DEVELOP AN ONTOLOGY FOR PAVEMENT LIFECYCLE MANAGEMENT

EngD Thesis

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by

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Executive Summary

Ontological modeling (also referred to as semantic modeling) has been used to address the problem of interoperability and information structure in different domains. Pavement sector is a valid example of cases where ontological modeling can help because the industry suffers from many problems that emanate from data interoperability and integration. Currently, pavement lifecycle information is collected over a long period of time and by different parties using different systems. The fragmentation of information and the absence of a structured information system makes the management of pavement prone to considerable rework, information loss, assessment errors, misinterpretation of the information, etc. To elaborate, valuable data about the construction process is seldom transferred to the subsequent phases of the pavement lifecycle. The same applies to the majority of the Information Technology (IT) systems that are developed to support the design and maintenance of pavements. The lack of interoperability, i.e., seamless exchange of data between systems, can lead to damages and loss of data, as well as increase in the cost and time for different parties. Hence, the absence of a structured information system makes it difficult to investigate the lifecycle impact of different decisions at different phases of pavement life on the overall quality of the pavement. This is because this type of study requires statistical correlation analysis on a database that is homogenous and structured.

The absence of such an ontology has contributed to a widespread fragmentation within the industry both across different players, e.g., clients and contractors, and across different phases, e.g., design and construction. This causes considerable rework, information loss, and inability to perform correlational analysis to identify hidden relationships between different decision variables and long-term pavement quality

indicators. Therefore, the main objective of this study was to develop a comprehensive ontological model for pavement projects considering the entire lifecycle in order to establish a more consistent structure for data collection, storage, and management. This ontology can be used to improve interoperability between fragmented systems used in the current practice.

Systematic Approach for Building Ontologies (SABiO) methodology was used to develop the pavement ontology in this research. In the first phase, around 20 interviews were performed to determine needs and goals and then the requirements for the ontology. In the next phase, the concepts and relations of the pavement ontology were identified. For representing the ontology, OntoUML was used as a conceptual modeling language and the ontology has been represented in Visual Paradigm software. The represented ontology has been implemented and tested with the help of experts (criteria- based evaluation) and making query (query-based evaluation).

The results indicated that the pavement ontology is capable of providing a clear, comprehensive, and accurate understanding of concepts and relations in the domain. Furthermore, the respondents showed that ontology can be favorably used for the purpose of integrating and exchanging different data in the road sector.

The developed ontology can be used to structure data management in the pavement lifecycle. The stakeholders of the pavement lifecycle can use ontology to identify the important data and improve their current approach of data collection storage.

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List of Acronyms

ASPARi	ASphalt PAving Research and innovation
BIM	Building Information Modeling
DSR	Design Science Research
EngD	Engineering Doctorate
FIPA	Foundation for Intelligent Physical Agents
GPS	Global Positioning System
IT	Information Technology
JHA	Job Hazard Analysis
OWL	Ontology Web language
PIM	Pavement Information Modeling
RDF	Resource Description Framework
RE	Requirement Engineering
SABiO	Systematic Approach for Building Ontologies
UML	Unified Modeling Language
W3C	World Wide Web Consortium

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Chapter 1. Background

1.1. Introduction

In the Netherlands, transition to performance-based contracting schemes and longer guarantee period of pavement projects has propelled contractors to improve the quality of pavement (S. R. Miller et al., 2015). As a rational response to these changes, new roles have been assigned to different parties involved in pavement projects, including the clients (government and municipality), contractors, and agencies. According to Bijleveld et al. (2015), while clients have a tendency to pay more attention to governance and inspection, contractors are responsible for the design, construction, and maintenance of pavements. Therefore, different parties have distinct perceptions and focus regarding quality improvement.

For the contractors, this quality improvement includes not only improving the mix design of asphalt pavement but also improving the operational strategies adopted on-site by controlling and monitoring the construction process to avoid and reduce failures that may influence the fulfilment of the guarantee period. In addition, because the new contracting scheme mandates that contractors are responsible for the maintenance of as-built roads, contractors' perception towards quality improvement of asphalt has gravitated more towards a lifecycle approach. This means that contractors are more sensitive to the long-term impact of their design, construction and maintenance activities.

On the other hand, clients need more transparency and access to the information from contractors. This information is needed to keep track of the quality of the road and to make sure if deteriorations occur during the guarantee period of a road project, the contractor can be informed and held responsible for repair and maintenance. Besides,

this information helps clients and contractors better assess the long-term impact of decisions made across the pavement lifecycle for continuous improvement of design, construction, and maintenance practices (Arbeider et al., 2017).

Currently, the pavement lifecycle information is collected over a long period of time and by different parties using different systems (Arbeider et al., 2017). The fragmentation of information and the absence of a structured information system makes the management of pavement prone to considerable rework, information loss, assessment errors, misinterpretation of the information, etc. For instance, several operator support systems have been developed for pavement operations over the past few years (Dennis et al., 2014, Kuenzel et al., 2016, Makarov et al., 2020). Although these systems proved to be very effective in supporting operators, they tend to operate in isolation. This means that valuable data about the construction process is seldom transferred to the subsequent phases of the pavement lifecycle. The same applies to the majority of the Information Technology (IT) systems that are developed to support the design and maintenance of pavements. The lack of interoperability, i.e., seamless exchange of data between systems, can lead to damages and loss of data, as well as increase in the cost and time for different parties (Zarli et al., 2003). In the US, more than 15 billion dollars are spent annually across all disciplines due to the interoperability problems between stakeholders involved in projects (Gallaher et al., 2004).

