there is a separate object for it, the clearance. Therefore, the attributes related to kinematics were excluded from the final PDT, as they are more relevant to another class of object.

Some of the properties of the IFC are related to the environment in a general sense and do not apply to rails. These Psets are more general, and not every attribute makes sense in the context of the materials used to make the rail. For example, the attribute *RadioactiveWastePerUnit*, presented in the property set *Pset_EnvironmentalImpactIndicators* would never be applicable to a rail. These attributes were removed from the adapted PDT. The possible values, notably those listed on the *PEnum* column were organized and only values relevant to a rail object were retained.

Both the FDK and the Crossrail Asset Dictionary present attributes relative to the position of the rail according to station or meterage. In the case of the IFC, the placement of the rail is handled through a more complex data structure, not as an alphanumerical attribute. However, to support cases where the IFC 4.3 is not yet fully integrated into the software tools used, a placement property set based on linear referencing was retained. This Pset was named *Group_LinearPlacementStation* to follow the UpperCamelCase requirement. Attributes related to placement by orthogonal coordinates, such as those referencing the London Survey Grid, were excluded, as this is not a common practice in the domain.

Other parameters found in the FDK and the Crossrail Asset Data Dictionary had their names changed to follow the UpperCamelCase convention and were included in existing Psets. Even if this does not represent full IFC integration, it makes sense to group similar attributes inside the same Pset based on their descriptions. For instance, the attribute *RailProfile* was created and added to the property set *Pset_RailTypeRail* with enumerated values taken from the FDK.

The Product Data Template created for the rail object is shown in Appendix 3. It contains 87 properties grouped into 17 property sets.

3.4.2. Catenary support

The conceptual documentation of the IFC Rail shows the energy supply system as a part of the “Overhead Line Supporting (OCS) Class” and includes an UML diagram, as seen in Figure 34. The UML structure even defines a specific type for tunnel overhead line support called “Bearer structure” which “ensures the function of holding registration component in tunnel context” (IFC Rail Project, 2019). In the latest version of the IFC published by ISO, the overhead catenary system is a predefined type of *IfcDistributionSystem* (*OVERHEAD_CONTACTLINE_SYSTEM*), having a specific property set called *Pset_DistributionSystemTypeOverheadContactlineSystem*.

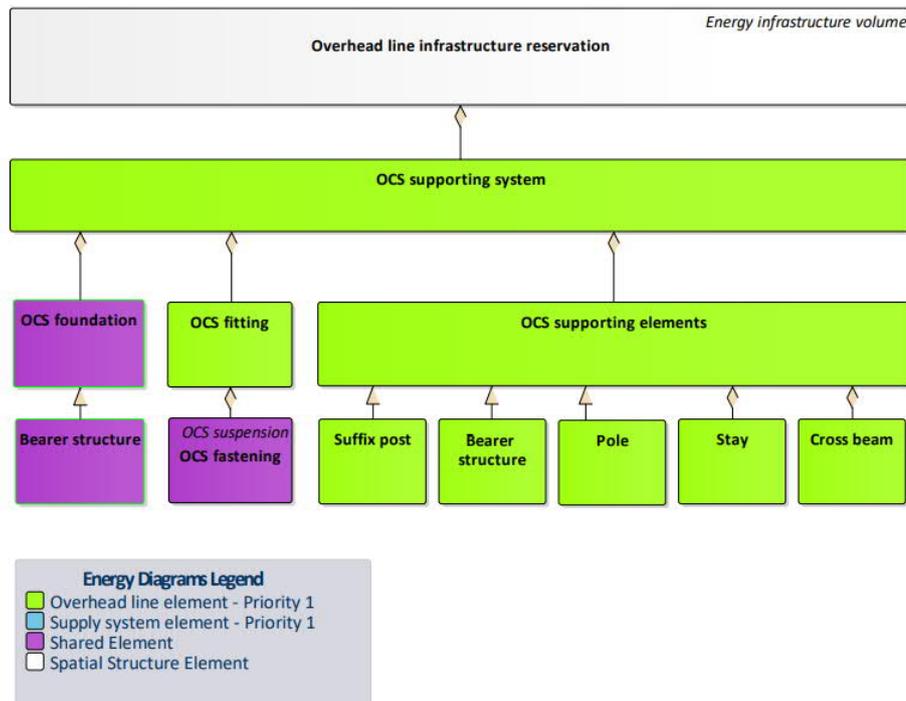


Figure 34 - Class diagram "OCS Support". (IFC Rail Project, 2019)

The entity that best describes the rigid catenary support is *IfcMember*. This entity is used for a “structural member designed to carry loads between or beyond points of support. The orientation of the member (being horizontal, vertical or sloped) is not relevant to its definition”. This entity is not part of the Rail Domain and was first introduced in IFC2x2 Addendum 1, being a generic entity also used for civil works when an object cannot be classified as *IfcColumn* or *IfcBeam*. The predefined type used is *MEMBER*, which is “a linear element within a girder or truss with no further meaning”. This predefined type allows the application of the property set *Pset_MemberTypeOCSRigidSupport*, which defines “properties of rigid catenary support used in railway overhead contact system.”.

The entity used could be easily mistaken by the entity *IfcElementAssembly* predefined type *SUPPORTINGASSEMBLY*. The description of this predefined type is “an assembly intends to support Overhead Contact Line System. It includes foundation, supporting elements and suspension assembly.”. This description is very generic compared to how specific a rigid catenary system is, and is more suitable for describing a mast with its foundation and equipment in an open-air project, not a tunnel. This distinction highlights the importance of defining the Level of Information Need and the IFC class for objects in the context of a project.

As was the case for the rail PDT, the property sets in the IFC related to other predefined types were excluded from the comparison. These include *Pset_MemberTypeAnchoringBar*, *Pset_MemberTypeCatenaryStay*, *Pset_MemberTypePost*, *Pset_MemberTypeTieBar*, *Pset_DoorLiningProperties*, *Pset_PermeableCoveringProperties*, *Pset_PrecastConcreteElementFabrication*, *Pset_PrecastConcreteElementGeneral* and *Pset_WindowLiningProperties*.

In the FDK, the object used is *Conductor wire fixing*. This object takes into account two aspects of the catenary support: its role as a mechanical support and its role as an electrical insulator. It is important to note that this object considers overhead contact lines of all types, both in tunnels and open-air conditions, while the IFC has a property set only for the rigid support, even though it only contains two attributes. The IFC, when classifying the rigid catenary support as an *IfcMember*, does not take into consideration the electrical properties.

When analyzing the Crossrail Asset Data Dictionary, the object closest to a rigid catenary support is the Dropper. This element is not correct, as it is used for non-rigid catenary systems. However, it is the closest in function to the object of this study. Compared to the other two references, the Crossrail Asset Data Dictionary is the only one to present an attribute for defining the stationing of the element. In the IFC, this would be represented elsewhere in the schema.

The final comparison has 193 attributes mined: 164 attributes from the IFC, after the exclusions listed above, 15 from the FDK and 14 from the Crossrail Asset Data Dictionary. Only five attributes appear in common in the three references used: *Status*, *InstallationDate*, *ModelNumber*, *TagNumber* and *AssetIdentifier*. These attributes are generic and primarily used for O&M. This is due to the fact that two references do not present the exact object needed: the IFC uses a patch of a preexisting object, the FDK is accurate even though the object used is for interior and exterior, and the Crossrail Asset Data Dictionary uses an adaptation of another object. The full list is found in Appendix 2.

The adapted PDT does not include property sets such as *Pset_ConcreteElementGeneral*, which is clearly intended for concrete objects, since the *IfcMember* entity is a very generic entity. This also suggests that the IFC entity *IfcMember* was not originally created for metallic elements. Both the FDK and the Crossrail Asset Data Dictionary include an attribute to define the installation date. The property set containing this attribute exists in the IFC and is called *Pset_ConstructionOccurrence*. However, this Pset is not a part of the property sets included in the *IfcMember* entity. It was then decided to add this Pset to the PDT.

The IFC property set *Pset_MemberCommon* contains the attribute *Status*, which is relevant to every object in the model. It was removed from the adapted PDT, as it is a general attribute and part of the property set “Identification” in every Level of Information Need. Similarly, the attribute related to linear placement was retained in the adapter PDT for the same reasons as the location properties for the rail object discussed previously.

As with the rail PDT, the property set *Pset_ElementKinematics* was excluded from the final version. The property set *Pset_ConcreteElementGeneral* was also excluded, as it contains only attributes relevant to objects made from concrete. Environmental property sets were reviewed and only those applicable to the object were retained. All attributes were reorganized into existing property sets and the property set *Group_LinearPlacementStation* was added. Attributes related to orthogonal coordinates were not included, as these are already handled by the authoring software tools.

The Product Data Template created for the catenary support object is shown in Appendix 3. It contains 90 properties grouped into 16 property sets.

3.4.3. Signal

A signal element is an active device that sends instructions or information to users, in this case, the conductor. In the case study, the object is a visual signal requiring energy and data connections for its operation.

In the IFC, the entity used is the *IfcSignal* with the predefined type *VISUAL*. In the railway context, this corresponds to an individual frame containing light bulbs. The support structure for the frame is not included in the entity *IfcSignal*. Several signs or signal frames may be mounted together forming a Signal Assembly. At the same time, several signal assemblies may form a signaling system, which is a type of distribution system.

As was the case for the rail and the catenary support PDTs, the property sets in the IFC related to other predefined types were excluded from the comparison. In this case, the property set *Pset_SoundGeneration* was excluded from the comparison.

The FDK defines different objects for different types of signal: main signal, pre-signal, dwarf signal, switch signal and additional signal. The “*FDK_ID*”_LO and “*FDK_ID*”_SPEZ property sets may vary depending on the signal object type, while the remaining attributes are similar. For the construction of the comparison list, it was decided to include all properties for different types of signals. This approach allows for the creation of a more generic PDT that can be used for any signaling element in Switzerland, considering that the signaling systems vary considerably between countries.

While the FDK distinguishes between signal types, the Crossrail Asset Data Dictionary uses a general object for all types of electronic signals. The FU Class is *Electronic Signage* and the asset class is *Switchable signage*. Both the FDK and the Crossrail Asset Data Dictionary have an attribute to define the status. As explained previously, this attribute was not included in the PDT.

The final comparison includes 264 attributes mined: 224 from the IFC, after the exclusion mentioned above, 21 from the FDK and 19 from the Crossrail Asset Data Dictionary. The following attributes were found in all three references: *SubmittalIdentifier*, *InstallationDate*, *ModelNumber*, *TagNumber* and *ArticleNumber*. The comparison table is the third one presented in Appendix 2.

As with the rail and the catenary support PDTs, the property set *Pset_ElementKinematics* was excluded from the final version. Attributes related to electricity were reviewed, and only those relevant to signals were retained. The environmental property sets were also organized and filtered according to the object’s requirements.

Some attributes mentioned in the FDK for the different signal objects are related to the systems used specifically in Switzerland. To accommodate this and still maintain a filterable Product Data Template, a dedicated property set was created for these attributes: *Group_CountryRailwaySignalCH*.

All attributes were reorganized into existing property sets and the property set *Group_LinearPlacementStation* was added. Attributes related to orthogonal coordinates were not included, as these are already handled by the authoring software tools.

The Product Data Template created for the signal object is shown in Appendix 3. It contains 147 properties grouped into 27 property sets.

3.5. Combined Level of Information Need for the selected objects

LOD is not applicable to the case study, as it evolves with the phase of the project. When the model is not developed from the preliminary phase, there's no need to model certain elements or insert attributes for a refurbishing use case. All the actors involved in the project need to consciously make a decision about the need of certain information in a model, since an overflow of it can quickly increase costs without adding value to the final built structure.

As explained in Section 2.2.2, Europe developed a standard for describing the level of information need in 2020, which then became an ISO in 2024. Level of Information Need gives more flexibility to the description of the information needed according to the purpose, but it also demands more from project managers and engineers when describing information. Following the MacLeamy curve, it requires more work at the beginning of the project.

Annex B of ISO 7817-1:2024 shows examples of methods to specify the Level of Information Need. This method is also briefly explained in Section 2.2.2. The present chapter aims to develop the why, when, who and what according to Annex B of the ISO. The how is explained in general as well, more detail is found in Sections 3.5.1, 3.5.2 and 3.5.3.

- General information
 - Information delivery milestone (when)

The EN 17412-1:2020 says that in practice, the Level of Information Need for each object must be considered in relation to all the intended uses at a given stage of information delivery. This means that the amount and type of information, whether geometric, alphanumerical or documentation, required for a specific object may exceed what is necessary for a single purpose, as it must also satisfy other current requirements defined for the same milestone.

For the case study, there is only one delivery milestone since the built asset project and construction phases were not developed using BIM. Therefore, the Level of Information Need is combined into a single specification per element. The delivery milestone is the design phase considering that the model will be used for the refurbishment design.

- Purpose (why)

The purpose of the Level of Information Need defined for each object is directly related to the use cases of the project.

- Image

Since the focus of this study is on modelling existing conditions for refurbishing purposes, it was decided to include an image of each element to illustrate how it appears in real life. This helps modelers without technical experience in the field to more easily identify the objects in the point cloud.

- Actors (who)

In the case study, the provider of the information is the operator and the claimant is the designer responsible for the refurbishment project. The appointing party is the operator, who holds the archives with plans and documentation, while the appointed party is the designer, or engineering team, who will use this information. These roles follow the definitions provided in the ISO 19650 series.

- Geometrical information

The level of detail varies according to the object. It is important for the BIM responsible to be as clear as possible in this item, so that decisions are made by experts in the field who will use the model during design phase. Especially if the modelers working on the project have no technical experience in the railway sector.

The dimensionality of an element, according to the EN 17412-1:2020 can be 0D (location point), 1D (line, curve, path), 2D (surface, face) or 3D (body, volume). The 0D dimension is not commonly used, but it was decided to leave this dimension as an option since it can be used for certain elements inside the tunnel that are small, but whose location and properties are important. For instance, there are multiple points of Earth grounding on the tunnel's walls, as seen in Figure 35. These points have a cable connecting them to the Earth, but this line was completely concreted and its exact position is not known, not even theoretically, since there is no sheet containing this detail. Taking this into consideration and the size of the model file, there's no reason to model this using more than a point containing alphanumerical information.



Figure 35 - Point of Earth grounding on the tunnel wall.

Chapter 6.1 of the EN 17412-1:2020 declares that if an aspect, whether alphanumerical, geometrical or document information, is not relevant for the project and/or for the element in question, “not applicable” may be used. (“EN 17412-1:2020,” 2020).

- Alphanumerical information
 - Identification (what)

The identification of the objects is what makes both users and machines to make assumptions about them. In order to identify an object as a unique element throughout the project’s lifecycle, the attribute *GlobalId* is used. Moreover, the *Name* and *Description* of the object are part of the Identification property set. If the object is part of an internal database in the operator’s O&M system, the *Tag* attribute is also available, even though the model does not aim this use case.

Considering that the case study is based in Switzerland, it was decided to add specific identification attributes from the FDK. These attributes correspond to the *ObjectTypeID* and *ObjectTypeName*. The first one is always the same for a given object type, regardless of language. The *ObjectTypeName* can be filled in four different languages. Even though the case study is located in the country’s French-speaking region, this attribute is filled in English for the purpose of this dissertation.

The identification of the objects is also what links them directly to an entity in the IFC schema. To support this, the attributes *PredefinedType*, *IFCExportAs* and *IFCExportType* are included in the identification group. If the *PredefinedType* is set to *USERDEFINED*, the attribute *ObjectType* may be used. To comply with IFC requirements, the identification attributes are grouped in a property set called *Pset_Identification*. When the information is not available to fill an identification attribute, “N/A” may be used, as all identification attributes must be present in the final IFC model.

- Information content

According to the ISO 7817-1:2024, section 3.5, “one purpose of defining the level of information need is to prevent delivery of too much information”. In that sense, if all the properties contained in the Product Data Template were inserted into the model, it would become more expensive and heavier, making it difficult to extract and analyze meaningful data when needed. That’s why the meta-consideration evaluated in Section 3.3 related to Filterability is so relevant. It allows to filter the property sets in the Product Data Template according to the project’s use cases. This method was the first step in defining alphanumeric information for the Level of Information Need.

When possible, it is also recommended to discuss the required attributes with a domain specialist. For instance, the maintenance strategy of the rail and the rail weld depends on the material used to manufacture the rail. Depending on the material, the rail can be inspected using ultrasound-equipped rolling stock, and its inspection frequency can be determined based on track usage. If the rail consists of a material that does not allow defect detection before rupture, visual inspection must be done, and the rail may need to be changed in regular periods of time. Understanding how the maintenance is carried out and which parameters influence it has a direct impact on the properties selected from the Product Data Template and used in the Level of Information Need specific to the project.

For the case study presented in this dissertation, discussions were held with domain specialists from GESTE Engineering SA to understand what information would be relevant. The final decision on the attributes retained in the Level of Information Need was made by the author, based on her experience. The decisions made and the results are further explained in Sections 3.5.1, 3.5.2 and 3.5.3.

It is worth noting that the data types used for the Level of Information Need are kept consistent with the IFC schema. This decision was made during the creation of the Product Data Template, considering that the goal is to export the models in IFC format.

- Documentation

IFC is the only data reference that includes properties for linking documents by using the data type *IfcDocumentReference*. Another attribute that can be inherited is the name of the document. Optional document metadata can also be captured through reference to *IfcDocumentInformation* (“8.6.3.5 IfcDocumentReference - IFC4.3.0.1 Documentation,” n.d.). The FDK and the Crossrail Asset Data Dictionary do not mention any attributes related to documentation.

Considering that there are no other references for documentation, the Level of Information Need developed for this dissertation focuses on alphanumeric and geometrical information only. In that sense, the mention “Not applicable” was used for the Level of Information Need created for each object.

3.5.1. Rail

Geometrical information

Gigante-Barrera et al. (2017) proposed a scale of LOD for rail elements, as shown in Table 4 and in Figure 6. It is possible to remark immediately that this definition is outdated. For the use cases proposed for this case study, it would be necessary to define the cant and the track alignment, which corresponds to LOD 400. However, LODs 350 and 400 demand the placement of the rail welding and the clearance profile. These details are not necessary for the case study. The Level of Information Need is more adapted to specify the actual requirements in a model without unnecessary modeling.

For the rail, the geometry needed is a swept continuous solid representation following the alignment of the track. The profile of the rail must correspond to the national regulations, as indicated by the operator. This allows for the placement of other objects in the tunnel according to the alignment, as well as for the modelling of a clearance zone representing the rolling stock, if and when needed. More importantly, the rail must be in accordance with the cant of the alignment, as well as with its vertical and horizontal positions. The location of the rail object must be directly referenced to an alignment and the name of the alignment must be part of the data structure of the model. The stations used to reference the element’s start and end are linked to the kilometric alignment defining the project. The location would be classified as “linear, line” according to the FDK as shown in Table 6. The geometrical requirements are summarized in Table 9.

When considered in the sense described by Seo and Lee (2020), the rail profile cross-section could be in an object library. This library would be composed of different rail profiles, categorized according to

different national rail standards. These cross-sections representing the profiles would be archived in file formats compatible with the authoring software tool used for modelling linear 3D solids.

Alphanumerical information

Following the method proposed above, the property sets are filtered according to their use cases. Since the case study does not include any environmental use cases, several property sets in the PDT were excluded from the Level of Information Need, such as *Pset_EnvironmentalImpactIndicators*. Other use cases not applied to the project, such as risk mitigation, evaluation and O&M, can also be directly traced to property sets that were excluded. These include: *Pset_ConstructionAdministration*, *Pset_MaintenanceStrategy*, *Pset_MaintenanceTriggerCondition*, *Pset_MaintenanceTriggerDuration*, *Pset_ManufacturerTypeInfoInformation*, *Pset_RepairOccurrence*, *Pset_Risk*, *Pset_ServiceLife*, *Pset_Tolerance* and *Pset_Warranty*.

After eliminating the property sets related to use cases not integrated into the project, 34 attributes remained. After this stage, domain experts would typically select the final attributes. For this case study, the author's experience was mainly used. Finally, 17 attributes were retained to define the alphanumerical information of the Level of Information Need. These attributes are grouped into four property sets: *Pset_RailTypeRail*, *Pset_ConstructionOccurrence*, *Pset_Uncertainty* and *Pset_LinearPlacementStation*.

Considering that the rail serves as the geometrical base for several other objects in the railway tunnel, the property set *Pset_Uncertainty* was included to provide model users with clear information about the geometric uncertainty of the model produced compared to reality. This uncertainty reflects both the modelling process and the precision of the point cloud used. As explained previously, the property set *Group_LinearPlacementStation* was retained to define the placement of the elements according to an alignment. If the exports from the modelling tools were done according to the IFC 4.3 schema, some attributes would not be necessary, such as *StartingMeterage* and *EndingMeterage*.

The resulting Level of Information Need for the rail is summarized in Table 9.

Table 9 - Level of Information Need for the rail element

Level of Information Need: Rail	
General information:	
Information delivery milestone	Design phase
Purpose	Existing conditions modelling
Image	

Actors:		
Provider	Operator	
Claimant	Designer	
Object	Rail	
Geometrical information		
Detail	According to the rail profile standard in the documentation	
Dimensionality	3D solid	
Location	Relative to an alignment and a station	
Appearance	Not applicable	
Parametric behaviour	Following the horizontal and vertical alignments as well as the cant information.	
Alphanumerical Information		
Identification		
Property name	Data Type	Description
GlobalId	IfcGloballyUniqueId	Assignment of a globally unique identifier within the entire software world.
Name	IfcLabel	Optional name for use by the participating software systems or users. For some subtypes of IfcRoot the insertion of the Name attribute may be required. This would be enforced by a where rule.
Description	IfcText	Optional description, provided for exchanging informative comments.
ObjectTypeID	IfcLabel	Alphanumerical code corresponding to the object type according to the FDK. In this case: OBJ_FB_4
ObjectTypeName	IfcLabel	Name corresponding to the object type according to the FDK, in English. In this case: Rail
Tag	IfcIdentifier	The tag (or label) identifier at the particular instance of a product, e.g. the serial number, or the position number. It is the identifier at the occurrence level.
ObjectType	IfcLabel	The type denotes a particular type that indicates the object further. The use has to be established at the level of instantiable subtypes. In particular it holds the user defined type, if the enumeration of the attribute PredefinedType is set to USERDEFINED.
PredefinedType	IfcRailTypeEnum	A list of types to further identify the object. Some property sets may be specifically applicable to one of these types. Type values: BLADE; CHECKRAIL; GUARDRAIL; RACKRAIL; RAIL; STOCKRAIL; USERDEFINED; NOTDEFINED. In this case the type used is RAIL.
IFCExportAs	IfcLabel	For IfcExportAs, specify the desired IFC class. For the rail the class is "IfcRail". It can also include directly one of the types on the list for <i>IfcRailTypeEnum</i> as "IfcRail.RAIL".
IFCExportType	IfcLabel	For IfcExportType, specify the desired IFC type. In this case one of the types on the list for the <i>IfcRailTypeEnum</i> should be used. For this case the type "RAIL" can be used.
Status	PEnum_ElementStatus	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exist only temporary (like a temporary support structure).

Information content				
Property group	Property name	Data Type	PENum	Description
Pset_RailTypeRail	PositionInTrack	PEnum_RelativePosition	LEFT; MIDDLE; RIGHT; OTHER; NOTKNOWN; UNSET	Indicates the relative position of the element in track, which lies to the left or right as facing in the direction of increasing stationing values.
Pset_RailTypeRail	RailCondition	PEnum_RailCondition	NEWRAIL; REGENERATEDRAIL; REUSEDRAIL; OTHER; NOTKNOWN; UNSET	Assessment of the condition of the rail at point of installation.
Pset_RailTypeRail	IsStainless	IfcBoolean		Indicates whether the rail is stainless or not.
Pset_RailTypeRail	SteelGrade	PEnum_SteelGrade	R260; B360; R370Cr HT; R320Cr; R400HT; R350LHT; R350HT; R200	Steel grade (material) of the rail.
Pset_RailTypeRail	RailProfile	PEnum_RailProfile	54 E2; VST 36; 49 E1; 46 E1; 60 E2; Ri 54 E1; 60 E1; Ri 46 E1; Am 90; 54 E6; 54 E1	Profile of the rail. The profile defines the geometric shape and size of the rail cross-section.
Pset_Construction Occurrence	InstallationDate	IfcDate		Date on which the element is installed.
Pset_Construction Occurrence	AssetIdentifier	IfcLabel		A unique identification assigned to an asset that enables its differentiation from other assets. NOTE The asset identifier is unique within the asset register. It differs from the globally unique id assigned to the instance of an entity populating a database.
Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty.

Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.
Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.
Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.
Group_LinearPlacementStation	StartingMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.
Group_LinearPlacementStation	EndingMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.
Group_LinearPlacementStation	StartAlignmentID	IfcLabel		Track edge = track axis. The ID of the track edge is the designation of each track edge (track axis). It is provided as a basis for the project. Designation scheme: BAA 78.Left > LITT 41.Right.
Group_LinearPlacementStation	EndAlignmentID	IfcLabel		Track edge = track axis. The ID of the track edge is the designation of each track edge (track axis). It is provided as a basis for the project. Designation scheme: BAA 78.Left > LITT 41.Right.
Group_LinearPlacementStation	StartLocationID	IfcLabel		Route = line. The route ID is the designation of the relevant route (line). It is provided as a basis for the project. Designation scheme: BAA – BAAN.
Group_LinearPlacementStation	EndLocationID	IfcLabel		Route = line. The route ID is the designation of the relevant route (line). It is provided as a basis for the project. Designation scheme: BAA – BAAN.
Documentation				
Not applicable				

3.5.2. Catenary support

Geometrical information

The catenary support must be modelled based on the 2D plans provided by the operator. Its representation should be as simplified as possible, provided it sufficiently conveys the physical presence and spatial constraints. Fine details such as bolts are unnecessary and should be avoided to prevent increasing the file size. The top plate of the object must rotate to adapt to the tunnel's shape, this part of the support should be parametric.

In terms of placement, the object must reflect its real-world position, based on survey data. It should be referenced to an alignment that includes stationing tied to the project's kilometre-based alignment. According to the FDK classification shown in Table 6, the location is categorized as "linear, point". The object's orthogonal offsets from the alignment should also be represented. The stationing concept follows the description of Section 0, Figure 14. Table 10 summarizes the geometrical information.

Alphanumerical information

As with the rail object, the first step involves removing property sets that are not relevant to the project's use cases. The following property sets were excluded based on their lack of relevance: *Pset_Condition*, *Pset_ConstructionAdministration*, *Pset_EnvironmentalImpactIndicators*, *Pset_MaintenanceStrategy*, *Pset_MaintenanceTriggerCondition*, *Pset_MaintenanceTriggerDuration*, *Pset_ManufacturerTypeInformation*, *Pset_Risk*, *Pset_ServiceLife*, *Pset_Tolerance* and *Pset_Warranty*.

Based on the author's experience and the specific requirements of the use cases, 12 attributes were retained for the information content component of the Level of Information Need for the catenary support. These attributes are organized into five property sets. The final Level of Information Need for the catenary support is presented in Table 10. Additionally, the object can be included in a library, as stipulated by the ISO 22014:2024. According to the standard, it may be modelled as a generic library object.

Table 10 - Level of Information Need for the catenary support elements

Level of Information Need: Catenary support	
General information:	
Information delivery milestone	Design phase
Purpose	Existing conditions modelling

Image		
Actors:		
Provider	Operator	
Claimant	Designer	
Object	Catenary support	
Geometrical information		
Detail	Modelling the element according to 2D plan as one single object, not parts. No need to represent bolts or fine details.	
Dimensionality	3D solid	
Location	Relative to an alignment and a station	
Appearance	Not applicable	
Parametric behaviour	The top plate needs to turn to adapt to the surface of the tunnel.	
Alphanumerical Information		
Identification		
Property name	Data Type	Description
GlobalId	IfcGlobally UniqueId	Assignment of a globally unique identifier within the entire software world.
Name	IfcLabel	Optional name for use by the participating software systems or users. For some subtypes of IfcRoot the insertion of the Name attribute may be required. This would be enforced by a where rule.
Description	IfcText	Optional description, provided for exchanging informative comments.
ObjectTypeID	IfcLabel	Alphanumerical code corresponding to the object type according to the FDK. In this case: OBJ_FS_19
ObjectTypeName	IfcLabel	Name corresponding to the object type according to the FDK, in English. In this case: Conductor wire fixing
Tag	IfcIdentifier	The tag (or label) identifier at the particular instance of a product, e.g. the serial number, or the position number. It is the identifier at the occurrence level.
ObjectType	IfcLabel	The type denotes a particular type that indicates the object further. The use has to be established at the level of instantiable subtypes. In particular it holds the user defined type, if the enumeration of the attribute PredefinedType is set to USERDEFINED.
PredefinedType	IfcDiscreteAccessoryTypeEnum	A list of types to further identify the object. Some property sets may be specifically applicable to one of these types. Type values: CABLEARRANGER; INSULATOR; USERDEFINED; NOTDEFINED

IFCExportAs	IfcLabel	For IfcExportAs, specify the desired IFC class. For the catenary support the class is "IfcMember". It can also include directly one of the types on the list for <i>IfcMemberTypeEnum</i> as "IfcDiscreteAccessoryType.MEMBER".		
IFCExportType	IfcLabel	For IfcExportType, specify the desired IFC type. In this case one of the types on the list for the <i>IfcMemberTypeEnum</i> should be used. For this case the type "MEMBER" can be used.		
Status	PEnum_ElementStatus	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exist only temporary (like a temporary support structure).		
Information content				
Property group	Property name	Data Type	PENum	Description
Pset_MemberTypeOCSRigidSupport	ContactWireStagger	IfcPositiveLengthMeasure		Lateral displacement of the contact wire to opposite sides of the track centre at successive supports.
Pset_MemberTypeOCSRigidSupport	IsolatorType	PEnum_IsolatorType	NOTKNOWN; USERDEFINED; NOTDEFINED	Type of isolator.
Pset_MemberTypeOCSRigidSupport	ConductorFixingType	PEnum_ConductorFixingType	WHEEL; CLAMPT; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of whether the conductor can be moved using a wheel or whether it is clamped.
Pset_MemberCommon	LoadBearing	IfcBoolean		Indicates whether the object is intended to carry loads (TRUE) or not (FALSE).
Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty
Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.
Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.

Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.
Pset_ConstructionOccurrence	InstallationDate	IfcDate		Date on which the element is installed.
Pset_ConstructionOccurrence	ModelNumber	IfcLabel		The model number and/or unit designator assigned by the manufacturer of the manufactured item.
Pset_ConstructionOccurrence	AssetIdentifier	IfcLabel		A unique identification assigned to an asset that enables its differentiation from other assets. NOTE The asset identifier is unique within the asset register. It differs from the globally unique id assigned to the instance of an entity populating a database.
Pset_LinearPlacementStation	PonctualMetreage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.
Documentation				
Not applicable				

3.5.3. Signal

Geometrical information

The signal shown in the images and subject of this dissertation is actually an assembly composed of two distinct elements: a main signal and a pre-signal. Each of these is treated as a separate object. Moreover, the IFC structure requires that the mounting parts are not a part of the signal object. Therefore, this Level of Information Need refers exclusively to the two signal types present in the tunnel and excludes the mounting parts.

No parametric behaviour is required, as the lamp positions used to convey images to the train's conductor are standardized. What differs in this specific signal compared to those typically used in open spaces is the frame, not the light bulbs. However, the lamps must be capable of changing colors to represent different signal images. This feature allows the model to be used during the design phase for signal sight verification.

As with the catenary supports, the signal must be placed according to an alignment and stationing system that corresponds to the project's kilometre-based alignment. It should also be positioned using orthogonal offset distances from the chosen alignment. According to the FDK classification shown in Table 6, the location is categorized as "linear, point".

The signal in this case study was designed specifically to accommodate the tunnel's form. In that sense, the object is not a part of a library of objects, it was modelled uniquely for this tunnel.

Alphanumerical information

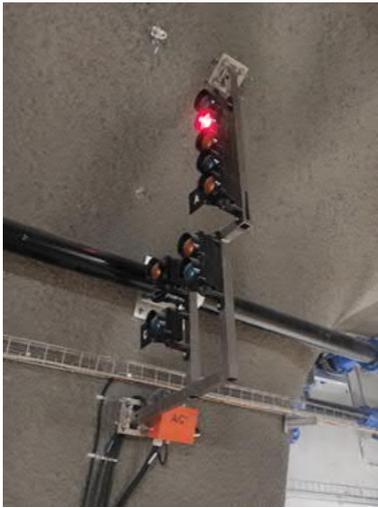
As with the other objects, the first step involves filtering out property sets that are not relevant to the use cases addresses in this study. Only attributes related to electrical requirements for the design phase were retained, while those related to O&M were removed.

A use case specific to sign and signal elements is visibility checking. Although this use case is not explicitly written in the study case description, it is mentioned that the model must support the design phase. One of the most critical design checks for validating a signalling concept is the visibility of the equipment. Therefore, attributes related to the visualisation were also retained.

The following property sets were removed from the Level of Information Need: *Pset_Condition*, *Pset_ConstructionAdministration*, *Pset_ConstructionOccurrence*, *Pset_EnergyRequirements*, *Pset_EnvironmentalImpactIndicators*, *Pset_EnvironmentalImpactValues*, *Pset_InstallationOccurrence*, *Pset_MaintenanceStrategy*, *Pset_MaintenanceTriggerCondition*, *Pset_MaintenanceTriggerDuration*, *Pset_ManufacturerOccurrence*, *Pset_ManufacturerTypeInformation*, *Pset_RepairOccurrence*, *Pset_Risk*, *Pset_ServiceLife*, *Pset_Tolerance* and *Pset_Warranty*.

The final Level of Information Need includes 31 attributes distributed into 8 property sets. The final Level of Information Need for the signal element is summarized in Table 11.

Table 11 - Level of Information Need for the signal elements

Level of Information Need: Signal	
General information:	
Information delivery milestone	Design phase
Purpose	Existing conditions modelling
Image	
Actors:	
Provider	Operator
Claimant	Designer
Object	Signal

Geometrical information				
Detail	Modelled according to 2D plan. Different objects if the signal is composed by two or more types of signal. For example: main signal and advance signal.			
Dimensionality	3D			
Location	Referenced to an alignment and a station			
Appearance	RGB for the lamps/images.			
Parametric behaviour	Not applicable			
Alphanumerical Information				
Identification				
Property name	Data Type	Description		
GlobalId	IfcGlobally UniqueId	Assignment of a globally unique identifier within the entire software world.		
Name	IfcLabel	Optional name for use by the participating software systems or users. For some subtypes of IfcRoot the insertion of the Name attribute may be required. This would be enforced by a where rule.		
Description	IfcText	Optional description, provided for exchanging informative comments.		
ObjectTypeID	IfcLabel	Alphanumerical code corresponding to the object type according to the FDK. In this case: OBJ_SA_18 (for a pre-signal) or OBJ_SA_17 (for a main signal).		
ObjectTypeName	IfcLabel	Name corresponding to the object type according to the FDK, in English. In this case: Pre-signal or Main signal.		
Tag	IfcIdentifier	The tag (or label) identifier at the particular instance of a product, e.g. the serial number, or the position number. It is the identifier at the occurrence level.		
ObjectType	IfcLabel	The type denotes a particular type that indicates the object further. The use has to be established at the level of instantiable subtypes. In particular it holds the user defined type, if the enumeration of the attribute PredefinedType is set to USERDEFINED.		
PredefinedType	IfcSignalTypeEnum	A list of types to further identify the object. Some property sets may be specifically applicable to one of these types. Type values: AUDIO; MIXED; VISUAL; USERDEFINED; NOTDEFINED		
IFCExportAs	IfcLabel	For IfcExportAs, specify the desired IFC class. For the rail the class is "IfcSignal". It can also include directly one of the types on the list for <i>IfcSignalTypeEnum</i> as "IfcSignalTypeEnum.VISUAL".		
IFCExportType	IfcLabel	For IfcExportType, specify the desired IFC type. In this case one of the types on the list for the <i>IfcSignalTypeEnum</i> should be used. For this case the type "VISUAL" can be used.		
Status	PEnum_ElementStatus	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exist only temporary (like a temporary support structure).		
Information content				
Property group	Property name	Data Type	PENum	Description

Pset_ElectricalDeviceCommon	RatedCurrent	IfcElectricCurrentMeasure		The current that a device is designed to handle.
Pset_ElectricalDeviceCommon	RatedVoltage	IfcElectricVoltageMeasure		The range of allowed voltage that a device is certified to handle. The upper bound of this value is the maximum.
Pset_ElectricalDeviceCommon	HasProtectiveEarth	IfcBoolean	TRUE; FALSE	Indicates whether the object has a protective earth connection (=TRUE) or not (=FALSE).
Pset_RailwaySignalAspect	SignalAspectSymbol	IfcExternalReference		Content which is shown on the signal or sign, e.g. text, number, arrow or icon.
Pset_RailwaySignalAspect	AppliesToTrainCategory	PEnum_TrainCategory	FREIGHT; PASSENGER; OTHER; NOTKNOWN; UNSET	Sign information relative to train category, e.g. freight, passenger.
Pset_RailwaySignalAspect	SignalAspectType	IfcLabel		The type of aspect, e.g. 2-display aspect for distant signal, 3-display aspect for block signal.
Pset_RailwaySignalAspect	SignalLegend	IfcText		Text information written on the signal or sign.
Pset_RailwaySignalAspect	LegendSize	PEnum_LegendSize	STANDARD; SMALL	Text size on the signboard.
Pset_RailwaySignalOccurrence	ApproachSpeed	IfcLinearVelocityMeasure		The design speed of trains approaching the signal if different from the line speed.
Pset_RailwaySignalOccurrence	DistanceToStopMark	IfcPositiveLengthMeasure		Distance from the signal to the nearest stop mark at a platform.
Pset_RailwaySignalOccurrence	SignalFixingType	IfcLabel		Switchable Signage Fixing Type
Pset_RailwaySignalSighting	SignalSightingAchievableDistance	IfcPositiveLengthMeasure		Reading distance of the signal, which is achievable with the help of mitigation works.
Pset_RailwaySignalSighting	SignalSightingAvailableDistance	IfcPositiveLengthMeasure		Reading distance of the signal without having any mitigation works.
Pset_RailwaySignalSighting	SignalSightingMinimum	IfcPositiveLengthMeasure		Minimal distance in which the signal has to be readable.
Pset_RailwaySignalSighting	SignalSightingPreferred	IfcPositiveLengthMeasure		Preferred distance in which the signal shall be readable.
Pset_RailwaySignalSighting	SignalSightingRouteIndicator	IfcPositiveLengthMeasure		Required reading distance for the route indicator.
Pset_RailwaySignalSighting	SignalSightingMinimumInFront	IfcPositiveLengthMeasure		Smallest distance where the signal has to be readable (for train very close to the signal).