Also, the absence of a structured information system makes it difficult to investigate the lifecycle impact of different decisions at different phases of pavement life on the overall quality of the pavement. This is because this type of study requires statistical correlation analysis on a database that is homogenous and structured. For better clarification, Figure 1 presents the interplay between some of the design and

construction parameters (Huerne, 2004). As shown in the figure, there are several qualitative and expected relations between these phases. For example, the temperature of a mixture can be affected by the bitumen type since the stiffness and softness of a bitumen influence the temperature of a mixture. This is because high temperature is required to reduce the viscosity and provide a condition for coating aggregate in the case of a stiff bitumen. Also, the temperature of a mixture can affect the temperature of compaction process (which is one parameter of the construction phase) and ageing (which is a parameter of construction and in-use phases). Needless to say, the addition of the maintenance phase to this casual model will render it more complex. To have a broader view of the complexity of pavement lifecycle, raveling (i.e., loss of particles from the road surface) can be used as an example. Raveling is the main defect of the porous asphalt, which is the common surface layer used in 90% of Dutch motorways (Liu et al., 2012). Adding raveling to the mentioned figure can induce several relations. For instance, mix temperature, bitumen type and viscosity (design parameters) and compaction temperature and final density of asphalt (construction parameters) can influence the raveling (Liu et al., 2012; B. Xu et al., 2016). The reason is that raveling occurs due to the loss of the bonding between aggregate and bitumen. In cases of insufficient bitumen bonding, compaction at an inappropriate temperature, or not reaching the target density, bonding between the aggregate and bitumen will be insufficient, making the surface more susceptible to raveling. Therefore, due to the complexity of the interplay between the parameters in the lifecycle of asphalt, it is important to pay more attention to enhanced information management strategies over the entire lifecycle (Sategna et al., 2019; Taher et al., 2021; Zarli et al., 2003).

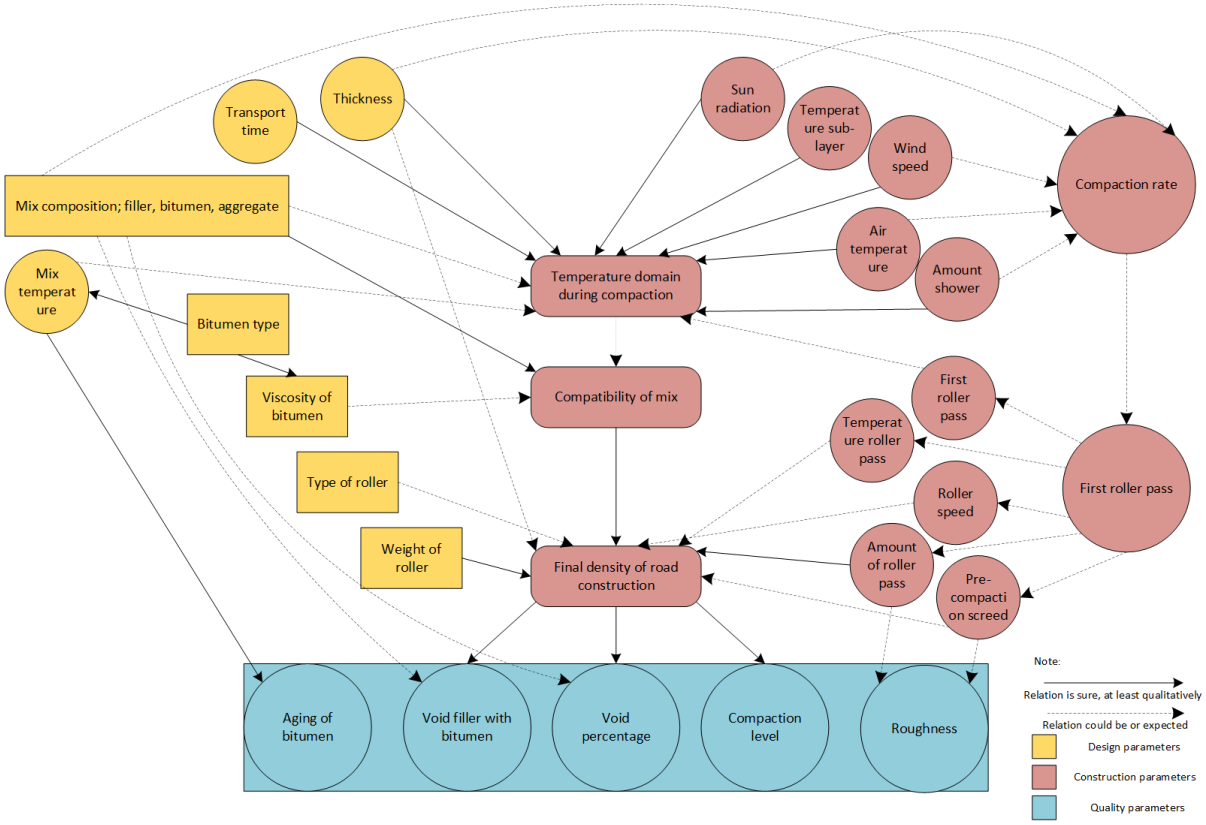


Figure 1. The causal model of design and construction phases of pavement lifecycle (Huerne, 2004)

Ontological modeling (also referred to as semantic modeling) has been used to address the problem of interoperability and information structure in different domains (MaduraiMeenachi & Baba, 2012; Pfaff et al., 2018).

Purely from a semantics perspective, ontology is defined as “the study of being and existence” (Studer et al., 1998) or, in other words, “categories of things that exist” (Sowa, 1999). When contextualized within the domain of knowledge management, ontology is defined as “an explicit specification of a conceptualization” (Gruber, 1995). Ontological modeling is an approach to represent and formalize the information and knowledge in a domain. This formalized knowledge is not only used by humans but also can be used by computers. In general, ontology provides a semantic data structure (common language) that can facilitate data exchange between humans and computers. In computer science, ontologies are used in Artificial Intelligence (AI) to

simulate human reasoning to the computer by representing a view of the reality (real-world behavior) in a computer system (Jakus et al., 2013). Nowadays, using ontology in the different domains of engineering has become popular due to the following advantages (Noy & McGuinness, 2001):

- Providing the ability to reuse the information in a domain
- Exchanging the knowledge between different users involved in a domain
- Distinguishing the operational knowledge from the domain knowledge
- Analysing the information in a domain

Ontologies consist of classes and relationships within the domain knowledge of interest (Taher et al., 2017, 2019), where classes represent the pieces of information and relationships demarcate how different pieces of information are associated with one another. Given the popularity of ontological modeling, World Wide Web Consortium (W3C) published the Ontology Web Language (OWL) in 2004. There are some successful examples of using OWL in the construction sector to show the importance of data structuring (Guizzardi, 2005; Hou et al., 2020; Karshenas & Niknam, 2013; Taher et al., 2021; L. Zhang & Issa, 2011), For instance, in Building Information Modeling (BIM), the concept of semantic modeling is used to generate a centralized (or seamlessly federated) digital representation of project information that can be used for decision-making process over the entire lifecycle (Kim et al., 2018). BIM has gained wide popularity and its effectiveness has been amply demonstrated (Du et al., 2018; Kim et al., 2018; Najjar et al., 2019).