Pset_RailwaySignalType	SignalIndicatorType	PEnum_SignalIndicatorType	DEPARTUR EINDICATO R; DEPARTUR EROUTEIND ICATOR; DERAILINDI CATOR; ROLLINGST OCKSTOPIN DICATOR; ROUTEINDI CATOR; SHUNTINGI NDICATOR; SWITCHIND ICATOR; OTHER; NOTKNOW N; UNSET	Type of the indicators on a signal, e.g. route indicator, speed restriction indicator etc.
Pset_RailwaySignalType	IsHighType	IfcBoolean	TRUE; FALSE	Indicates if the signal is high (TRUE) or dwarf (ground mounted) (FALSE).
Pset_RailwaySignalType	NumberOfLamps	IfcCountMeasure		Number of lamps the signal is composed of.
Pset_RailwaySignalType	SignalMessage	IfcText		All possible message available at this signal, e.g. "3/4- display automatic blocking".
Pset_RailwaySignalType	RailwaySignalType	PEnum_RailwaySignalType	APPROACH SIGNAL; BLOCKSIGN AL; DISTANTSI GNAL; HOMESIGN AL; HUMPAUXI LIARYSIGN AL; HUMPSIGN AL; LEVELCROS SINGSIGNA L; OBSTRUCTI ON SIGNAL; REPEATING SIGNAL; SHUNTINGS IGNAL; STARTINGS IGNAL; OTHER; NOTKNOW N; UNSET	The type of railway signal, e.g. home signal, starting signal, shunting signal, level crossing signal.

Pset_Uncertainty	Uncertainty Basis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty
Pset_Uncertainty	Uncertainty Description	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.
Pset_Uncertainty	Horizontal Uncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.
Pset_Uncertainty	Vertical Uncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.
Group_CountryRailwaySignalCH	PresignalSignalFunctions	PEnum_DistantSignalFunctions	GROUPDISTANTSIGNAL; BLOCKDISTANTSIGNAL; EXITDISTANTSIGNAL; TRACKSECTIONDISTANTSIGNAL; PROTECTIONDISTANTSIGNAL; TRACKDISTANTSIGNAL; REPEATERDISTANTSIGNAL; OTHERDISTANTSIGNAL; ENTRYDISTANTSIGNAL	Type of signal, such as entry or exit signal.

Group_CountryRailwaySignalCH	SwissSignalSystemType	PEnum_SwissSignalSystemType	NSYSTEMWITHSPEEDINDICATION; NSYSTEM; LSYSTEM; COMBINEDSIGNALWITHOUTSTOPBOARD; FOREIGNSIGNAL; COMBINEDSIGNALWITHSPEEDBOARD	Type of signaling system: L or N.
Group_CountryRailwaySignalCH	MainSignalFunctions	PEnum_MainSignalFunctions	TRACKSECTION; ENTRY; BLOCK; GROUPSIGNAL; REPEATERSIGNAL; TRACKSIGNAL; PROTECTION; OTHER; BUFFERSTOP SIGNAL; EXIT	Type of signal, such as entry or exit signal.
Group_CountryRailwaySignalCH	IsItTriangle	IfcBoolean		Indicates whether the signal is equipped with a triangular attachment, which gives it validity even when not illuminated.
Group_LinearPlacementStation	PonctualMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.
Documentation				
Not applicable				

4. MODELLING WORKFLOW AND INTEGRATED APPLICATION TO CASE STUDY

4.1. Overview

This chapter presents the modelling strategy adopted for the case study, focusing on how both geometrical and alphanumeric information were integrated according to the Level of Information Need defined for the selected objects: rail, catenary support and signal. These objects were chosen based on the criteria discussed in Section 3.2, which considered their relevance to the case study.

The chapter begins by describing the input data, which includes a point cloud survey and documentation provided by the line's operator. It then discusses different approaches to working with alignments in a railway context, highlighting how these choices affect the modelling process and the structure of the resulting data.

Next, the chapter compares the modelling platforms tested during the project, explaining the criteria used and the reasons behind the final selection. The modelling workflow is then described in detail, starting with point cloud processing, followed by the modelling of linear objects, and concluding with the placement of punctual elements.

Although the focus is on three specific objects, other elements such as the tunnel were also integrated to ensure a consistent model. However, the Level of Information Need for these additional objects was not defined in this study. The modelling was therefore non-exhaustive, allowing more time to be dedicated to the structuring and IFC integration of the selected objects.

The final section compares the AS-IS and TO-BE workflows for exporting the model to the IFC format. This comparison helps clarify the practical challenges of achieving interoperability with IFC 4.3 in the current state of the art of the modelling tools market.

4.2. Input data

The modelling process relied on multiple sources of input data, each contributing to different aspects of the model. These sources were used not only to support the geometric representation of the objects but also to apply the alphanumeric information defined for each of them. This section presents the three main categories of input data: the 2D plans and company documentation, the terrestrial laser scan survey and the alignment information, which was analyzed both from the point cloud and from the alignment file provided by the operator.

The point cloud survey was conducted by the author and the topographer of the company, using terrestrial laser scanning methods to capture the geometry of the tunnel and its components with the precision deemed necessary for the case study. This dataset formed the backbone of the modeling process, especially for objects whose location or dimensions were not clearly documented.

4.2.1. 2D plans and company information

The documentation provided by the operator consisted of 2D plans produced for the construction phase. No as-built plans were available, which introduced a degree of uncertainty regarding the current state of the infrastructure. Despite this limitation, the available drafts were valuable for understanding the intended design and for identifying the types and approximate locations of key elements within the tunnel.

These plans supported the modelling of objects whose geometry and placement could not be fully understood using only the point cloud. In particular, they helped clarify the theoretical positioning of signals and the general layout of the tunnel and tracks.

Figure 36 presents an extract of the signalling plan, showing the exact signal assembly studied in this dissertation. It illustrates the theoretical placement of a signal within the tunnel, including its type and its spatial relationship with other signalling elements. This plan was essential for understanding the types of signals used, the images they display, and the functional relationship between the main signal and the pre-signal.

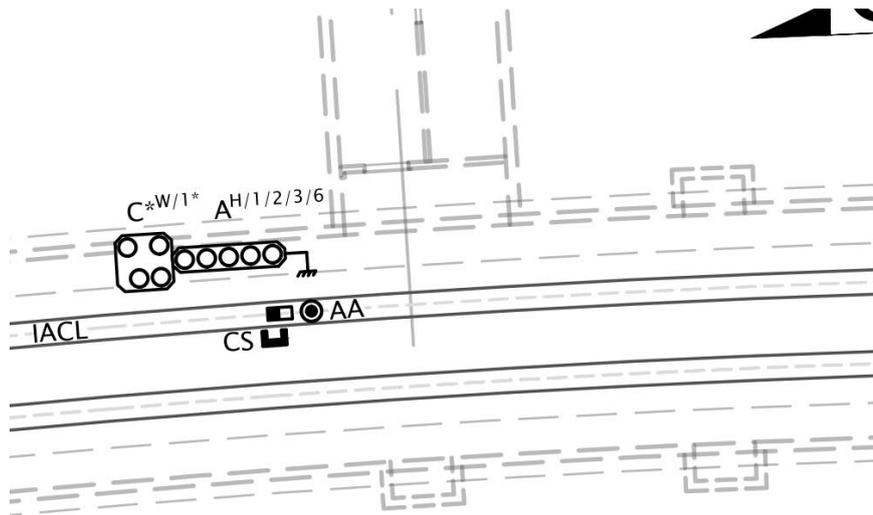


Figure 36 - Theoretical placement of a signal in the tunnel containing the type and its relationship with other signals.

Figure 37 shows a plan view of the tunnel section analyzed in the case study. It includes the emergency exit and the placement of equipment niches along the tunnel walls. This extract helped contextualize the location of key components and provided a reference for modelling the tunnel's internal layout.

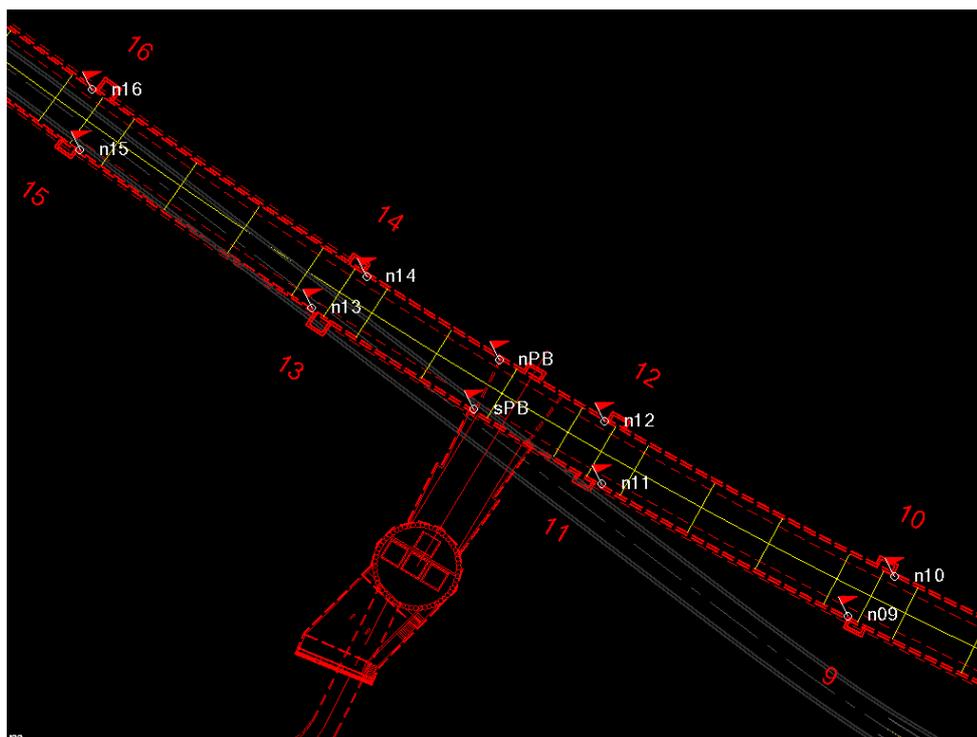


Figure 37 – Plan view showing the theoretical tunnel shape.

Figure 38 displays a theoretical cross-section of the tunnel, detailing the structural layers, cable troughs and track placement. This drawing, along with other cross-sections representing different cants and niche configurations, was used to model the tunnel geometry. It also provided precise information about the rail profiles, which were used to create a custom template for modelling the 3D rail objects.

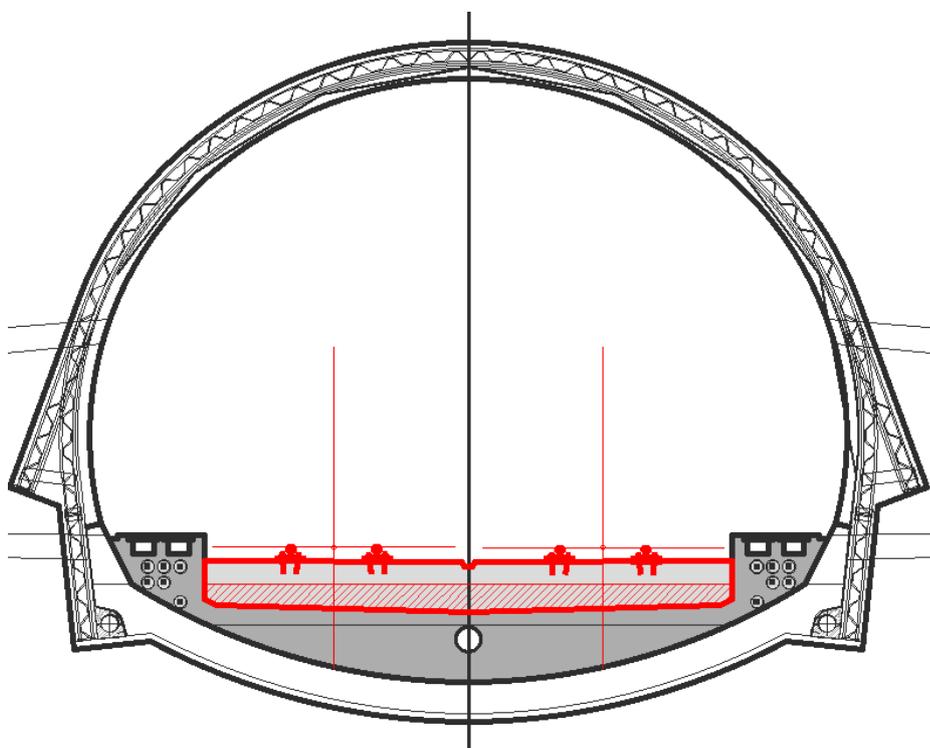


Figure 38 – Theoretical cross-section view of the tunnel and the tracks.

Although these documents were not as-built plans, they were highly important in interpreting the point cloud and validating the plausibility of the modelled elements. Their integration into the modelling process was therefore essential, especially in the early stages of object identification and classification. In addition to the graphical documentation, other non-graphic elements were also used to enrich the model with alphanumerical information and to better understand the context of the project.

4.2.2. Terrestrial laser scan survey

Due to the absence of as-built plans and the limitations of the available construction phase documentation, it was decided to conduct a terrestrial laser scan survey to obtain accurate geometric data of the tunnel and its components. This method was selected to ensure that the modelling process would be based on reliable, high-resolution spatial information, especially for elements whose location or dimensions were not clearly documented.

A terrestrial laser scanner was chosen because the study focused on a relatively short section of the tunnel, making it feasible to manually position the equipment throughout the survey. The Trimble X7, in particular, was selected for its lightweight design and its ability to automatically regulate its position, saving time on adjustments related to the horizontal plane. Moreover, the level of precision available was deemed appropriate for the modelling objectives of the case study. The scanner's datasheet is included in Appendix 4 and Figure 39 shows the equipment inside the tunnel on the day of the survey.

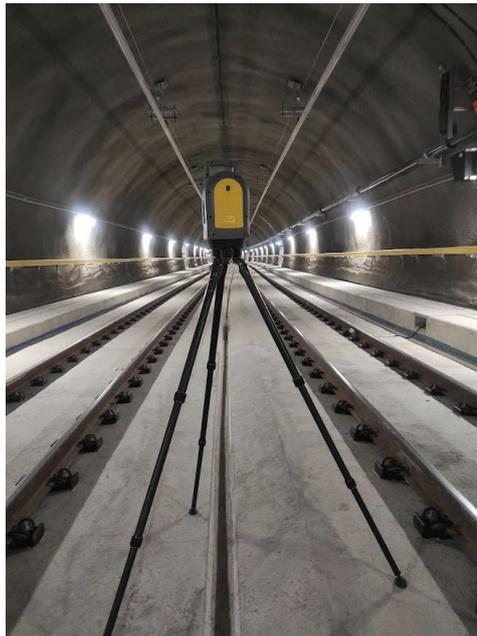


Figure 39 - Terrestrial laser scanner used for the study.

The survey was carried out by the author with the company's topographer. Prior to the data collection, the modelling needs were discussed in detail, including the required precision, the number of scan stations, and the specific equipment that needed to be captured. The survey took place shortly before the final tests of the railway systems were completed and the infrastructure was opened to the public.

The scanner offers two output options: a point cloud without RGB data and a coloured point cloud. In order to add the RGB data, after the rotation is done using laser, a 360-degree pictures needs to be taken to add the colour information to each point. For this project, it was decided to include RGB data despite the increase in file size, as the colour information significantly facilitates the interpretation of elements within the tunnel.

To improve registration accuracy, reference points were established inside the tunnel. These reflectors were attached to geolocated points referenced in the Swiss grid system EPSG:2056 – Swiss CH1903+ / LV95. Since GPS systems often fail to function correctly inside underground tunnels, the operator of the line provided the coordinates of the reference points, allowing the point cloud and, later, the model to be correctly georeferenced. One of these reflectors is shown attached to a referenced base point in Figure 40.

Scanning inside a tunnel presents specific challenges, particularly when relying on automatic registration between scan stations. For this process to work reliably, the scanner must detect overlapping features across scans. This typically requires the presence of reflective targets throughout the tunnel, as shown in Figure 40. During the survey, it became evident that there were not enough reflectors available. To overcome this, water bottles were used as improvised targets, enabling the Trimble software to correctly adjust the overlapping stations and complete the registration process successfully.



Figure 40 - Reflector attached to a referenced base point inside the tunnel.

The placement of the scan stations was carefully planned to ensure sufficient coverage and overlap. This distribution was essential for capturing the geometry of the tunnel and its components from multiple angles, as illustrated in Figure 41, the layout of the tunnel section studied in this project

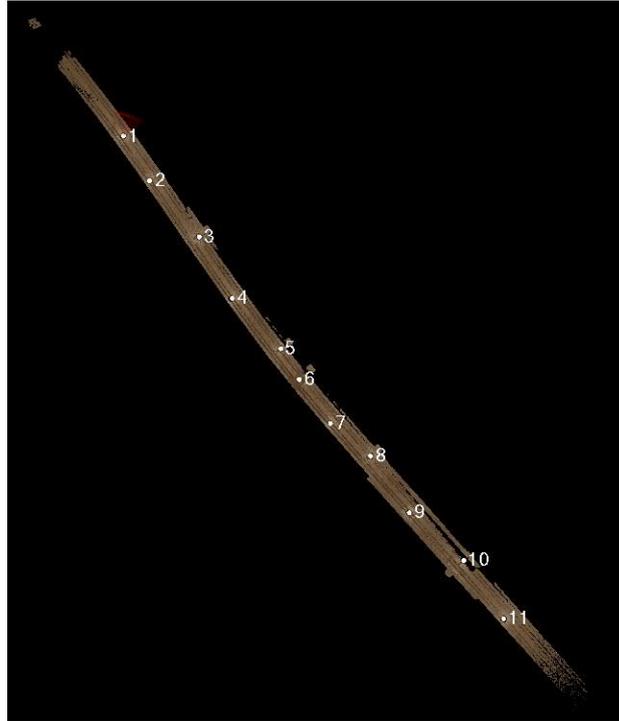


Figure 41 - Scans' placement in the case study tunnel.

A total of 11 scan stations were performed using the Trimble X7, covering approximately 200 meters of the tunnel. Each scan was configured to run for 7 minutes, followed by an additional minute to capture 360-degree images. This setup resulted in a registration accuracy of 12 mm at a distance of 35 meters, following the datasheet of the Trimble X7. An average accuracy of 7,4 mm across all scans was found according to the scan report from the laser scanner itself. Each station produced a point cloud containing over 42 million points. Figure 42 shows an extract of the point cloud report. This dataset formed the foundation for the modelling process described in the following sections.

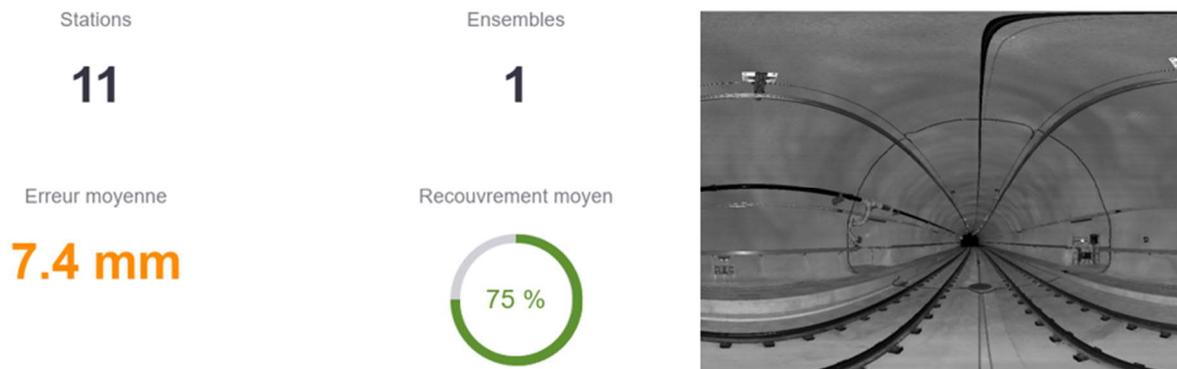


Figure 42 - Resulting point cloud report from the Trimble X7 scanner.

4.2.3. Alignment information

Accurate alignment information is essential for positioning objects within the tunnel and for ensuring consistency across the model. In railway modelling, the alignment defines the spatial reference system used to locate elements along the track, typically based on kilometer stationing and orthogonal offsets. A complete railway alignment includes four key components: the horizontal alignment, the vertical alignment, the cant and, depending on the case, turnout information. This relationship can be summarized as seen in Figure 43.

$$\text{Track alignment} = \text{Horizontal alignment} + \text{Vertical alignment} + \text{Cant} + \left(\text{Turnout information} \right)$$

Figure 43 - Components of a railway track alignment.

For this case study, two approaches were analyzed as input data for the track alignment. The first approach explores how alignment can be extracted from the point cloud surveyed in the tunnel. The second approach relies on alignment files provided by the operator. Each method offers distinct advantages, and the final choice is explained by the end of this section.

First approach, extraction from a point cloud:

When working with existing condition surveys based on point clouds, several strategies can be applied to identify the rails and reconstruct the track alignment. Four main methods were identified and evaluated for this case study.

- **Programming extraction:** this method was described in the works of Cheng et al. (2019) and Soilán et al. (2021). It uses point interpolation techniques to derive the alignment directly from the point cloud data. This approach is particularly useful when no other data is available, when the surveyed point cloud has very high precision, or when the tracks have undergone significant changes over time and require updated alignment information. Although the method is relevant, it was not applied in this study, as the programme referenced the literature review was not replicated.
- **Point intensity values:** this method relies on the intensity values of the points, which can reveal wear patterns in the rail caused from the contact between the rail and the train wheels. Point cloud intensity refers to the strength of the signal returned from a surface when scanned by a laser scanner. Its variation depends on several factors related to the scanner, the target surface, and environmental conditions. In this case, the target surface changes reflectivity in the zone where wear between rail and wheel occurs, making it possible to detect these patterns. This technique is available in software such as OpenRail Designer by Bentley and is effective when working with worn rails. However, it could not be applied in this case study, as the rails in the tunnel are brand new and do not yet show the necessary wear patterns. This difference in reflectivity is exemplified in Figure 44.



Figure 44 - Point cloud showing the difference in reflectivity on the rail head.

- Rail profile recognition and feature extraction: this method uses the recognition of the rail profile in an orthogonal direction to the track. It allows for the identification of feature lines by analysing cross-sections of the point cloud according to a direction vector. This method is summarized in Figure 45, where we see a rectangle highlighting the cross-section and a green arrow with orthogonal vector representing the direction of the search.

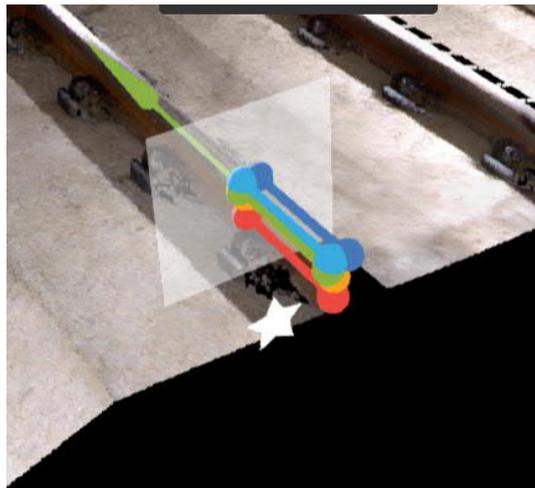


Figure 45 - Image summarizing the feature extraction method. The rectangle is the cross-section and the green arrow is the vector.

This technique is applicable to both new and worn rails and was tested using both Trimble Business Center and Autodesk ReCap. The tests made with Trimble Business Center (TBC) at the time indicated that the method worked well for simple profile geometries, such as curb walks, but not as well for more complex profiles like a rail head. In that sense, a decision was made to only detail the extractions made with ReCap.

The extraction tool is not available in the stand-alone version of Autodesk ReCap PRO. This tool is available on ReCap Cloud-based Services, which is the online version of Autodesk's tool to deal with point cloud files. This service is available in collaboration with Autodesk Construction Cloud (ACC). To start, it is necessary to create a project in ACC related to the case

study. This project was created only with the goal of applying the feature extraction tool to the surveyed point cloud.

The tool uses the definition of three parameters as well as the identification of the cross-section it needs to look for. The Alignment Algorithm Threshold specifies the confidence threshold of the reference data to continue linear feature extraction; if the value during extraction becomes lower than this baseline, auto extraction will pause. The step interval specifies the distance between each cross section during extraction. The cross section depth is the depth of the view as seen in the Cross Section View (“Autodesk ReCap Help | Specifying Extraction Settings | Autodesk,” n.d.). The Alignment Algorithm Threshold used was 75%, the step interval was 0.5 m and the Cross Section Depth 0.3 m. Figure 46 shows the rail head profile used in Cross Section View. The profile is cut in half due to the “shadow” created by the placement of the laser scanner.

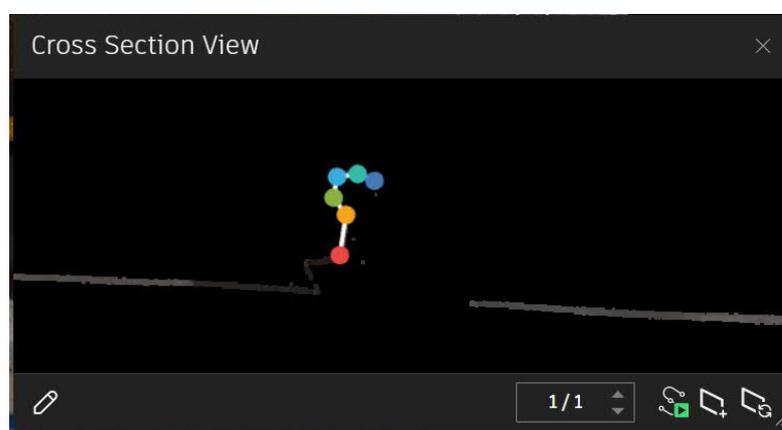


Figure 46 - Cross Section View containing the rail head profile.

When not in a curve, the software managed to find the next cross-section more easily, and the Alignment Algorithm Threshold showed better percentages. However, in the final zone, where the density of points is lower due to the presence of only one scan station without any overlapping ones, the software had more difficulty identifying the expected pattern, resulting in a significantly lower Alignment Algorithm Threshold. This limitation highlights the importance of planning the laser scanning perimeter carefully: the zone of interest should always be covered by at least two stations simultaneously to ensure sufficient point density and pattern recognition accuracy. Figure 47 shows, on the right, the Alignment Algorithm Threshold for the section selected. On the left, Figure 47 shows the breakdown structure for the feature lines.

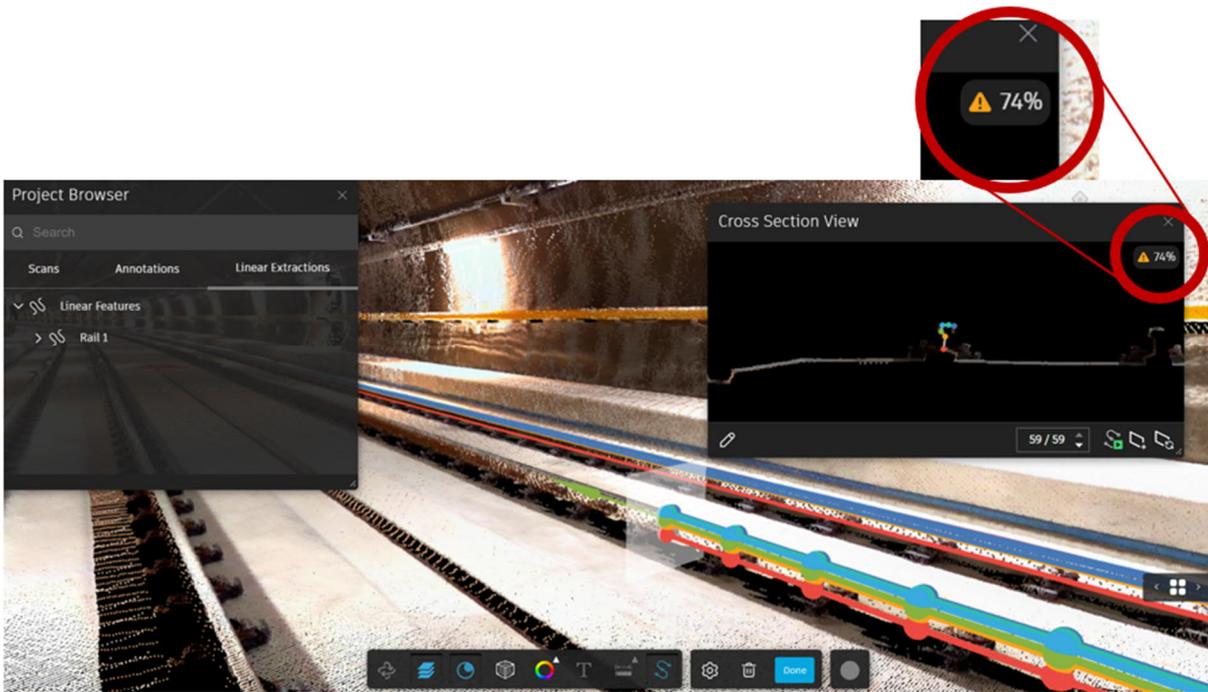


Figure 47 - On the left of the image, the feature line extracted. On the right, the Alignment Algorithm Threshold for the selected section.

Figure 48 shows the resulting feature lines defining the rail heads of the two tracks in the tunnel. The software allows for the export of the line as a .dxf, a LandXML or a .csv file.



Figure 48 - Collection of feature lines defining the rail heads of the two tracks in the tunnel.

- Highest point of the rail head: the last method consists of finding the highest point of the rail head, which corresponds to the topmost surface of the rail. This technique can be applied directly within Bentley OpenRail Designer by defining parameters that limit the search area to a cylindrical volume around the expected rail position. However, this method requires a point cloud with minimal noise to ensure accurate detection. Moreover, this method may be used to

both new and worn tracks. Figure 49 and Figure 50 present, respectively, the parameters used to define the zone of research and the cylinder itself.



Figure 49 - Parameters used to search for the highest point using OpenRail Designer.

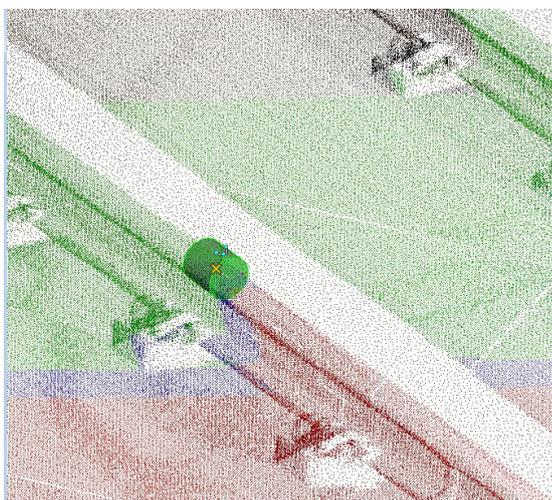


Figure 50 - Cylinder zone for the creation of the rail feature line.

The three last methods explained above result in the definition of polylines representing the left and right rails of the track. In zones without cant, these polylines are sufficient to model the rails accurately. However, in zones where cant is applied, the alignment must include cant information to ensure the rail geometry is correctly represented.

Even though the software tools available on the market can extract a polyline defining the center axis for the two sets of rails, they cannot make a mathematical regression that accounts for clothoids, which mark the transitions between a tangent and a curve or between two curves.

A clothoid, in highway and railway design, is a spiral used as transition curve. During a curve, the track has a cant, which is the elevation of one of the rails to prevent derailling. The clothoid serves as the transition zone where the elevation changes from 0 (when both tracks are parallel) to a specific value depending on the radius of the curve and the speed of the rolling stock (Meek and Walton, 2004). The polyline generated is in fact a combination of small lines, not an assemble of lines, curves, and spirals that are perceived as an object by the machine, containing the mathematical information needed for modelling.

In Figure 51, it is possible to observe the difference in modelling rails when the cant information is present in the alignment versus when it is absent. Cant is not only the representation of a superelevation from one rail to the other, but also a rotation of the running surface based on the track alignment. In the image on the left, the rails follow a rotation according to the cant information. This rotation is based on the circle at the center of the tracks, which represent the alignment. When compared to the grey concrete shown in the image, the rails remain parallel to it. In the image on the right, the rails have a superelevation applied but they do not rotate according to the alignment. If a rail track were built as

shown in the image on the right, the risk of derailment would be significantly higher, as it would cause a break in the running surface.

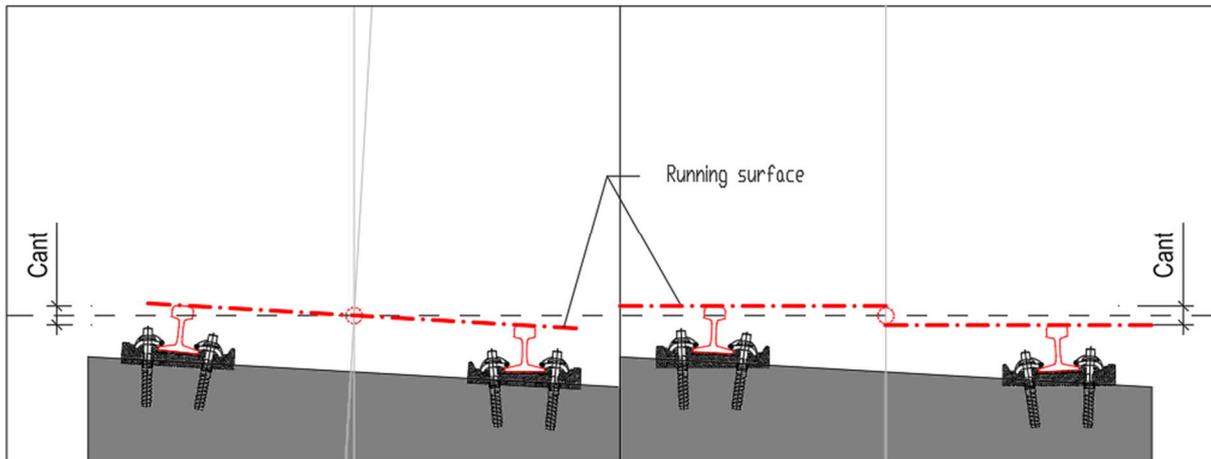


Figure 51 - Representation of rail sections. The image on the left uses the cant information correctly while the image on the right does not apply the cant properly.

Second approach, using alignment file

Railway tracks and lines require constant maintenance and careful attention to preserving their geometry, even when they are not undergoing refurbishment or major changes. For this reason, railway operators maintain numerical files containing alignment geometry, even for older tracks. Several open file formats support the exchange of railway alignment information, including .xtr, .xml and .railML.

One of the XML-based formats developed for the exchange of railway alignment data is the RailML (“railML.org,” n.d.). RailML enables open data exchange between infrastructure managers and national bodies, containing not only the alignment information but also traffic management and rolling stock data. The schema currently under development is non-excludent to the IFC Rail initiative (Augele, 2017). However, this format is not supported by any of the modelling softwares used, so only Toporail and LandXML were analyzed.

One of the inputs provided by the railway operator for modelling the alignment was a native file from a software called Toporail. This software is primarily used in Switzerland and is not available for purchase. Developed by the Swiss Federal Railways (SBB), Toporail supports not only the design and analysis of railway alignments but also the direct creation of execution plans, the export of bills of quantities and, most importantly, the export of machine files for the specialized construction equipment used to tamp the ballast (“SM-03-2014-1_01.pdf,” n.d.).

Although not available for direct use, the Toporail file format is open and features a simple data structure for alignment information as shown in Figure 52. The structure of the .XTR file is very similar to the data structure of a LandXML file (Figure 54), which also describes the alignment information of a railway track including the cant information (“LandXML-1.2Doc - Cant,” n.d.). Both formats begin by describing the horizontal alignment, followed by the vertical alignment, and finally the cant information.

A key difference between them is that the Toporail format also includes the rail profile used and the turnouts classification and position as shown in Figure 53.

N	0/1	REFLECTION	VOIES	M	CM	Alignment name			
16	D	2537978.38262	1152455.26952	11.74271	6.24811	0.000	0.000		
17	C	2537979.52858	1152461.41164	11.74271	90.65839	-180.000	-180.000		
18	C	2537973.48941	1152550.91132	379.67886	32.20076	-90.500	-90.500		
19	R	2537958.21420	1152579.06560	357.02733	19.79130	-90.500	0.000		
20	D	2537944.76109	1152593.56709	350.06626	29.75013	0.000	0.000		
21	R	2537923.74647	1152614.62549	350.06626	22.25318	0.000	-202.500		Horizontal information
22	C	2537907.74379	1152630.08464	346.56828	22.54740	-202.500	-202.500		
23	R	2537890.16153	1152644.18160	339.47983	55.39071	-202.500	0.000		
24	D	2537842.38075	1152672.11061	330.77296	86.65220	0.000	0.000		
25	C	2537765.65640	1152712.38439	330.77296	34.28550	482.638	482.638		
26	d	0.00000	116.82242	0.00000	0.000	472.5384			
27	c	116.82242	39.59977	0.00000	12000.000	472.5384			
28	d	156.42220	107.13606	-3.30000	0.000	472.4730			
29	c	263.55826	27.99963	-3.30000	-40000.000	472.1195			Vertical information
30	d	291.55790	88.25601	-2.60000	0.000	472.0369			
31	c	379.81390	10.83194	-2.60000	17000.000	471.8074			
32	d	390.64584	9.13183	-3.23718	0.000	471.7758			
33	Q	0.00000	6.24810	0.0	0.0	35			
34	Q	6.24811	19.20870	0.0	-10.0	35			
35	Q	25.45680	66.47592	-10.0	-10.0	35			
36	Q	91.93273	11.77087	-10.0	-28.0	35			
37	Q	103.70360	25.40365	-28.0	-28.0	35			
38	Q	129.10726	19.79130	-28.0	0.0	35			Cant information
39	Q	148.89856	29.75013	0.0	0.0	35			
40	Q	178.64869	22.25318	0.0	-55.0	35			
41	Q	200.90187	22.54740	-55.0	-55.0	35			
42	Q	223.44927	55.39070	-55.0	0.0	35			
43	Q	278.83998	120.93770	0.0	0.0	45			
44	Q								

Figure 52 - Alignment information structure in a XTR (Toporail) file.

N	1/0	TUNNEL	AV	ECHALLENS	M	CM	Turnout name, type and rail profile								
813	W	UPR	52	EW	IV	500 M	1:14	R	STAR	F	Be	47	0.0004	0	1
814	1	C	2537461.79413	1152841.40255	126.10955	0.00000	-1158.862								Horizontal information
815	2	C	2537494.71668	1152827.68683	124.15020	0.00000	-1158.862								
816	3	C	2537495.14502	1152828.88366	119.61139	0.00000	-349.294								
817	21	D	2537478.15118	1152834.29083	119.61139	0.00000	0.000	0.000							
818	43	D	2537501.24069	1152826.96244	221.83300	1.72542	0.000	0.000							Vertical information
819	53	C	2537527.74632	1152816.80240	121.46100	0.00000	3.200	3.200							
820	61	C	2537461.79413	1152841.40255	126.10837	35.63854	-349.294	-349.294							
821	C	0.00000	35.63854	-4.99481	26400.000	471.9150									
822	Q	0.00000	35.63854	-20.0	-20.0	45									Cant information
823	Q														

Figure 53 - Turnout information structure in a XTR (Toporail) file.

</Alignment>														
<Alignment name="REFLECTION VOIES" length="5.889159556735" staStart="0.00000000189" desc="REFLECTION VOIES">														
Horizontal information														
Cant information														
Vertical information														
</Alignment>														

Figure 54 - Alignment structure in a LandXML file.

Finally, it was decided to use an alignment file describing the track. This approach was easily applicable to the case study because the tracks had been barely used by the time the study began, and the precision of the track positioning, horizontal, vertical and cant was within 3 mm. The author took a few of the measurements herself and also analyzed the reports of the topographer responsible for measuring the differences between the designed tracks and the actual conditions. Moreover, the methods available for use based on the first approach did not include the cant information needed for correctly modelling the rails. For this reason, it was decided to base the modelling workflow on the XTR file, because it includes more information about the rail profiles and turnouts than the LandXML file received.

4.3. Selection of modelling platforms

The selection of modelling platforms is a key step in defining a workflow that supports both technical feasibility and IFC interoperability. In this case study, two main types of software were used: those dedicated to point cloud processing and those focused on modelling. The modelling tools are further categorized into Building Information Modelling Authoring Tools (BATs) and Alignment-centered Modelling Tools (AMTs), as described by Kwon et al. (2020).

Beyond technical capabilities, the choice of platforms is also essential to ensure a workflow that minimizes information loss and avoids unnecessary rework. Each tool must be able to handle the input data formats described in Section 4.2 support, support the modelling workflow outlined in Section 4.4 and contribute to the IFC translation discussed in Section 4.5.

4.3.1. Point cloud processing

Point cloud processing tools are primarily used to interpret and manipulate raw survey data, enabling the extraction of geometric features and spatial references. These platforms must be capable of handling large datasets, performing decimation, classification and separation into zones to prepare the data for modelling.

Understanding how to process and manage point clouds is crucial for creating a BIM model from existing conditions. Point clouds are essentially raw data containing information about geographical coordinates (X, Y and Z) as well as RGB colour values (Red, Green and Blue). This raw data must be made usable when attached to modelling platforms in order to create a structured BIM model. To achieve this, several techniques can be applied, such as decimation, classification and separation into zones.

Point cloud decimation reduces the number of points in the cloud to improve performance and manageability, while preserving essential geometric features. This process is crucial for enabling the use of point clouds in modelling tools. Decimation works by selecting representative points to retain and discarding the rest. There are different types of decimation, notably simple decimation, spatial decimation and nearest-neighbour decimation.

For this case study, the decimation method chosen is the spatial decimation. This method divides the space into cubes or cubic zones and retains one point per cube or zone. This method allows for an even distribution of points while preserving the original shape of the point cloud. It is important to note that the spatial decimation does not alter the precision of the survey done, only the density of points.

The classification process involves assigning semantic meaning to different regions of the point cloud, such as distinguishing between rails, walls of the tunnel and equipment. This process allows for the use of semantic regions of the point cloud at a time. It also allows modelling software to focus only on the relevant points for the type of modelling being performed.

The separation of the point cloud into zones is also a valuable method, especially when decimation and classification alone are insufficient to make the point cloud manageable for modelling tools. Unlike classification, zone separation is not semantic, it is a simple division into regions based on spatial or functional criteria.

For the case study, two software tools were available and used for the point cloud processing: CloudCompare and Autodesk ReCap Pro. Cloud Compare is an open-source 3D point cloud and mesh processing software originally developed in France (“CloudCompare - Open Source project,” n.d.). The main documentation of the software is available online and its functions are transparent. Nevertheless, it does not integrate well with Autodesk tools, as it does not export the .rcp file format required for Autodesk modelling platforms. Recap Pro is Autodesk’s point cloud processing tool, it is user friendly and integrates well within the Autodesk environment through the .rcp file format.

Cloud Compare offers three different non-destructive methods for subsampling the point cloud. The first one is the random method, which consists of randomly separating points into a different group until reaching a chosen remaining number of points. This method results in a non-homogenous point cloud. The second is the space method, which consists of choosing the minimum space between points. This method results in a more homogenous point cloud with points better distributed over the vault. The third method is called Octree. The octree is a spatial decimation method that divides the point cloud into cubes (“CloudCompare octree - CloudCompare wiki,” n.d.).

Recap Pro, for decimation, uses a grid-based decimation method. It separates the space into a uniform grid, typically retaining only the point at the center of each grid cell. This process results in a regular density of points that do not account for geometric features. At the time the point cloud processing was studied, Recap Pro only allowed decimation during the point cloud import process. In CloudCompare, the decimation process was better documented and offered greater control.

Finally, it was decided to use CloudCompare for the decimation process, allowing for better control of the decimation method used, in this case, the octree method. Recap Pro was also used for the classification part, due to its user-friendly interface and compatibility with the modelling platforms.

4.3.2. 3D modelling platforms

Once the point cloud data has been processed and prepared, the next step involves selecting appropriate platforms for 3D modelling. These platforms are responsible for transforming raw spatial data into structured digital representations of the tunnel and its components. The choice of modelling tools directly affects the quality of the final BIM model, the productivity of the modelling workflow and the ability to export data in IFC.

As described by Kwon et al. (2020), modelling platforms can be categorized into two main types: Building Information Modelling Authoring Tools (BATs) and Alignment-centered Modelling Tools (AMTs). In most linear infrastructure models, both tools are needed in order to create a sustainable modelling workflow. Each category offers distinct advantages depending on the nature of the project and the modelling requirements.

AMTs are particularly well-suited for corridor-type projects, such as railway tunnels, which follow both horizontal and vertical alignments. These tools are designed to handle large coordinate values, which is essential for infrastructure projects that span long distances. In contrast, many building-focused platforms assume local coordinate systems and may struggle with the scale of linear infrastructure. AMTs also support the modelling of non-planar elements, including horizontal curves, vertical slopes and complex cross-sections.

BATs, on the other hand, are typically used for architectural and infrastructure modelling within a more structured, planar environment. These tools usually operate using levels and grids, which are ideal for modelling punctual objects and tunnel components that follow regular geometries. BATs offer parametric object classes, allowing for detailed and adaptable object creation. They are also good in document production, enabling an easier production of sections and schedules directly from the model.

In this case study, both types of platforms were considered to ensure that the modelling workflow could accommodate the specific needs of tunnel geometry and railway infrastructure. The selection was based on criteria such as compatibility with processed point cloud data and support for IFC 4.3 export.

Alignment-centered Modelling Tools (AMTs)

Several tools on the market support alignment-based modelling, including Trimble Novapoint, Autodesk Civil 3D, Bentley OpenRail Designer etc. In the context of this case study, two platforms were available for testing: Bentley OpenRail Designer and Autodesk Civil 3D. The selection process was guided by seven criteria, each reflecting the specific needs of railway tunnel modelling and the requirements for IFC 4.3 interoperability:

1. Creation of dynamic cross sections along the alignment.
2. Import capability for alignment files, preferably in .XTR format or at minimum in LandXML.
3. Attachment of point clouds to assist in element placement and verification.
4. Availability of a turnout library compliant with Swiss standards.
5. Export functionality for IFC 4.3, as approved by ISO.
6. Support for property mapping aligned with the Level of Information Need.
7. Ability to map objects to IFC entities, ensuring semantic consistency.

These criteria were chosen to ensure that the selected platform could handle both the geometric complexity of the tunnel and the semantic richness required for IFC-based data exchange.

Both software tools allowed for the creation of dynamic cross sections along the alignment. Each platform enabled the parametrization of cross-section behavior based on user-defined rules, which is

essential for modelling geometries that vary along the corridor. In Civil 3D, this task can be done using *Subassembly Composer*. However, a notable difference between the two lies in the availability of learning resources and community support. Autodesk Civil 3D benefits from a broader user base, with extensive online documentation, tutorials and active forums. This ecosystem facilitates self-learning and troubleshooting, especially for users new to alignment-based modelling.

Despite this advantage, the author was able to successfully create a custom cross-section in Bentley OpenRail Designer, based on input provided by the line operator. This cross-section was then used to generate a 3D solid representing the tunnel geometry. Figure 55 presents the custom cross-section created from the operator's input. Figure 56 illustrates how this cross-section was extruded along the alignment to form a 3D solid. Figure 57 compares the resulting solid with the point cloud surveyed in that zone, demonstrating the accuracy of the modelling process.

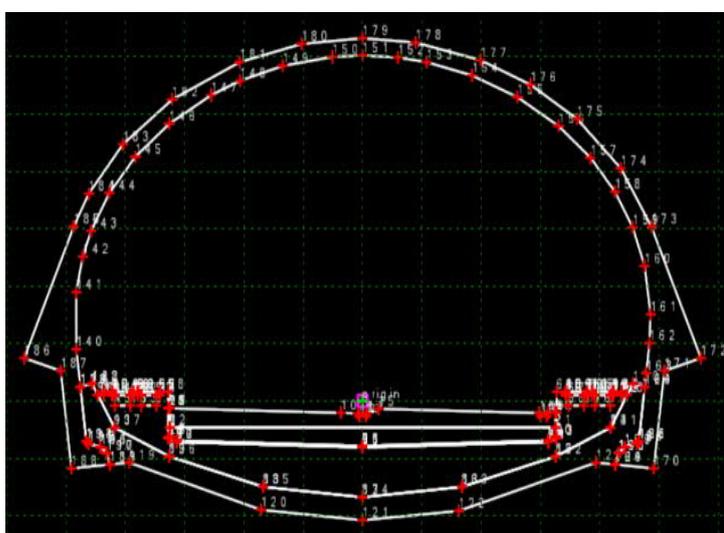


Figure 55 - Custom cross-section of the tunnel in OpenRail Designer.

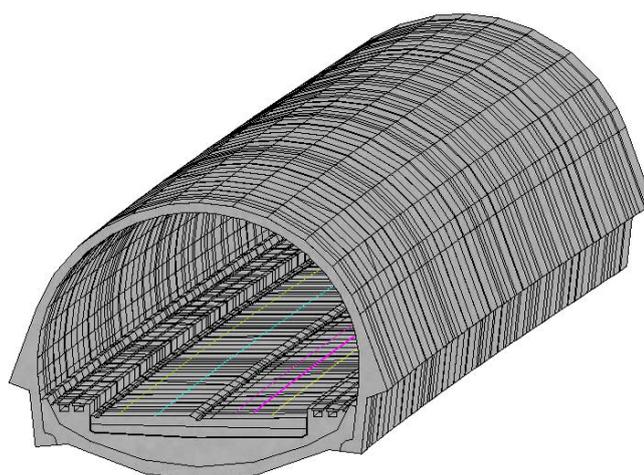


Figure 56 - 3D model of the tunnel created using OpenRail Designer. The colored lines represent the alignments and the rails.

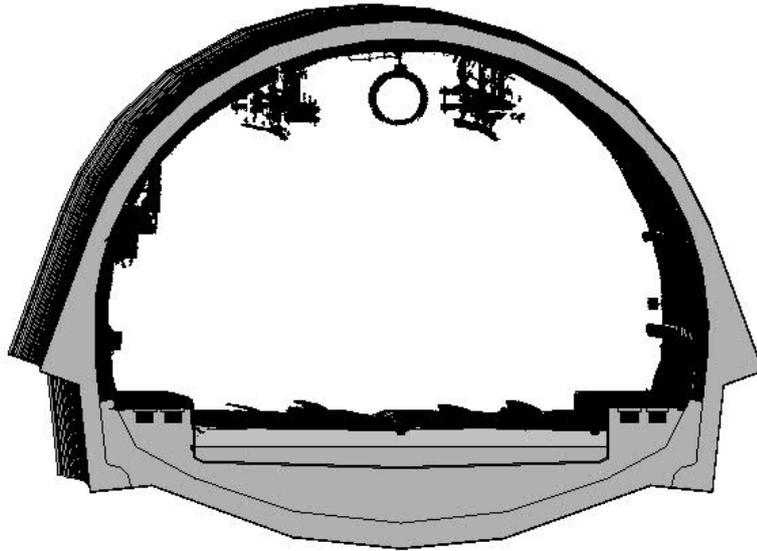


Figure 57 - Comparison of the 3D tunnel model created using OpenRail Designer with the surveyed point cloud.

Regarding the import of .XTR files, both OpenRail Designer and Autodesk Civil 3D support this file format. OpenRail Designer can import .XTR files natively, without requiring any additional patches or extensions. In contrast, Civil 3D requires the installation of the *Rail Data Extension*, which is freely available on Autodesk's website and does not require an additional license beyond the main software. As such, this requirement was not considered a limiting factor.

Despite their ability to import .XTR files, both platforms present limitations. Neither software can import or export switches from directly .XTR files, these must be manually inserted after the alignment is imported. Another limitation is that certain alignments or profiles, particularly those beginning or ending with clothoids or circular arcs, may not be fully generated (Autodesk, 2023).

A further distinction lies in the availability of turnout libraries. Civil3D does not include built-in turnout catalogs for Switzerland. This complicates the modeler's task, as they must either create custom turnouts or rely on generic metric options, which can reduce the quality of the model. Currently, Autodesk Civil 3D includes turnout libraries for the United States and France.

Both platforms support the attachment of point clouds and both allow for railway modelling using either the alignment extracted from the point cloud or the theoretical alignment file. However, the cant issue discussed in the previous section affects both platforms similarly.

One of the most significant advantages of Civil 3D is its ability to export to the IFC 4.3 format. This requires the installation of the *Autodesk IFC 4.3 Extension for Civil 3D*, which is also freely available and does not require an additional license. This extension enables the export of semantic and geometric elements, including alignments, profiles, cant information, kilometre alignment and survey points ("Rail Data Exchange Extension for Autodesk® Civil 3D®," n.d.).

In contrast, OpenRail Designer does not currently support the direct export of the ISO approved IFC 4.3 format directly from the software. The most recent version of the software only supports export of IFC

4x3 (Release Candidate 4). At the beginning of this study, even this functionality was not yet available. Furthermore, the export is limited to meshes and alignments. A potential workaround is the use of Bentley's iTwin platform, which supports full IFC 4.3 export and property mapping. However, iTwin requires an additional license and could not be tested within the scope of this case study.

The ability of mapping properties according to the Level of Information Need and to assign objects to the correct IFC entities is essential for producing structured and interoperable data. Civil 3D supports this functionality directly within the software. On the other hand, OpenRail Designer relies on iTwin for property mapping and IFC schema assignment.

At the moment this dissertation was being written, no software tool had yet received official certification for the import or export of IFC 4.3. A summary of the comparison between the two platforms is presented in Table 12.

Table 12 - Comparison between OpenRail Designer and Civil 3D

<i>Criteria</i>	Bentley OpenRail Designer	Autodesk Civil 3D
<i>Dynamic cross section</i>	✓	✓
<i>Alignment import (.XTR)</i>	✓	✓
<i>Attachment of point clouds</i>	✓	✓
<i>Turnout library (Switzerland)</i>	✓	✗
<i>IFC 4.3 export</i>	✗	✓
<i>Properties mapping</i>	✗	✓
<i>IFC mapping</i>	✗	✓

Due to its limitations regarding exporting IFC 4.3 files and the steeper learning curve caused by the lack of accessible training resources, OpenRail was not selected. Autodesk Civil 3D with *Subassembly Composer* was the final AMT choice to integrate the modelling workflow. The version used was Civil 3D 2025 with two extensions: *Autodesk IFC 4.3 Extension 2025.1 for Civil 3D* and *Rail Data Exchange Extension 2025.0.1 for Autodesk Civil 3D*.

Building Information Modelling Authoring Tools (BATs)

Autodesk Revit is recognized as a modelling platform for buildings, but it is not typically used for infrastructure projects. As previously explained, building-focused modelling platforms rely on levels

and floors to position objects, whereas infrastructure platforms use alignments as reference geometry. Despite this distinction, Revit was selected for this case study due to the author's prior experience with the software.

Learning a new platform requires time and effort, especially when dealing with complex workflows and unfamiliar interfaces. Given that a significant amount of time had already been invested in understanding the functionalities of OpenRail Designer and Civil 3D, the decision to use Revit was made to optimize time and focus on other critical aspects of the dissertation. Moreover, Revit 2024 allows the export of IFC 4.3, although no software tool has been certified by buildingSMART International till now.

Revit also proved to be a suitable platform for modelling punctual objects, such as signals and catenary supports. Its support for parametric object classes enabled the creation of adaptable and reusable objects, which could be configured according to the specified Level of Information Need. This ensured that the objects were not only geometrically accurate but also semantically rich. Finally, Revit 2024 was used for the case study.

4.4. Modelling workflow

The modelling workflow developed for this case study is summarized in Figure 58. It is structured around three main tasks: point cloud processing, linear modelling and punctual modelling. Each of these tasks represents a distinct subprocess within the overall workflow and is supported by specific inputs and intermediate outputs.

The process begins with point cloud processing, which prepared the spatial data for modelling. Following this, the linear modelling and punctual modelling tasks can be carried out in parallel, using the AMT and BAT selected in the previous section. The next subsections describe each of these three processes in more detail.

The final step in the workflow involves assembling the IFC models. In the context of this case study, this step was limited to viewing the models together to support analysis and draw conclusions. In the industry, however, the approach may vary depending on the appointing party's preferences. Some clients may request a federated model that integrates all disciplines into a single file, while others may prefer to keep models separated by discipline, or even maintain both options for different use cases.

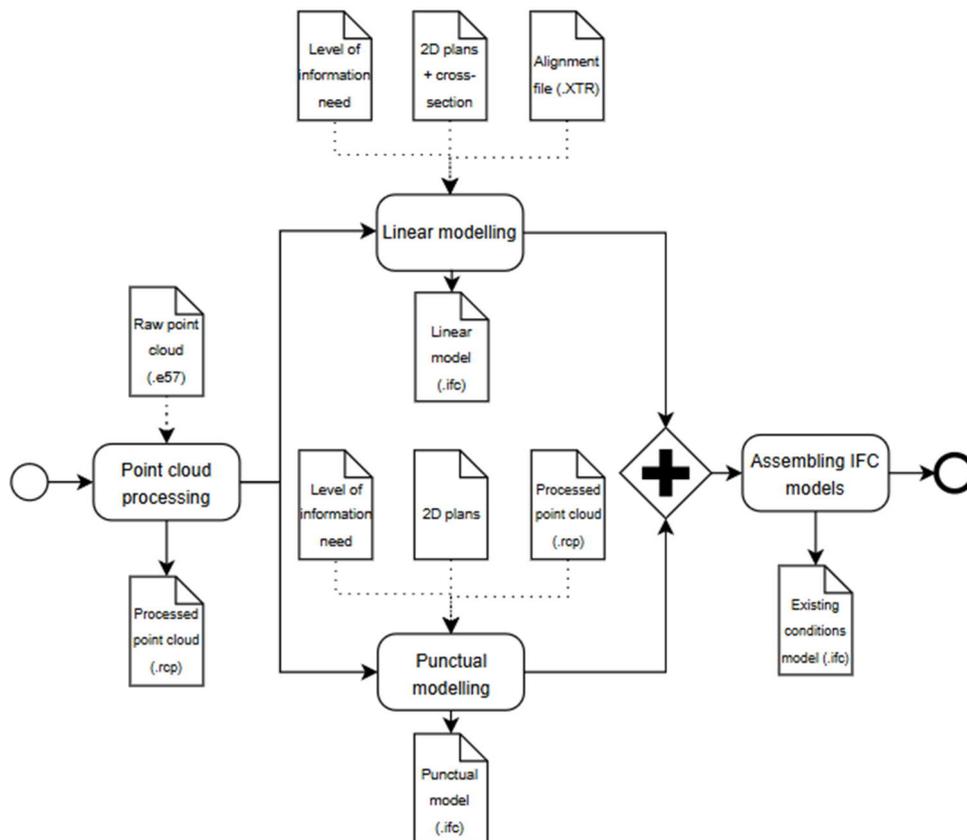


Figure 58 - Summarized modelling workflow for existing conditions used for the case study.

4.4.1. Point cloud processing

The detailed workflow for point cloud processing is shown in Figure 59. The process begins with the decimation of the raw point cloud, carried out in CloudCompare. The original data is imported into the software in .e57 format, which is extracted directly from the Trimble scanner. Once decimated, the point cloud is transferred to Recap Pro for classification of points and the processed data is then exported in .rcp format for use in subsequent modelling tasks.

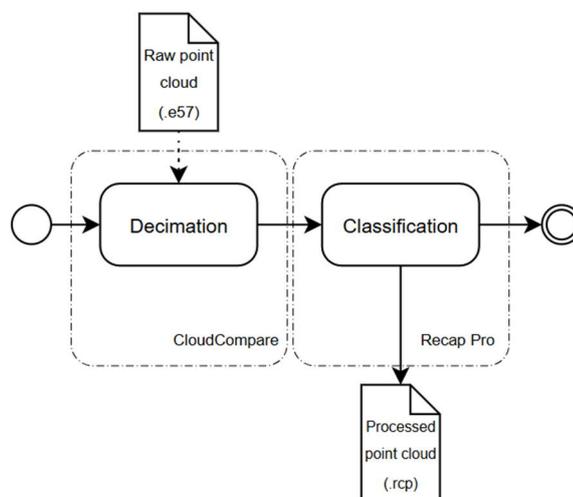


Figure 59 - Detailed workflow for the point cloud processing task.

The tunnel was surveyed in eleven separate scans, each saved in .e57 format and loaded individually into CloudCompare. The section shown in Figure 60 represents a 46.6-meter segment of the tunnel located between two niches. This portion of the tunnel vault alone contains 57.765.997 points and was created by merging three overlapping scans. Overlaying scans was a deliberate strategy to improve referencing and ensure coverage of areas that may have been missed in individual surveys. It also simplifies the assembling process, which can be particularly challenging in tunnel environments where successive scans often appear visually similar.

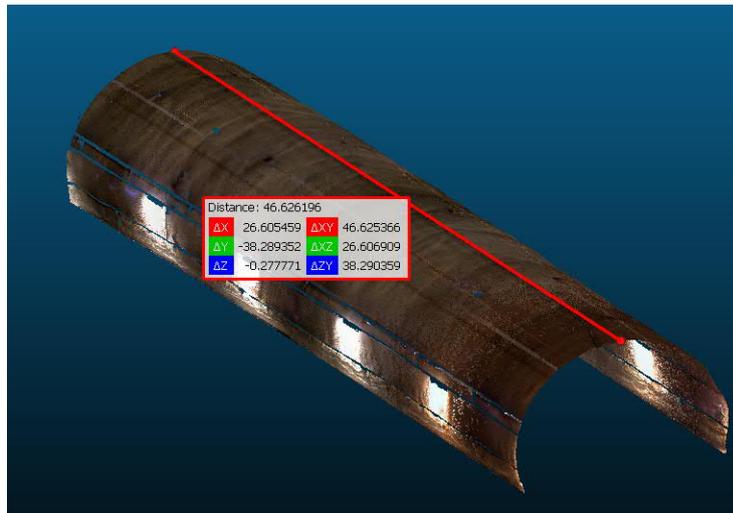


Figure 60 - 46.6 meters long extraction of the tunnel containing over 57 million points.

Once the relevant section was isolated, the point cloud was segmented to include only the tunnel vault. To reduce data volume and improve processing efficiency, several decimation tests were performed using the octree method in CloudCompare. As shown in Figure 61, the original point cloud contained 57.765.997 points. After applying a 1 cm decimation, the number of points was reduced to 5.271.491. A 3 cm decimation resulted in 645.876 points and the most aggressive decimation of 5 cm left 236.113 points.

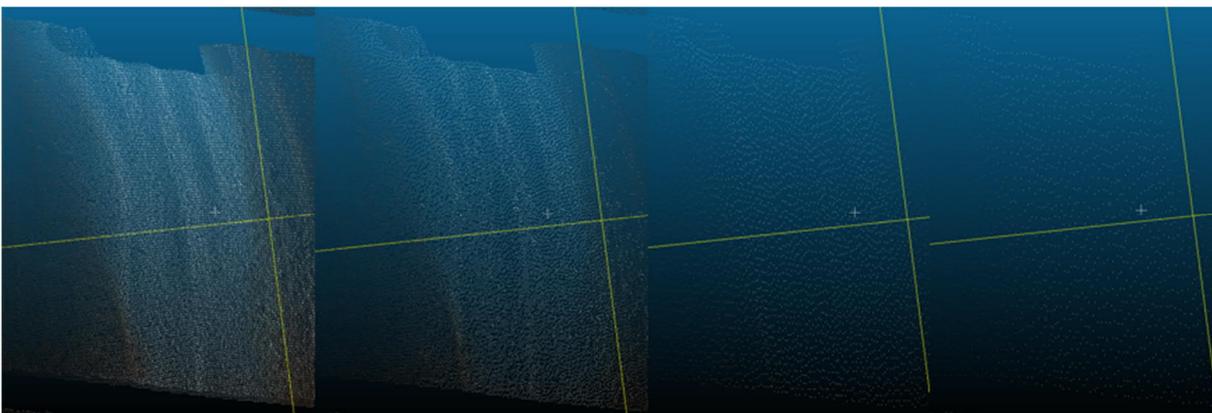


Figure 61 - Different degrees of decimation of the same point cloud section using the octree method in CloudCompare.

After evaluating the test results, a 3 cm decimation factor was selected for this study. This resolution was found to be sufficient for accurately representing the tunnel geometry while maintaining manageable file sizes for subsequent modelling tasks.

After decimation in CloudCompare, the point cloud was exported and imported into Recap Pro for classification. The imported point cloud is shown in Figure 62. In this step, the data was classified into three distinct classes, each corresponding to a different modelling purpose and moment in the workflow. One of the advantages of segmenting the point cloud is the reduction in computational power needed during modelling. By working with smaller datasets, the modelling platforms can operate more efficiently, especially when dealing with large infrastructure projects.

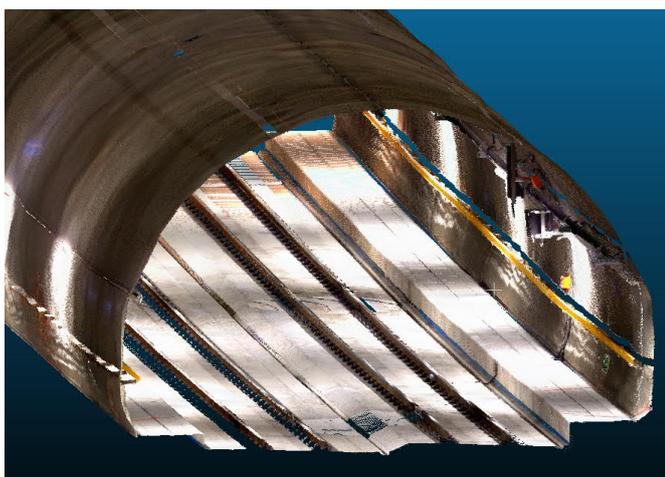


Figure 62 - Colored surveyed point cloud before any classification.

Another practical consideration is the division of the tunnel into sections based on its length. Depending on the available processing power and memory of the computer used, it may not be feasible to load the entire tunnel point cloud at once. However, in the case study presented here, the author's computer was able to handle the entire point cloud after decimation and classification, so it was not necessary to further divide the tunnel into separate zones.

To facilitate the modelling, the point cloud was classified into three classes: slab and rails; equipment and vault. As shown in Figure 63, the classified point cloud uses different colors to distinguish between these categories: red represents the equipment, orange corresponds to the slab and rails and green indicates the tunnel vault. This classification aligns with the modelling strategy in Civil 3D, where the vault, rails and slab are modelled using different subassemblies.

Finally, the classified point cloud was exported in .rcp format, which is compatible with Autodesk's software environment. This ensured a smooth transition into the modelling phase, as both selected platforms are part of the Autodesk's environment.

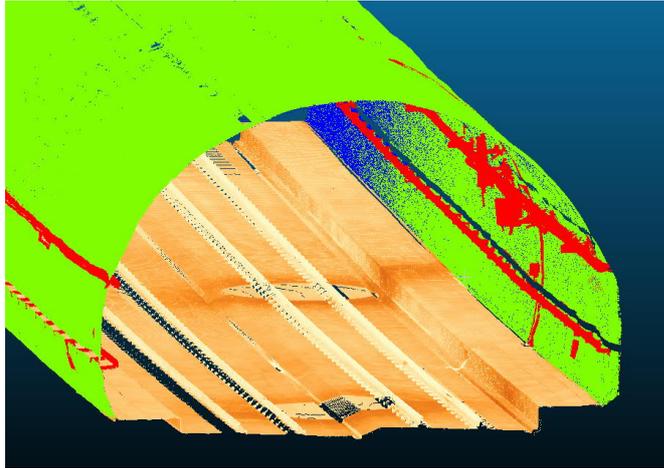


Figure 63 - Classified point cloud in Recap Pro. The slab and rails are shown in orange; equipment are shown in red and the tunnel's vault is green.

4.4.2. Modelling linear objects

The workflow for modelling linear objects is detailed in Figure 64. It begins with the creation of subassemblies using Subassembly Composer, based on the Level of Information Need, the 2D plans and the cross-sections provided by the operator. Once the subassemblies are defined, the .XTR alignment file can be imported into Civil 3D, allowing the assemblies to be referenced to the imported alignments. A quick verification is then performed to confirm that the generated 3D solids correspond to the processed point cloud. Following this, metadata can be inserted into the resulting objects to enrich them with semantic information. Finally, the model can be exported in IFC 4.3 format, enabling interoperability and structured data exchange.

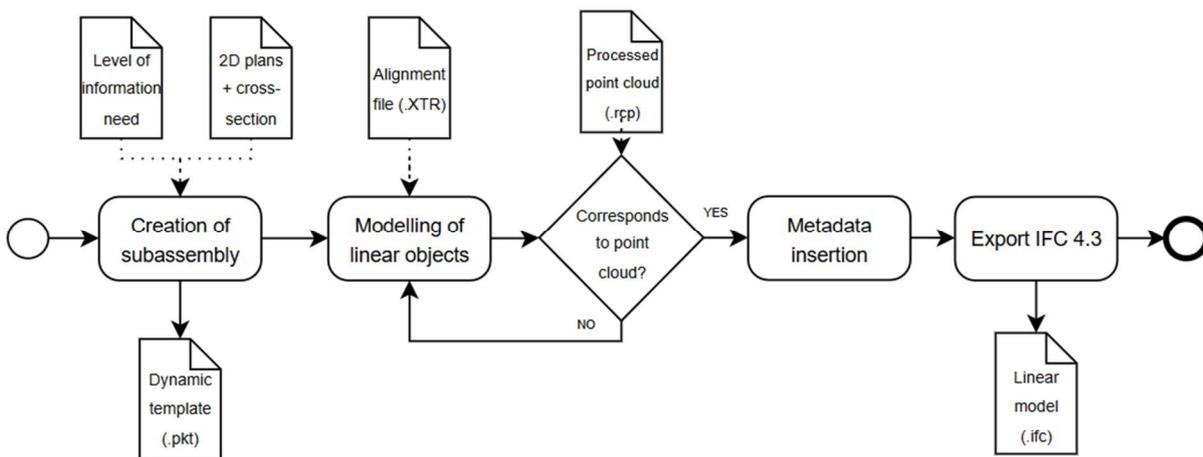


Figure 64 - Detailed workflow for the linear modelling task.

Four dynamic templates were developed with the help of Subassembly Composer to represent the main linear components of the tunnel infrastructure: one for the tunnel geometry with and without niches; one for the rails following the cant; one for the left side of the slab track and one for the right side of the slab

track. These dynamic templates were created to reflect the geometric requirements defined by the Level of Information Need, especially for the rail object, and the input data provided by the operator.

Complex subassembly for the tunnel structure

The subassembly for the tunnel structure was the most complex one developed in this workflow. As shown in Figure 65, it incorporated three decision points to determine the presence or absence of niches on each side of the tunnel. These decisions were made by a rule based on the relative position of two feature lines, the *Line_Niche_Left* and the *Line_Niche_Right*, in relation to the center alignment of the tunnel.

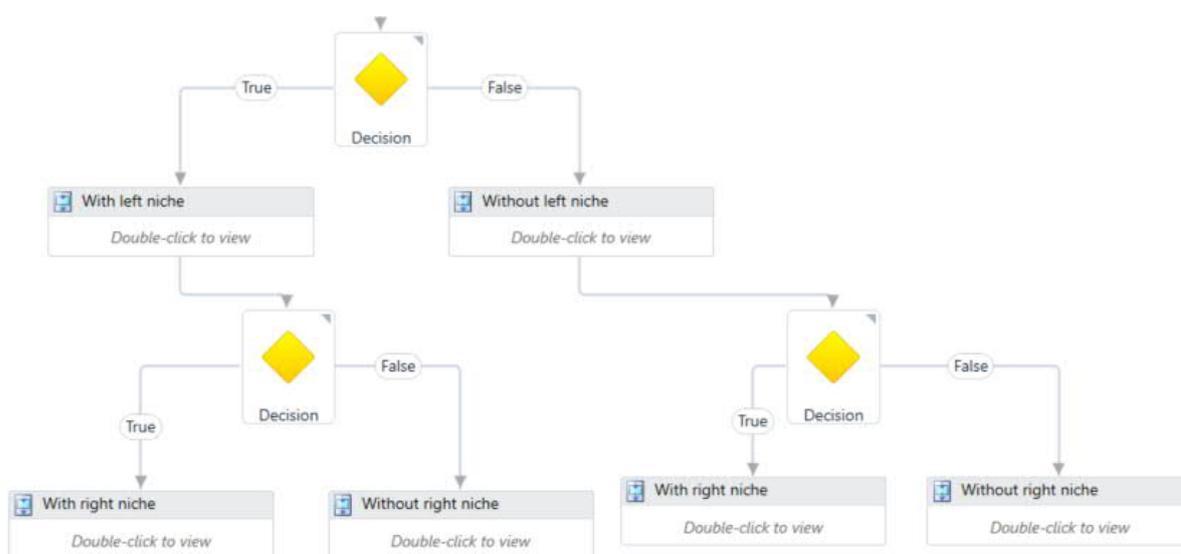


Figure 65 – Subassembly Composer view showing the points of decision regarding the presence of niches on each side of the tunnel.

The feature lines were drawn manually based on the processed point cloud, ensuring that the niche geometry accurately reflected the surveyed conditions. The subassembly was designed to interpret these lines and dynamically adjust the tunnel geometry to include or exclude niches as needed. Figure 66 and Figure 67 illustrate the behaviour of the dynamic template in response to the feature lines, showing a transition from a situation with niches on both sides to one without niches.

This approach enabled the correct placement of tunnel niches, following the polylines extracted directly from the point cloud and ensured that the resulting 3D solids matched the real-world geometry of the tunnel.

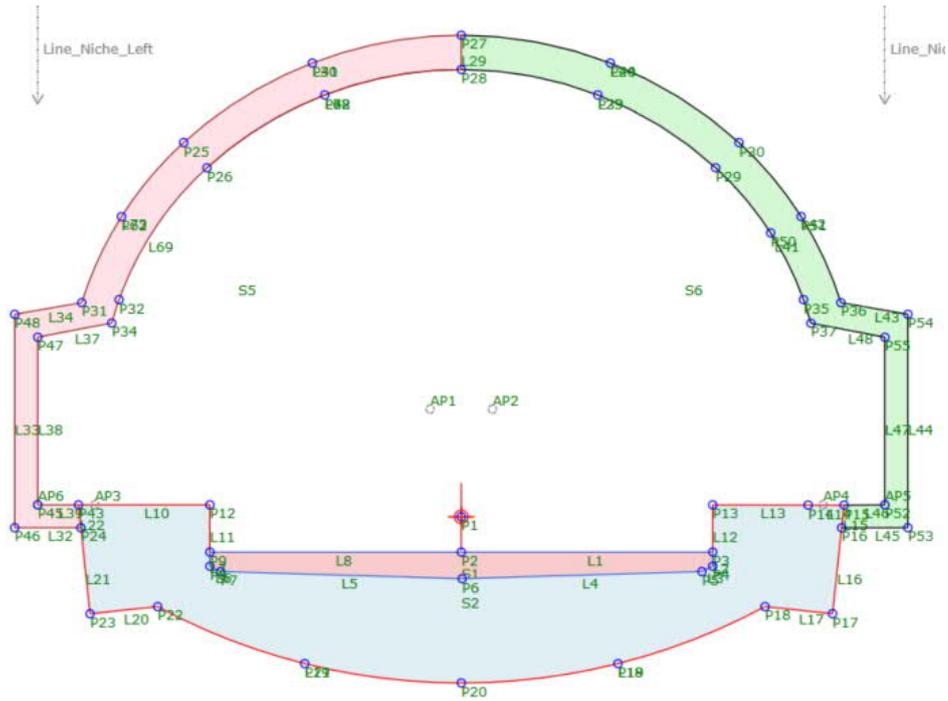


Figure 66 - Subassembly cross-section view containing niches.

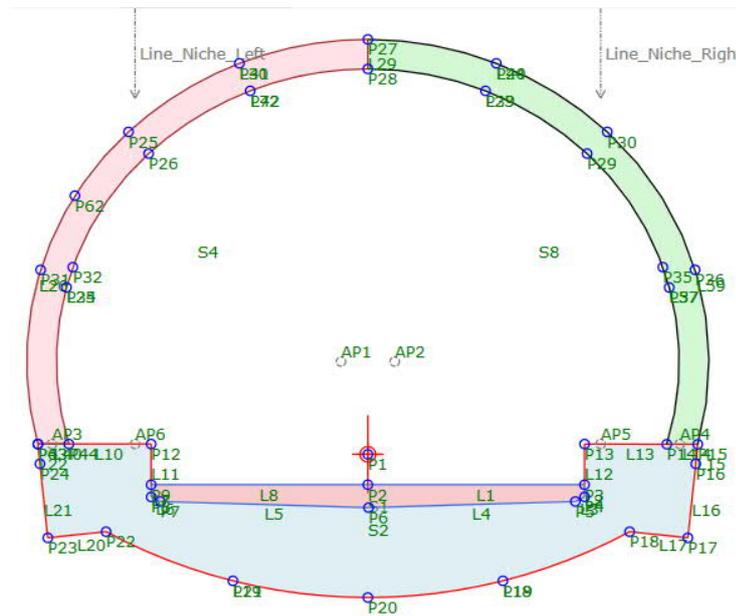


Figure 67 - Subassembly cross-section view without niches.