Despite successful examples of using OWL in the construction sector, to the best of the author's knowledge, there are only a few studies on the use of ontology and ontological modeling in the pavement industry. These limited studies are still in the domain of research and there is no well-established standardized data structure that

has the same level of maturity and popularity as BIM in the building sector. Besides, the existing pavement ontologies have commonly been developed for specific applications (e.g., operator support systems) and therefore has a limited and isolated view of the entire lifecycle (Denisov et al., 2013; France-Mensah & O'Brien, 2019; Le & David Jeong, 2016; X. Xu et al., 2019). Because of this limited view, the existing ontologies provide little to no support for the lifecycle management of pavement information. Having said that, Le and David Jeong (2016) tried to develop a pavement ontology considering the entire lifecycle. However, although the design, construction event, and maintenance phases were incorporated into the ontology, the construction phase was only considered in terms of the event parameters, such as schedule, cost and construction type. This is a major limitation because the construction phase plays a crucial role in the quality of pavement (S. R. Miller, 2010). It is demonstrated that the high temperature and compaction variability during the construction phase can have a long-term impact on the pavement quality (F. R. Bijleveld et al., 2015; F. R. Bijleveld & Dorée, 2014; S. R. Miller et al., 2015; Vasenev, 2015). Therefore, the temperature, density and environmental parameters that influence the temperature homogeneity and compaction consistency should be taken into account. This may strike as a simple addition to the existing ontologies but given the fact that previous ontology ignored the construction phase, many of the information relationships need to be completely revamped in view of the new insights and concepts. In general, considering the whole phase of the pavement lifecycle is significant because of the complex correlation of parameters across different phases of the pavement lifecycle.

In addition to the mentioned literature, there was an effort to build an information modeling for the pavement in the Netherlands. Pavement Information Modeling (PIM) has been developed from 2016 to 2018 by 8 Dutch road contractors (F. Bijleveld,

2019). The objective of PIM is to centralize the information regarding the contracts, specifications, requirements, characteristics of the materials, on-site construction information, and quality assurance parameters in one system. PIM is purported to facilitate the data exchange between the 8 contractors and Rijkswaterstaat (the public road client in the Netherlands).

Nevertheless, there are some important limitations in the current state of PIM. The first is that while the design and construction phases have been considered in PIM, the maintenance phase is neglected. Hence, it cannot provide a comprehensive view of the entire pavement lifecycle. Also, PIM system has been developed for the management of pavement construction data but it is only one of the systems necessary to manage the complete lifecycle. In fact, the specific data of the design phase of a pavement (not only asphalt mixes) is managed with other systems (pavement design system, transport logistic system, asset management system, etc). Furthermore, developing PIM is based on the requirements of these 8 contractors and the requirement of the rest of the contractors (such as local companies) and public clients (municipalities) have not been taken into account. It means that small companies may not have access to the same technologies as larger companies in the Netherlands, then PIM databases in the current format and shape may have little use for them. Last but not least, PIM has been developed based on a bottom-up approach. It means that the 8 Dutch companies developed PIM based on the available data in their database. In this way, PIM cannot provide a comprehensive view of pavement lifecycle, because there might be some parameters and relations that have been neglected because of the absence of relevant data in the current mainstream practices. To ensure that the ontology has a comprehensive view of the entire pavement lifecycle, the top-down approach seems to be more suitable. In a top-down approach, the structure of the data

and the inherent relationship between them are developed based on the review of different mechanisms that are in play over the lifecycle of pavement rather than what is available.

1.2. Design Problem

The main problem this design project intends to address is that a comprehensive pavement ontological model that considers all phases of the lifecycle is missing in the literature. The absence of such an ontology has contributed to a widespread fragmentation within the industry both across different players, e.g., clients and contractors, and across different phases, e.g., design and construction. This causes considerable rework, information loss, and inability to perform correlational analysis to identify hidden relationships between different decision variables and long-term pavement quality indicators.

1.3. Design Objective

Given the above design problem, the main objective of this study is to develop a comprehensive ontological model for pavement projects considering the entire lifecycle in order to establish a more consistent structure for the data collection, storage, and management. This ontology can be used to improve interoperability between fragmented systems used in the current practice.

1.4. Design Scope

The ontology developed in this research will be more geared towards the context of the Netherlands. The primary reason is that the recent contractual transformation in the Netherlands has created a sense of urgency for innovation.

This pavement ontology will consider the entire lifecycle but will be developed only for flexible pavement (asphalt pavement). Therefore, rigid pavement (concrete pavement) will not be taken into account because asphalt is the most important type of pavement

in the Netherlands. The flexible pavement can have different layers of asphalt and granular materials. In this study, the focus is just on the asphalt layer.

The study will concentrate on asset owners and contractors within the Netherlands that are involved in the pavement lifecycle. They will be considered and interviewed for the study to recognize the type, format, and correlation of data needed for the design system.

Another important point to be mentioned is that the pavement ontology will be developed mainly at a conceptual level. While a proof of concept will be developed for the validation of the ontology, a full-fledged implementation of the ontology into a comprehensive database or pavement management tool is out of the scope of this project.