Left and right slab tracks

Two subassemblies were developed to represent the slab tracks, one for the left track and another for the right track. Both subassemblies use the cant information extracted from the alignment (baseline), ensuring that the geometry accurately reflects the real-world conditions of the railway infrastructure.

Accounting for cant is essential for two reasons. First, it ensures that the upper surface of the slab track aligns correctly with the sleepers that hold the rails in place. Second, it supports the proper drainage of water within the tunnel.

Figure 68 shows the left slab track, which follows the alignment information provided by the left track. This subassembly includes a central drainage gutter positioned along the middle of the tunnel. Figure 69 illustrates the right slab track, which follows the alignment of the right track. In this case, the subassembly includes both the central gutter and an additional gutter located on the right, which becomes active when cant is applied and water needs to be diverted following it.

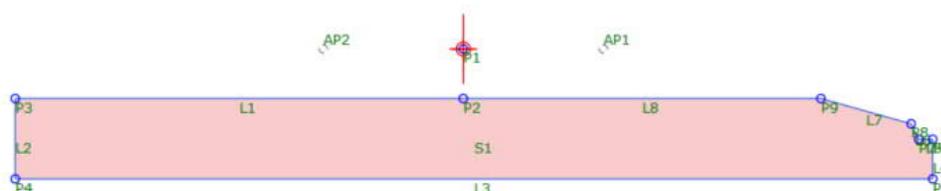


Figure 68 - Left side of the concrete slab of the ballastless track.

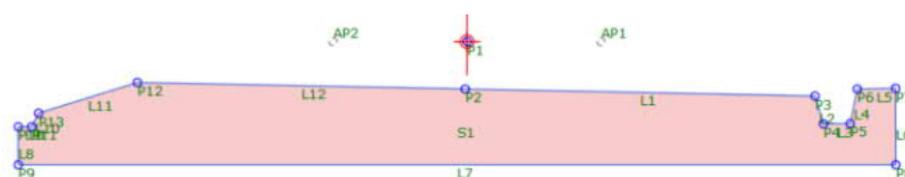


Figure 69 - Right side of the concrete slab of the ballastless track.

Rails

One subassembly was developed to represent the rails and it was applied twice, once on the right alignment and once on the left alignment, to generate the two tracks. This subassembly follows the geometric information provided by the alignment, including the cant, ensuring that the rails are positioned correctly in relation to the slab track and tunnel geometry.

The inclusion of cant is essential for maintaining the correct rail elevation and orientation. It also ensures consistency with the sleepers and supports accurate modelling of the railway's dynamic behaviour. The rail subassembly is shown in Figure 70.

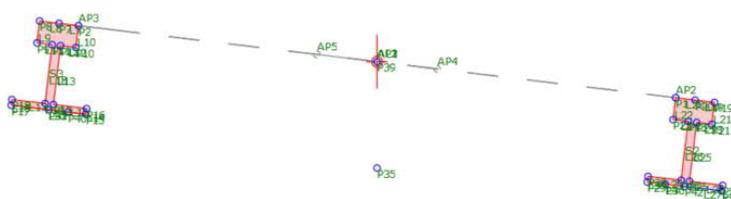


Figure 70 - Subassembly view of the rails when cant is applied.

Three alignments were imported from the .XTR file: one representing the right track, one for the left track and one for the center of the tunnel. Both alignments included horizontal, vertical and cant information, which were essential for accurately modelling the rails and slab tracks. The central alignment, however, contained only horizontal geometry and the project's stationing, no vertical profile was attached to it.

Since the central alignment was used exclusively for applying the dynamic template for the tunnel structure, cant information was not required. However, the vertical profile was still needed. To address this, a workaround was implemented: the vertical profile for the central alignment was created by calculating the average elevation between the two track alignments. This approach ensured that the tunnel geometry remained consistent with the surrounding infrastructure and was later validated through the correct placement of the model against the processed point cloud. Figure 71 shows the linear model, including the tunnel with niches, the slab track and both rails. Figure 72 highlights the correct placement and alignment based on the cant information extracted from the track profiles.

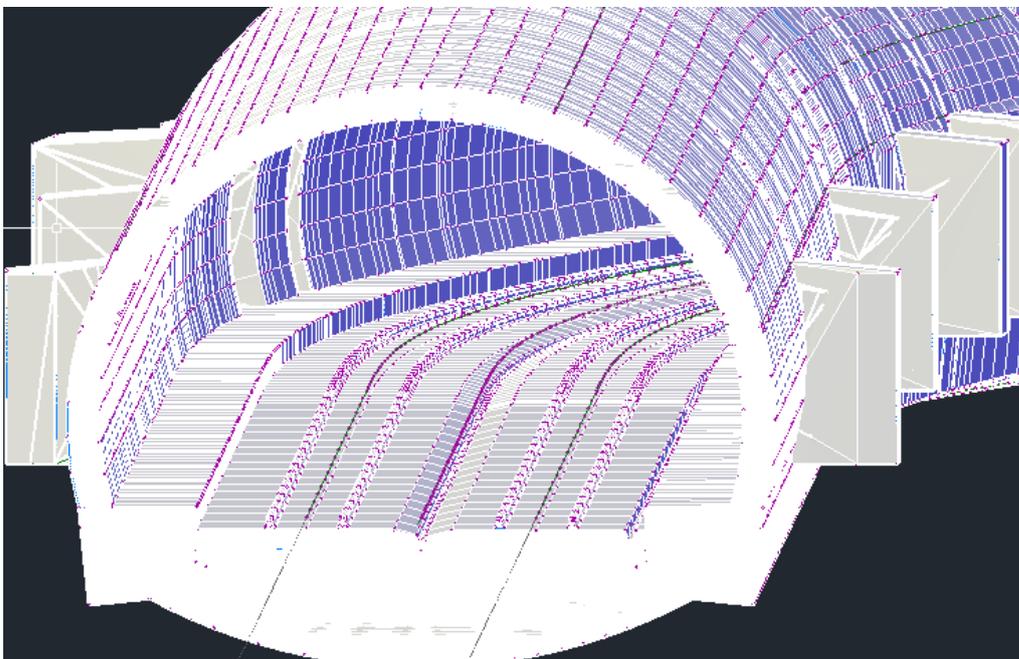


Figure 71 - 3D solid representing the tunnel with niches and ballastless track.

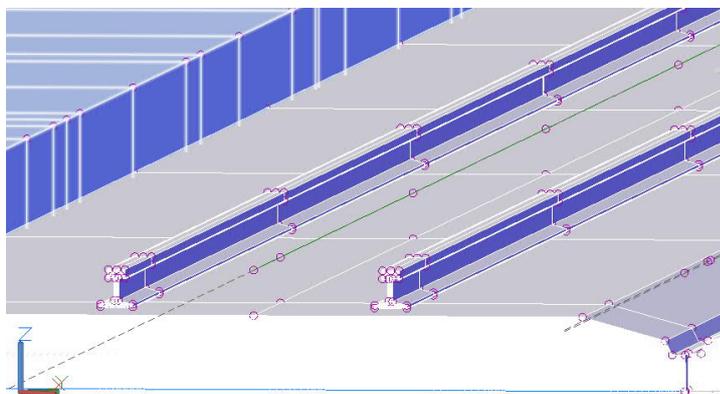


Figure 72 - 3D solids of the rails inserted in the linear model.

To ensure the quality of the model, a visual comparison was performed between the generated 3D solids and the processed point cloud. This step was essential to validate the geometry created using the subassemblies and alignments. The comparison confirmed that the tunnel structure, slab tracks and rails were correctly positioned and followed the surveyed geometry. Figure 73 captures a viewpoint of this comparison, where it is possible to see that the modelled tunnel wall aligns with the point cloud and the tracks are placed in accordance with their real-world positions.

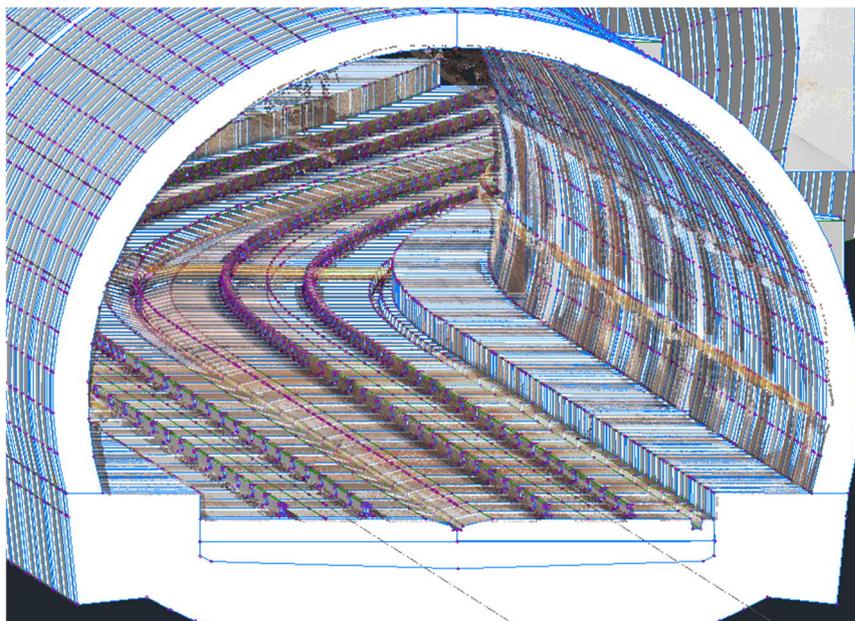


Figure 73 - Visual comparison of the linear model with the processed point cloud.

Once the geometry was validated, metadata was inserted into the 3D solid objects. In this case study, for the linear model, only the rails had their Level of Information Need defined. The necessary property sets were created in Civil 3D and applied to the rails. During this step, the attributes `IfcExportAs` and `IfcExportType` were filled in, allowing for the correct mapping of the objects when exporting to IFC. Further details about the export process and IFC 4.3 integration are discussed in Section 4.5.

4.4.3. Modelling punctual objects

The punctual modelling workflow begins with the creation of parametric object families in Revit 2024. These families are developed based on the Level of Information Need defined for this case study, as well as the 2D plans provided by the operator. The resulting parametric object classes can be considered as part of a library of objects to be properly stored and reused when needed.

Once the object families are prepared, the surveyed point cloud is inserted into Revit as an .rcp file. Punctual objects are then placed manually according to their position in the point cloud. This step ensures that each object is accurately located within the tunnel environment.

Finally, metadata is added to each object, guided by the Level of Information Need and the requirements for IFC 4.3 export. The complete workflow is summarized in Figure 74.

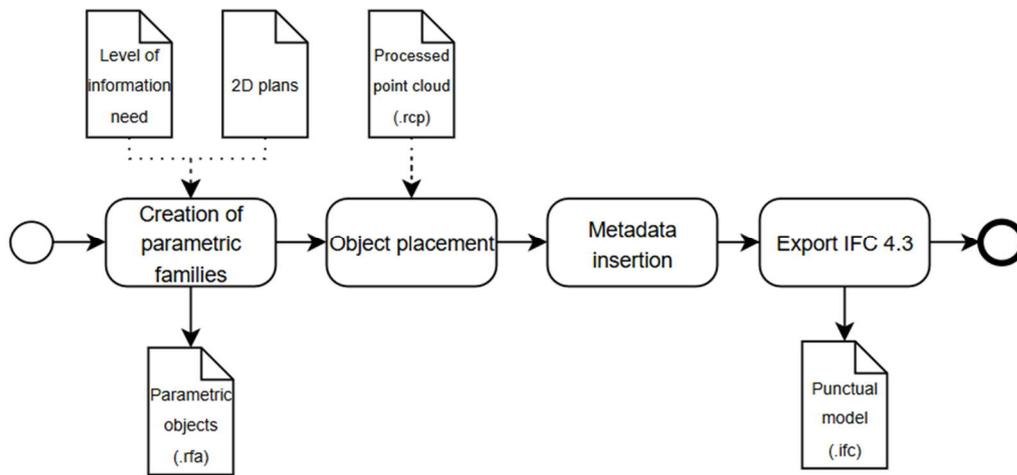


Figure 74 - Detailed workflow for the punctual modelling task.

For this study case, two objects were modelled: the catenary support and the signal. The catenary support could potentially have been found in an object library, but railway related components are still scarce in open-source BIM libraries. Therefore, the catenary support was modelled from scratch in Revit, as shown in Figure 75.



Figure 75 - Catenary support in the tunnel. From left to right: point cloud, object and photo.

As for the signal, its design was created specifically for this tunnel. Considering the signal is custom made, it would be impossible to find it in a library of BIM objects. For that reason, it was also modelled from zero in Revit. As seen in Figure 76, the signal object replicates the exact number of lamps and their real-world arrangement. Moreover, the parametric object allows for changing the lamp colours and masking the main signal, the pre-signal or the complementary signal as needed, making it possible to use each signal independently.



Figure 76 - Signal in the tunnel. From left to right: point cloud, object and photo.

Regarding object placement, the processed point cloud was imported into Revit using the .rcp file format. Although some workarounds were explored to place objects according to an alignment, this functionality is not supported by the software studied. As a result, objects have their insertion point defined by cartesian coordinates, rather than following the alignment-based approach that is essential for fully leveraging the value of IFC 4.3.

Given that this is a modelling of existing conditions and considering that the type of object being modelled must be correctly positioned within the tunnel's cross-section to support the future refurbishment project, it was decided to place the catenary supports manually.

Regarding metadata insertion, it was decided to create a shared properties file. This approach allows the property sets to be reused in similar projects or at least adapted, helping to avoid redundant work in the future. The IFC 4.3 export process is further discussed in the next section.

4.5. Translation to IFC: AS-IS and TO-BE workflows

The IFC 4.3 schema is relatively new, especially considering that the ISO 16739-1:2024 standard was only published in March 2024. As with any major update, it takes time for software vendors to adapt their platforms and for users to provide feedback that helps refine export and import functionalities.

At the time of writing this dissertation, buildingSMART International has not yet certified any modelling platforms for IFC 4.3 import or export. This reflects the transitional phase the industry is currently in, where early adopters are testing workflows and identifying limitations.

This section aims to compare how the export to IFC 4.3 was carried out in the context of this case study and how it could ideally be done, considering the current limitations and future potential of IFC 4.3 for infrastructure modelling.

4.5.1. AS-IS workflow for interoperability

Both software platforms studied in this case, Autodesk Civil 3D and Revit, offer different approaches to exporting models in IFC 4.3. In the case of Civil 3D, the export functionality is not available natively within the software. Instead, it requires the installation of the *Autodesk IFC 4.3 Extension 2025.1 for Civil 3D*. The version supported by this extension is IFC4x3_ADD2.

Regarding the object classification and mapping, Civil 3D provides two main strategies: explicit classification and implicit classification. Explicit classification relies on predefined categories, but these are currently very limited. Since the software cannot infer object types based on geometry, only certain elements, such as alignments, are correctly exported using this method.

Implicit classification, on the other hand, can be based on CAD layers, codes or object names. For this case study, it was decided to directly assign IFC class and type using a predefined group of properties from Civil 3D called *IfcObject Properties*, which includes two attributes: *IFC::GlobalId* and *IFC::IfcExportAs*. This method allows for more precise control over classification. However, it also means that the attribute *IfcExportAs* cannot be grouped under the *Identification* property set, as defined in the Level of Information Need for the rail object.

As shown in Figure 77, one possible approach is to map the object directly using its attributes. In the case of the rail object, for example, it was mapped to *IfcRail.RAIL*. The remaining configuration is handled through three JSON files: *InfraConfiguration.json*, *ExportMapping.json* and *PropertyMapping.json*.

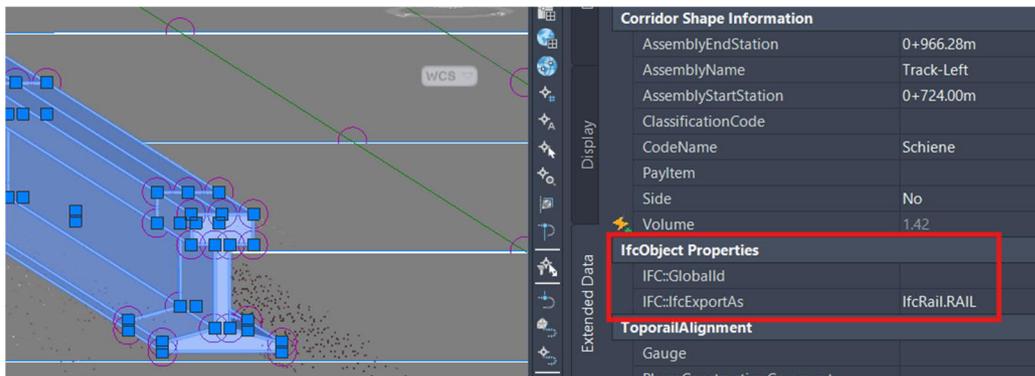


Figure 77 - IfcExportAs attribute for the rail object.

These files are specific to each project, as they contain object names and layer structures unique to each model. Therefore, they must be exported from Civil 3D and ideally saved in the same directory as the native model or the resulting IFC file. The files are written in JSON format and must be edited manually using an external text tool. For this case study, Notepad++ was used.

It is important to note that the mapping defined directly in the object properties takes precedence over the configuration in the JSON files. This was one of the reasons why the explicit property based method was chosen. Given the multiple mapping options, by layer, code, object name, etc, and the complexity of the JSON files, there is a significant margin for error. In this context, implicit mapping using object properties is recommended for clarity and control.

The three configuration files are processed in a specific order, as illustrated in Figure 78. The first file read is *InfraConfiguration.json*, which contains general export parameters, mostly in Boolean format. For example, if the export of alignments is set to true in the first file, but later set to false in the second, the alignment will not be exported. The JSON file used for this case study is shown in Appendix 5.

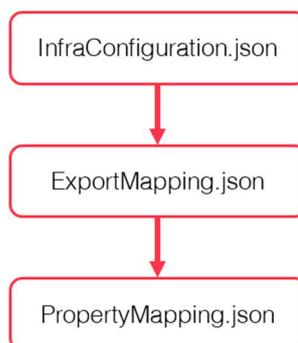


Figure 78 - Hierarchy behind the export JSON files in Civil 3D.

Another significant limitation encountered in Civil 3D relates to the export of custom subassemblies used in corridor modelling. While some subassemblies are successfully exported, others lose their geometrical consistency during the IFC export process. This inconsistency poses a challenge, especially considering that custom subassemblies are among the most commonly used elements in Civil 3D for tunnel and railway design.

The workaround identified in this case study involved transforming these subassemblies into solids before export. While this method preserves the geometry, it introduces a problem. Once converted into solids, the objects lose their association with the alignment. As a result, the exported IFC model lacks the structural relationships expected in IFC 4.3, specifically the connection to entities such as *IfcAlignment* or *IfcRailwayPart*. Figure 79 shows the correct structure of the file when a corridor is exported, not a solid. This loss of alignment-based structure is a problem for the export, since it loses one of the key advantages of IFC 4.3 for linear infrastructure modelling, which is the ability to represent objects in relation to a linear reference system.

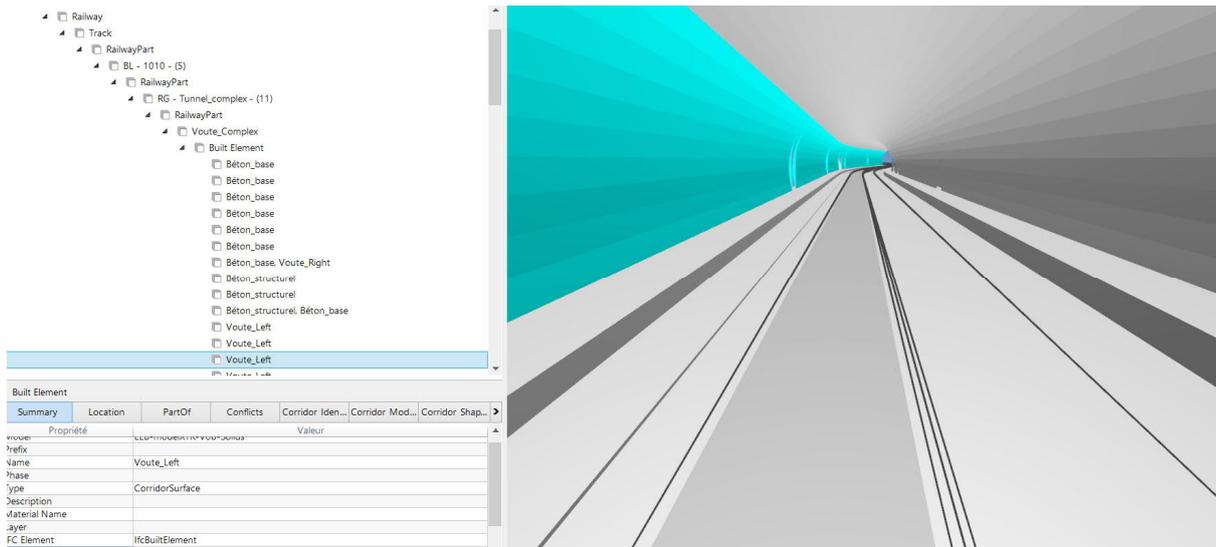


Figure 79 - Structure of the IFC seen in BIMcollab Zoom for an object exported as a corridor.

In the case of Revit, IFC mapping is handled directly at the object level. Each object includes a built-in parameter that allows users to assign an IFC classification by selecting from a list of supported schema versions. This list includes several versions of the IFC, including IFC 4.3, along with their respective entity types.

For this case study, the mapping was done manually by selecting the appropriate IFC entity for each object. As shown in Figure 80, one of the catenary support objects was mapped to *IfcMemberType.MEMBER*.

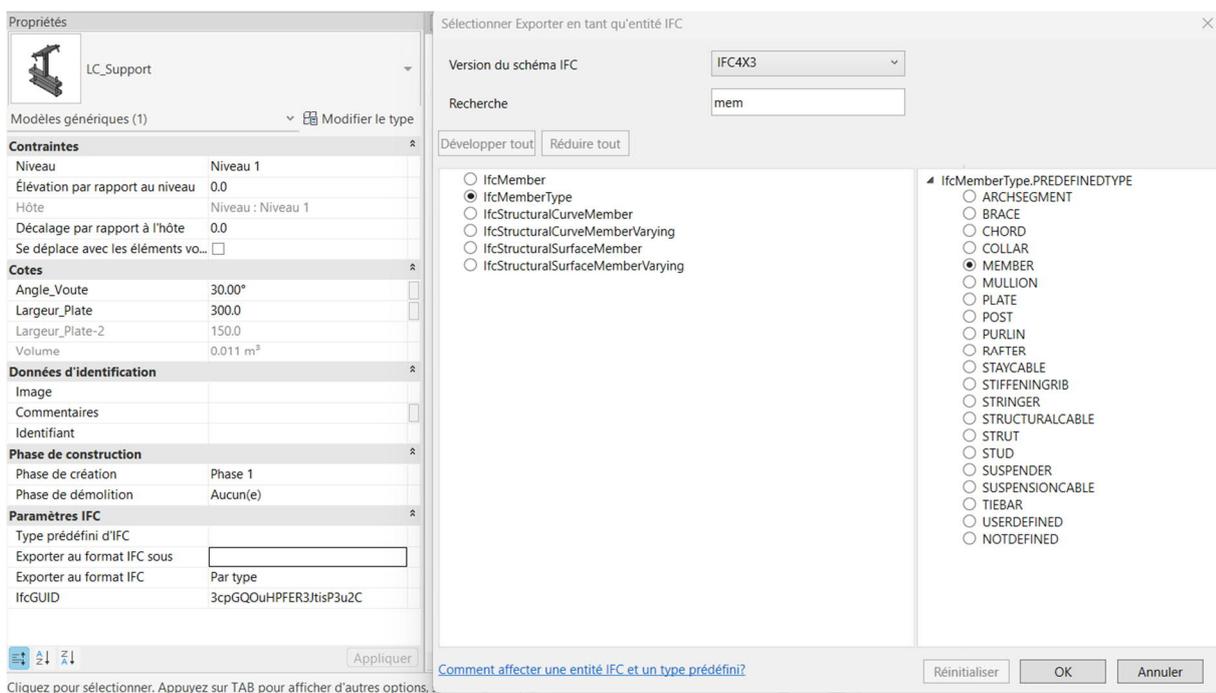


Figure 80 - Mapping of the catenary support object according to IFC4x3 in Revit.

However, while Revit allows for this type of manual mapping, it does not fully support the infrastructure specific features of IFC 4.3, such as alignment-based placement or the use of *IfcRailwayPart*. Instead, the objects are placed according to *IfcBuildingStorey*. As a result, although the objects are correctly classified and geometrically represented, the exported IFC model lacks the alignment structure that would be expected in a linear infrastructure model.

4.5.2. TO-BE workflow for interoperability

The TO-BE workflow proposes an improved approach to exporting infrastructure models to IFC 4.3, based on the limitations identified in the current AS-IS process. The goal is to align more closely with the intended use of IFC 4.3, particularly its support for alignment-based modelling, spatial structure and infrastructure specific entities while being more user friendly.

According to ISO 22014:2024, objects need to be given context in the sense of a spatial structure. They need to be contained or positioned relative to a space, site, building, etc in a project. This structure needs to be sufficient for the object to be recognized in a report or visualization. However, current modelling platforms do not yet support exporting IFC 4.3 models with objects correctly attached to a spatial structure, as prescribed in Section 2.2.5. Ideally, these spatial divisions should reflect both cross-sections and plan-view separations, including whether or not the object is part of a turnout system.

In Civil 3D, the export process currently requires a deep understanding of the IFC schema. Any small typing error can compromise the export, and the structure of the JSON configuration files demands careful attention, as precedence rules between files can override earlier settings. This results in overwork since the exports need to be done several times to ensure their quality. Moreover, it is not a user friendly process.

In contrast, Revit offers a more accessible mapping process. Each object can be classified using a built-in parameter that includes a searchable list of IFC schema versions and entities. This reduces the need for deep IFC knowledge and makes the process more approachable for broader users. If the class and type are defined in the Level of Information Need, the modeler can simply search and assign the correct entity directly within Revit.

Currently, the AS-IS workflow often requires post-processing in external tools such as Blender + Bonsai or Simplebim to correct the IFC structure exported from the modelling platforms (“Update on IFC 4.3 for Rail and Infrastructure,” 2025). This is not a recommended practice, as it introduces the risk of errors and increases the time required for delivery, especially since the corrections must be repeated every time the model is exported.

Given that many countries now require BIM for publicly funded infrastructure projects and software vendors are still catching up with IFC 4.3 compliance, initiatives like “Applying IFC 4.3 for Rail Projects” (aIFC4Rail) by the RailwayRoom at buildingSMART International are essential. This project aims to accelerate the ability of software solutions to import and export data in IFC 4.3 format (“Applying IFC 4.3 for Rail Project - buildingSMART International,” 2022). It highlights the ongoing need for development and collaboration to enhance interoperability in the railway BIM sector.

To move toward a more robust and interoperable workflow, the TO-BE scenario envisions a modelling and export process that aligns more closely with the intended use of IFC 4.3. One of the most critical improvements would be the native integration of alignment-based modelling within authoring platforms. Rather than relying solely on traditional cartesian coordinates, objects should be positioned relative to an *IfcAlignment*, enabling a more accurate and semantically rich representation of linear infrastructures.

In the case of Civil 3D, several improvements would be necessary to support this vision. The software should expand its support for custom subassemblies, ensuring that they retain both their geometry and their relationship to the alignment during export. The current reliance on manually edited JSON files introduces a high risk of error is not user friendly. A more intuitive mapping interface would help users, as the interface currently available in Revit.

Revit, while more user friendly in terms of IFC mapping, also requires enhancements to fully support infrastructure workflows. The software should offer better compatibility with IFC 4.3 infrastructure entities, such as *IfcRailwayPart* and *IfcAlignment* and integrate alignment placement. This alignment placement would have to be deeply studied by Autodesk since Revit was not conceived for linear infrastructure modelling. Possibly, a better workflow would use a connection with Civil 3D.

5. CONCLUSIONS

This dissertation explored the digitalization of existing railway tunnel infrastructure with a focus on IFC interoperability, particularly using the IFC 4.3 schema and the concept of Level of Information Need. The modelling workflow developed from a point cloud survey demonstrated the importance of understanding how linear models function and how the alignment entity is the base for any linear infrastructure model.

Navigating the IFC schema and applying property sets to specific railway projects is still a complicated task. Not all railway objects are included in the Rail Domain. In many cases, they are predefined types embedded within existing entities. Identifying these entities and filtering the relevant property sets and attributes is a complex task that requires both a deep understanding of the IFC schema structure and technical knowledge of the infrastructure components. Even language barriers play a role despite the development of the buildingSMART Data Dictionary (bSDD). Its search engine does not yet replace the need to manually explore the IFC structure.

Another significant limitation is the current state of software support for IFC 4.3. The TO-BE workflow for interoperability heavily depends on software vendors implementing reliable export and import functionalities. As of the time of writing this dissertation, no software tool has been officially certified for IFC 4.3, which restricts the practical application of the schema and hinders full interoperability.

Despite these challenges, the dissertation successfully demonstrated a structured approach to modelling existing infrastructure using IFC 4.3, supported by the Level of Information Need and Product Data Templates. The case study provided a practical framework for integrating geometric and alphanumeric data while highlighting the importance of having a structured BIM model.

The work done in this dissertation opens space for future research and practical implementation. One of the most urgent needs is the development of open libraries of BIM objects that follow international standards for railway subsystems. This is particularly relevant for signalling and overhead contact line equipment. The recent publication of ISO 22014:2024 provides a foundation for this development.

Another direction involves the further exploration of ISO 7817, particularly Parts 2 and 3, which define how the Level of Information Need can be implemented in real-world projects. During the development of this dissertation, these parts were still under review by the ISO/TC 59/SC 13 technical committee. Their finalization will provide more concrete guidance for practitioners and researchers to apply the Level of Information Need into their projects.

Expanding the modelling workflows developed in this study to include use cases related to operations and maintenance (O&M) is also a valuable next step. The integration of big data into predictive maintenance strategies for tunnels and railway systems could significantly enhance asset management. Structuring data lakes into KPI driven, accessible information would allow facility managers to make informed decisions.

Further work could also focus on the continued development of Product Data Templates for infrastructure, building on initiatives such as pdts.pt. These templates are essential for standardizing thw

way information is structured and exchanged across platforms and stakeholders. In parallel, more detailed studies are needed to better define the geometrical information requirements for tunnel modelling, which remain insufficient in current literature and practice.

Finally, once the IFC 4.3 is more widely implemented and supported by modelling platforms, the use of Information Delivery Specifications (IDS) should be tested. IDS offers a way to formalize and validate the information requirements of a project, ensuring that models meet expectations. Its integration into workflows could significantly improve the reliability and precision of data exchanges in infrastructure projects.

REFERENCES

- 7.8.2.1 IfcRailTypeEnum - IFC4.3.0.1 Documentation [WWW Document], n.d. URL <http://ifc43-docs.standards.buildingsmart.org/IFC/RELEASE/IFC4x3/HTML/lexical/IfcRailTypeEnum.htm> (accessed 8.11.22).
- 7.8.2.2 IfcRailwayPartTypeEnum - IFC 4.3.2 Documentation [WWW Document], n.d. URL <https://ifc43-docs.standards.buildingsmart.org/IFC/RELEASE/IFC4x3/HTML/lexical/IfcRailwayPartTypeEnum.htm> (accessed 6.18.25).
- 7.8.3.2 IfcRailType - IFC 4.3.2 Documentation [WWW Document], n.d. URL <https://ifc43-docs.standards.buildingsmart.org/IFC/RELEASE/IFC4x3/HTML/lexical/IfcRailType.htm> (accessed 8.5.25).
- 8.6.3.5 IfcDocumentReference - IFC4.3.0.1 Documentation [WWW Document], n.d. URL <http://ifc43-docs.standards.buildingsmart.org/IFC/RELEASE/IFC4x3/HTML/lexical/IfcDocumentReference.htm> (accessed 8.12.22).
- 8.7.3.15 IfcObjectPlacement - IFC4.3.0.1 Documentation [WWW Document], n.d. URL <http://ifc43-docs.standards.buildingsmart.org/IFC/RELEASE/IFC4x3/HTML/lexical/IfcObjectPlacement.htm> (accessed 8.14.22).
- 12C-004-01_Asset-Tag-and-Equipment-Label-Guidance-7.0_Redacted.pdf, n.d.
- 12C-06_Crossrail-OM-Information-Guide-LL.pdf, n.d.
- Abualdenien, J., Borrmann, A., 2022. LEVELS OF DETAIL, DEVELOPMENT, DEFINITION, AND INFORMATION NEED: A CRITICAL LITERATURE REVIEW. *J. Inf. Technol. Constr.* 27, 363–392. <https://doi.org/10.36680/j.itcon.2022.018>
- Applying IFC 4.3 for Rail Project - buildingSMART International, 2022. URL <https://www.buildingsmart.org/standards/domains/railway/applying-ifc-4-3-for-rail-project/> (accessed 7.19.25).
- Augele, V., 2017. Comparative Analysis of Building Information Modelling (BIM) and RailTopoModel/railML in View of their Application to Operationally Relevant Railway Infrastructure. Technical University of Dresden.
- Autodesk, 2023. Autodesk® Civil 3D® Country Kit Documentation - Version 2024.
- Autodesk ReCap Help | Specifying Extraction Settings | Autodesk [WWW Document], n.d. URL https://help.autodesk.com/view/RECAP/ENU/?guid=linear_feature_settings (accessed 8.22.25).
- Bâtir digital Suisse, 2018. Définition swiss BIM LOIN- (LOD) Compréhension.
- BIM Fachdaten katalog [WWW Document], n.d. URL <https://fdk.app.sbb.ch/en/explanation> (accessed 8.5.25).
- BIM implementation schedule and ongoing BIM projects | SBB [WWW Document], n.d. URL <https://company.sbb.ch/en/sbb-as-business-partner/procurement/bim/schedule-ongoing-bim-projects.html> (accessed 7.13.25).
- BIM4INFRA2020, 2019. Handreichung BIMFachmodelle und Ausarbeitungsgrad.
- Borrmann, A., Forster, C., Liebich, T., König, M., Tulke, J., 2021. Germany's Governmental BIM Initiative – The BIM4INFRA2020 Project Implementing the BIM Roadmap, in: Proceedings of the 18th International Conference on Computing in Civil and Building Engineering (Pp.452-465). Presented at the 18th International Conference on Computing in Civil and Building Engineering. https://doi.org/10.1007/978-3-030-51295-8_31
- buildingSMART Data Dictionary - buildingSMART International, 2024. URL <https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/> (accessed 1.9.25).
- Bundesministerium für Verkehr und digitale Infrastruktur, 2015. Stufenplan Digitales Planen und Bauen.
- Cheng, Y.-J., Qiu, W.-G., Duan, D.-Y., 2019. Automatic creation of as-is building information model from single-track railway tunnel point clouds. *Autom. Constr.* 106, 102911. <https://doi.org/10.1016/j.autcon.2019.102911>
- Ciccione, A., Di Stasio, S., Asprone, D., Salzano, A., Nicoletta, M., 2022. Application of openBIM for the Management of Existing Railway Infrastructure: Case Study of the Cancellò–Benevento Railway Line. *Sustain. Switz.* 14. <https://doi.org/10.3390/su14042283>

- CloudCompare - Open Source project [WWW Document], n.d. URL <https://www.cloudcompare.org/> (accessed 8.24.25).
- CloudCompare octree - CloudCompare wiki [WWW Document], n.d. URL https://www.cloudcompare.org/doc/wiki/index.php/CloudCompare_octree (accessed 8.24.25).
- Crossrail Asset Data Dictionary [WWW Document], n.d. . Crossrail Learn. Leg. URL <https://learninglegacy.crossrail.co.uk/documents/crossrail-asset-data-dictionary/> (accessed 5.12.22).
- CT197 BIM, n.d. pdts.pt [WWW Document]. URL <http://pdts.pt/pdts/index.php> (accessed 8.10.22).
- Dentten, R., 2018. Better Information Management to Optimise Whole Life Business Decisions [WWW Document]. Crossrail Learn. Leg. URL <https://learninglegacy.crossrail.co.uk/documents/better-information-management-to-optimise-whole-life-business-decisions/> (accessed 7.17.22).
- Deutsche Bahn AG, 2022. Implementation of BIM in the infrastructure Division at DB data.
- Deutsche-Bahn, 2019. BIM Strategy - Implementation of Building Information Modeling (BIM) in the Infrastructure Division of Deutsche Bahn AG.
- Documents, media and contacts BIM @SBB | SBB [WWW Document], n.d. URL <https://company.sbb.ch/en/the-company/projects/national-projects/bim/documents.html> (accessed 3.18.22).
- EN 17412-1:2020, 2020.
- FDK - Deckenströmschiene (DSS) [WWW Document], n.d. URL https://fdk.app.sbb.ch/objects/OBJ_FS_22 (accessed 7.20.22).
- FDK - Objekttypen [WWW Document], n.d. URL <https://fdk.app.sbb.ch/objects> (accessed 7.20.22).
- FDK - welded rail joint [WWW Document], n.d. URL https://fdk.app.sbb.ch/objects/OBJ_FB_14 (accessed 7.20.22).
- Federal Ministry of Transport and Digital Infrastructure, 2015. Road Map for Digital Design and Construction - Introduction of modern, IT-based processes and technologies for the design, construction and operation of assets in the built environment.
- GESTE Engineering SA, 2022. Commissioning of the new LEB tunnel [WWW Document]. URL <https://geste.group/en/news/32-projects/276-commissioning-of-the-new-leb-tunnel> (accessed 8.12.22).
- GESTE Engineering SA, S., 2025. GESTE Group - Home [WWW Document]. GESTE Eng. SA. URL <https://geste.group/en/> (accessed 7.27.25).
- Gigante-Barrera, Á., Dindar, S., Kaewunruen, S., Ruikar, D., 2017. LOD BIM Element specification for Railway Turnout Systems Risk Mitigation using the Information Delivery Manual. IOP Conf. Ser. Mater. Sci. Eng. 245, 042022. <https://doi.org/10.1088/1757-899X/245/4/042022>
- History of the Elizabeth line - Crossrail [WWW Document], 2022. URL <https://web.archive.org/web/20221228162709/https://www.crossrail.co.uk/project/history/> (accessed 7.13.25).
- IFC Rail Project, 2019. IFC Rail Project - WP3 Conceptual Model Report.
- IFC Rail Project Context & Approach, 2019.
- Introduction - IFC4.3.2.0 Documentation [WWW Document], n.d. URL https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/HTML/content/introduction.htm (accessed 7.19.25).
- ISO 7817-1:2024, 2024.
- ISO 19650-1:2018, 2018.
- ISO 22014:2024, 2024.
- ISO 23386:2020, 2020.
- ISO 23387:2020, 2020.
- Jaud, Š., Esser, S., Wikström, L., Muhic, S., Mirtschin, J., Borrmann, A., 2021. A critical analysis of linear placement in IFC models.
- Kwon, T., Park, S., Jang, Y.-H., Lee, S.-H., 2020. Design of Railway Track Model with Three-Dimensional Alignment Based on Extended Industry Foundation Classes. Appl. Sci. 10, 3649. <https://doi.org/10.3390/app10103649>
- LandXML-1.2Doc - Cant [WWW Document], n.d. URL http://www.landxml.org/schema/landxml-1.2/documentation/LandXML-1.2Doc_Cant.html (accessed 6.28.25).