1.5. Research Questions

The general research question for this study can be derived from the mentioned research objective. Then, based on the main research question, several sub-questions can be stated as follows:

How can pavement lifecycle data (design, construction, operation and maintenance) be represented in a comprehensive ontology to support lifecycle management of pavement?

1. *What are the requirements of the lifecycle pavement management (stakeholder analysis and requirement analysis)?*
2. *What types of data are being generated at different phases of the pavement lifecycle and how are they interrelated?*
3. *How can the complex interrelation between data components of pavement lifecycle be captured and represented in an ontology?*

4. *To what extent can the developed ontology address the requirements of the lifecycle pavement management?*

1.6. Outline of the EngD Report

The remainder of this report is organized as follows. Chapter 2 presents the literature review. This is followed by design methodology in Chapter 3. Next, Chapter 4 elaborates on the stakeholders and requirement analysis. Chapter 5 presents the developed ontology. Ontology testing which consists of verifying and validating the ontology is presented in Chapter 6. Finally, the discussion and conclusions of the project are presented in Chapter 7.

Chapter 2. Literature Review

This review chapter provides an overview of ontological development in the construction industry, and in particular pavement ontology.

2.1. Development of Ontology in Construction

Ontologies can improve the data exchange among various stakeholders involved in construction projects. Construction ontologies not only enhance the integration and sharing of knowledge among stakeholders but also improve the insight into the final product by providing the important parameters and their relations in a domain (El-Gohary & El-Diraby, 2010). As mentioned earlier, there are several successful examples of using ontologies in the construction domain.

Taher et al. (2021) developed an earthwork ontology to facilitate data exchange and to support decision-making for future projects in the planning and execution phases. After gathering the concepts and relations regarding the earthwork operation and equipment, the built class hierarchy has been implemented in Protégé software. It is worth mentioning that the METHONTOLOGY approach (Fernández-López et al., 1997), which is recommended by the Foundation for Intelligent Physical Agents (FIPA), was used for the development of the earthwork ontology. In this method, the development process is divided into initial (identification of scope, objective, concepts and taxonomy), development (implementing and verifying the ontology) and final (validation based on the survey of experts and end-users) stages. The results of the survey showed that the developed earthwork ontology could be efficiently used for data exchange in the earthwork domain.

Zhang et al. (2015) developed a construction safety ontology to capture and formalize the construction safety information and connect the safety knowledge to BIM. The

developed safety ontologies consisted of three different domains of product, process and construction safety. The evaluation stage of the safety ontology has been performed based on expert interviews and showed that the developed ontology is efficient for data exchanging in the safety domain.

Ren et al. (2019) developed an ontological model to formalize the information in the operation phase of bridges. Due to the importance of the operation phase of bridge lifecycle compared to other phases and also lack of a systematic approach for communication between computer-aided tools in this field, the bridge ontology has been developed. After the implementation of the ontology in the Protégé, three different validation approaches have been performed, namely semantic, syntactical and case study validations. The results of the study showed that bridge ontology can integrate knowledge in this domain and also can be helpful for bridge engineers to select comprehensive decisions about bridges. Similar observations have been made about the effectiveness of ontological modeling in the transportation domain (Swarnamugi & Chinnaiyan, 2020), urban infrastructure assets (Wei et al., 2020), buildings (Viljamaa & Peltomaa, 2014) and disaster-resilient construction practices (Dhakal et al., 2020).

Overall, the effectiveness of ontology in various aspects of construction fields has been amply demonstrated in the literature. Nevertheless, efforts to formalize knowledge in the road domain using an ontological modeling approach are limited in both number and scope. To better clarify the mentioned statement, the next section will provide an overview of developments in pavement ontology.

2.2. Development of Pavement Ontology

The application of sensors, Geographic Information Systems (GID), weather data, drone aerial photography systems, real-time operating systems, etc. have improved the management of road networks for the past few years (Sategna et al., 2019).

However, the implementation of different technologies creates challenges for road lifecycle data exchange and integration. Lack of inconsistency in data syntax and semantics creates a significant interoperability issue. Potentially, ontological modeling can be used to address the above-mentioned problem. However, the ontologies developed in this domain concentrate on specific phases of pavement lifecycle or cannot provide a comprehensive view of the pavement lifecycle.

Xu et al. (2019) developed an ontology for road inspection, which takes place during the operation phase of road projects as a quality control measure. OWL and Resource Description Framework (RDF) have been used to formalize and integrate the information regarding how, what and when the inspection should take place. The parameters such as the name of inspector, frequency of check, checking criteria, name of the contractors, field data, etc. have been taken into account. However, construction and design parameters that have impacts on the long-term quality of roads are neglected in the study.

Denisov et al. (2013) use ontological modeling to formalize the knowledge regarding the repair and maintenance of road construction equipment. The focus was on the equipment used in the construction project to optimize the repair and maintenance cost and time and to increase the productivity of the project. Similarly, France-Mensah & O'Brien (2019) developed an ontology for highway planning. In this ontology, parameters such as pavement section (location, geometry information, distress and treatment history) and maintenance & repair (available budget, costs, treatment, etc) have been considered. The ontology has been developed in Protégé software and validated based on criteria-based evaluation and data-driven evaluation. However, both these studies offer a limited view of the pavement lifecycle. The design parameters (such as material properties, mix design and compaction properties) and

construction performance parameters (such as compaction temperature, number of roller passes, target density of asphalt section, etc) have not been taken into account. Le & David Jeong (2016) tried to take a broader view of the pavement lifecycle. In this study, ontology development has been divided into three different phases of design, construction, and maintenance. For each of these phases, the pertinent parameters have been considered. Despite the wide scope of the developed ontology, construction performance parameters such as compaction temperature, environmental information during the construction, roller information and target density have not been taken into account. To have a comprehensive view of pavement lifecycle, considering the entire lifecycle is crucial.

2.3. Principles of Ontology Development

There are several methods for developing an ontology. From the 1990s, several methods have been proposed such as Toronto Virtual Enterprise (Grüninger & Fox, 1995), METHONTOLOGY (Fernández-López et al., 1997), Noy and McGuinnes (Noy & McGuinness, 2001), On-To-Knowledge (Sure et al., 2004), DILIGENT (Pinto et al., 2009) and SABiO (Systematic Approach for Building Ontologies) (Falbo, 2014). There are some similarities and differences between the mentioned methodologies and there is no absolute best approach for developing an ontology. This means that the best approach for selection should be based on the specific purpose and context of the ontology at hand (Noy & McGuinness, 2001). Among all of the mentioned methodologies, one of the newest ones, which is explained in detail and used for this study, is SABiO (Falbo, 2014). SABiO 2.0 is the last update of the SABiO and can be used to develop an ontology from scratch or reuse an ontology in a new domain. SABiO is used for this study because it has been developed by the Ontology and Conceptual Modeling Research Group and the approach is evaluated by the members frequently

to update the last version and reduce its deficiencies. Before explaining each phase in SABiO methodology, first, the core definitions used in this methodology need to be explained. According to SABiO (Falbo, 2014):

1. *Domain expert* is an expert who has or provides the information and knowledge in the ontology domain;

2. *Ontology use*r is a person who aims to use the ontology for a defined objective;

3. *Ontology engineer* is someone who has responsibility regarding reference ontology (the starting phases for ontological development);

4. *Ontology designer* is someone who has responsibility regarding the design of an operational ontology;

5. *Ontology programmer* is someone who has responsibility regarding the implementation of an operational ontology;

6. *Ontology tester* is someone who has responsibility regarding the test of an operational ontology;

7. *Reference ontology* is an ontology (conceptual model) that is developed to provide the best description of a domain for the aims of learning, communication and problem-solving;

8. *Operational ontology* is a designed ontology guaranteeing computational properties.

It is worth mentioning that one person might have several roles in the process of ontology development. For example, ontology engineer, designer, programmer and tester can be performed by the same person. Also, it should be mentioned that one of the most powerful points of SABiO is the separation between the reference and operational ontologies. Thus, every study with different levels of ontological development can use SABiO.

Figure 2 provides an overview of SABiO methodology. In the rest of this section, each of the 5 phases of SABiO methodology will be explained.

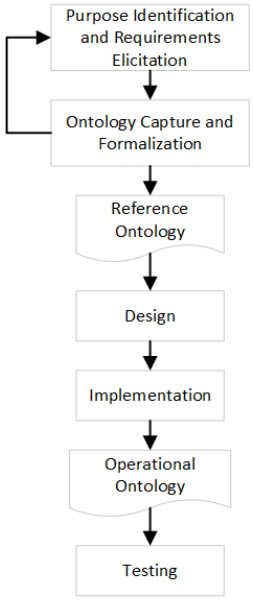


Figure 2. Development process proposed by (Falbo, 2014)

2.3.1. 6.3.1. Purpose identification and requirements elicitation

The first phase is dedicated to the identification of the purpose of the ontology and elicitation of the requirements. As shown in Figure 3, this phase consists of 4 different iterative activities. The activities are purpose and intended uses identification, requirement elicitation, competency questions identification, and ontology modularization.

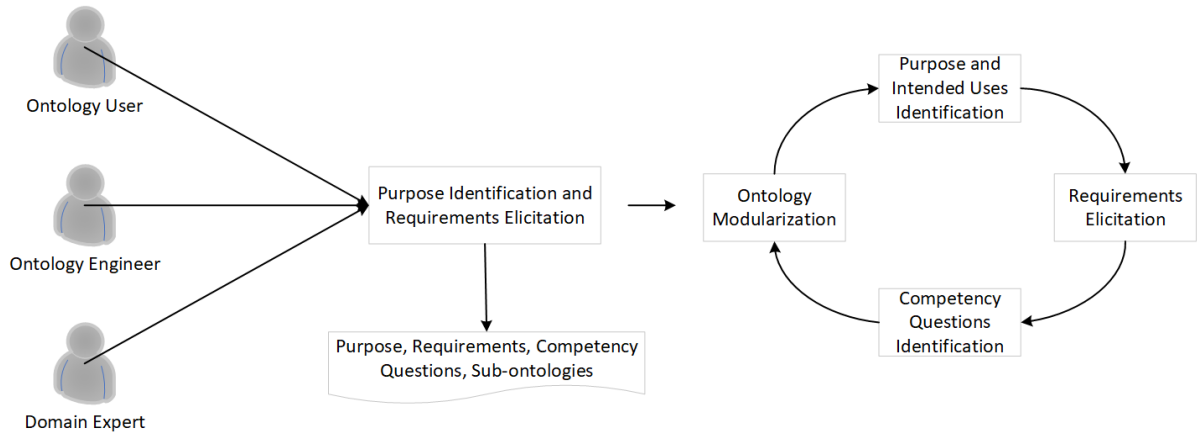


Figure 3. Purpose identification and requirements elicitation process proposed by (Falbo, 2014)

The first activity in this phase is to recognize the purpose and intended uses of the ontology with the help of domain experts and users. By defining the aims and intended uses, the requirements can be elicited from them, in the next phase.

In the second activity, two types of requirements are identified: (1) Functional requirements which are the content that should be represented by the ontology. These requirements can be translated to the competency questions (i.e. the questions that the ontology should be able to answer) (Grüninger & Fox, 1995); and (2) non-functional requirements focus on qualities, characteristics and general aspects of the ontology. Two common examples of non-functional requirements proposed by SABiO are usability (e.g., understandability) and maintainability (e.g., extensibility). Based on the recommendation of SABiO, the non-functional requirement can be obtained from the stakeholder analysis. The goal and needs of the stakeholders should be translated to the requirements that should be considered by the ontology.