- Linking BIM and GIS Models in Infrastructure by Example of IFC and CityGML, 2017. , in: ResearchGate.
- Livrables saison 1 Projet MINnD, n.d. . MINnD Saison 2. URL <https://www.minnd.fr/livrables/> (accessed 6.8.22).
- Maier, C., 2015. Grundzüge einer open BIM Methodik für die Schweiz Version 1.0.
- Meek, D.S., Walton, D.J., 2004. A note on finding clothoids. *J. Comput. Appl. Math.* 170, 433–453. <https://doi.org/10.1016/j.cam.2003.12.047>
- Mitera-Kiełbasa, E., Zima, K., 2024. BIM Policy Trends in Europe: Insights from a Multi-Stage Analysis. *Appl. Sci.* 14, 4363. <https://doi.org/10.3390/app14114363>
- Pham, C., Le, B., Nguyen, T., 2021. railBIM Catalogue -LOD Specifications for Construction Elements in Railway Models in Vietnam.
- Qu'est-ce que MINnD ?, n.d. . MINnD Saison 2. URL <https://www.minnd.fr/le-projet-minnd/quest-ce-que-minnd/> (accessed 5.26.22).
- Rail Data Exchange Extension for Autodesk® Civil 3D® [WWW Document], n.d. URL https://up1.autodesk.com/2024/CIV3D/Autodesk_Rail_Data_Exchange_Extension_2024_Release_Notes.htm#StandaloneInstallation (accessed 11.26.23).
- railML.org [WWW Document], n.d. URL <https://www.railml.org/en/> (accessed 6.28.25).
- Railway Information Modeling RIM: The Track to Rail Modernization, n.d.
- Šarkiene, E., 2020. BIM Application in Infrastructure Projects. *Balt. J. Road Bridge Eng.* <https://doi.org/10.7250/BJRBE.2020-15.485>
- Seo, M.B., Lee, D., 2020. Development of Railway Infrastructure BIM Prototype Libraries. *Appl. Sci.* 10, 8118. <https://doi.org/10.3390/app10228118>
- Shin, M.-H., Kim, H.-Y., Liao, J.-F., 2024. Performance Measurement and Analysis of Building Information Modeling (BIM) Applications in the Railway Infrastructure Construction Phase. *Appl. Sci.* 14, 502. <https://doi.org/10.3390/app14020502>
- Sibaii, M.E., Granja, J., Ribeiro, R.R., Meda, P., Resende, R., Santos, J.D., Martins, P.L., Costa, A.A., Martins, J.P., Azenha, M., 2022. Rumo à definição de 'Product Data Templates' nacionais para aplicação generalizada em contexto BIM: Esforços da CT197, in: 4º congresso português de 'Building Information Modelling' vol. 2 - ptBIM. UMinho Editora, pp. 245–256. <https://doi.org/10.21814/uminho.ed.77.21>
- Sibaii, M.E., Pinto, D., Sanhudo, L., Martins, J.P., Patrício, H., Granja, J., Azenha, M., 2024. Proposta de modelos de dados de produto para túneis ferroviários, in: UMinho Editora. Presented at the 5º CONGRESSO PORTUGUÊS DE BUILDING INFORMATION MODELLING. <https://doi.org/10.21814/uminho.ed.164.9>
- SM-03-2014-1_01.pdf, n.d.
- Soilán, M., Justo, A., Sánchez-Rodríguez, A., Lamas, D., Riveiro, B., 2021. 3D point cloud data processing and infrastructure information models: Methods and findings from safeway project. Presented at the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, pp. 239–246. <https://doi.org/10.5194/isprs-archives-XLIII-B2-2021-239-2021>
- Update on IFC 4.3 for Rail and Infrastructure [WWW Document], 2025. . Autodesk Community. URL <https://forums.autodesk.com/t5/autodesk-rail-summit-2024-forum/update-on-ifc-4-3-for-rail-and-infrastructure/td-p/13248847> (accessed 7.19.25).
- Using Train-Borne Lidar to improve design confidence in railway electrification [WWW Document], n.d. . HS2 Learn. Leg. URL <https://learninglegacy.hs2.org.uk/document/electrifying-a-virtual-railway-with-train-borne-lidar/> (accessed 8.18.22).
- Wagner, A., Sprenger, W., Maurer, C., Kuhn, T.E., Ruppel, U., 2022. Building product ontology: Core ontology for Linked Building Product Data. *Autom. Constr.* 133, 103927. <https://doi.org/10.1016/j.autcon.2021.103927>

APPENDICES

APPENDIX 1: NON-EXHAUSTIVE LIST OF OBJECTS IDENTIFIED WITHIN THE PERIMETER OF THE CASE STUDY

Objects	
1	Rail
2	Rail weld
3	Rail fasteners, sleepers
4	Rail grounding/earthwire
5	Catenary line
6	Catenary support
7	Tunnel envelope/sprayed concrete
8	Track bed/Floating track slab
8	Elastomeric layer for insulation
9	Light fixtures
11	Handrail
12	Emergency door
13	Signage
14	Signaling
15	Ventilator
16	Level crossing grid
16	Clearance space
17	Electric panel
18	Cable tray
19	Electrical plug
20	Intercom
21	Fire pipes
22	Fire pipes connections/valves
23	Smoke sensor
24	Manhole for drainage
25	Concrete joint
26	Pipes for sewers and drains
27	High tension cables
28	Drains couplings/connectors
29	Structure wall for cut and cover tunnel
30	Slab
31	Metallic frame

APPENDIX 2: LISTS OF COMPARISON OF PROPERTIES

RAIL							
Property set	Property name	Data type	PEnum	Description	IFC	FDK	Crossrail
Pset_RailTypeRail	PositionInTrack	PEnum_RelativePosition	LEFT; MIDDLE; RIGHT; OTHER; NOTKNOWN; UNSET	Indicates the relative position of the element in track, which lies to the left or right as facing in the direction of increasing stationing values.	X	X	X
Pset_RailTypeRail	RailDeliveryState	PEnum_RailDeliveryState	HEATTREATMENT; HOTROLLING; OTHER; NOTKNOWN; UNSET	The delivery state of rail, which indicates the final treatment at the end in manufacturing.	X	X	
Pset_RailTypeRail	RailCondition	PEnum_RailCondition	NEWRAIL; REGENERATEDRAIL; REUSEDRAIL; OTHER; NOTKNOWN; UNSET	Assessment of the condition of the rail at point of installation.	X	X	
Pset_RailTypeRail	DrillOnRail	PEnum_DrillOnRail	BOTHENDS; NONE; ONEEND; OTHER; NOTKNOWN; UNSET	Indicates if the manufactured rail is drilled at its extremities or not. It can have holes on one, both or none of its extremities.	X		

Pset_RailTypeRail	RailElementaryLength	PEnum_RailElementaryLength	100M; 108M; 120M; 12M; 144M; 18M; 24M; 25M; 27M; 30M; 36M; 400M; 48M; 54M; 60M; 6M; 72M; 75M; OTHER; NOTKNOWN; UNSET	The standardised length of rail supplied from the manufacturer.	X	X	X
Pset_RailTypeRail	MinimumTensileStrength	IfcForceMeasure		Indicates the minimum tensile strength.	X	X	
Pset_RailTypeRail	IsStainless	IfcBoolean		Indicates whether the rail is stainless or not.	X		
Pset_Condition	AssessmentDate	IfcDate		Date on which the overall condition is assessed	X		
Pset_Condition	AssessmentCondition	IfcLabel		The overall condition of a product based on an assessment of the contributions to the overall condition made by the various criteria considered. The meanings given to the values of assessed condition should be agreed and documented by local agreements. For instance, is overall condition measured on a scale of 1 - 10 or by assigning names such as Good, OK, Poor.	X		X
Pset_Condition	AssessmentDescription	IfcText		Qualitative description of the condition.	X		
Pset_Condition	AssessmentType	IfcLabel		Category of latest condition assessment report of the asset.	X		
Pset_Condition	LastAssessmentReport	IfcLabel		Reference to latest condition (state of health) report.	X		

Pset_Condition	NextAssessmentDate	IfcDate		Date of next condition inspection	X		
Pset_Condition	AssessmentFrequency	IfcTimeMeasure		Indicates how often the equipment should be assessed, to have a clear estimation on its working state, based on which the maintenance staff can decide whether it requires maintenance or requires to be updated or replaced.	X		
Pset_ConstructionAdministration	ProcurementMethod	IfcLabel		The method by which an IfcProductType/IfcProduct is acquired and installed. The value provided shall be one of the following four character acronyms: "CFCI" (meaning Contractor Furnished Contractor Installed), "OFCI" (meaning Owner Furnished Contractor Installed), or "OFOI" (meaning Owner Furnished Owner Installed).	X		
Pset_ConstructionAdministration	SpecificationSectionNumber	IfcLabel		A reference number to an external contract technical specification section describing either (a) minimum performance requirements of a given IfcProductType/IfcProduct or (b) a preselection for a specific IfcProductType/IfcProduct made for this project.	X		
Pset_ConstructionAdministration	SubmittalIdentifier	IfcLabel		The reference number to an external construction administration submittal used by the construction contractor and/or subcontractor to verify that the referenced IfcProductType/IfcProduct selection conforms with the requirements found in the referenced SpecificationSectionNumber.	X		

Pset_ConstructionOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	X	X	X
Pset_ConstructionOccurrence	ModelNumber	IfcLabel		The model number and/or unit designator assigned by the manufacturer of the manufactured item.	X	X	
Pset_ConstructionOccurrence	TagNumber	IfcLabel		Tag number.	X	X	X
Pset_ConstructionOccurrence	AssetIdentifier	IfcLabel		A unique identification assigned to an asset that enables its differentiation from other assets. NOTE The asset identifier is unique within the asset register. It differs from the globally unique id assigned to the instance of an entity populating a database.	X	X	
Pset_ElementKinematics	CyclicPath	IfcPlaneAngleMeasure/IfcTimeMeasure		Represents the time:angle table of the kinematic behaviour.	X		
Pset_ElementKinematics	CyclicRange	IfcPlaneAngleMeasure		Identifies the angular range of the kinematic behaviour	X		
Pset_ElementKinematics	LinearPath	IfcLengthMeasure/IfcTimeMeasure		Represents the time:distance table of the kinematic behaviour.	X		
Pset_ElementKinematics	LinearRange	IfcPositiveLengthMeasure		Identifies the linear range of the kinematic behaviour.	X		
Pset_ElementKinematics	MaximumAngularVelocity	IfcAngularVelocityMeasure		Identifies the maximum angular velocity of the kinematic behaviour.	X		
Pset_ElementKinematics	MaximumConstantSpeed	IfcLinearVelocityMeasure		Identifies the maximum constant speed over the kinematic path.	X		
Pset_ElementKinematics	MinimumTime	IfcTimeMeasure		Identifies the minimum time for the kinematic behaviour.	X		
Pset_EnvironmentalCondition	ReferenceAirRelativeHumidity	IfcNormalisedRatioMeasure		Measurement of the ratio of water vapor in the air.	X		
Pset_EnvironmentalCondition	ReferenceEnvironmentTemperature	IfcThermodynamicTemperatureMeasure		Ideal temperature range.	X		

Pset_EnvironmentalCondition	MaximumAtmosphericPressure	IfcPressureMeasure		Maximum level of atmospheric pressure that the equipment can operate effectively in.	X		
Pset_EnvironmentalCondition	StorageTemperatureRange	IfcThermodynamicTemperatureMeasure		Allowed storage temperature range that the element complies with.	X		
Pset_EnvironmentalCondition	MaximumWindSpeed	IfcLinearVelocityMeasure		Maximum resistance to wind load exposure.	X		
Pset_EnvironmentalCondition	OperationalTemperatureRange	IfcThermodynamicTemperatureMeasure		The temperature range in which the device operates normally. Allowable operation ambient air temperature range.	X		
Pset_EnvironmentalCondition	MaximumRainIntensity	IfcReal		Maximum level of rain intensity that the equipment can operate effectively in. It is usually measured in millimeter per hour (mm/h).	X		
Pset_EnvironmentalCondition	SaltMistLevel	IfcLabel		Maximum level of salt mist that the equipment can operate effectively in. It is provided according to an international or national standard.	X		
Pset_EnvironmentalCondition	SeismicResistance	IfcReal		Maximum magnitude of earthquake that the equipment complies with. The value indicates earthquake intensity measured in Richter scale.	X		
Pset_EnvironmentalCondition	SmokeLevel	IfcLabel		Maximum level of smoke that the equipment complies with. It is provided according to an international or national standard.	X		
Pset_EnvironmentalCondition	MaximumSolarRadiation	IfcReal		Maximum level of solar irradiance that the equipment can operate effectively in. This is usually tested and measured by a national or international standard. The value indicates power density measured in watt per square meter (w/m ²).	X		

Pset_EnvironmentalImpactIndicators	Reference	IfcIdentifier		Reference ID for this specified type in this project (e.g. type 'A-1'), Also referred to as "construction type". It should be provided as an alternative to the name of the "object type", if the software does not support object types and no classification reference to a recognized classification system used.	X		
Pset_EnvironmentalImpactIndicators	FunctionalUnitReference	IfcLabel		Reference to a database or a classification	X		
Pset_EnvironmentalImpactIndicators	IndicatorsUnit	IfcText		The unit of the quantity the environmental indicators values are related with.	X		
Pset_EnvironmentalImpactIndicators	LifeCyclePhase	PEnum_LifeCyclePhase	ACQUISITION; CRADLETOSITE; DECONSTRUCTION; DISPOSAL; DISPOSALTRANSPORT; GROWTH; INSTALLATION; MAINTENANCE; MANUFACTURE; OCCUPANCY; OPERATION; PROCUREMENT; PRODUCTION; PRODUCTIONTRANSPORT; RECOVERY; REFURBISHMENT; REPAIR; REPLACEMENT;	The whole life cycle or only a given phase from which environmental data are valid.	X		

			TRANSPORT; USAGE; WASTE; WHOLELIFECYCLE ; USERDEFINED; NOTDEFINED			
Pset_EnvironmentalImpactIndicators	ExpectedServiceLife	IfcTimeMeasure		Expected service life in years.	X	
Pset_EnvironmentalImpactIndicators	TotalPrimaryEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	X	
Pset_EnvironmentalImpactIndicators	WaterConsumptionPerUnit	IfcVolumeMeasure		Quantity of water used.	X	
Pset_EnvironmentalImpactIndicators	HazardousWastePerUnit	IfcMassMeasure		Quantity of hazardous waste generated	X	
Pset_EnvironmentalImpactIndicators	NonHazardousWastePerUnit	IfcMassMeasure		Quantity of non hazardous waste generated	X	
Pset_EnvironmentalImpactIndicators	ClimateChangePerUnit	IfcMassMeasure		Quantity of greenhouse gases emitted calculated in equivalent CO2	X	
Pset_EnvironmentalImpactIndicators	AtmosphericAcidificationPerUnit	IfcMassMeasure		Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO2	X	
Pset_EnvironmentalImpactIndicators	RenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	X	
Pset_EnvironmentalImpactIndicators	NonRenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	X	

Pset_EnvironmentalImpactIndicators	ResourceDepletionPerUnit	IfcMassMeasure		Quantity of resources used calculated in equivalent antimony	X		
Pset_EnvironmentalImpactIndicators	InertWastePerUnit	IfcMassMeasure		Quantity of inert waste generated	X		
Pset_EnvironmentalImpactIndicators	RadioactiveWastePerUnit	IfcMassMeasure		Quantity of radioactive waste generated	X		
Pset_EnvironmentalImpactIndicators	StratosphericOzoneLayerDestructionPerUnit	IfcMassMeasure		Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11	X		
Pset_EnvironmentalImpactIndicators	PhotochemicalOzoneFormationPerUnit	IfcMassMeasure		Quantity of gases creating the photochemical ozone calculated in equivalent ethylene	X		
Pset_EnvironmentalImpactIndicators	EutrophicationPerUnit	IfcMassMeasure		Quantity of eutrophication compounds calculated in equivalent PO4	X		
Pset_EnvironmentalImpactValues	TotalPrimaryEnergyConsumption	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	X		
Pset_EnvironmentalImpactValues	WaterConsumption	IfcVolumeMeasure		Quantity of water used.	X		
Pset_EnvironmentalImpactValues	HazardousWaste	IfcMassMeasure		Quantity of hazardous waste generated.	X		
Pset_EnvironmentalImpactValues	NonHazardousWaste	IfcMassMeasure		Quantity of non hazardous waste generated.	X		
Pset_EnvironmentalImpactValues	ClimateChange	IfcMassMeasure		Quantity of greenhouse gases emitted calculated in equivalent CO2.	X		
Pset_EnvironmentalImpactValues	AtmosphericAcidification	IfcMassMeasure		Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO2.	X		

Pset_EnvironmentalImpactValues	RenewableEnergyConsumption	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactValues	NonRenewableEnergyConsumption	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactValues	ResourceDepletion	IfcMassMeasure		Quantity of resources used calculated in equivalent antimony.	X		
Pset_EnvironmentalImpactValues	InertWaste	IfcMassMeasure		Quantity of inert waste generated.	X		
Pset_EnvironmentalImpactValues	RadioactiveWaste	IfcMassMeasure		Quantity of radioactive waste generated.	X		
Pset_EnvironmentalImpactValues	StratosphericOzoneLayerDestruction	IfcMassMeasure		Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11.	X		
Pset_EnvironmentalImpactValues	PhotochemicalOzoneFormation	IfcMassMeasure		Quantity of gases creating the photochemical ozone calculated in equivalent ethylene.	X		
Pset_EnvironmentalImpactValues	Eutrophication	IfcMassMeasure		Quantity of eutrophication compounds calculated in equivalent PO4.	X		
Pset_EnvironmentalImpactValues	LeadInTime	IfcDuration		Lead in time before start of process.	X		
Pset_EnvironmentalImpactValues	Duration	IfcDuration		Duration of process.	X		
Pset_EnvironmentalImpactValues	LeadOutTime	IfcDuration		Lead out time after end of process.	X		
Pset_InstallationOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	X	X	X
Pset_InstallationOccurrence	AcceptanceDate	IfcDate		Date on which the element is accepted by the manager or administrator.	X		
Pset_InstallationOccurrence	PutIntoOperationDate	IfcDate		Date on which the element is put into operation.	X		

Pset_MaintenanceStrategy	AssetCriticality	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's criticality to the operation of the facility	X		X
Pset_MaintenanceStrategy	AssetFrailty	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's frailty to breakage or deterioration	X		
Pset_MaintenanceStrategy	AssetPriority	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Combined criticality and frailty rating indicating the operational and maintenance priority of the asset	X		
Pset_MaintenanceStrategy	MonitoringType	PEnum_MonitoringType	FEEDBACK; INSPECTION; IOT; PPM; SENSORS	Monitoring strategy chosen for the asset	X		
Pset_MaintenanceStrategy	AccidentResponse	PEnum_AccidentResponse	EMERGENCYINSPECTION; EMERGENCYPROCEDURE; REACTIVE; URGENTINSPECTION; URDENTPROCEDURE	Accident response chosen for the asset	X		
Pset_MaintenanceTriggerCondition	ConditionTargetPerformance	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Target condition of the asset	X		
Pset_MaintenanceTriggerCondition	ConditionMaintenanceLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger maintenance	X		

Pset_MaintenanceTriggerCondition	ConditionReplacementLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a replacement process	X		
Pset_MaintenanceTriggerCondition	ConditionDisposalLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a disposal process	X		
Pset_MaintenanceTriggerDuration	DurationTargetPerformance	IfcDuration		Target time to failure of the asset	X		
Pset_MaintenanceTriggerDuration	DurationMaintenanceLevel	IfcDuration		Duration interval at which maintenance is performed	X		
Pset_MaintenanceTriggerDuration	DurationReplacementLevel	IfcDuration		Duration interval at which replacement is performed	X		
Pset_MaintenanceTriggerDuration	DurationDisposalLevel	IfcDuration		Duration interval at which disposal is performed	X		
Pset_MaintenanceTriggerPerformance	TargetPerformance	IfcReal		Target capacity or performance of the asset. Units of the performance value are specified through the propertyValue units attribute.	X		
Pset_MaintenanceTriggerPerformance	PerformanceMaintenanceLevel	IfcReal		Performance level at which maintenance takes place	X		
Pset_MaintenanceTriggerPerformance	ReplacementLevel	IfcReal		Performance level at which replacement takes place	X		
Pset_MaintenanceTriggerPerformance	DisposalLevel	IfcReal		Performance level at which disposal takes place	X		
Pset_ManufacturerTypeInfo	GlobalTradeItemNumber	IfcIdentifier		The Global Trade Item Number (GTIN) is an identifier for trade items developed by GS1 (www.gs1.org).	X		

Pset_ManufacturerTypeInformation	ArticleNumber	IfcIdentifier		Article number or reference that is applied to a configured product according to a standard scheme for article number definition as defined by the manufacturer. It is often used as the purchasing number.	X		X
Pset_ManufacturerTypeInformation	ModelReference	IfcLabel		The model number or designator of the product model (or product line) as assigned by the manufacturer of the manufactured item.	X		
Pset_ManufacturerTypeInformation	ModelLabel	IfcLabel		The descriptive model name of the product model (or product line) as assigned by the manufacturer of the manufactured item.	X		
Pset_ManufacturerTypeInformation	Manufacturer	IfcLabel		The organization that manufactured and/or assembled the item.	X	X	
Pset_ManufacturerTypeInformation	ProductionYear	IfcLabel		The year of production of the manufactured item.	X	X	
Pset_ManufacturerTypeInformation	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER; NOTKNOWN; UNSET	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	X		
Pset_RepairOccurrence	RepairContent	IfcText		Content of repair, reason and nature can be given, e.g. display faults, communication failure, display exchange.	X		
Pset_RepairOccurrence	RepairDate	IfcDate		Date on which the last repair is done on the asset.	X		
Pset_RepairOccurrence	MeanTimeToRepair	IfcTimeMeasure		Mean time to repair.	X		
Pset_Risk	RiskName	IfcLabel		A locally unique identifier for the risk entry that can be used to track the development	X		

				and mitigation of the risk throughout the project life cycle			
Pset_Risk	RiskType	PEnum_RiskType	ASBESTOSEFFECTS; ASPHIXIATION; BUSINESS; BUSINESSISSUES; CHEMICALEFFECTS; COMMERCIALISSUES; CONFINEMENT; CRUSHING; DROWNINGANDFLOODING; ELECTRICSHOCK; ENVIRONMENTALISSUES; EVENT; FALL; FALLEGE; FALLFRAGILEMATERIAL; FALLSCAFFOLD; FALL_LADDER; FIRE_EXPLOSION; HANDLING; HAZARD; HAZARDOUSDUST; ; HEALTHANDSAFETY; HEALTHISSUE; INSURANCE; INSURANCE_ISSUES; LEADEFFECTS; MACHINERYGUA	Identifies the predefined types of risk from which the type required may be set.	X		

			RDING; MATERIALEFFECTS; MATERIALSHANDLING; MECHANICALEFFECTS; MECHANICAL_LIFTING; MOBILE_ELEVATEDWORKPLATFORM; NOISE_EFFECTS; OPERATIONALISSUES; OTHERISSUES; OVERTURINGPLANT; PUBLICPROTECTIONISSUES; SAFETYISSUE; SILICADUST; SLIPTRIP; SOCIALISSUES; STRUCK; STRUCKFALLINOBJECT; STRUCKVEHICLE; TOOLUSAGE; TRAPPED; UNINTENDEDCOLLAPSE; VIBRATION;				
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			WELFAREISSUE; WOODDUST; WORKINGOVERH EAD; OTHER; NOTKNOWN; UNSET				
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Pset_Risk	NatureOfRisk	IfcLabel		A description of the generic nature of the context or hazard that might be encountered.	X		
Pset_Risk	RiskAssessment Methodology	IfcLabel		An indication or link to the chosen risk assessment methodology, for example PAS1192-6 or a chosen ISO13100 annex.	X		
Pset_Risk	UnmitigatedRisk Likelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard prior to any specific mitigation.	X		
Pset_Risk	UnmitigatedRisk Consequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard prior to any specific mitigation.	X		

Pset_Risk	UnmitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the likelihood and consequence prior to any specific mitigation.	X		
Pset_Risk	MitigationPlanned	IfcLabel		The planned (agreed and irrevocable) mitigation of the likelihood and consequences of the hazard.	X		
Pset_Risk	MitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard given the planned mitigation.	X		
Pset_Risk	MitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW;	Identifies the consequence of the hazard given the planned mitigation.	X		

			OTHER; NOTKNOWN; UNSET			
Pset_Risk	MitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the mitigation of likelihood and consequence.	X	
Pset_Risk	MitigationProposed	IfcLabel		Any proposed, but not yet agreed and irrevocable, mitigation of the likelihood and consequences of the hazard.	X	
Pset_Risk	AssociatedProduct	IfcLabel		An indication or link to any associated product or material that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X	
Pset_Risk	AssociatedActivity	IfcLabel		An indication or link to any associated activity or process that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X	
Pset_Risk	AssociatedLocation	IfcLabel		An indication or link to any associated location or space that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X	

Pset_ServiceLife	ServiceLifeDuration	IfcDuration		The length or duration of a service life. The lower bound indicates pessimistic service life, the upper bound indicates optimistic service life, and the setpoint indicates the typical service life.	X		X
Pset_ServiceLife	MeanTimeBetweenFailure	IfcDuration		The average time duration between instances of failure of a product.	X		
Pset_Tolerance	ToleranceDescription	IfcText		General description of the tolerance associated to the element or feature, its source and implications.	X		
Pset_Tolerance	ToleranceBasis	PEnum_ToleranceBasis	APPEARANCE; ASSEMBLY; DEFLECTION; EXPANSION; FUNCTIONALITY; SETTLEMENT; STRUCTURAL; OTHER; NOTKNOWN; UNSET	Indication of the basis of the tolerance requirement	X		
Pset_Tolerance	OverallTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the intended shape and position in XYZ.	X		
Pset_Tolerance	HorizontalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in X, if different to the overall tolerance.	X		
Pset_Tolerance	OrthogonalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in Y, if different to the overall tolerance.	X		

Pset_Tolerance	VerticalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the vertical shape and position in Z, if different to the overall tolerance.	X		
Pset_Tolerance	PlanarFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the intended shape and position in XYZ.	X		
Pset_Tolerance	HorizontalFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the horizontal surface in XY, if different to the overall flatness.	X		
Pset_Tolerance	ElevationalFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the elevational surface in ZX, if different to the overall flatness.	X		
Pset_Tolerance	SideFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the side surface in YZ, if different to the overall flatness.	X		
Pset_Tolerance	OverallOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the intended shape and orientation in XYZ.	X		
Pset_Tolerance	HorizontalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in X, if different to the overall orthogonality.	X		
Pset_Tolerance	OrthogonalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in Y, if different to the overall orthogonality.	X		
Pset_Tolerance	VerticalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the vertical shape and orientation in Z, if different to the overall orthogonality.	X		

Pset_Tolerance	OverallStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the intended shape.	X		
Pset_Tolerance	HorizontalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in X, if different to the overall straightness.	X		
Pset_Tolerance	OrthogonalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in Y, if different to the overall straightness.	X		
Pset_Tolerance	VerticalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the vertical shape in Z, if different to the overall straightness.	X		
Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty	X		
Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.	X		
Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.	X		
Pset_Uncertainty	LinearUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the overall shape and position in XYZ.	X		
Pset_Uncertainty	OrthogonalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the horizontal shape and	X		

				position in Y, if different to the horizontal uncertainty.			
Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.	X		
Pset_Warranty	WarrantyIdentifier	IfcIdentifier		The identifier assigned to a warranty.	X		X
Pset_Warranty	WarrantyStartDate	IfcDate		The date on which the warranty commences.	X	X	
Pset_Warranty	IsExtendedWarranty	IfcBoolean	TRUE; FALSE	Indication of whether this is an extended warranty whose duration is greater than that normally assigned to an artefact (=TRUE) or not (= FALSE).	X		
Pset_Warranty	WarrantyPeriod	IfcDuration		The time duration during which a manufacturer or supplier guarantees or warrants the performance of an artefact.	X		
Pset_Warranty	WarrantyContent	IfcText		The content of the warranty.	X		
Pset_Warranty	PointOfContact	IfcLabel		The organization that should be contacted for action under the terms of the warranty. Note that the role of the organization (manufacturer, supplier, installer etc.) is determined by the IfcActorRole attribute of IfcOrganization.	X		
Pset_Warranty	Exclusions	IfcText		Items, conditions or actions that may be excluded from the warranty or that may cause the warranty to become void.	X		
SBB-CFF-FFS_lineare_GLT	StartingMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.		X	X

SBB-CFF-FFS_lineare_GLT	EndingMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.		X	X
SBB-CFF-FFS_lineare_GLT	StartAlignmentID	IfcLabel		Track edge = track axis. The ID of the track edge is the designation of each track edge (track axis). It is provided as a basis for the project. Designation scheme: BAA 78.Left > LITT 41.Right.		X	
SBB-CFF-FFS_lineare_GLT	EndAlignmentID	IfcLabel		Track edge = track axis. The ID of the track edge is the designation of each track edge (track axis). It is provided as a basis for the project. Designation scheme: BAA 78.Left > LITT 41.Right.		X	
SBB-CFF-FFS_lineare_GLT	StartLocationID	IfcLabel		Route = line. The route ID is the designation of the relevant route (line). It is provided as a basis for the project. Designation scheme: BAA – BAAN.		X	
SBB-CFF-FFS_lineare_GLT	EndLocationID	IfcLabel		Route = line. The route ID is the designation of the relevant route (line). It is provided as a basis for the project. Designation scheme: BAA – BAAN.		X	
OBJ_FB_4_SPEZ	SteelGrade	PENum_SteelGrade	R260; B360; R370Cr HT; R320Cr; R400HT; R350LHT; R350HT; R200	Steel grade (material) of the rail		X	X
OBJ_FB_4_SPEZ	RailProfile	PENum_RailProfile	54 E2; VST 36; 49 E1; 46 E1; 60 E2; Ri 54 E1; 60 E1; Ri 46 E1; Am 90; 54 E6; 54 E1	Profile of the rail. The profile defines the geometric shape and size of the rail cross-section		X	X

SBB-CFF-FFS_LO	EbkpPosition	IfcLabel		eBKP position of the object type up to the second level of the eBKP (eBKP element). May indicate the value 'n.a.' (see the explanations related to the CDT).		X	
SBB-CFF-FFS_PO	WarrantyTwoYears	IfcDate		End date of the 2-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').		X	
SBB-CFF-FFS_PO	WarrantyFiveYears	IfcDate		End date of the 5-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').		X	
Crossrail_Data	ExpectedExpiryDate	IfcDate		Expected expiry date for the end of the service life of an equipment.			X
Crossrail_Data	WeightPerMetre	IfcMassPerLengthMeasure		Km of the rail per metre.			X
Crossrail_Data	LondonSurveyGridX	IfcReal		London Survey Grid X			X
Crossrail_Data	LondonSurveyGridY	IfcReal		London Survey Grid Y			X
Crossrail_Data	LondonSurveyGridZ	IfcReal		London Survey Grid Y			X

CATENARY SUPPORT							
Property group	Property name	Data type	PEnum	Description	IFC	FDK	Crossrail
Pset_MemberTypeOCSRigidSupport	AssemblyInstruction	IfcExternalReference		Instructions to describe how the system / equipment / facility is assembled.	X		
Pset_MemberTypeOCSRigidSupport	ContactWireStagger	IfcPositiveLengthMeasure		Lateral displacement of the contact wire to opposite sides of the track centre at successive supports.	X		
Pset_ConcreteElementGeneral	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER; NOTKNOWN; UNSET	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	X		
Pset_ConcreteElementGeneral	CastingMethod	PEnum_ConcreteCastingMethod	INSITU; MIXED; PRECAST; PRINTED; OTHER; NOTKNOWN; UNSET	The method of casting the concrete into its designed form.	X		
Pset_ConcreteElementGeneral	StructuralClass	IfcLabel		The structural class defined for the concrete structure (e.g. '1').	X		
Pset_ConcreteElementGeneral	StrengthClass	IfcLabel		Classification of the concrete strength in accordance with the concrete design code which is applied in the project.	X		
Pset_ConcreteElementGeneral	ExposureClass	IfcLabel		Classification of exposure to environmental conditions, usually specified in accordance with the concrete design code which is applied in the project.	X		
Pset_ConcreteElementGeneral	ReinforcementVolumeRatio	IfcMassDensityMeasure		The required ratio of the effective mass of the reinforcement to the effective volume of the concrete of a reinforced concrete structural element.	X		

Pset_ConcreteElementGeneral	ReinforcementAreaRatio	IfcAreaDensityMeasure		The required ratio of the effective area of the reinforcement to the effective area of the concrete At any section of a reinforced concrete structural element.	X		
Pset_ConcreteElementGeneral	DimensionalAccuracyClass	IfcLabel		Classification designation of the dimensional accuracy requirement according to local standards.	X		
Pset_ConcreteElementGeneral	ConstructionToleranceClass	IfcLabel		Classification designation of the on-site construction tolerances according to local standards.	X		
Pset_ConcreteElementGeneral	ConcreteCover	IfcPositiveLengthMeasure		The protective concrete cover at the reinforcing bars according to local building regulations.	X		
Pset_ConcreteElementGeneral	ConcreteCoverAtMainBars	IfcPositiveLengthMeasure		The protective concrete cover at the main reinforcing bars according to local building regulations.	X		
Pset_ConcreteElementGeneral	ConcreteCoverAtLinks	IfcPositiveLengthMeasure		The protective concrete cover at the reinforcement links according to local building regulations.	X		
Pset_ConcreteElementGeneral	ReinforcementStrengthClass	IfcLabel		Classification of the reinforcement strength in accordance with the concrete design code which is applied in the project. The reinforcing strength class often combines strength and ductility.	X		
Pset_Condition	AssessmentDate	IfcDate		Date on which the overall condition is assessed	X		
Pset_Condition	AssessmentCondition	IfcLabel		The overall condition of a product based on an assessment of the contributions to the overall condition made by the various criteria considered. The meanings given to the values of assessed condition should be agreed and documented by local agreements. For instance, is overall condition measured on a scale of 1 -	X		

				10 or by assigning names such as Good, OK, Poor.			
Pset_Condition	AssessmentDescription	IfcText		Qualitative description of the condition.	X		
Pset_Condition	AssessmentType	IfcLabel		Category of latest condition assessment report of the asset.	X		
Pset_Condition	LastAssessmentReport	IfcLabel		Reference to latest condition (state of health) report.	X		
Pset_Condition	NextAssessmentDate	IfcDate		Date of next condition inspection	X		
Pset_Condition	AssessmentFrequency	IfcTimeMeasure		Indicates how often the equipment should be assessed, to have a clear estimation on its working state, based on which the maintenance staff can decide whether it requires maintenance or requires to be updated or replaced.	X		
Pset_ConstructionAdministration	ProcurementMethod	IfcLabel		The method by which an IfcProductType/IfcProduct is acquired and installed. The value provided shall be one of the following four character acronyms: "CFCI" (meaning Contractor Furnished Contractor Installed), "OFCl" (meaning Owner Furnished Contractor Installed), or "OFOl" (meaning Owner Furnished Owner Installed).	X		
Pset_ConstructionAdministration	SpecificationSectionNumber	IfcLabel		A reference number to an external contract technical specification section describing either (a) minimum performance requirements of a given IfcProductType/IfcProduct or (b) a preselection for a specific	X		

				IfcProductType/IfcProduct made for this project.			
Pset_ConstructionAdministration	SubmittalIdentifier	IfcLabel		The reference number to an external construction administration submittal used by the construction contractor and/or subcontractor to verify that the referenced IfcProductType/IfcProduct selection conforms with the requirements found in the referenced SpecificationSectionNumber.	X		
Pset_ElementKinematics	CyclicPath	IfcPlaneAngleMeasure/IfcTimeMeasure		Represents the time:angle table of the kinematic behaviour.	X		
Pset_ElementKinematics	CyclicRange	IfcPlaneAngleMeasure		Identifies the angular range of the kinematic behaviour	X		
Pset_ElementKinematics	LinearPath	IfcLengthMeasure/IfcTimeMeasure		Represents the time:distance table of the kinematic behaviour.	X		
Pset_ElementKinematics	LinearRange	IfcPositiveLengthMeasure		Identifies the linear range of the kinematic behaviour.	X		
Pset_ElementKinematics	MaximumAngularVelocity	IfcAngularVelocityMeasure		Identifies the maximum angular velocity of the kinematic behaviour.	X		
Pset_ElementKinematics	MaximumConstantSpeed	IfcLinearVelocityMeasure		Identifies the maximum constant speed over the kinematic path.	X		
Pset_ElementKinematics	MinimumTime	IfcTimeMeasure		Identifies the minimum time for the kinematic behaviour.	X		
Pset_EnvironmentalCondition	ReferenceAirRelativeHumidity	IfcNormalisedRatioMeasure		Measurement of the ratio of water vapor in the air.	X		
Pset_EnvironmentalCondition	ReferenceEnvironmentTemperature	IfcThermodynamicTemperatureMeasure		Ideal temperature range.	X		