Based on the functional requirements, the competency questions can be derived. The competency questions can act as an instruction for ontological development. Since they can define the scope of the ontology, they are also useful for the evaluation of the ontology. There are inherently three approaches to determine the competency questions (Falbo, 2014; Suárez-Figueroa et al., 2012). In the top-down approach, the ontology engineer starts with complex questions that are decomposed in simpler ones. Conversely, in the bottom-up approach, the ontology engineer starts with simple questions that are then aggregated to create complex ones. Finally, in the middle-out approach, the ontology engineer starts just writing down important questions (regarding the intended uses of the ontology) that are composed or decomposed later on to form abstract and simple questions, respectively. The approach for selecting the

competency questions depends on the ontology engineer, but at the end, the questions should have two levels of simple and abstract.

In some cases, domains have some complexity, and developing one ontology is cumbersome. To solve the problem, modularization should be considered in which the ontology will be divided into sub-ontologies, where each sub-ontology has its purpose and requirement. But there should be links between the sub-ontologies to connect all of the modules as a whole. The advantages of having ontology modularization are to first facilitate and ease the ontological development for the ontology engineer and second to enhance the performance of the ontology by increasing the accuracy (Suárez-Figueroa et al., 2012). Based on the suggestion of SABiO, considering the minimum criteria of cohesion, independence and size is required for the sub-ontologies. It is recommended to use Unified Modeling Language (UML) for representing the dependency between the sub-ontologies (Falbo, 2014).

2.3.2. Ontology Capture and Formalization

Identifying the concepts and relations is one of the most important phases of ontology development. The main purpose of this phase is to represent the domain conceptualization. This representation should be based on the competency questions. It means that the competency questions can act as a guideline to check the sufficiency of the list of concepts. Furthermore, it is recommended that communication with the ontology expert and users and also reviewing books, literature and international standards can be helpful for identifying the concepts and relations (Falbo, 2014; Taher et al., 2021).

After identifying the concepts and relations, the class hierarchy (taxonomy) should be developed and thus the reference ontology is created. For better communication with the ontology expert, it is recommended by SABiO to represent the reference ontology

in OntoUML. OntoUML is the language for representing the reference category. The main point regarding this phase is that ontology capture and formalization have an iterative relation with the previous phase. It means that the sufficiency and comprehension of this phase should be guided by the competency questions developed in the previous phase. If the concepts, relations, and classes cannot provide enough answers to the competency questions, extra concepts and relations should be added to the reference ontology. Also, this phase might provide some new information and knowledge for ontology engineer and this results in adding or revising the competency questions.

2.3.3. Design

After developing a reference ontology, making an operational ontology is the next step. For developing an operational version, using a machine-readable language is essential. Since 1991, many ontological languages have been developed such as LOOM (MacGregor, 1991), KIF (Genesereth & Fikes, 1992), Ontolingua (Gruber, 1992), FLogic (Kifer et al., 1995), OCML (Motta, 1998). However, increasing the use of internet has changed ontological languages by introducing web-based ontology language. Among web-based ontology languages, XML (Bray et al., n.d.), XOL (Karp et al., 1999) and RDF (Lassila, 1999) are popular. All of the mentioned languages have been used in many studies, but the most popular language, which has been developed by W3C, is OWL (McGuinness & Van Harmelen, 2004). OWL is a language that can represent concepts, relations, taxonomy, etc. Nowadays, OWL is the most common language to make an operational ontology (Falbo, 2014). It should be mentioned that the design phase should be performed by an ontology designer since this phase is a bridge to convert the conceptual reference ontology to the coding. Also, the tools for using in design phase should be selected by the recommendation of ontology designer.

In addition to the language, the tool for implementing the ontology should be selected. Many development tools such as WebODE, Ontolingua, SWOOP, Hozo and KAON have been proposed (Corcho et al., 2003; Mizoguchi & Kozaki, 2009). However, the most popular tool for ontological development is Protégé. Protégé is a leading ontological development tool that is a free and open-source editor established by the University of Stanford. One important advantage of Protégé is that the designer can develop an ontology in different languages, e.g., XML, RDF and OWL. Also, it is a plug-in extendible architecture, which means the integration with other tools is applicable with this tool. In addition to all the features, this tool can recognize the inconsistency in the ontology classes which is an appropriate feature for ontological verification.

2.3.4. Implementation

In this phase, the reference ontology should be implemented based on the language and tool that have been selected in the previous phase and by the ontology programmer.

2.3.5. Testing

Based on SABiO, the testing phase should be divided into two different tasks, verification and validation. Verification refers to the checking of the representation of the ontology by assessing the definition of the implemented ontology in the domain (Lovrenčić & Čubrilo, n.d.). It means that the internal consistency between class hierarchy (concepts) should be checked and corrected. There are some methods to verify the ontology such as ontology taxonomy evaluation (an expert in a domain should be checked the class hierarchy manually based on criteria) and logic reasoners in Protégé (this feature can check the inconsistency in the taxonomy of the developed ontology).

The other important step of the testing phase is validation. Validating an ontology means that the content of the ontology should be compared to the real world. There are several methods for validating an ontology such as the gold standard, application-based evaluation and criteria-based evaluation (Taher et al., 2021). In the gold standard approach, the developed ontology should be compared with a “golden” standard or a benchmark (an ontology developed in the domain previously) (Yu et al., 2007). The application-based evaluation can be used to check if an ontology meets its objectives, but it cannot evaluate the content and design of a developed ontology (Haghighi et al., 2013). Based on this approach, an ontology can be evaluated if it is used in an application. In the criteria-based evaluation approach, several questions (evaluation questions) will be created to obtain views regarding an ontology such as concepts, taxonomies and relations (Yu et al., 2007). This is a qualitative approach in which the evaluators are ontology experts and users in the domain and the questions are concentrating on the criteria that will be identified in the ontology requirement phase.

In case the ontology is divided into sub-ontologies, first, the sub-ontologies should be evaluated. Then, the integration of the sub-ontologies should take place and then the integrated ontology should be evaluated.

To sum up, it should be mentioned that SABiO explains the ontological development in an understandable and simple format and that is why it will be used for this study. In the next section, the design methodology is explained for this study.

Chapter 3. Design Methodology

While using design science engineering approach is recommended for EngD projects, SABiO is used for this project. This is because of several similarities between SABiO and the design science approach (see Appendix). The overall methodology used in this project is presented in *Figure 4*. In the rest of this chapter, the design process will be explained in detail. Before starting the ontological development process, the problem context, which consists of social and knowledge contexts, should be explained (i.e., pre-phase).

3.1. Problem Investigation

As shown in Figure 4, the problem investigation activities are divided into two different contexts of social (stakeholders' analysis of pavement ontology) and knowledge (existing literature in pavement and construction ontology and ontological development). In order to have a better design solution, the social and knowledge contexts had to be explored precisely.

To gain more insights into the social context of the system under design, a stakeholder's analysis was performed. The stakeholder analysis is an approach to capture the goal of stakeholders and to create conceptual connections between the system and elements that can deliver the societal functions. It is worth mentioning that based on the stakeholder analysis (finding their goals), the stakeholder needs and the subsequent system requirements were identified, as will be discussed in Chapter 4.

The method for defining the stakeholder goals is the interview and it should be mentioned that stakeholder analysis has been conducted using semi-structured interviews (Schmidt, 2004). The stakeholders can be individuals or organizations "having a vested interest in the decision process and either directly affecting or being

affected by its resolution" (Ferretti, 2016). The questions of the interview are shown in Table 1. Also, the experts who have been interviewed are presented in Table 2.

Table 1. Interview questions for identifying the goals and needs of stakeholders and identifying the requirements for the ontology

No.	Questions
1	"Why do we need to develop the ontology for pavement?"
2	"Who are the users of the pavement ontology?"
3	"How is the pavement data exchanged between the departments in your company?"
4	"How is data transferred between different companies currently?"
5	"Do you have access to PIM, if yes, what are the current issues of the PIM?"
6	"What type of data do you need in the pavement lifecycle?"
7	"What type of data do you send to the other stakeholders involved in a project?"
8	"What is the intended use of the pavement ontology?"
9	"What should be considered in the design phase?"
10	"What should be considered in the construction phase?"
11	"What should be considered in the operation and maintenance phase?"
12	"What should not be considered the pavement ontology? (constraints)"

Table 2. Interviewee information for the stakeholder's analysis and identifying the requirements of the ontology

No.	Interviewee Name	Interviewee Company	Interviewee Position
1	Jasper Keizer	KWS	Research project leader and road advisor
2	Sylvia Drok	Rijkswaterstaat	Road construction advisor
3	Rutger Krans	Rijkswaterstaat	Program manager of road maintenance
4	Marjolein Galesloot	Bam	Road advisor
5	Marco Oosterveld	Bam	Head advisor of road construction
6	Frits Stas	Heijmans Infra B.V.	Road advisor
7	Jeroen Heesbeen	Van Gelder B.V.	Quality service advisor
8	André Houtepen	Gemeente Rotterdam	Advisor of paving and road construction materials

9	Niels Hop	DV	Sustainability advisor
10	Frank Bijleveld	Strukton	Research manager and quality control of road construction
11	Herman Reinten	TWW	Managing director
12	Wouter Heijsser	Heijmans Infra B.V.	Program manager of asphalt paving
13	Berwich Sluer	Boskalis	Research and quality manager
14	Maurits Koenders	Dusseldorp	Pavement designer
15	Jerry Bouwmeester	Dusseldorp	Head of engineering department
16	Iacopo Malquori	Kiwa Koac	Measurement specialist

The main aim of knowledge context is to explore and extract the required knowledge regarding ontological development. An integrative literature review (Torraco, 2016) was performed to collect all the knowledge about ontological development and the results were presented in Chapter 2.

3.2. Ontological Development

The methodology used for this study is based on SABiO (Falbo, 2014) which has been explained in the literature review chapter but in this section, it will be contextualized. In the rest of this chapter, the detailed explanation of each phase is shown.

3.2.1. Ontology Requirements

For obtaining the list of requirements for the pavement ontology, two steps had to be taken, including the identification of the competency questions and translation of the stakeholders' goals into the system requirements. The competency questions were used to clarify the functional requirements of the pavement ontology and stakeholders' goals were used to identify the non-functional requirements or structural requirements of the system.