Pset_EnvironmentalCondition	MaximumAtmosphericPressure	IfcPressureMeasure		Maximum level of atmospheric pressure that the equipment can operate effectively in.	X		
Pset_EnvironmentalCondition	StorageTemperatureRange	IfcThermodynamicTemperatureMeasure		Allowed storage temperature range that the element complies with.	X		
Pset_EnvironmentalCondition	MaximumWindSpeed	IfcLinearVelocityMeasure		Maximum resistance to wind load exposure.	X		
Pset_EnvironmentalCondition	OperationalTemperatureRange	IfcThermodynamicTemperatureMeasure		The temperature range in which the device operates normally. Allowable operation ambient air temperature range.	X		
Pset_EnvironmentalCondition	MaximumRainIntensity	IfcReal		Maximum level of rain intensity that the equipment can operate effectively in. It is usually measured in millimeter per hour (mm/h).	X		
Pset_EnvironmentalCondition	SaltMistLevel	IfcLabel		Maximum level of salt mist that the equipment can operate effectively in. It is provided according to an international or national standard.	X		
Pset_EnvironmentalCondition	SeismicResistance	IfcReal		Maximum magnitude of earthquake that the equipment complies with. The value indicates earthquake intensity measured in Richter scale.	X		
Pset_EnvironmentalCondition	SmokeLevel	IfcLabel		Maximum level of smoke that the equipment complies with. It is provided according to an international or national standard.	X		
Pset_EnvironmentalCondition	MaximumSolarRadiation	IfcReal		Maximum level of solar irradiance that the equipment can operate effectively in. This is usually tested and measured by a national or international standard. The value indicates power density measured in watt per square meter (w/m ²).	X		

Pset_EnvironmentalImpactIndicators	Reference	IfcIdentifier		Reference ID for this specified type in this project (e.g. type 'A-1'), Also referred to as "construction type". It should be provided as an alternative to the name of the "object type", if the software does not support object types and no classification reference to a recognized classification system used.	X		
Pset_EnvironmentalImpactIndicators	FunctionalUnitReference	IfcLabel		Reference to a database or a classification	X		
Pset_EnvironmentalImpactIndicators	IndicatorsUnit	IfcText		The unit of the quantity the environmental indicators values are related with.	X		

Pset_EnvironmentalImpactIndicators	LifeCyclePhase	PEnum_LifeCyclePhase	ACQUISITION; CRADLETOSITE; DECONSTRUCTION; DISPOSAL; DISPOSALTRANSPORT; GROWTH; INSTALLATION; MAINTENANCE; MANUFACTURE; OCCUPANCY; OPERATION; PROCUREMENT; PRODUCTION; PRODUCTIONTRANSPORT; RECOVERY; REFURBISHMENT; REPAIR; REPLACEMENT; TRANSPORT; USAGE; WASTE; WHOLELIFECYCLE; USERDEFINED; NOTDEFINED	The whole life cycle or only a given phase from which environmental data are valid.	X		
Pset_EnvironmentalImpactIndicators	ExpectedServiceLife	IfcTimeMeasure		Expected service life in years.	X		X
Pset_EnvironmentalImpactIndicators	TotalPrimaryEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	X		

Pset_EnvironmentalImpactIndicators	WaterConsumptionPerUnit	IfcVolumeMeasure		Quantity of water used.	X		
Pset_EnvironmentalImpactIndicators	HazardousWastePerUnit	IfcMassMeasure		Quantity of hazardous waste generated	X		
Pset_EnvironmentalImpactIndicators	NonHazardousWastePerUnit	IfcMassMeasure		Quantity of non hazardous waste generated	X		
Pset_EnvironmentalImpactIndicators	ClimateChangePerUnit	IfcMassMeasure		Quantity of greenhouse gases emitted calculated in equivalent CO2	X		
Pset_EnvironmentalImpactIndicators	AtmosphericAcidificationPerUnit	IfcMassMeasure		Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO2	X		
Pset_EnvironmentalImpactIndicators	RenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactIndicators	NonRenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactIndicators	ResourceDepletionPerUnit	IfcMassMeasure		Quantity of resources used calculated in equivalent antimony	X		
Pset_EnvironmentalImpactIndicators	InertWastePerUnit	IfcMassMeasure		Quantity of inert waste generated	X		
Pset_EnvironmentalImpactIndicators	RadioactiveWastePerUnit	IfcMassMeasure		Quantity of radioactive waste generated	X		

Pset_EnvironmentalImpactIndicators	StratosphericOzoneLayerDestructionPerUnit	IfcMassMeasure		Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11	X		
Pset_EnvironmentalImpactIndicators	PhotochemicalOzoneFormationPerUnit	IfcMassMeasure		Quantity of gases creating the photochemical ozone calculated in equivalent ethylene	X		
Pset_EnvironmentalImpactIndicators	EutrophicationPerUnit	IfcMassMeasure		Quantity of eutrophivating compounds calculated in equivalent PO4	X		
Pset_EnvironmentalImpactValues	TotalPrimaryEnergyConsumption	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	X		
Pset_EnvironmentalImpactValues	WaterConsumption	IfcVolumeMeasure		Quantity of water used.	X		
Pset_EnvironmentalImpactValues	HazardousWaste	IfcMassMeasure		Quantity of hazardous waste generated.	X		
Pset_EnvironmentalImpactValues	NonHazardousWaste	IfcMassMeasure		Quantity of non hazardous waste generated.	X		
Pset_EnvironmentalImpactValues	ClimateChange	IfcMassMeasure		Quantity of greenhouse gases emitted calculated in equivalent CO2.	X		
Pset_EnvironmentalImpactValues	AtmosphericAcidification	IfcMassMeasure		Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO2.	X		
Pset_EnvironmentalImpactValues	RenewableEnergyConsumption	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactValues	NonRenewableEnergyConsumption	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactValues	ResourceDepletion	IfcMassMeasure		Quantity of resources used calculated in equivalent antimony.	X		

Pset_EnvironmentallImpactValues	InertWaste	IfcMassMeasure		Quantity of inert waste generated.	X		
Pset_EnvironmentallImpactValues	RadioactiveWaste	IfcMassMeasure		Quantity of radioactive waste generated.	X		
Pset_EnvironmentallImpactValues	StratosphericOzoneLayerDestruction	IfcMassMeasure		Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11.	X		
Pset_EnvironmentallImpactValues	PhotochemicalOzoneFormation	IfcMassMeasure		Quantity of gases creating the photochemical ozone calculated in equivalent ethylene.	X		
Pset_EnvironmentallImpactValues	Eutrophication	IfcMassMeasure		Quantity of eutrophication compounds calculated in equivalent PO4.	X		
Pset_EnvironmentallImpactValues	LeadInTime	IfcDuration		Lead in time before start of process.	X		
Pset_EnvironmentallImpactValues	Duration	IfcDuration		Duration of process.	X		
Pset_EnvironmentallImpactValues	LeadOutTime	IfcDuration		Lead out time after end of process.	X		
Pset_MaintenanceStrategy	AssetCriticality	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's criticality to the operation of the facility	X		X
Pset_MaintenanceStrategy	AssetFrailty	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's frailty to breakage or deterioration	X		
Pset_MaintenanceStrategy	AssetPriority	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Combined criticality and frailty rating indicating the operational and maintenance priority of the asset	X		

Pset_MaintenanceStrategy	MonitoringType	PEnum_MonitoringType	FEEDBACK; INSPECTION; IOT; PPM; SENSORS	Monitoring strategy chosen for the asset	X		
Pset_MaintenanceStrategy	AccidentResponse	PEnum_AccidentResponse	EMERGENCYINSPECTION; EMERGENCYPROCEDURE; REACTIVE; URGENTINSPECTION; URDENTPROCEDURE	Accident response chosen for the asset	X		
Pset_MaintenanceTriggerCondition	ConditionTargetPerformance	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Target condition of the asset	X		
Pset_MaintenanceTriggerCondition	ConditionMaintenanceLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger maintenance	X		
Pset_MaintenanceTriggerCondition	ConditionReplacementLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a replacement process	X		
Pset_MaintenanceTriggerCondition	ConditionDisposalLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a disposal process	X		
Pset_MaintenanceTriggerDuration	DurationTargetPerformance	IfcDuration		Target time to failure of the asset	X		
Pset_MaintenanceTriggerDuration	DurationMaintenanceLevel	IfcDuration		Duration interval at which maintenance is performed	X		

Pset_MaintenanceTriggerDuration	DurationReplacementLevel	IfcDuration		Duration interval at which replacement is performed	X		
Pset_MaintenanceTriggerDuration	DurationDisposalLevel	IfcDuration		Duration interval at which disposal is performed	X		
Pset_MaintenanceTriggerPerformance	TargetPerformance	IfcReal		Target capacity or performance of the asset. Units of the performance value are specified through the propertyValue units attribute.	X		
Pset_MaintenanceTriggerPerformance	PerformanceMaintenanceLevel	IfcReal		Performance level at which maintenance takes place	X		
Pset_MaintenanceTriggerPerformance	ReplacementLevel	IfcReal		Performance level at which replacement takes place	X		
Pset_MaintenanceTriggerPerformance	DisposalLevel	IfcReal		Performance level at which disposal takes place	X		
Pset_ManufacturerTypeInformation	GlobalTradeItemNumber	IfcIdentifier		The Global Trade Item Number (GTIN) is an identifier for trade items developed by GS1 (www.gs1.org).	X		
Pset_ManufacturerTypeInformation	ArticleNumber	IfcIdentifier		Article number or reference that is be applied to a configured product according to a standard scheme for article number definition as defined by the manufacturer. It is often used as the purchasing number.	X		
Pset_ManufacturerTypeInformation	ModelReference	IfcLabel		The model number or designator of the product model (or product line) as assigned by the manufacturer of the manufactured item.	X	X	
Pset_ManufacturerTypeInformation	ModelLabel	IfcLabel		The descriptive model name of the product model (or product line) as assigned by the manufacturer of the manufactured item.	X		

Pset_ManufacturerTypeInformation	Manufacturer	IfcLabel		The organization that manufactured and/or assembled the item.	X		
Pset_ManufacturerTypeInformation	ProductionYear	IfcLabel		The year of production of the manufactured item.	X		
Pset_ManufacturerTypeInformation	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER; NOTKNOWN; UNSET	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	X		
Pset_MemberCommon	Reference	IfcIdentifier		The Reference property is deprecated and shall no longer be used, use attribute Name on the relating type instead.	X		
Pset_MemberCommon	Status	PEnum_ElementStatus	DEMOLISH; EXISTING; NEW; TEMPORARY; OTHER; NOTKNOWN; UNSET	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exist only temporary (like a temporary support structure).	X	X	X
Pset_MemberCommon	Span	IfcPositiveLengthMeasure		Clear span for this object. The shape information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the shape properties, provided in the attached property, the geometric parameters take precedence. For geometry editing applications, like CAD: this value should be write-only.	X		

Pset_MemberCommon	Slope	IfcPlaneAngleMeasure		Slope angle - relative to horizontal (0.0 degrees). The shape information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the shape properties, provided in the attached property, the geometric parameters take precedence. For geometry editing applications, like CAD: this value should be write-only.	X		
Pset_MemberCommon	Roll	IfcPlaneAngleMeasure		Rotation against the longitudinal axis. Relative to the global Z direction for all members that are non-vertical in regard to the global coordinate system (Profile direction equals global Z is Roll = 0.) The shape information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the shape properties, provided in the attached property, the geometric parameters take precedence. Note: new property in IFC4.	X		
Pset_MemberCommon	IsExternal	IfcBoolean		Indication whether the element is designed for use in the exterior (TRUE) or not (FALSE). If (TRUE) it is an external element and faces the outside of the building.	X		
Pset_MemberCommon	ThermalTransmittance	IfcThermalTransmittanceMeasure		Thermal transmittance coefficient (U-Value) of an element, within the direction of the thermal flow (including all materials).	X		
Pset_MemberCommon	LoadBearing	IfcBoolean		Indicates whether the object is intended to carry loads (TRUE) or not (FALSE).	X		
Pset_MemberCommon	FireRating	IfcLabel		Fire rating for this object. It is given according to the national fire safety classification.	X		

Pset_Risk	RiskName	IfcLabel		A locally unique identifier for the risk entry that can be used to track the development and mitigation of the risk throughout the project life cycle	X		
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Pset_Risk	RiskType	PEnum_RiskType	ASBESTOSEFFECTS; ASPHIXIATION; BUSINESS; BUSINESSISSUES; CHEMICALEFFECTS; COMMERCIALISSUES; CONFINEMENT; CRUSHING; DROWNINGANDFLOODING; ELECTRICSHOCK; ENVIRONMENTALISSUES; EVENT; FALL; FALLEDGE; FALLFRAGILEMATERIAL; FALLSCAFFOLD; FALL_LADDER; FIRE_EXPLOSION; HANDLING; HAZARD; HAZARDOUSDUST; HEALTHANDSAFETY; HEALTHISSUE; INSURANCE; INSURANCE_ISSUES; LEAEFFECTS; MACHINERYGUARDING; MATERIALEFFECTS; MATERIALSHANDLING; MECHANICALEFFEC	Identifies the predefined types of risk from which the type required may be set.	X		
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			TS; MECHANICAL_LIFTING; MOBILE_ELEVATED WORKPLATFORM; NOISE_EFFECTS; OPERATIONALISSUES; OTHERISSUES; OVERTURINGPLAN T; PUBLICPROTECTIO NISSUES; SAFETYISSUE; SILICADUST; SLIPTRIP; SOCIALISSUES; STRUCK; STRUCKFALLINFOBJ ECT; STRUCKVEHICLE; TOOLUSAGE; TRAPPED; UNINTENDEDCOLL APSE; VIBRATION; WELFAREISSUE; WOODDUST; WORKINGOVERHE AD; OTHER; NOTKNOWN; UNSET			
Pset_Risk	NatureOfRisk	IfcLabel		A description of the generic nature of the context or hazard that might be encountered.	X	

Pset_Risk	RiskAssessmentMethodology	IfcLabel		An indication or link to the chosen risk assessment methodology, for example PAS1192-6 or a chosen ISO13100 annex.	X		
Pset_Risk	UnmitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard prior to any specific mitigation.	X		
Pset_Risk	UnmitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard prior to any specific mitigation.	X		
Pset_Risk	UnmitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the likelihood and consequence prior to any specific mitigation.	X		
Pset_Risk	MitigationPlanned	IfcLabel		The planned (agreed and irrevocable) mitigation of the likelihood and consequences of the hazard.	X		

Pset_Risk	MitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard given the planned mitigation.	X		
Pset_Risk	MitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard given the planned mitigation.	X		
Pset_Risk	MitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the mitigation of likelihood and consequence.	X		
Pset_Risk	MitigationProposed	IfcLabel		Any proposed, but not yet agreed and irrevocable, mitigation of the likelihood and consequences of the hazard.	X		
Pset_Risk	AssociatedProduct	IfcLabel		An indication or link to any associated product or material that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X		

Pset_Risk	AssociatedActivity	IfcLabel		An indication or link to any associated activity or process that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X		
Pset_Risk	AssociatedLocation	IfcLabel		An indication or link to any associated location or space that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X		
Pset_ServiceLife	ServiceLifeDuration	IfcDuration		The length or duration of a service life. The lower bound indicates pessimistic service life, the upper bound indicates optimistic service life, and the setpoint indicates the typical service life.	X		X
Pset_ServiceLife	MeanTimeBetweenFailure	IfcDuration		The average time duration between instances of failure of a product.	X		
Pset_Tolerance	ToleranceDescription	IfcText		General description of the tolerance associated to the element or feature, its source and implications.	X		
Pset_Tolerance	ToleranceBasis	PEnum_ToleranceBasis	APPEARANCE; ASSEMBLY; DEFLECTION; EXPANSION; FUNCTIONALITY; SETTLEMENT; STRUCTURAL; OTHER; NOTKNOWN; UNSET	Indication of the basis of the tolerance requirement	X		
Pset_Tolerance	OverallTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the intended shape and position in XYZ.	X		

Pset_Tolerance	HorizontalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in X, if different to the overall tolerance.	X		
Pset_Tolerance	OrthogonalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in Y, if different to the overall tolerance.	X		
Pset_Tolerance	VerticalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the vertical shape and position in Z, if different to the overall tolerance.	X		
Pset_Tolerance	PlanarFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the intended shape and position in XYZ.	X		
Pset_Tolerance	HorizontalFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the horizontal surface in XY, if different to the overall flatness.	X		
Pset_Tolerance	ElevationalFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the elevational surface in ZX, if different to the overall flatness.	X		
Pset_Tolerance	SideFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the side surface in YZ, if different to the overall flatness.	X		
Pset_Tolerance	OverallOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the intended shape and orientation in XYZ.	X		
Pset_Tolerance	HorizontalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in X, if different to the overall orthogonality.	X		
Pset_Tolerance	OrthogonalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in Y, if different to the overall orthogonality.	X		

Pset_Tolerance	VerticalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the vertical shape and orientation in Z, if different to the overall orthogonality.	X		
Pset_Tolerance	OverallStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the intended shape.	X		
Pset_Tolerance	HorizontalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in X, if different to the overall straightness.	X		
Pset_Tolerance	OrthogonalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in Y, if different to the overall straightness.	X		
Pset_Tolerance	VerticalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the vertical shape in Z, if different to the overall straightness.	X		
Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty	X		
Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.	X		
Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.	X		
Pset_Uncertainty	LinearUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the overall shape and position in XYZ.	X	X	

Pset_Uncertainty	OrthogonalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the horizontal shape and position in Y, if different to the horizontal uncertainty.	X		
Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.	X		
Pset_Warranty	WarrantyIdentifier	IfcIdentifier		The identifier assigned to a warranty.	X	X	
Pset_Warranty	WarrantyStartDate	IfcDate		The date on which the warranty commences.	X	X	
Pset_Warranty	IsExtendedWarranty	IfcBoolean	TRUE; FALSE	Indication of whether this is an extended warranty whose duration is greater than that normally assigned to an artefact (=TRUE) or not (= FALSE).	X		
Pset_Warranty	WarrantyPeriod	IfcDuration		The time duration during which a manufacturer or supplier guarantees or warrants the performance of an artefact.	X		
Pset_Warranty	WarrantyContent	IfcText		The content of the warranty.	X		
Pset_Warranty	PointOfContact	IfcLabel		The organization that should be contacted for action under the terms of the warranty. Note that the role of the organization (manufacturer, supplier, installer etc.) is determined by the IfcActorRole attribute of IfcOrganization.	X		
Pset_Warranty	Exclusions	IfcText		Items, conditions or actions that may be excluded from the warranty or that may cause the warranty to become void.	X		
Pset_ConstructionOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	X	X	X
Pset_ConstructionOccurrence	ModelNumber	IfcLabel		The model number and/or unit designator assigned by the manufacturer of the manufactured item.	X	X	X

Pset_ConstructionOccurrence	TagNumber	IfcLabel		Tag number.	X	X	X
Pset_ConstructionOccurrence	AssetIdentifier	IfcLabel		A unique identification assigned to an asset that enables its differentiation from other assets. NOTE The asset identifier is unique within the asset register. It differs from the globally unique id assigned to the instance of an entity populating a database.	X	X	X
SBB-CFF-FFS_LO	EbkpPosition	IfcLabel		eBKP position of the object type up to the second level of the eBKP (eBKP element). May indicate the value 'n.a.' (see the explanations related to the CDT).		X	
SBB-CFF-FFS_PO	WarrantyTwoYears	IfcDate		End date of the 2-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').		X	
SBB-CFF-FFS_PO	WarrantyFiveYears	IfcDate		End date of the 5-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').		X	
OBJ_FS_19_SPEZ	IsolatorType	Penum_IsolatorType	NOTKNOWN; USERDEFINED; NOTDEFINED	Type of isolator.		X	
OBJ_FS_19_SPEZ	ConductorFixingType	Penum_ConductorFixingType	WHEEL; CLAMPT; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of whether the conductor can be moved using a wheel or whether it is clamped.		X	
OBJ_FS_19_SPEZ	BirdProtectionType	Penum_BirdProtectionType	NOTKNOWN; USERDEFINED; NOTDEFINED	Type of bird protection.		X	
Crossrail_Data	ExpectedExpiryDate	IfcDate		Expected expiry date for the end of the service life of an equipment.			X

Crossrail_Data	LondonSurveyGridX	IfcReal		London Survey Grid X			X
Crossrail_Data	LondonSurveyGridY	IfcReal		London Survey Grid Y			X
Crossrail_Data	LondonSurveyGridZ	IfcReal		London Survey Grid Y			X
Crossrail_Data	Material	IfcLabel		Material.			X
Crossrail_Data	PonctualMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.			X

SIGNAL

Property group	Property name	Data type	PEnum	Description	IFC	FDK	Crossrail
Pset_Condition	AssessmentDate	IfcDate		Date on which the overall condition is assessed	X		
Pset_Condition	AssessmentCondition	IfcLabel		The overall condition of a product based on an assessment of the contributions to the overall condition made by the various criteria considered. The meanings given to the values of assessed condition should be agreed and documented by local agreements. For instance, is overall condition measured on a scale of 1 - 10 or by assigning names such as Good, OK, Poor.	X		
Pset_Condition	AssessmentDescription	IfcText		Qualitative description of the condition.	X		
Pset_Condition	AssessmentType	IfcLabel		Category of latest condition assessment report of the asset.	X		

Pset_Condition	LastAssessmentReport	IfcLabel		Reference to latest condition (state of health) report.	X		
Pset_Condition	NextAssessmentDate	IfcDate		Date of next condition inspection	X		
Pset_Condition	AssessmentFrequency	IfcTimeMeasure		Indicates how often the equipment should be assessed, to have a clear estimation on its working state, based on which the maintenance staff can decide whether it requires maintenance or requires to be updated or replaced.	X		
Pset_ConstructionAdministration	ProcurementMethod	IfcLabel		The method by which an IfcProductType/IfcProduct is acquired and installed. The value provided shall be one of the following four character acronyms: "CFCI" (meaning Contractor Furnished Contractor Installed), "OFCI" (meaning Owner Furnished Contractor Installed), or "OFOI" (meaning Owner Furnished Owner Installed).	X		
Pset_ConstructionAdministration	SpecificationSectionNumber	IfcLabel		A reference number to an external contract technical specification section describing either (a) minimum performance requirements of a given IfcProductType/IfcProduct or (b) a preselection for a specific IfcProductType/IfcProduct made for this project.	X		
Pset_ConstructionAdministration	SubmittalIdentifier	IfcLabel		The reference number to an external construction administration submittal used by the construction contractor and/or subcontractor to verify that the referenced IfcProductType/IfcProduct selection conforms with the requirements found in the referenced SpecificationSectionNumber.	X	X	X

Pset_ConstructionOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	X	X	X
Pset_ConstructionOccurrence	ModelNumber	IfcLabel		The model number and/or unit designator assigned by the manufacturer of the manufactured item.	X	X	X
Pset_ConstructionOccurrence	TagNumber	IfcLabel		Tag number.	X	X	X
Pset_ElectricalDeviceCommon	RatedCurrent	IfcElectricCurrentMeasure		The current that a device is designed to handle.	X		X
Pset_ElectricalDeviceCommon	RatedVoltage	IfcElectricVoltageMeasure		The range of allowed voltage that a device is certified to handle. The upper bound of this value is the maximum.	X		X
Pset_ElectricalDeviceCommon	NominalFrequencyRange	IfcFrequencyMeasure		The upper and lower limits of frequency for which the operation of the device is certified.	X		
Pset_ElectricalDeviceCommon	PowerFactor	IfcNormalisedRatioMeasure		Power factor; usually as ratio. The ratio between the rated electrical power and the product of the rated current and rated voltage	X		
Pset_ElectricalDeviceCommon	ConductorFunction	PEnum_ConductorFunctionEnum	NEUTRAL; PHASE_L1; PHASE_L2; PHASE_L3; PROTECTIVEEARTH; PROTECTIVEEARTH_NEUTRAL; OTHER; NOTKNOWN; UNSET	Indicates function of the conductors to which the load is connected. Where L1, L2 and L3 represent the phase lines according to IEC 60446 notation (sometimes phase lines may be referenced by color [Red, Blue, Yellow] or by number [1, 2, 3] etc). Protective Earth is sometimes also known as CPC or common protective conductor. Note that for an electrical device, a set of line conductor functions may be applied.	X		
Pset_ElectricalDeviceCommon	NumberOfPoles	IfcCountMeasure		Number of poles that the object would affect. The number of live lines that is intended to be handled by the device.	X		
Pset_ElectricalDeviceCommon	HasProtectiveEarth	IfcBoolean	TRUE; FALSE	Indicates whether the object has a protective earth connection (=TRUE) or not (=FALSE).	X		

Pset_ElectricalDeviceCommon	InsulationStandardClass	PEnum_InsulationStandardClasses		Insulation standard classes provides basic protection information against electric shock. Defines levels of insulation required in terms of constructional requirements (creepage and clearance distances) and electrical requirements (compliance with electric strength tests). Basic insulation is considered to be shorted under single fault conditions. The actual values required depend on the working voltage to which the insulation is subjected, as well as other factors. Also indicates whether the electrical device has a protective earth connection.	X		
Pset_ElectricalDeviceCommon	IP_Code	IfcLabel		IP Code, the International Protection Marking, IEC 60529), classifies and rates the degree of protection provided against intrusion.	X		
Pset_ElectricalDeviceCommon	IK_Code	IfcLabel		IK Code according to IEC 62262 (2002) is a numeric classification for the degree of protection provided by enclosures for electrical equipment against external mechanical impacts. NOTE In earlier labeling, the third numeral (1..) had been occasionally added to the closely related IP Code on ingress protection, to indicate the level of impact protection.	X		
Pset_ElectricalDeviceCommon	EarthingStyle	IfcLabel		Indicates the earthing style of the electric device.	X		
Pset_ElectricalDeviceCommon	HeatDissipation	IfcPowerMeasure		Indicates the heat dissipation of the electric device measured in power.	X		
Pset_ElectricalDeviceCommon	Power	IfcPowerMeasure		The actual power and operable range.	X		

Pset_ElectricalDeviceCommon	NominalPowerConsumption	IfcPowerMeasure		Nominal total power consumption.	X		
Pset_ElectricalDeviceCommon	NumberOfPowerSupplyPorts	IfcInteger/IfcLabel		Indicates the number of power supply ports of the electric device.	X		
Pset_ElectricalDeviceCompliance	ElectroMagneticStandardsCompliance	IfcBoolean/IfcLabel	TRUE; FALSE	Information about compliance with regard to electro magnetic related standards.	X		
Pset_ElectricalDeviceCompliance	ExplosiveAtmosphereStandardsCompliance	IfcBoolean/IfcLabel	TRUE; FALSE	Information about compliance with regard to explosive atmosphere related standards.	X		
Pset_ElectricalDeviceCompliance	FireProofingStandardsCompliance	IfcBoolean/IfcLabel	TRUE; FALSE	Information about compliance with regard to fire proofing related standards.	X		
Pset_ElectricalDeviceCompliance	LightningProtectionStandardsCompliance	IfcBoolean/IfcLabel	TRUE; FALSE	Information about compliance with regard to lightning protection related standards.	X		
Pset_ElementKinematics	CyclicPath	IfcPlaneAngleMeasure/IfcTimeMeasure		Represents the time:angle table of the kinematic behaviour.	X		
Pset_ElementKinematics	CyclicRange	IfcPlaneAngleMeasure		Identifies the angular range of the kinematic behaviour	X		
Pset_ElementKinematics	LinearPath	IfcLengthMeasure/IfcTimeMeasure		Represents the time:distance table of the kinematic behaviour.	X		
Pset_ElementKinematics	LinearRange	IfcPositiveLengthMeasure		Identifies the linear range of the kinematic behaviour.	X		
Pset_ElementKinematics	MaximumAngularVelocity	IfcAngularVelocityMeasure		Identifies the maximum angular velocity of the kinematic behaviour.	X		
Pset_ElementKinematics	MaximumConstantSpeed	IfcLinearVelocityMeasure		Identifies the maximum constant speed over the kinematic path.	X		
Pset_ElementKinematics	MinimumTime	IfcTimeMeasure		Identifies the minimum time for the kinematic behaviour.	X		

Pset_ElementSize	NominalLength	IfcPositiveLengthMeasure		The nominal overall length of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In case of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	X		
Pset_ElementSize	NominalWidth	IfcPositiveLengthMeasure		The nominal overall width of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	X		
Pset_ElementSize	NominalHeight	IfcPositiveLengthMeasure		The nominal height of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	X		
Pset_EnergyRequirements	EnergyConsumption	IfcEnergyMeasure		Annual energy consumption requirement	X		
Pset_EnergyRequirements	PowerDemand	IfcPowerMeasure		Power demand of the element	X		
Pset_EnergyRequirements	EnergySourceLabel	IfcLabel		Type of energy source e.g. Electricity, Diesel, LPG etc. utilised by the element.	X		
Pset_EnergyRequirements	EnergyConversionEfficiency	IfcRatioMeasure		Measure of the efficiency of conversion of fuel energy to mechanical energy	X		

Pset_EnvironmentalCondition	ReferenceAirRelativeHumidity	IfcNormalisedRatioMeasure		Measurement of the ratio of water vapor in the air.	X		
Pset_EnvironmentalCondition	ReferenceEnvironmentTemperature	IfcThermodynamicTemperatureMeasure		Ideal temperature range.	X		
Pset_EnvironmentalCondition	MaximumAtmosphericPressure	IfcPressureMeasure		Maximum level of atmospheric pressure that the equipment can operate effectively in.	X		
Pset_EnvironmentalCondition	StorageTemperatureRange	IfcThermodynamicTemperatureMeasure		Allowed storage temperature range that the element complies with.	X		
Pset_EnvironmentalCondition	MaximumWindSpeed	IfcLinearVelocityMeasure		Maximum resistance to wind load exposure.	X		
Pset_EnvironmentalCondition	OperationalTemperatureRange	IfcThermodynamicTemperatureMeasure		The temperature range in which the device operates normally. Allowable operation ambient air temperature range.	X		
Pset_EnvironmentalCondition	MaximumRainIntensity	IfcReal		Maximum level of rain intensity that the equipment can operate effectively in. It is usually measured in millimeter per hour (mm/h).	X		
Pset_EnvironmentalCondition	SaltMistLevel	IfcLabel		Maximum level of salt mist that the equipment can operate effectively in. It is provided according to an international or national standard.	X		
Pset_EnvironmentalCondition	SeismicResistance	IfcReal		Maximum magnitude of earthquake that the equipment complies with. The value indicates earthquake intensity measured in Richter scale.	X		
Pset_EnvironmentalCondition	SmokeLevel	IfcLabel		Maximum level of smoke that the equipment complies with. It is provided according to an international or national standard.	X		

Pset_EnvironmentalCondition	MaximumSolarRadiation	IfcReal		Maximum level of solar irradiance that the equipment can operate effectively in. This is usually tested and measured by a national or international standard. The value indicates power density measured in watt per square meter (w/m ²).	X		
Pset_EnvironmentalEmissions	CarbonDioxideEmissions	IfcMassFlowRateMeasure		Rate of emission of carbon dioxide	X		
Pset_EnvironmentalEmissions	SulphurDioxideEmissions	IfcMassFlowRateMeasure		Rate of emission of sulphur dioxide	X		
Pset_EnvironmentalEmissions	NitrogenOxideEmissions	IfcMassFlowRateMeasure		Rate of emission of nitrogen oxides	X		
Pset_EnvironmentalEmissions	ParticulateMatterEmissions	IfcMassFlowRateMeasure		Rate of emission of particulate matter	X		
Pset_EnvironmentalEmissions	NoiseEmissions	IfcSoundPowerLevelMeasure		Level of sound emission	X		
Pset_EnvironmentalImpactIndicators	Reference	IfcIdentifier		Reference ID for this specified type in this project (e.g. type 'A-1'), Also referred to as "construction type". It should be provided as an alternative to the name of the "object type", if the software does not support object types and no classification reference to a recognized classification system used.	X		
Pset_EnvironmentalImpactIndicators	FunctionalUnitReference	IfcLabel		Reference to a database or a classification	X		
Pset_EnvironmentalImpactIndicators	IndicatorsUnit	IfcText		The unit of the quantity the environmental indicators values are related with.	X		

Pset_EnvironmentalImpactIndicators	LifeCyclePhase	PEnum_LifeCyclePhase	ACQUISITION; CRADLETOSITE; DECONSTRUCTION; DISPOSAL; DISPOSALTRANSPORT; GROWTH; INSTALLATION; MAINTENANCE; MANUFACTURE; OCCUPANCY; OPERATION; PROCUREMENT; PRODUCTION; PRODUCTIONTRANSPORT; RECOVERY; REFURBISHMENT; REPAIR; REPLACEMENT; TRANSPORT; USAGE; WASTE; WHOLELIFECYCLE; USERDEFINED; NOTDEFINED	The whole life cycle or only a given phase from which environmental data are valid.	X		
Pset_EnvironmentalImpactIndicators	ExpectedServiceLife	IfcTimeMeasure		Expected service life in years.	X		
Pset_EnvironmentalImpactIndicators	TotalPrimaryEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	X		
Pset_EnvironmentalImpactIndicators	WaterConsumptionPerUnit	IfcVolumeMeasure		Quantity of water used.	X		

Pset_EnvironmentalImpactIndicators	HazardousWastePerUnit	IfcMassMeasure		Quantity of hazardous waste generated	X		
Pset_EnvironmentalImpactIndicators	NonHazardousWastePerUnit	IfcMassMeasure		Quantity of non hazardous waste generated	X		
Pset_EnvironmentalImpactIndicators	ClimateChangePerUnit	IfcMassMeasure		Quantity of greenhouse gases emitted calculated in equivalent CO2	X		
Pset_EnvironmentalImpactIndicators	AtmosphericAcidificationPerUnit	IfcMassMeasure		Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO2	X		
Pset_EnvironmentalImpactIndicators	RenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactIndicators	NonRenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactIndicators	ResourceDepletionPerUnit	IfcMassMeasure		Quantity of resources used calculated in equivalent antimony	X		
Pset_EnvironmentalImpactIndicators	InertWastePerUnit	IfcMassMeasure		Quantity of inert waste generated	X		
Pset_EnvironmentalImpactIndicators	RadioactiveWastePerUnit	IfcMassMeasure		Quantity of radioactive waste generated	X		
Pset_EnvironmentalImpactIndicators	StratosphericOzoneLayerDestructionPerUnit	IfcMassMeasure		Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11	X		

Pset_EnvironmentalImpactIndicators	PhotochemicalOzoneFormationPerUnit	IfcMassMeasure		Quantity of gases creating the photochemical ozone calculated in equivalent ethylene	X		
Pset_EnvironmentalImpactIndicators	EutrophicationPerUnit	IfcMassMeasure		Quantity of eutrophivating compounds calculated in equivalent PO4	X		
Pset_EnvironmentalImpactValues	TotalPrimaryEnergyConsumption	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	X		
Pset_EnvironmentalImpactValues	WaterConsumption	IfcVolumeMeasure		Quantity of water used.	X		
Pset_EnvironmentalImpactValues	HazardousWaste	IfcMassMeasure		Quantity of hazardous waste generated.	X		
Pset_EnvironmentalImpactValues	NonHazardousWaste	IfcMassMeasure		Quantity of non hazardous waste generated.	X		
Pset_EnvironmentalImpactValues	ClimateChange	IfcMassMeasure		Quantity of greenhouse gases emitted calculated in equivalent CO2.	X		
Pset_EnvironmentalImpactValues	AtmosphericAcidification	IfcMassMeasure		Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO2.	X		
Pset_EnvironmentalImpactValues	RenewableEnergyConsumption	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactValues	NonRenewableEnergyConsumption	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	X		
Pset_EnvironmentalImpactValues	ResourceDepletion	IfcMassMeasure		Quantity of resources used calculated in equivalent antimony.	X		
Pset_EnvironmentalImpactValues	InertWaste	IfcMassMeasure		Quantity of inert waste generated.	X		

Pset_EnvironmentallImpactValues	RadioactiveWaste	IfcMassMeasure		Quantity of radioactive waste generated.	X		
Pset_EnvironmentallImpactValues	StratosphericOzoneLayerDestruction	IfcMassMeasure		Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11.	X		
Pset_EnvironmentallImpactValues	PhotochemicalOzoneFormation	IfcMassMeasure		Quantity of gases creating the photochemical ozone calculated in equivalent ethylene.	X		
Pset_EnvironmentallImpactValues	Eutrophication	IfcMassMeasure		Quantity of eutrophication compounds calculated in equivalent PO4.	X		
Pset_EnvironmentallImpactValues	LeadInTime	IfcDuration		Lead in time before start of process.	X		
Pset_EnvironmentallImpactValues	Duration	IfcDuration		Duration of process.	X		
Pset_EnvironmentallImpactValues	LeadOutTime	IfcDuration		Lead out time after end of process.	X		
Pset_InstallationOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	X		
Pset_InstallationOccurrence	AcceptanceDate	IfcDate		Date on which the element is accepted by the manager or administrator.	X		X
Pset_InstallationOccurrence	PutIntoOperationDate	IfcDate		Date on which the element is put into operation.	X		
Pset_MaintenanceStrategy	AssetCriticality	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's criticality to the operation of the facility	X		X
Pset_MaintenanceStrategy	AssetFrailty	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's frailty to breakage or deterioration	X		

Pset_MaintenanceStrategy	AssetPriority	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Combined criticality and frailty rating indicating the operational and maintenance priority of the asset	X		
Pset_MaintenanceStrategy	MonitoringType	PEnum_MonitoringType	FEEDBACK; INSPECTION; IOT; PPM; SENSORS	Monitoring strategy chosen for the asset	X		
Pset_MaintenanceStrategy	AccidentResponse	PEnum_AccidentResponse	EMERGENCYINSPECTION; EMERGENCYPROCEDURE; REACTIVE; URGENTINSPECTION; URDENTPROCEDURE	Accident response chosen for the asset	X		
Pset_MaintenanceTriggerCondition	ConditionTargetPerformance	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Target condition of the asset	X		
Pset_MaintenanceTriggerCondition	ConditionMaintenanceLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger maintenance	X		
Pset_MaintenanceTriggerCondition	ConditionReplacementLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a replacement process	X		
Pset_MaintenanceTriggerCondition	ConditionDisposalLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a disposal process	X		

Pset_MaintenanceTriggerDuration	DurationTargetPerformance	IfcDuration		Target time to failure of the asset	X		
Pset_MaintenanceTriggerDuration	DurationMaintenanceLevel	IfcDuration		Duration interval at which maintenance is performed	X		
Pset_MaintenanceTriggerDuration	DurationReplacementLevel	IfcDuration		Duration interval at which replacement is performed	X		
Pset_MaintenanceTriggerDuration	DurationDisposalLevel	IfcDuration		Duration interval at which disposal is performed	X		
Pset_MaintenanceTriggerPerformance	TargetPerformance	IfcReal		Target capacity or performance of the asset. Units of the performance value are specified through the propertyValue units attribute.	X		
Pset_MaintenanceTriggerPerformance	PerformanceMaintenanceLevel	IfcReal		Performance level at which maintenance takes place	X		
Pset_MaintenanceTriggerPerformance	ReplacementLevel	IfcReal		Performance level at which replacement takes place	X		
Pset_MaintenanceTriggerPerformance	DisposalLevel	IfcReal		Performance level at which disposal takes place	X		
Pset_ManufacturerOccurrence	AcquisitionDate	IfcDate		The date that the manufactured item was purchased.	X		
Pset_ManufacturerOccurrence	BarCode	IfcIdentifier		The identity of the bar code given to an occurrence of the product.	X		
Pset_ManufacturerOccurrence	SerialNumber	IfcIdentifier		The manufacturer's serial number assigned to an occurrence of a product.	X		
Pset_ManufacturerOccurrence	BatchReference	IfcIdentifier		The identity of the batch reference from which an occurrence of a product is taken.	X		
Pset_ManufacturerOccurrence	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER;	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	X		

			NOTKNOWN; UNSET				
Pset_ManufacturerOccurrence	Manufacturing Date	IfcDate		Date on which the element was manufactured.	X		
Pset_ManufacturerTypeInformation	GlobalTradeItemNumber	IfcIdentifier		The Global Trade Item Number (GTIN) is an identifier for trade items developed by GS1 (www.gs1.org).	X		
Pset_ManufacturerTypeInformation	ArticleNumber	IfcIdentifier		Article number or reference that is be applied to a configured product according to a standard scheme for article number definition as defined by the manufacturer. It is often used as the purchasing number.	X	X	X
Pset_ManufacturerTypeInformation	ModelReference	IfcLabel		The model number or designator of the product model (or product line) as assigned by the manufacturer of the manufactured item.	X		
Pset_ManufacturerTypeInformation	ModelLabel	IfcLabel		The descriptive model name of the product model (or product line) as assigned by the manufacturer of the manufactured item.	X		
Pset_ManufacturerTypeInformation	Manufacturer	IfcLabel		The organization that manufactured and/or assembled the item.	X	X	
Pset_ManufacturerTypeInformation	ProductionYear	IfcLabel		The year of production of the manufactured item.	X		
Pset_ManufacturerTypeInformation	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER; NOTKNOWN; UNSET	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	X		
Pset_RailwaySignalAspect	SignalAspectSymbol	IfcExternalReference		Content which is shown on the signal or sign, e.g. text, number, arrow or icon.	X		

Pset_RailwaySignalAspect	AppliesToTrainCategory	PEnum_TrainCategory	FREIGHT; PASSENGER; OTHER; NOTKNOWN; UNSET	Sign information relative to train category, e.g. freight, passenger.	X		
Pset_RailwaySignalAspect	SignalAspectType	IfcLabel		The type of aspect, e.g. 2-display aspect for distant signal, 3-display aspect for block signal.	X		
Pset_RailwaySignalAspect	SignLegend	IfcText		Text information written on the signal or sign.	X	X	
Pset_RailwaySignalOccurrence	ApproachSpeed	IfcLinearVelocityMeasure		The design speed of trains approaching the signal if different from the line speed.	X		
Pset_RailwaySignalOccurrence	HandSignallingProhibited	IfcBoolean	TRUE; FALSE	Indicates if hand signalling is prohibited in case of any failure.	X		
Pset_RailwaySignalOccurrence	LimitedClearances	IfcText		Special conditions for placing the signal post telephone: tunnels, bridges, viaducts.	X		
Pset_RailwaySignalOccurrence	NumberOfLampsNotUsed	IfcCountMeasure		Number of lamps which are not needed and blanked out (sealed).	X		
Pset_RailwaySignalOccurrence	RequiresOLEMesh	IfcBoolean	TRUE; FALSE	Indicates whether an OLE mesh is required to protect the signal or maintainer.	X		
Pset_RailwaySignalOccurrence	RequiresSafetyHandrail	IfcBoolean	TRUE; FALSE	Indicates whether a safety handrail is required.	X		
Pset_RailwaySignalOccurrence	SignalPostTelephoneID	IfcIdentifier		The identifier of the signal post telephone attached to the signal.	X		
Pset_RailwaySignalOccurrence	SignalPostTelephoneType	IfcLabel		Indicates the type of the signal post telephone, e.g. locked, direct line, dial phone.	X		
Pset_RailwaySignalOccurrence	SpecialPositionArrangement	IfcLabel		Type of special position at which the signal is placed.	X		
Pset_RailwaySignalOccurrence	HinderingObstaclesDescription	IfcText		Description of obstacles that hinder the visibility for the staff in the station.	X		

Pset_RailwaySignalOccurrence	SignalWalkwayLength	IfcPositiveLengthMeasure		Indicates the length of the walkway from signal to signal post telephone.	X		
Pset_RailwaySignalOccurrence	RequiresBannerSignal	IfcBoolean	TRUE; FALSE	Indicates whether a banner repeater signal is required.	X		
Pset_RailwaySignalOccurrence	DistanceToStopMark	IfcPositiveLengthMeasure		Distance from the signal to the nearest stop mark at a platform.	X		
Pset_RailwaySignalSighting	SignalSightingAchievableDistance	IfcPositiveLengthMeasure		Reading distance of the signal, which is achievable with the help of mitigation works.	X		
Pset_RailwaySignalSighting	SignalSightingAvailableDistance	IfcPositiveLengthMeasure		Reading distance of the signal without having any mitigation works.	X		
Pset_RailwaySignalSighting	SignalSightingCombinedWithRepeater	IfcPositiveLengthMeasure		Combined reading distance for the signal and any associated repeaters.	X		
Pset_RailwaySignalSighting	SignalSightingMinimum	IfcPositiveLengthMeasure		Minimal distance in which the signal has to be readable.	X		
Pset_RailwaySignalSighting	SignalSightingPreferred	IfcPositiveLengthMeasure		Preferred distance in which the signal shall be readable.	X		
Pset_RailwaySignalSighting	SignalSightingRouteIndicator	IfcPositiveLengthMeasure		Required reading distance for the route indicator.	X		
Pset_RailwaySignalSighting	SignalViewingMinimumInFront	IfcPositiveLengthMeasure		Smallest distance where the signal has to be readable (for train very close to the signal).	X		

Pset_RailwaySignalType	SignalIndicatorType	PEnum_SignalIndicatorType	DEPARTUREINDICATOR; DEPARTUREROUTEINDICATOR; DERAILINDICATOR; ROLLINGSTOCKSTOPINDICATOR; ROUTEINDICATOR; SHUNTINGINDICATOR; SWITCHINDICATOR; OTHER; NOTKNOWN; UNSET	Type of the indicators on a signal, e.g. route indicator, speed restriction indicator etc.	X		
Pset_RailwaySignalType	LensDiffuserType	IfcLabel		Type of the lens diffuser the signal is equipped with.	X		
Pset_RailwaySignalType	HasConductorRailGuardBoard	IfcBoolean	TRUE; FALSE	Indicates if a guard board is provided.	X		
Pset_RailwaySignalType	MaximumDisplayDistance	IfcPositiveLengthMeasure		The maximum distance that can be displayed. The value relates only to the signal type, not to the circumstances at a special position.	X		
Pset_RailwaySignalType	RequiredDisplayDistance	IfcPositiveLengthMeasure		The required distance that has to be displayed. The value relates only to the signal type, not to the circumstances at a special position.	X		
Pset_RailwaySignalType	IsHighType	IfcBoolean	TRUE; FALSE	Indicates if the signal is high (TRUE) or dwarf (ground mounted) (FALSE).	X	X	
Pset_RailwaySignalType	SignalHoodLength	IfcPositiveLengthMeasure		Nominal length of the signal hood, which is the signal lamp cover against glaring sun.	X		
Pset_RailwaySignalType	HotStripOrientation	IfcLabel		Orientation the lens diffuser has to have, which indicates the direction of the lens diffuser and is	X		

				given in terms like "left upper quadrant (LUQ)" or "5 o'clock".			
Pset_RailwaySignalType	LensDiffuserOrientation	IfcLabel		Orientation the lens diffuser has to have, which indicates the direction of the lens diffuser and is given in terms like "left upper quadrant (LUQ)" or "5 o'clock".	X		
Pset_RailwaySignalType	NumberOfLamps	IfcCountMeasure		Number of lamps the signal is composed of.	X		X
Pset_RailwaySignalType	SignalMessage	IfcText		All possible message available at this signal, e.g. "3/4- display automatic blocking".	X	X	
Pset_RailwaySignalType	RailwaySignalType	PEnum_RailwaySignalType	APPROACHSIGNAL; BLOCKSIGNAL; DISTANTSIGNAL; HOMESIGNAL; HUMPAUXILIARYSIGNAL; HUMPSIGNAL; LEVELCROSSINGSIGNAL; OBSTRUCTIONSIGNAL; REPEATINGSIGNAL; SHUNTINGSIGNAL; STARTINGSIGNAL; OTHER; NOTKNOWN; UNSET	The type of railway signal, e.g. home signal, starting signal, shunting signal, level crossing signal.	X		
Pset_RepairOccurrence	RepairContent	IfcText		Content of repair, reason and nature can be given, e.g. display faults, communication failure, display exchange.	X		
Pset_RepairOccurrence	RepairDate	IfcDate		Date on which the last repair is done on the asset.	X		

Pset_RepairOccurrence	MeanTimeToRepair	IfcTimeMeasure		Mean time to repair.	X		
Pset_Risk	RiskName	IfcLabel		A locally unique identifier for the risk entry that can be used to track the development and mitigation of the risk throughout the project life cycle	X		

Pset_Risk	RiskType	PEnum_RiskType	ASBESTOSEFFECTS; ASPHIXIATION; BUSINESS; BUSINESSISSUES; CHEMICALEFFECTS; COMMERCIALISSUES; CONFINEMENT; CRUSHING; DROWNINGANDFLOODING; ELECTRICSHOCK; ENVIRONMENTALISSUES; EVENT; FALL; FALLEGE; FALLFRAGILEMATERIAL; FALLSCAFFOLD; FALL_LADDER; FIRE_EXPLOSION; HANDLING; HAZARD; HAZARDOUSDUST; HEALTHANDSAFETY; HEALTHISSUE; INSURANCE; INSURANCE_ISSUES; LEAFFECTS; MACHINERYGUARDING; MATERIALEFFECTS; MATERIALSHANDLING; MECHANICALEFFEC	Identifies the predefined types of risk from which the type required may be set.	X		
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			TS; MECHANICAL_LIFTING; MOBILE_ELEVATED_WORKPLATFORM; NOISE_EFFECTS; OPERATIONALISSUES; OTHERISSUES; OVERTURINGPLAN T; PUBLICPROTECTIONISSUES; SAFETYISSUE; SILICADUST; SLIPTRIP; SOCIALISSUES; STRUCK; STRUCKFALLINOBJECT; STRUCKVEHICLE; TOOLUSAGE; TRAPPED; UNINTENDEDCOLLAPSE; VIBRATION; WELFAREISSUE; WOODDUST; WORKINGOVERHEAD; OTHER; NOTKNOWN; UNSET				
Pset_Risk	NatureOfRisk	IfcLabel		A description of the generic nature of the context or hazard that might be encountered.	X		

Pset_Risk	RiskAssessmentMethodology	IfcLabel		An indication or link to the chosen risk assessment methodology, for example PAS1192-6 or a chosen ISO13100 annex.	X		
Pset_Risk	UnmitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard prior to any specific mitigation.	X		
Pset_Risk	UnmitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard prior to any specific mitigation.	X		
Pset_Risk	UnmitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the likelihood and consequence prior to any specific mitigation.	X		
Pset_Risk	MitigationPlanned	IfcLabel		The planned (agreed and irrevocable) mitigation of the likelihood and consequences of the hazard.	X		

Pset_Risk	MitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard given the planned mitigation.	X		
Pset_Risk	MitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard given the planned mitigation.	X		
Pset_Risk	MitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the mitigation of likelihood and consequence.	X		
Pset_Risk	MitigationProposed	IfcLabel		Any proposed, but not yet agreed and irrevocable, mitigation of the likelihood and consequences of the hazard.	X		
Pset_Risk	AssociatedProduct	IfcLabel		An indication or link to any associated product or material that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X		

Pset_Risk	AssociatedActivity	IfcLabel		An indication or link to any associated activity or process that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X		
Pset_Risk	AssociatedLocation	IfcLabel		An indication or link to any associated location or space that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	X		
Pset_ServiceLife	ServiceLifeDuration	IfcDuration		The length or duration of a service life. The lower bound indicates pessimistic service life, the upper bound indicates optimistic service life, and the setpoint indicates the typical service life.	X		X
Pset_ServiceLife	MeanTimeBetweenFailure	IfcDuration		The average time duration between instances of failure of a product.	X		
Pset_SignalFrame	BackboardType	IfcLabel		The type of the backboard of the signal frame.	X		
Pset_SignalFrame	SignalFrameType	IfcLabel		Type of frame, e.g. main frame, route indicator, speed indicator, direction indicator, etc.	X		
Pset_SignalFrame	NominalWidth	IfcNonNegativeLengthMeasure		The nominal overall width of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	X		

Pset_SignalFrame	SignalIndicatorType	PEnum_SignalIndicatorType	DEPARTUREINDICATOR; DEPARTUREROUTEINDICATOR; DERAILINDICATOR; ROLLINGSTOCKSTOPINDICATOR; ROUTEINDICATOR; SHUNTINGINDICATOR; SWITCHINDICATOR; OTHER; NOTKNOWN; UNSET	Type of the indicators on a signal, e.g. route indicator, speed restriction indicator etc.	X		
Pset_SignalFrame	SignalFrameBackboardHeight	IfcPositiveLengthMeasure		The nominal height of the signal frame backboard.	X		
Pset_SignalFrame	SignalFrameBackboardDiameter	IfcPositiveLengthMeasure		The nominal diameter of the signal frame backboard.	X		
Pset_Tolerance	ToleranceDescription	IfcText		General description of the tolerance associated to the element or feature, its source and implications.	X		
Pset_Tolerance	ToleranceBasis	PEnum_ToleranceBasis	APPEARANCE; ASSEMBLY; DEFLECTION; EXPANSION; FUNCTIONALITY; SETTLEMENT; STRUCTURAL; OTHER; NOTKNOWN; UNSET	Indication of the basis of the tolerance requirement	X		

Pset_Tolerance	OverallTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the intended shape and position in XYZ.	X		
Pset_Tolerance	HorizontalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in X, if different to the overall tolerance.	X		
Pset_Tolerance	OrthogonalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in Y, if different to the overall tolerance.	X	X	
Pset_Tolerance	VerticalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the vertical shape and position in Z, if different to the overall tolerance.	X		
Pset_Tolerance	PlanarFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the intended shape and position in XYZ.	X		
Pset_Tolerance	HorizontalFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the horizontal surface in XY, if different to the overall flatness.	X		
Pset_Tolerance	ElevationalFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the elevational surface in ZX, if different to the overall flatness.	X		
Pset_Tolerance	SideFlatness	IfcPositiveLengthMeasure		Indicative (95%-100%) range flatness associated to the side surface in YZ, if different to the overall flatness.	X		
Pset_Tolerance	OverallOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the intended shape and orientation in XYZ.	X		
Pset_Tolerance	HorizontalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in X, if different to the overall orthogonality.	X		

Pset_Tolerance	OrthogonalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in Y, if different to the overall orthogonality.	X		
Pset_Tolerance	VerticalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the vertical shape and orientation in Z, if different to the overall orthogonality.	X		
Pset_Tolerance	OverallStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the intended shape.	X		
Pset_Tolerance	HorizontalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in X, if different to the overall straightness.	X		
Pset_Tolerance	OrthogonalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in Y, if different to the overall straightness.	X		
Pset_Tolerance	VerticalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the vertical shape in Z, if different to the overall straightness.	X		
Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty	X		
Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.	X		

Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.	X		
Pset_Uncertainty	LinearUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the overall shape and position in XYZ.	X		
Pset_Uncertainty	OrthogonalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the horizontal shape and position in Y, if different to the horizontal uncertainty.	X		
Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.	X		
Pset_Warranty	WarrantyIdentifier	IfcIdentifier		The identifier assigned to a warranty.	X		
Pset_Warranty	WarrantyStartDate	IfcDate		The date on which the warranty commences.	X	X	
Pset_Warranty	IsExtendedWarranty	IfcBoolean	TRUE; FALSE	Indication of whether this is an extended warranty whose duration is greater than that normally assigned to an artefact (=TRUE) or not (= FALSE).	X		
Pset_Warranty	WarrantyPeriod	IfcDuration		The time duration during which a manufacturer or supplier guarantees or warrants the performance of an artefact.	X		
Pset_Warranty	WarrantyContent	IfcText		The content of the warranty.	X		
Pset_Warranty	PointOfContact	IfcLabel		The organization that should be contacted for action under the terms of the warranty. Note that the role of the organization (manufacturer, supplier, installer etc.) is determined by the IfcActorRole attribute of IfcOrganization.	X		

Pset_Warranty	Exclusions	IfcText		Items, conditions or actions that may be excluded from the warranty or that may cause the warranty to become void.	X		
SBB-CFF-FFS_LO	EbkpPosition	IfcLabel		eBKP position of the object type up to the second level of the eBKP (eBKP element). May indicate the value 'n.a.' (see the explanations related to the CDT).		X	
SBB-CFF-FFS_PO	WarrantyTwoYears	IfcDate		End date of the 2-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').		X	
SBB-CFF-FFS_PO	WarrantyFiveYears	IfcDate		End date of the 5-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').		X	
OBJ_SA_18_LO	NumberOfRepeaters	IfcCountMeasure		Statement indicating whether the distant signal has one or more repeater signals.		X	

OBJ_SA_18_LO	PresignalSignalFunctions	PEnum_DistantSignalFunctions	GROUPDISTANTSIGNAL; BLOCKDISTANTSIGNAL; EXITDISTANTSIGNAL; TRACKSECTIONDISTANTSIGNAL; PROTECTIONDISTANTSIGNAL; TRACKDISTANTSIGNAL; REPEATERDISTANTSIGNAL; OTHERDISTANTSIGNAL; ENTRYDISTANTSIGNAL	Type of signal, such as entry or exit signal.		X	
OBJ_SA_18_LO; OBJ_SA_17_LO	SwissSignalSystemType	PEnum_SwissSignalSystemType	NSYSTEMWITHSPEEDINDICATION; NSYSTEM; LSYSTEM; COMBINEDSIGNALWITHOUTSTOPBOARD; FOREIGNSIGNAL; COMBINEDSIGNALWITHSPEEDBOARD	Type of signaling system: L or N.		X	
OBJ_SA_18_SPEZ; OBJ_SA_17_SPEZ	FrameForm	PEnum_FrameForm	RECTANGLE2X5; RECTANGLE3X5; OTHER; NSYSTEM; SQUARE3X3	Frame form.		X	

OBJ_SA_18_SPEZ; OBJ_SA_17_SPEZ	TextSize	PEnum_TextSize	STANDARD; SMALL	Text size on the signboard.		X	
OBJ_SA_17_LO	MainSignalFunctions	PEnum_MainSignalFunctions	TRACKSECTION; ENTRY; BLOCK; GROUPSIGNAL; REPEATERSIGNAL; TRACKSIGNAL; PROTECTION; OTHER; BUFFERSTOPSIGNAL; EXIT	Type of signal, such as entry or exit signal.		X	
OBJ_SA_19_LO	IsItTriangle	IfcBoolean		Indicates whether the signal is equipped with a triangular attachment, which gives it validity even when not illuminated.		X	
Crossrail_Data	LampType	IfcLabel		The type/model of the lamp used for future replacements.			X
Crossrail_Data	ExpectedExpiryDate	IfcDate		Expected expiry date for the end of the service life of an equipment.			X
Crossrail_Data	LondonSurveyGridX	IfcReal		London Survey Grid X			X
Crossrail_Data	LondonSurveyGridY	IfcReal		London Survey Grid Y			X
Crossrail_Data	LondonSurveyGridZ	IfcReal		London Survey Grid Y			X
Crossrail_Data	PonctualMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.			X
Crossrail_Data	SignalFixingType	IfcLabel		Switchable Signage Fixing Type			X
Crossrail_Data	SignalLampType	IfcLabel		Switchable Signage Lamp Type			X

APPENDIX 3: PRODUCT DATA TEMPLATES

RAIL					
Property set	Property name	Data type	PEnum	Description	Document
Pset_RailTypeRail	PositionInTrack	PEnum_Relative Position	LEFT; MIDDLE; RIGHT; OTHER; NOTKNOWN; UNSET	Indicates the relative position of the element in track, which lies to the left or right as facing in the direction of increasing stationing values.	IFC, SBB, Crossrail
Pset_RailTypeRail	RailDeliveryState	PEnum_RailDeliveryState	HEATTREATMENT; HOTROLLING; OTHER; NOTKNOWN; UNSET	The delivery state of rail, which indicates the final treatment at the end in manufacturing.	IFC, FDK
Pset_RailTypeRail	RailCondition	PEnum_RailCondition	NEWRAIL; REGENERATEDRAIL; REUSEDRAIL; OTHER; NOTKNOWN; UNSET	Assessment of the condition of the rail at point of installation.	IFC, FDK
Pset_RailTypeRail	DrillOnRail	PEnum_DrillOnRail	BOTHENDS; NONE; ONEEND; OTHER; NOTKNOWN; UNSET	Indicates if the manufactured rail is drilled at its extremities or not. It can have holes on one, both or none of its extremities.	IFC
Pset_RailTypeRail	RailElementaryLength	PEnum_RailElementaryLength	100M; 108M; 120M; 12M; 144M; 18M; 24M; 25M; 27M; 30M; 36M; 400M; 48M; 54M; 60M; 6M; 72M; 75M; OTHER; NOTKNOWN; UNSET	The standardised length of rail supplied from the manufacturer.	IFC, SBB, Crossrail
Pset_RailTypeRail	MinimumTensileStrength	IfcForceMeasure		Indicates the minimum tensile strength.	IFC, FDK

Pset_RailTypeRail	IsStainless	IfcBoolean		Indicates whether the rail is stainless or not.	IFC
Pset_RailTypeRail	SteelGrade	PENum_SteelGrade	R260; B360; R370Cr HT; R320Cr; R400HT; R350LHT; R350HT; R200	Steel grade (material) of the rail	FDK, Crossrail
Pset_RailTypeRail	WeightPerMetre	IfcMassPerLengthMeasure		Km of the rail per metre.	Crossrail
Pset_RailTypeRail	RailProfile	PENum_RailProfile	54 E2; VST 36; 49 E1; 46 E1; 60 E2; Ri 54 E1; 60 E1; Ri 46 E1; Am 90; 54 E6; 54 E1	Profile of the rail. The profile defines the geometric shape and size of the rail cross-section	FDK, Crossrail
Pset_Condition	AssessmentDate	IfcDate		Date on which the overall condition is assessed	IFC
Pset_Condition	AssessmentCondition	IfcLabel		The overall condition of a product based on an assessment of the contributions to the overall condition made by the various criteria considered. The meanings given to the values of assessed condition should be agreed and documented by local agreements. For instance, is overall condition measured on a scale of 1 - 10 or by assigning names such as Good, OK, Poor.	IFC, Crossrail
Pset_Condition	AssessmentDescription	IfcText		Qualitative description of the condition.	IFC
Pset_Condition	AssessmentType	IfcLabel		Category of latest condition assessment report of the asset.	IFC
Pset_Condition	LastAssessmentReport	IfcLabel		Reference to latest condition (state of health) report.	IFC
Pset_Condition	NextAssessmentDate	IfcDate		Date of next condition inspection	IFC

Pset_Condition	AssessmentFrequency	IfcTimeMeasure		Indicates how often the equipment should be assessed, to have a clear estimation on its working state, based on which the maintenance staff can decide whether it requires maintenance or requires to be updated or replaced.	IFC
Pset_ConstructionAdministration	ProcurementMethod	IfcLabel		The method by which an IfcProductType/IfcProduct is acquired and installed. The value provided shall be one of the following four character acronyms: "CFCI" (meaning Contractor Furnished Contractor Installed), "OFCI" (meaning Owner Furnished Contractor Installed), or "OFOI" (meaning Owner Furnished Owner Installed).	IFC
Pset_ConstructionAdministration	SpecificationSectionNumber	IfcLabel		A reference number to an external contract technical specification section describing either (a) minimum performance requirements of a given IfcProductType/IfcProduct or (b) a preselection for a specific IfcProductType/IfcProduct made for this project.	IFC
Pset_ConstructionAdministration	SubmittalIdentifier	IfcLabel		The reference number to an external construction administration submittal used by the construction contractor and/or subcontractor to verify that the referenced IfcProductType/IfcProduct selection conforms with the requirements found in the referenced SpecificationSectionNumber.	IFC
Pset_ConstructionOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	IFC, FDK, Crossrail
Pset_ConstructionOccurrence	ModelNumber	IfcLabel		The model number and/or unit designator assigned by the manufacturer of the manufactured item.	IFC, FDK
Pset_ConstructionOccurrence	TagNumber	IfcLabel		Tag number.	IFC, FDK, Crossrail

Pset_ConstructionOccurrence	AssetIdentifier	IfcLabel		A unique identification assigned to an asset that enables its differentiation from other assets. NOTE The asset identifier is unique within the asset register. It differs from the globally unique id assigned to the instance of an entity populating a database.	IFC, FDK
Pset_EnvironmentalImpactIndicators	FunctionalUnitReference	IfcLabel		Reference to a database or a classification	IFC
Pset_EnvironmentalImpactIndicators	IndicatorsUnit	IfcText		The unit of the quantity the environmental indicators values are related with.	IFC
Pset_EnvironmentalImpactIndicators	LifeCyclePhase	PEnum_LifeCyclePhase	ACQUISITION; CRADLETOSITE; DECONSTRUCTION; DISPOSAL; DISPOSALTRANSPORT; INSTALLATION; MAINTENANCE; MANUFACTURE; OPERATION; PROCUREMENT; PRODUCTION; PRODUCTIONTRANSPORT; RECOVERY; REFURBISHMENT; REPAIR; REPLACEMENT; TRANSPORT; USAGE; WASTE; WHOLELIFECYCLE; USERDEFINED; NOTDEFINED	The whole life cycle or only a given phase from which environmental data are valid.	IFC
Pset_EnvironmentalImpactIndicators	ExpectedServiceLife	IfcTimeMeasure		Expected service life in years.	IFC

Pset_InstallationOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	IFC, FDK, Crossrail
Pset_InstallationOccurrence	AcceptanceDate	IfcDate		Date on which the element is accepted by the manager or administrator.	IFC
Pset_InstallationOccurrence	PutIntoOperationDate	IfcDate		Date on which the element is put into operation.	IFC
Pset_MaintenanceStrategy	AssetCriticality	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's criticality to the operation of the facility	IFC, Crossrail
Pset_MaintenanceStrategy	AssetFrailty	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's frailty to breakage or deterioration	IFC
Pset_MaintenanceStrategy	AssetPriority	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Combined criticality and frailty rating indicating the operational and maintenance priority of the asset	IFC
Pset_MaintenanceStrategy	MonitoringType	PEnum_MonitoringType	FEEDBACK; INSPECTION; SENSORS	Monitoring strategy chosen for the asset	IFC
Pset_MaintenanceStrategy	AccidentResponse	PEnum_AccidentResponse	EMERGENCYINSPECTION; EMERGENCYPROCEDURE; REACTIVE; URGENTINSPECTION; URGENTPROCEDURE	Accident response chosen for the asset	IFC
Pset_MaintenanceTriggerCondition	ConditionTargetPerformance	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Target condition of the asset	IFC
Pset_MaintenanceTriggerCondition	ConditionMaintenanceLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger maintenance	IFC

Pset_MaintenanceTriggerCondition	ConditionReplacementLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a replacement process	IFC
Pset_MaintenanceTriggerCondition	ConditionDisposalLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a disposal process	IFC
Pset_MaintenanceTriggerDuration	DurationTargetPerformance	IfcDuration		Target time to failure of the asset	IFC
Pset_MaintenanceTriggerDuration	DurationMaintenanceLevel	IfcDuration		Duration interval at which maintenance is performed	IFC
Pset_MaintenanceTriggerDuration	DurationReplacementLevel	IfcDuration		Duration interval at which replacement is performed	IFC
Pset_MaintenanceTriggerDuration	DurationDisposalLevel	IfcDuration		Duration interval at which disposal is performed	IFC
Pset_ManufacturerTypeInformation	ArticleNumber	IfcIdentifier		Article number or reference that is be applied to a configured product according to a standard scheme for article number definition as defined by the manufacturer. It is often used as the purchasing number.	IFC, Crossrail
Pset_ManufacturerTypeInformation	Manufacturer	IfcLabel		The organization that manufactured and/or assembled the item.	IFC, FDK
Pset_ManufacturerTypeInformation	ProductionYear	IfcLabel		The year of production of the manufactured item.	IFC, FDK
Pset_RepairOccurrence	RepairContent	IfcText		Content of repair, reason and nature can be given, e.g. display faults, communication failure, display exchange.	IFC
Pset_RepairOccurrence	RepairDate	IfcDate		Date on which the last repair is done on the asset.	IFC
Pset_RepairOccurrence	MeanTimeToRepair	IfcTimeMeasure		Mean time to repair.	IFC

Pset_Risk	RiskName	IfcLabel		A locally unique identifier for the risk entry that can be used to track the development and mitigation of the risk throughout the project life cycle	IFC
Pset_Risk	RiskType	PEnum_RiskType	BUSINESS; COMMERICALISSUES; ENVIRONMENTALISSUES; EVENT; HANDLING; INSURANCE; INSURANCE_ISSUES; MATERIALEFFECTS; MECHANICALEFFECTS; MECHANICAL_LIFTING; NOISE_EFFECTS; OPERATIONALISSUES; OTHERISSUES; PUBLICPROTECTIONISSUES; SAFETYISSUE; SOCIALISSUES; STRUCK; STRUCKVEHICLE; TOOLUSAGE; UNINTENDED-collapse; VIBRATION; OTHER; NOTKNOWN; UNSET	Identifies the predefined types of risk from which the type required may be set.	IFC
Pset_Risk	NatureOfRisk	IfcLabel		A description of the generic nature of the context or hazard that might be encountered.	IFC
Pset_Risk	RiskAssessmentMethodology	IfcLabel		An indication or link to the chosen risk assessment methodology, for example PAS1192-6 or a chosen ISO13100 annex.	IFC

Pset_Risk	UnmitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard prior to any specific mitigation.	IFC
Pset_Risk	UnmitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard prior to any specific mitigation.	IFC
Pset_Risk	UnmitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the likelihood and consequence prior to any specific mitigation.	IFC
Pset_Risk	MitigationPlanned	IfcLabel		The planned (agreed and irrevocable) mitigation of the likelihood and consequences of the hazard.	IFC

Pset_Risk	MitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard given the planned mitigation.	IFC
Pset_Risk	MitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard given the planned mitigation.	IFC
Pset_Risk	MitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the mitigation of likelihood and consequence.	IFC
Pset_Risk	MitigationProposed	IfcLabel		Any proposed, but not yet agreed and irrevocable, mitigation of the likelihood and consequences of the hazard.	IFC
Pset_ServiceLife	ServiceLifeDuration	IfcDuration		The length or duration of a service life. The lower bound indicates pessimistic service life, the upper bound indicates optimistic service life, and the setpoint indicates the typical service life.	IFC, Crossrail
Pset_ServiceLife	MeanTimeBetweenFailure	IfcDuration		The average time duration between instances of failure of a product.	IFC

Pset_ServiceLife	ExpectedExpiryDate	IfcDate		Expected expiry date for the end of the service life of an equipment.	Crossrail
Pset_Tolerance	ToleranceDescription	IfcText		General description of the tolerance associated to the element or feature, its source and implications.	IFC
Pset_Tolerance	ToleranceBasis	PEnum_ToleranceBasis	EXPANSION; FUNCTIONALITY; SETTLEMENT; STRUCTURAL; OTHER; NOTKNOWN; UNSET	Indication of the basis of the tolerance requirement	IFC
Pset_Tolerance	OverallTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the intended shape and position in XYZ.	IFC
Pset_Tolerance	HorizontalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in X, if different to the overall tolerance.	IFC
Pset_Tolerance	VerticalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the vertical shape and position in Z, if different to the overall tolerance.	IFC
Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty	IFC
Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.	IFC

Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.	IFC
Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.	IFC
Pset_Warranty	WarrantyIdentifier	IfcIdentifier		The identifier assigned to a warranty.	IFC, Crossrail
Pset_Warranty	WarrantyStartDate	IfcDate		The date on which the warranty commences.	IFC, FDK
Pset_Warranty	IsExtendedWarranty	IfcBoolean	TRUE; FALSE	Indication of whether this is an extended warranty whose duration is greater than that normally assigned to an artefact (=TRUE) or not (=FALSE).	IFC
Pset_Warranty	WarrantyPeriod	IfcDuration		The time duration during which a manufacturer or supplier guarantees or warrants the performance of an artefact.	IFC
Pset_Warranty	WarrantyContent	IfcText		The content of the warranty.	IFC
Pset_Warranty	WarrantyTwoYears	IfcDate		End date of the 2-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').	FDK
Pset_Warranty	WarrantyFiveYears	IfcDate		End date of the 5-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').	FDK
Group_LinearPlacementStation	StartingMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.	FDK, Crossrail
Group_LinearPlacementStation	EndingMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.	FDK, Crossrail

Group_LinearPlace mentStation	StartAlignmentID	IfcLabel		Track edge = track axis. The ID of the track edge is the designation of each track edge (track axis). It is provided as a basis for the project. Designation scheme: BAA 78.Left > LITT 41.Right.	FDK
Group_LinearPlace mentStation	EndAlignmentID	IfcLabel		Track edge = track axis. The ID of the track edge is the designation of each track edge (track axis). It is provided as a basis for the project. Designation scheme: BAA 78.Left > LITT 41.Right.	FDK
Group_LinearPlace mentStation	StartLocationID	IfcLabel		Route = line. The route ID is the designation of the relevant route (line). It is provided as a basis for the project. Designation scheme: BAA – BAAN.	FDK
Group_LinearPlace mentStation	EndLocationID	IfcLabel		Route = line. The route ID is the designation of the relevant route (line). It is provided as a basis for the project. Designation scheme: BAA – BAAN.	FDK

CATENARY SUPPORT

Property set	Property name	Data type	PEnum	Description	Document
Pset_MemberType OCSRigidSupport	AssemblyInstruction	IfcExternalRefer ence		Instructions to describe how the system / equipment / facility is assembled.	IFC
Pset_MemberType OCSRigidSupport	ContactWireStagger	IfcPositiveLengt hMeasure		Lateral displacement of the contact wire to opposite sides of the track centre at successive supports.	IFC
Pset_MemberType OCSRigidSupport	IsolatorType	Penum_Isolator Type	NOTKNOWN; USERDEFINED; NOTDEFINED	Type of isolator.	FDK
Pset_MemberType OCSRigidSupport	ConductorFixingType	Penum_Conduc torFixingType	WHEEL; CLAMPT; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of whether the conductor can be moved using a wheel or whether it is clamped.	FDK

Pset_MemberType OCSRigidSupport	BirdProtectionType	Penum_BirdProtectionType	NOTKNOWN; USERDEFINED; NOTDEFINED	Type of bird protection.	FDK
Pset_Condition	AssessmentDate	IfcDate		Date on which the overall condition is assessed	IFC
Pset_Condition	AssessmentCondition	IfcLabel		The overall condition of a product based on an assessment of the contributions to the overall condition made by the various criteria considered. The meanings given to the values of assessed condition should be agreed and documented by local agreements. For instance, is overall condition measured on a scale of 1 - 10 or by assigning names such as Good, OK, Poor.	IFC
Pset_Condition	AssessmentDescription	IfcText		Qualitative description of the condition.	IFC
Pset_Condition	AssessmentType	IfcLabel		Category of latest condition assessment report of the asset.	IFC
Pset_Condition	LastAssessmentReport	IfcLabel		Reference to latest condition (state of health) report.	IFC
Pset_Condition	NextAssessmentDate	IfcDate		Date of next condition inspection	IFC
Pset_Condition	AssessmentFrequency	IfcTimeMeasure		Indicates how often the equipment should be assessed, to have a clear estimation on its working state, based on which the maintenance staff can decide whether it requires maintenance or requires to be updated or replaced.	IFC
Pset_Construction Administration	ProcurementMethod	IfcLabel		The method by which an IfcProductType/IfcProduct is acquired and installed. The value provided shall be one of the following four character acronyms: "CFCI" (meaning Contractor Furnished Contractor Installed), "OFCI" (meaning Owner Furnished Contractor Installed), or "OFOI" (meaning Owner Furnished Owner Installed).	IFC

Pset_Construction Administration	SpecificationSectionNumber	IfcLabel		A reference number to an external contract technical specification section describing either (a) minimum performance requirements of a given IfcProductType/IfcProduct or (b) a preselection for a specific IfcProductType/IfcProduct made for this project.	IFC
Pset_Construction Administration	SubmittalIdentifier	IfcLabel		The reference number to an external construction administration submittal used by the construction contractor and/or subcontractor to verify that the referenced IfcProductType/IfcProduct selection conforms with the requirements found in the referenced SpecificationSectionNumber.	IFC
Pset_EnvironmentalImpactIndicators	FunctionalUnitReference	IfcLabel		Reference to a database or a classification	IFC
Pset_EnvironmentalImpactIndicators	IndicatorsUnit	IfcText		The unit of the quantity the environmental indicators values are related with.	IFC

Pset_EnvironmentalImpactIndicators	LifeCyclePhase	PEnum_LifeCyclePhase	ACQUISITION; CRADLETOSITE ; DECONSTRUCTION; DISPOSAL; DISPOSALTRANSPORT; GROWTH; INSTALLATION ; MAINTENANCE; MANUFACTURE; OPERATION; PROCUREMENT; PRODUCTION; PRODUCTIONTRANSPORT; RECOVERY; REFURBISHMENT; REPAIR; REPLACEMENT ; TRANSPORT; USAGE; WASTE; WHOLELIFECYCLE; USERDEFINED; NOTDEFINED	The whole life cycle or only a given phase from which environmental data are valid.	IFC
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Pset_EnvironmentalImpactIndicators	ExpectedServiceLife	IfcTimeMeasure		Expected service life in years.	IFC, Crossrail
Pset_MaintenanceStrategy	AssetCriticality	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's criticality to the operation of the facility	IFC, Crossrail
Pset_MaintenanceStrategy	AssetFrailty	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's frailty to breakage or deterioration	IFC
Pset_MaintenanceStrategy	AssetPriority	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Combined criticality and frailty rating indicating the operational and maintenance priority of the asset	IFC
Pset_MaintenanceStrategy	MonitoringType	PEnum_MonitoringType	FEEDBACK; INSPECTION; IOT; PPM; SENSORS	Monitoring strategy chosen for the asset	IFC
Pset_MaintenanceStrategy	AccidentResponse	PEnum_AccidentResponse	EMERGENCYINSPECTION; EMERGENCYPROCEDURE; REACTIVE; URGENTINSPECTION; URGENTPROCEDURE	Accident response chosen for the asset	IFC
Pset_MaintenanceTriggerCondition	ConditionTargetPerformance	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Target condition of the asset	IFC

Pset_MaintenanceTriggerCondition	ConditionMaintenanceLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger maintenance	IFC
Pset_MaintenanceTriggerCondition	ConditionReplacementLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a replacement process	IFC
Pset_MaintenanceTriggerCondition	ConditionDisposalLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a disposal process	IFC
Pset_MaintenanceTriggerDuration	DurationMaintenanceLevel	IfcDuration		Duration interval at which maintenance is performed	IFC
Pset_MaintenanceTriggerDuration	DurationReplacementLevel	IfcDuration		Duration interval at which replacement is performed	IFC
Pset_MaintenanceTriggerDuration	DurationDisposalLevel	IfcDuration		Duration interval at which disposal is performed	IFC
Pset_ManufacturerTypeInformation	ArticleNumber	IfcIdentifier		Article number or reference that is be applied to a configured product according to a standard scheme for article number definition as defined by the manufacturer. It is often used as the purchasing number.	IFC
Pset_ManufacturerTypeInformation	ModelReference	IfcLabel		The model number or designator of the product model (or product line) as assigned by the manufacturer of the manufactured item.	IFC, FDK
Pset_ManufacturerTypeInformation	ModelLabel	IfcLabel		The descriptive model name of the product model (or product line) as assigned by the manufacturer of the manufactured item.	IFC

Pset_Manufacturer TypeInformation	Manufacturer	IfcLabel		The organization that manufactured and/or assembled the item.	IFC
Pset_Manufacturer TypeInformation	ProductionYear	IfcLabel		The year of production of the manufactured item.	IFC
Pset_Manufacturer TypeInformation	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER; NOTKNOWN; UNSET	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	IFC
Pset_MemberCommon	Roll	IfcPlaneAngleMeasure		Rotation against the longitudinal axis. Relative to the global Z direction for all members that are non-vertical in regard to the global coordinate system (Profile direction equals global Z is Roll = 0.) The shape information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the shape properties, provided in the attached property, the geometric parameters take precedence. Note: new property in IFC4.	IFC
Pset_MemberCommon	IsExternal	IfcBoolean		Indication whether the element is designed for use in the exterior (TRUE) or not (FALSE). If (TRUE) it is an external element and faces the outside of the building.	IFC
Pset_MemberCommon	LoadBearing	IfcBoolean		Indicates whether the object is intended to carry loads (TRUE) or not (FALSE).	IFC
Pset_Risk	RiskName	IfcLabel		A locally unique identifier for the risk entry that can be used to track the development and mitigation of the risk throughout the project life cycle	IFC
Pset_Risk	RiskType	PEnum_RiskType	BUSINESS; BUSINESSISSUES; COMMERCIALI	Identifies the predefined types of risk from which the type required may be set.	IFC

			SSUES; ELECTRICSHOC K; EVENT; FALL; FALLSCAFFOLD ; FALL_LADDER; HANDLING; INSURANCE; INSURANCE_IS SUES; MOBILE_ELEV ATEDWORKPL ATFORM; OPERATIONALI SSUES; OTHERISSUES; PUBLICPROTE CTIONISSUES; SAFETYISSUE; TOOLUSAGE; UNINTENDED COLLAPSE; VIBRATION; WELFAREISSU E; WORKINGOVE RHEAD; OTHER; NOTKNOWN; UNSET		
Pset_Risk	NatureOfRisk	IfcLabel		A description of the generic nature of the context or hazard that might be encountered.	IFC

Pset_Risk	RiskAssessmentMethodology	IfcLabel		An indication or link to the chosen risk assessment methodology, for example PAS1192-6 or a chosen ISO13100 annex.	IFC
Pset_Risk	UnmitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard prior to any specific mitigation.	IFC
Pset_Risk	UnmitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard prior to any specific mitigation.	IFC

Pset_Risk	UnmitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the likelihood and consequence prior to any specific mitigation.	IFC
Pset_Risk	MitigationPlanned	IfcLabel		The planned (agreed and irrevocable) mitigation of the likelihood and consequences of the hazard.	IFC
Pset_Risk	MitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard given the planned mitigation.	IFC

Pset_Risk	MitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard given the planned mitigation.	IFC
Pset_Risk	MitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the mitigation of likelihood and consequence.	IFC
Pset_Risk	MitigationProposed	IfcLabel		Any proposed, but not yet agreed and irrevocable, mitigation of the likelihood and consequences of the hazard.	IFC
Pset_Risk	AssociatedProduct	IfcLabel		An indication or link to any associated product or material that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	IFC

Pset_Risk	AssociatedActivity	IfcLabel		An indication or link to any associated activity or process that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	IFC
Pset_Risk	AssociatedLocation	IfcLabel		An indication or link to any associated location or space that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	IFC
Pset_ServiceLife	ServiceLifeDuration	IfcDuration		The length or duration of a service life. The lower bound indicates pessimistic service life, the upper bound indicates optimistic service life, and the setpoint indicates the typical service life.	IFC, Crossrail
Pset_ServiceLife	MeanTimeBetweenFailure	IfcDuration		The average time duration between instances of failure of a product.	IFC
Pset_ServiceLife	ExpectedExpiryDate	IfcDate		Expected expiry date for the end of the service life of an equipment.	Crossrail
Pset_Tolerance	ToleranceDescription	IfcText		General description of the tolerance associated to the element or feature, its source and implications.	IFC
Pset_Tolerance	ToleranceBasis	PEnum_ToleranceBasis	APPEARANCE; ASSEMBLY; DEFLECTION; EXPANSION; FUNCTIONALITY; SETTLEMENT; STRUCTURAL; OTHER; NOTKNOWN; UNSET	Indication of the basis of the tolerance requirement	IFC
Pset_Tolerance	OverallTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the intended shape and position in XYZ.	IFC

Pset_Tolerance	HorizontalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in X, if different to the overall tolerance.	IFC
Pset_Tolerance	OrthogonalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in Y, if different to the overall tolerance.	IFC
Pset_Tolerance	VerticalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the vertical shape and position in Z, if different to the overall tolerance.	IFC
Pset_Tolerance	OverallOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the intended shape and orientation in XYZ.	IFC
Pset_Tolerance	HorizontalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in X, if different to the overall orthogonality.	IFC
Pset_Tolerance	OrthogonalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the horizontal shape and orientation in Y, if different to the overall orthogonality.	IFC
Pset_Tolerance	VerticalOrthogonality	IfcPlaneAngleMeasure		Indicative (95%-100%) range orthogonality associated to the vertical shape and orientation in Z, if different to the overall orthogonality.	IFC
Pset_Tolerance	OverallStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the intended shape.	IFC
Pset_Tolerance	HorizontalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in X, if different to the overall straightness.	IFC
Pset_Tolerance	OrthogonalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the horizontal shape in Y, if different to the overall straightness.	IFC
Pset_Tolerance	VerticalStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the vertical shape in Z, if different to the overall straightness.	IFC

Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty	IFC
Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.	IFC
Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.	IFC
Pset_Uncertainty	LinearUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the overall shape and position in XYZ.	IFC, FDK
Pset_Uncertainty	OrthogonalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the horizontal shape and position in Y, if different to the horizontal uncertainty.	IFC
Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.	IFC
Pset_Warranty	WarrantyIdentifier	IfcIdentifier		The identifier assigned to a warranty.	IFC, FDK
Pset_Warranty	WarrantyStartDate	IfcDate		The date on which the warranty commences.	IFC, FDK
Pset_Warranty	IsExtendedWarranty	IfcBoolean	TRUE; FALSE	Indication of whether this is an extended warranty whose duration is greater than that normally assigned to an artefact (=TRUE) or not (=FALSE).	IFC
Pset_Warranty	WarrantyPeriod	IfcDuration		The time duration during which a manufacturer or supplier guarantees or warrants the performance of an artefact.	IFC

Pset_Warranty	WarrantyContent	IfcText		The content of the warranty.	IFC
Pset_Warranty	WarrantyTwoYears	IfcDate		End date of the 2-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').	FDK
Pset_Warranty	WarrantyFiveYears	IfcDate		End date of the 5-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').	FDK
Pset_Construction Occurrence	InstallationDate	IfcDate		Date on which the element is installed.	IFC, FDK, Crossrail
Pset_Construction Occurrence	ModelNumber	IfcLabel		The model number and/or unit designator assigned by the manufacturer of the manufactured item.	IFC, FDK, Crossrail
Pset_Construction Occurrence	TagNumber	IfcLabel		Tag number.	IFC, FDK, Crossrail
Pset_Construction Occurrence	AssetIdentifier	IfcLabel		A unique identification assigned to an asset that enables its differentiation from other assets. NOTE The asset identifier is unique within the asset register. It differs from the globally unique id assigned to the instance of an entity populating a database.	IFC, FDK, Crossrail
Group_LinearPlacementStation	PonctualMeterage	IfcLinearPlacement		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.	Crossrail

SIGNAL					
Property set	Property name	Data type	PEnum	Description	Document
Pset_Condition	AssessmentDate	IfcDate		Date on which the overall condition is assessed	IFC
Pset_Condition	AssessmentCondition	IfcLabel		The overall condition of a product based on an assessment of the contributions to the overall condition made by the various criteria considered. The meanings given to the values of assessed condition should be agreed and documented by local agreements. For instance, is overall condition measured on a scale of 1 - 10 or by assigning names such as Good, OK, Poor.	IFC
Pset_Condition	AssessmentDescription	IfcText		Qualitative description of the condition.	IFC
Pset_Condition	AssessmentType	IfcLabel		Category of latest condition assessment report of the asset.	IFC
Pset_Condition	NextAssessmentDate	IfcDate		Date of next condition inspection	IFC
Pset_Condition	AssessmentFrequency	IfcTimeMeasure		Indicates how often the equipment should be assessed, to have a clear estimation on its working state, based on which the maintenance staff can decide whether it requires maintenance or requires to be updated or replaced.	IFC

Pset_ConstructionAdministration	ProcurementMethod	IfcLabel		The method by which an IfcProductType/IfcProduct is acquired and installed. The value provided shall be one of the following four character acronyms: "CFCI" (meaning Contractor Furnished Contractor Installed), "OFCI" (meaning Owner Furnished Contractor Installed), or "OFOI" (meaning Owner Furnished Owner Installed).	IFC
Pset_ConstructionAdministration	SpecificationSectionNumber	IfcLabel		A reference number to an external contract technical specification section describing either (a) minimum performance requirements of a given IfcProductType/IfcProduct or (b) a preselection for a specific IfcProductType/IfcProduct made for this project.	IFC
Pset_ConstructionAdministration	SubmittalIdentifier	IfcLabel		The reference number to an external construction administration submittal used by the construction contractor and/or subcontractor to verify that the referenced IfcProductType/IfcProduct selection conforms with the requirements found in the referenced SpecificationSectionNumber.	IFC, FDK, Crossrail
Pset_ConstructionOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	IFC, FDK, Crossrail
Pset_ConstructionOccurrence	ModelNumber	IfcLabel		The model number and/or unit designator assigned by the manufacturer of the manufactured item.	IFC, FDK, Crossrail
Pset_ConstructionOccurrence	TagNumber	IfcLabel		Tag number.	IFC, FDK, Crossrail
Pset_ElectricalDeviceCommon	RatedCurrent	IfcElectricCurrentMeasure		The current that a device is designed to handle.	IFC, Crossrail
Pset_ElectricalDeviceCommon	RatedVoltage	IfcElectricVoltageMeasure		The range of allowed voltage that a device is certified to handle. The upper bound of this value is the maximum.	IFC, Crossrail
Pset_ElectricalDeviceCommon	HasProtectiveEarth	IfcBoolean	TRUE; FALSE	Indicates whether the object has a protective earth connection (=TRUE) or not (= FALSE).	IFC

Pset_ElectricalDeviceCommon	EarthingStyle	IfcLabel		Indicates the earthing style of the electric device.	IFC
Pset_ElectricalDeviceCommon	Power	IfcPowerMeasure		The actual power and operable range.	IFC
Pset_ElectricalDeviceCommon	NominalPowerConsumption	IfcPowerMeasure		Nominal total power consumption.	IFC
Pset_ElementSize	NominalLength	IfcPositiveLengthMeasure		The nominal overall length of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In case of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	IFC
Pset_ElementSize	NominalWidth	IfcPositiveLengthMeasure		The nominal overall width of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	IFC

Pset_ElementSize	NominalHeight	IfcPositiveLengthMeasure		The nominal height of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	IFC
Pset_EnergyRequirements	EnergyConsumption	IfcEnergyMeasure		Annual energy consumption requirement	IFC
Pset_EnergyRequirements	PowerDemand	IfcPowerMeasure		Power demand of the element	IFC
Pset_EnergyRequirements	EnergySourceLabel	IfcLabel		Type of energy source e.g. Electricity, Diesel, LPG etc. utilised by the element.	IFC
Pset_EnvironmentalImpactIndicators	FunctionalUnitReference	IfcLabel		Reference to a database or a classification	IFC
Pset_EnvironmentalImpactIndicators	IndicatorsUnit	IfcText		The unit of the quantity the environmental indicators values are related with.	IFC

Pset_EnvironmentalImpactIndicators	LifeCyclePhase	PEnum_LifeCyclePhase	ACQUISITION; CRADLETOSITE; DECONSTRUCTION; DISPOSAL; DISPOSALTRANSPORT; INSTALLATION; MAINTENANCE; MANUFACTURE; OPERATION; PROCUREMENT; PRODUCTION; PRODUCTIONTRANSPORT; REFURBISHMENT; REPAIR; REPLACEMENT; TRANSPORT; USAGE; WASTE; WHOLELIFECYCLE; USERDEFINED; NOTDEFINED	The whole life cycle or only a given phase from which environmental data are valid.	IFC
Pset_EnvironmentalImpactIndicators	ExpectedServiceLife	IfcTimeMeasure		Expected service life in years.	IFC
Pset_EnvironmentalImpactIndicators	TotalPrimaryEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	IFC
Pset_EnvironmentalImpactIndicators	RenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	IFC

Pset_EnvironmentalImpactIndicators	NonRenewableEnergyConsumptionPerUnit	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	IFC
Pset_EnvironmentalImpactValues	TotalPrimaryEnergyConsumption	IfcEnergyMeasure		Quantity of energy used as defined in ISO21930:2007.	IFC
Pset_EnvironmentalImpactValues	RenewableEnergyConsumption	IfcEnergyMeasure		Quantity of renewable energy used as defined in ISO21930:2007	IFC
Pset_EnvironmentalImpactValues	NonRenewableEnergyConsumption	IfcEnergyMeasure		Quantity of non-renewable energy used as defined in ISO21930:2007	IFC
Pset_InstallationOccurrence	InstallationDate	IfcDate		Date on which the element is installed.	IFC
Pset_InstallationOccurrence	AcceptanceDate	IfcDate		Date on which the element is accepted by the manager or administrator.	IFC, Crossrail
Pset_InstallationOccurrence	PutIntoOperationDate	IfcDate		Date on which the element is put into operation.	IFC
Pset_MaintenanceStrategy	AssetCriticality	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's criticality to the operation of the facility	IFC, Crossrail
Pset_MaintenanceStrategy	AssetFrailty	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Rating of the asset's frailty to breakage or deterioration	IFC
Pset_MaintenanceStrategy	AssetPriority	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Combined criticality and frailty rating indicating the operational and maintenance priority of the asset	IFC

Pset_MaintenanceStrategy	MonitoringType	PEnum_MonitoringType	FEEDBACK; INSPECTION; IOT; PPM; SENSORS	Monitoring strategy chosen for the asset	IFC
Pset_MaintenanceStrategy	AccidentResponse	PEnum_AccidentResponse	EMERGENCYINSPECTION; EMERGENCYPROCEDURE; REACTIVE; URGENTINSPECTION; URDENTPROCEDURE	Accident response chosen for the asset	IFC
Pset_MaintenanceTriggerCondition	ConditionTargetPerformance	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Target condition of the asset	IFC
Pset_MaintenanceTriggerCondition	ConditionMaintenanceLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger maintenance	IFC
Pset_MaintenanceTriggerCondition	ConditionReplacementLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a replacement process	IFC
Pset_MaintenanceTriggerCondition	ConditionDisposalLevel	PEnum_AssetRating	HIGH; LOW; MODERATE; VERYHIGH; VERYLOW	Condition that will trigger a disposal process	IFC
Pset_MaintenanceTriggerDuration	DurationTargetPerformance	IfcDuration		Target time to failure of the asset	IFC
Pset_MaintenanceTriggerDuration	DurationMaintenanceLevel	IfcDuration		Duration interval at which maintenance is performed	IFC
Pset_MaintenanceTriggerDuration	DurationReplacementLevel	IfcDuration		Duration interval at which replacement is performed	IFC

Pset_MaintenanceTriggerDuration	DurationDisposalLevel	IfcDuration		Duration interval at which disposal is performed	IFC
Pset_ManufacturerOccurrence	AcquisitionDate	IfcDate		The date that the manufactured item was purchased.	IFC
Pset_ManufacturerOccurrence	BarCode	IfcIdentifier		The identity of the bar code given to an occurrence of the product.	IFC
Pset_ManufacturerOccurrence	SerialNumber	IfcIdentifier		The manufacturer's serial number assigned to an occurrence of a product.	IFC
Pset_ManufacturerOccurrence	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER; NOTKNOWN; UNSET	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	IFC
Pset_ManufacturerOccurrence	ManufacturingDate	IfcDate		Date on which the element was manufactured.	IFC
Pset_ManufacturerTypeInformation	ArticleNumber	IfcIdentifier		Article number or reference that is be applied to a configured product according to a standard scheme for article number definition as defined by the manufacturer. It is often used as the purchasing number.	IFC, FDK, Crossrail
Pset_ManufacturerTypeInformation	ModelReference	IfcLabel		The model number or designator of the product model (or product line) as assigned by the manufacturer of the manufactured item.	IFC
Pset_ManufacturerTypeInformation	ModelLabel	IfcLabel		The descriptive model name of the product model (or product line) as assigned by the manufacturer of the manufactured item.	IFC
Pset_ManufacturerTypeInformation	Manufacturer	IfcLabel		The organization that manufactured and/or assembled the item.	IFC, FDK
Pset_ManufacturerTypeInformation	ProductionYear	IfcLabel		The year of production of the manufactured item.	IFC

Pset_ManufacturerTypeInformation	AssemblyPlace	PEnum_AssemblyPlace	FACTORY; OFFSITE; SITE; OTHER; NOTKNOWN; UNSET	Enumeration defining where the assembly is intended to take place, either in a factory, other offsite location or on the building site.	IFC
Pset_RailwaySignalAspect	SignalAspectSymbol	IfcExternalReference		Content which is shown on the signal or sign, e.g. text, number, arrow or icon.	IFC
Pset_RailwaySignalAspect	AppliesToTrainCategory	PEnum_TrainCategory	FREIGHT; PASSENGER; OTHER; NOTKNOWN; UNSET	Sign information relative to train category, e.g. freight, passenger.	IFC
Pset_RailwaySignalAspect	SignalAspectType	IfcLabel		The type of aspect, e.g. 2-display aspect for distant signal, 3-display aspect for block signal.	IFC
Pset_RailwaySignalAspect	SignLegend	IfcText		Text information written on the signal or sign.	IFC, FDK, Crossrail
Pset_RailwaySignalAspect	LegendSize	PEnum_LegendSize	STANDARD; SMALL	Text size on the signboard.	FDK
Pset_RailwaySignalOccurrence	ApproachSpeed	IfcLinearVelocityMeasure		The design speed of trains approaching the signal if different from the line speed.	IFC
Pset_RailwaySignalOccurrence	HandSignallingProhibited	IfcBoolean	TRUE; FALSE	Indicates if hand signalling is prohibited in case of any failure.	IFC
Pset_RailwaySignalOccurrence	LimitedClearances	IfcText		Special conditions for placing the signal post telephone: tunnels, bridges, viaducts.	IFC
Pset_RailwaySignalOccurrence	NumberOfLampsNotUsed	IfcCountMeasure		Number of lamps which are not needed and blanked out (sealed).	IFC
Pset_RailwaySignalOccurrence	LampType	IfcLabel		The type/model of the lamp used for future replacements.	Crossrail
Pset_RailwaySignalOccurrence	RequiresOLEMesh	IfcBoolean	TRUE; FALSE	Indicates whether an OLE mesh is required to protect the signal or maintainer.	IFC
Pset_RailwaySignalOccurrence	RequiresSafetyHandrail	IfcBoolean	TRUE; FALSE	Indicates whether a safety handrail is required.	IFC
Pset_RailwaySignalOccurrence	SpecialPositionArrangement	IfcLabel		Type of special position at which the signal is placed.	IFC

Pset_RailwaySignalOccurrence	HinderingObstaclesDescription	IfcText		Description of obstacles that hinder the visibility for the staff in the station.	IFC
Pset_RailwaySignalOccurrence	RequiresBannerSignal	IfcBoolean	TRUE; FALSE	Indicates whether a banner repeater signal is required.	IFC
Pset_RailwaySignalOccurrence	DistanceToStopMark	IfcPositiveLengthMeasure		Distance from the signal to the nearest stop mark at a platform.	IFC
Pset_RailwaySignalOccurrence	SignalFixingType	IfcLabel		Switchable Signage Fixing Type	Crossrail
Pset_RailwaySignalSighting	SignalSightingAchievableDistance	IfcPositiveLengthMeasure		Reading distance of the signal, which is achievable with the help of mitigation works.	IFC
Pset_RailwaySignalSighting	SignalSightingAvailableDistance	IfcPositiveLengthMeasure		Reading distance of the signal without having any mitigation works.	IFC
Pset_RailwaySignalSighting	SignalSightingCombinedWithRepeater	IfcPositiveLengthMeasure		Combined reading distance for the signal and any associated repeaters.	IFC
Pset_RailwaySignalSighting	SignalSightingMinimum	IfcPositiveLengthMeasure		Minimal distance in which the signal has to be readable.	IFC
Pset_RailwaySignalSighting	SignalSightingPreferred	IfcPositiveLengthMeasure		Preferred distance in which the signal shall be readable.	IFC
Pset_RailwaySignalSighting	SignalSightingRouteIndicator	IfcPositiveLengthMeasure		Required reading distance for the route indicator.	IFC
Pset_RailwaySignalSighting	SignalViewingMinimumInFront	IfcPositiveLengthMeasure		Smallest distance where the signal has to be readable (for train very close to the signal).	IFC

Pset_RailwaySignalType	SignalIndicatorType	PEnum_SignalIndicatorType	DEPARTUREINDICATOR; DEPARTUREROUTEINDICATOR; DERAILINDICATOR; ROLLINGSTOCKSTOPINDICATOR; ROUTEINDICATOR; SHUNTINGINDICATOR; SWITCHINDICATOR; OTHER; NOTKNOWN; UNSET	Type of the indicators on a signal, e.g. route indicator, speed restriction indicator etc.	IFC
Pset_RailwaySignalType	LensDiffuserType	IfcLabel		Type of the lens diffuser the signal is equipped with.	IFC
Pset_RailwaySignalType	HasConductorRailGuardBoard	IfcBoolean	TRUE; FALSE	Indicates if a guard board is provided.	IFC
Pset_RailwaySignalType	MaximumDisplayDistance	IfcPositiveLengthMeasure		The maximum distance that can be displayed. The value relates only to the signal type, not to the circumstances at a special position.	IFC
Pset_RailwaySignalType	RequiredDisplayDistance	IfcPositiveLengthMeasure		The required distance that has to be displayed. The value relates only to the signal type, not to the circumstances at a special position.	IFC
Pset_RailwaySignalType	IsHighType	IfcBoolean	TRUE; FALSE	Indicates if the signal is high (TRUE) or dwarf (ground mounted) (FALSE).	IFC, FDK
Pset_RailwaySignalType	SignalHoodLength	IfcPositiveLengthMeasure		Nominal length of the signal hood, which is the signal lamp cover against glaring sun.	IFC

Pset_RailwaySignalType	HotStripOrientation	IfcLabel		Orientation the lens diffuser has to have, which indicates the direction of the lens diffuser and is given in terms like "left upper quadrant (LUQ)" or "5 o'clock".	IFC
Pset_RailwaySignalType	LensDiffuserOrientation	IfcLabel		Orientation the lens diffuser has to have, which indicates the direction of the lens diffuser and is given in terms like "left upper quadrant (LUQ)" or "5 o'clock".	IFC
Pset_RailwaySignalType	NumberOfLamps	IfcCountMeasure		Number of lamps the signal is composed of.	IFC, Crossrail
Pset_RailwaySignalType	SignalMessage	IfcText		All possible message available at this signal, e.g. "3/4-display automatic blocking".	IFC, FDK
Pset_RailwaySignalType	RailwaySignalType	PEnum_RailwaySignalType	APPROACHSIGNAL; BLOCKSIGNAL; DISTANTSIGNAL; HOMESIGNAL; HUMPAUXILIARYSIGNAL; HUMPSIGNAL; LEVELCROSSINGSIGNAL; OBSTRUCTIONSIGNAL; REPEATINGSIGNAL; SHUNTINGSIGNAL; STARTINGSIGNAL; OTHER; NOTKNOWN; UNSET	The type of railway signal, e.g. home signal, starting signal, shunting signal, level crossing signal.	IFC
Pset_RailwaySignalType	NumberOfRepeaters	IfcCountMeasure		Statement indicating whether the distant signal has one or more repeater signals.	FDK

Pset_RepairOccurrence	RepairContent	IfcText		Content of repair, reason and nature can be given, e.g. display faults, communication failure, display exchange.	IFC
Pset_RepairOccurrence	RepairDate	IfcDate		Date on which the last repair is done on the asset.	IFC
Pset_RepairOccurrence	MeanTimeToRepair	IfcTimeMeasure		Mean time to repair.	IFC
Pset_Risk	RiskName	IfcLabel		A locally unique identifier for the risk entry that can be used to track the development and mitigation of the risk throughout the project life cycle	IFC
Pset_Risk	RiskType	PEnum_RiskType	BUSINESS; BUSINESSISSUES; ELECTRICSHOCK; EVENT; FALL; FALLFRAGILEMATERIAL; FALL_LADDER; HANDLING; INSURANCE; INSURANCE_ISSUES; OPERATIONALISSUES; OTHERISSUES; PUBLICPROTECTIONISSUES; SAFETYISSUE; STRUCKVEHICLE; TOOLUSAGE; OTHER; NOTKNOWN; UNSET	Identifies the predefined types of risk from which the type required may be set.	IFC
Pset_Risk	NatureOfRisk	IfcLabel		A description of the generic nature of the context or hazard that might be encountered.	IFC

Pset_Risk	RiskAssessmentMethodology	IfcLabel		An indication or link to the chosen risk assessment methodology, for example PAS1192-6 or a chosen ISO13100 annex.	IFC
Pset_Risk	UnmitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard prior to any specific mitigation.	IFC
Pset_Risk	UnmitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard prior to any specific mitigation.	IFC
Pset_Risk	UnmitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the likelihood and consequence prior to any specific mitigation.	IFC
Pset_Risk	MitigationPlanned	IfcLabel		The planned (agreed and irrevocable) mitigation of the likelihood and consequences of the hazard.	IFC

Pset_Risk	MitigatedRiskLikelihood	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the likelihood of the hazard given the planned mitigation.	IFC
Pset_Risk	MitigatedRiskConsequence	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the consequence of the hazard given the planned mitigation.	IFC
Pset_Risk	MitigatedRiskSignificance	PEnum_RiskRating	CONSIDERABLE; CRITICAL; HIGH; INSIGNIFICANT; LOW; MODERATE; SOME; VERYHIGH; VERYLOW; OTHER; NOTKNOWN; UNSET	Identifies the significance of the risk given the mitigation of likelihood and consequence.	IFC
Pset_Risk	MitigationProposed	IfcLabel		Any proposed, but not yet agreed and irrevocable, mitigation of the likelihood and consequences of the hazard.	IFC
Pset_Risk	AssociatedProduct	IfcLabel		An indication or link to any associated product or material that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	IFC

Pset_Risk	AssociatedActivity	IfcLabel		An indication or link to any associated activity or process that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	IFC
Pset_Risk	AssociatedLocation	IfcLabel		An indication or link to any associated location or space that may trigger the hazard. If used directly on an annotation or semantic object. for an alternative see group use encoding template	IFC
Pset_ServiceLife	ServiceLifeDuration	IfcDuration		The length or duration of a service life. The lower bound indicates pessimistic service life, the upper bound indicates optimistic service life, and the setpoint indicates the typical service life.	IFC, Crossrail
Pset_ServiceLife	MeanTimeBetweenFailure	IfcDuration		The average time duration between instances of failure of a product.	IFC
Pset_ServiceLife	ExpectedExpiryDate	IfcDate		Expected expiry date for the end of the service life of an equipment.	Crossrail
Pset_SignalFrame	BackboardType	IfcLabel		The type of the backboard of the signal frame.	IFC
Pset_SignalFrame	SignalFrameType	IfcLabel		Type of frame, e.g. main frame, route indicator, speed indicator, direction indicator, etc.	IFC
Pset_SignalFrame	NominalWidth	IfcNonNegativeLengthMeasure		The nominal overall width of the object. The size information is provided in addition to the shape representation and the geometric parameters used within. In cases of inconsistency between the geometric parameters and the size properties, provided in the attached property set, the geometric parameters take precedence.	IFC

Pset_SignalFrame	SignalIndicatorType	PEnum_SignalIndicatorType	DEPARTUREINDICATOR; DEPARTUREROUTEINDICATOR; DERAILINDICATOR; ROLLINGSTOCKSTOPINDICATOR; ROUTEINDICATOR; SHUNTINGINDICATOR; SWITCHINDICATOR; OTHER; NOTKNOWN; UNSET	Type of the indicators on a signal, e.g. route indicator, speed restriction indicator etc.	IFC
Pset_SignalFrame	SignalFrameBackboardHeight	IfcPositiveLengthMeasure		The nominal height of the signal frame backboard.	IFC
Pset_SignalFrame	SignalFrameBackboardDiameter	IfcPositiveLengthMeasure		The nominal diameter of the signal frame backboard.	IFC
Pset_Tolerance	ToleranceDescription	IfcText		General description of the tolerance associated to the element or feature, its source and implications.	IFC
Pset_Tolerance	ToleranceBasis	PEnum_ToleranceBasis	APPEARANCE; ASSEMBLY; DEFLECTION; FUNCTIONALITY; SETTLEMENT; OTHER; NOTKNOWN; UNSET	Indication of the basis of the tolerance requirement	IFC
Pset_Tolerance	OverallTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the intended shape and position in XYZ.	IFC
Pset_Tolerance	HorizontalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the horizontal shape and position in X, if different to the overall tolerance.	IFC

Pset_Tolerance	VerticalTolerance	IfcPositiveLengthMeasure		Indicative (95%-100%) range tolerance associated to the vertical shape and position in Z, if different to the overall tolerance.	IFC
Pset_Tolerance	OverallStraightness	IfcPositiveLengthMeasure		Indicative (95%-100%) range straightness associated to the intended shape.	IFC
Pset_Uncertainty	UncertaintyBasis	PEnum_UncertaintyBasis	ASSESSMENT; ESTIMATE; INTERPRETATION; MEASUREMENT; OBSERVATION; NOTKNOWN; USERDEFINED; NOTDEFINED	Indication of the basis of the uncertainty	IFC
Pset_Uncertainty	UncertaintyDescription	IfcText		General description of the uncertainty associated to the element or feature, its source and implications.	IFC
Pset_Uncertainty	HorizontalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in X, if different to the linear uncertainty.	IFC
Pset_Uncertainty	LinearUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the overall shape and position in XYZ.	IFC
Pset_Uncertainty	VerticalUncertainty	IfcPositiveLengthMeasure		Indicative (95%-100%) range diameter associated to the vertical shape and position in Z, if different to the linear uncertainty.	IFC
Pset_Warranty	WarrantyIdentifier	IfcIdentifier		The identifier assigned to a warranty.	IFC
Pset_Warranty	WarrantyStartDate	IfcDate		The date on which the warranty commences.	IFC, FDK
Pset_Warranty	IsExtendedWarranty	IfcBoolean	TRUE; FALSE	Indication of whether this is an extended warranty whose duration is greater than that normally assigned to an artefact (=TRUE) or not (= FALSE).	IFC

Pset_Warranty	WarrantyPeriod	IfcDuration		The time duration during which a manufacturer or supplier guarantees or warrants the performance of an artefact.	IFC
Pset_Warranty	WarrantyTwoYears	IfcDate		End date of the 2-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').	FDK
Pset_Warranty	WarrantyFiveYears	IfcDate		End date of the 5-year warranty period. If the property cannot be filled in, the value 01.01.1900 may be used (corresponds to the value 'n.a.').	FDK
Group_Country RailwaySignalCH	PresignalSignalFunc tions	PEnum_DistantS ignalFunctions	GROUPDISTANTSIGNA L; BLOCKDISTANTSIGNAL ; EXITDISTANTSIGNAL; TRACKSECTIONDISTAN TSIGNAL; PROTECTIONDISTANTS IGNAL; TRACKDISTANTSIGNAL ; REPEATERDISTANTSIG NAL; OTHERDISTANTSIGNAL ; ENTRYDISTANTSIGNAL	Type of signal, such as entry or exit signal.	FDK
Group_Country RailwaySignalCH	SwissSignalSystemT ype	PEnum_SwissSig nalSystemType	NSYSTEMWITHSPEEDI NDICATION; NSYSTEM; LSYSTEM; COMBINEDSIGNALWIT HOUTSTOPBOARD; FOREIGNSIGNAL; COMBINEDSIGNALWIT HSPEEDBOARD	Type of signaling system: L or N.	FDK

Group_Country RailwaySignalCH	MainSignalFunction s	PEnum_MainSig nalFunctions	TRACKSECTION; ENTRY; BLOCK; GROUPSIGNAL; REPEATERSIGNAL; TRACKSIGNAL; PROTECTION; OTHER; BUFFERSTOPSIGNAL; EXIT	Type of signal, such as entry or exit signal.	FDK
Group_Country RailwaySignalCH	IsItTriangle	IfcBoolean		Indicates whether the signal is equipped with a triangular attachment, which gives it validity even when not illuminated.	FDK
Group_LinearPl acementStation	PonctualMeterage	IfcLinearPlacem ent		Indication of the station value on the track edge (track axis) in 'm'. The station value must be specified with a precision of four decimal places.	Crossrail

APPENDIX 4: PRODUCT DATASHEET – TRIMBLE X7 SCANNER

DATASHEET

Trimble X7

3D Laser Scanning System



High-speed 3D laser scanning system allowing for scan and BIM data to be referenced, registered & refined in the field.

Trimble X7

- Increase productivity with fast, high quality scanning combined with Trimble FieldLink construction software
- New Trimble X-Drive deflection system enables automatic calibration to ensure accuracy on every scan with no downtime for calibration service
- High sensitivity time-of-flight EDM to effectively capture dark and reflective surfaces
- Fast image capture for full panoramas and scan colorization with Trimble® VISION™ technology
- Integrated laser pointer to support in-field deliverables and workflows

Trimble Field Link Scan Module

- Construction specific software to easily operate the Trimble X7 and reference scan projects with BIM Data
- Unique Trimble Registration Assist for automatic registration, refinement and referencing to leave the site with confidence
- Process, view and validate scan data and imagery before you leave the site
- Visualize scan data, layout points and BIM data from variety of CAD solutions



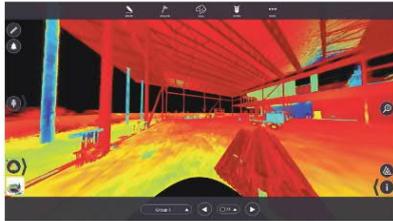
Find out more at:
fieldtech.trimble.com



DATASHEET

Trimble X7

3D Laser Scanning System



- 1 On matte surface with normal angle of incidence
- 2 Specification given as 1 sigma
- 3 Albedo given @ 1550nm
- 4 Including automatic leveling & calibration
- 5 Laser Class 2, visible, 620-650 nm, for auto calibration
- 6 See FieldLink datasheet for info on BIM model and point data types

Specifications subject to change without notice.

TRIMBLE X7 SPECIFICATIONS

Scanning EDM Laser Class	Laser class 1, eye safe in accordance with IEC EN60825-1
Scanning Speed	Up to 500kHz
Scan Duration ⁴	Fastest 1 min 34 sec without images, 2 min 34 sec with images.
Range Principle	High speed, digital time-of-flight distance measurement
Range ¹	0.6 m - 80 m
Range Accuracy ²	2 mm
Range Noise ²	<3 mm @ 60 m on 80% albedo ³
Imaging	
Imaging Sensors	3 coaxial, calibrated 10MP cameras
Raw Image Capture	Fast 1 minute - 15 images - 158MP Quality 2 minutes - 30 images - 316MP
Automatic Level Compensation	
Range	± 5°
Accuracy	< 3" = 0.3 mm @ 20 m
Environmental	
Operating Temperature	-20 °C to 50 °C (-4 °F to 122 °F)
Ingress Protection Rating	IP55 (dust protected and water jet)
Weight & Size	5.8 kg (12.78 lbs), 178 mm (W) x 353 mm (H) x 170 mm (D)
Controller	Trimble T10 Tablet with Trimble FieldLink over WiFi or Cable
Integrated Calibration System ⁵	Full auto-calibration of range and angular systems in 25 seconds with no user interaction or targets

TRIMBLE FIELDLINK FEATURES

Trimble Registration Assist	X7's IMU that tracks scanner orientation when moving from one station to the next. Automatic registration, alignment and refinement ensure the scan data is right before leaving the field.
Scan & Model ⁶	Scan data can now be viewed with BIM model data for infield analysis.
Infield Georeference	Reference scan data to the project coordinate system.
Integrated Laser Pointer	Allows for collection of single point measurements as well as field layout workflows.
Export Formats	TDX, POD, LAS, Structured & Non-Structured RCP, E57 and TZF

Trimble Building Construction Field Solutions

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fieldtech.trimble.com

APPENDIX 5: IFCINFRACONFIGURATION.JSON

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