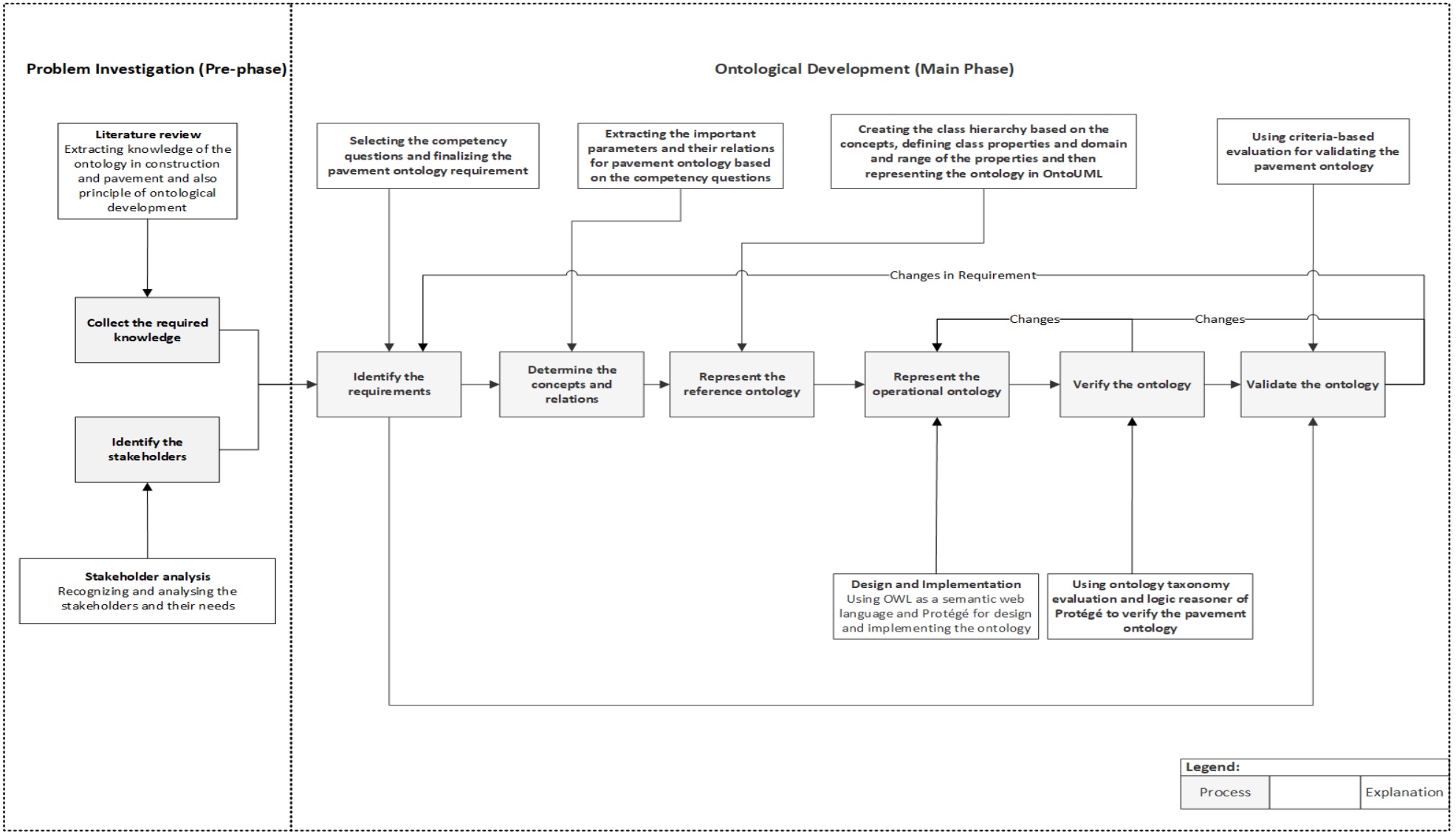


Figure 4. The actual design process with its explanation

By having several semi-structured interviews with the end-users of the ontology (contractors, clients and third parties) mentioned in Section 3.1, the competency questions were defined in Chapter 4. Since identifying the competency questions is related to identifying the use-cases of the pavement ontology, the end-users were asked to discuss different ways in which they intend/envision to use of the ontology. Because ontology development is a complex process, the ontology was divided into different sub-ontology based on SABiO. Then, different competency questions for each sub-ontology were extracted based on the interview with the experts.

It is worth mentioning that due to the iterative process of ontology development, the competency questions had to be revised during the subsequent phases.

The structural requirements were derived from the stakeholder's goals, which were obtained based on several interviews with the users (Section 3.1). The translation of goals to requirements was done based on the INCOSE method (Haskins et al., 2006). In this method, the stakeholder's analysis should be performed to identify the goals and needs of the stakeholders. Then, the function of the system (ontology) to satisfy the goals and needs should be obtained. It should be mentioned that this method has been performed by ontology developer.

3.2.2. Capturing the Concepts and relations

Once the requirements were determined, the following steps took place:

Determining the relevant concepts for the pavement ontology: A list that consists of all of the relevant concepts related to the pavement ontology needs to be generated. The list was collected based on literature, books, studies and international standards. However, the competency questions that were defined with the help of the domain experts and users can check the comprehensiveness and sufficiency of the list of concepts.

In this list, each term (item) has been defined and the source of the term has been determined. The source of the term means how the term was identified, e.g., based on the literature or software Object Type Libraries (OTLs) such as PIM OTL.

Defining the class hierarchy and its properties: The identified concepts (previous step) were then divided into different hierarchical, i.e., the top-down approach, classes. It means that the general classes were placed at the top and then decomposed to subclasses. It should be mentioned that the definitions of class and attribute are explained in the next sections.

3.2.3. Representing the Ontology

In this stage, the reference ontology was developed in OntoUML. OntoUML enabled us to present ontology concepts and relations to the expert and end-users.

OntoUML is a conceptual modelling language which is extending the UML based on the Unified Foundational Ontology (UFO) (Guizzardi, 2005). OntoUML has been used by many different groups and ontology developers around the world because it is considered to be robus (Guizzardi et al., 2021). Before, explaining the OntoUML, some core definitions need to be presented, as follows:

Class: Collections, sets, concepts or types of individuals (instances) that share the same attribute, relations and semantics.

Attribute: Aspects, properties, features or parameters that a class can have.

Relations: Ways that a class can be related to another class in ontology.

Class

Similar to UML, classes are represented by a box in the OntoUML. However, each class has a stereotype that makes it more accurate to classify the class according to reality. Before explaining the important types of stereotypes that are used in this project, two definitions of identity and rigidity should be explained. Identity can help

distinguish between sortal and non-sortal classes in the OntoUML. A sortal class, which has the identity, creates clear properties that no two different instances can have in common. More simply, two instances of A and B can be identified the same if and only if they have the same elements. Rigidity is the principle that can distinguish the rigid and anti-rigid classes. Individuals of a rigid class exist in all possible scenarios. For example, a person (Mohammad) will be always a person in all of the scenarios (rigid) however, a Student (Mohammad) is anti-rigid since there is at least one possible scenario where Mohammad has already graduated and he is no longer a student. Understating the definitions of identity and rigidity makes it easier to explain the different types of stereotypes used in the OntoUML as follows (Guizzardi et al., 2022):

Kind: A rigid class that provides the principle of identity such as Person, Forest, Car, etc.

Sub-kind: A rigid class that has the principle identity of a provider (Kind, Quantity, Collective, etc.) such as Man or Woman that has the principle identity of a Person (kind).

Quantity: A rigid class that provides the principle of identity; while, it is mostly used for uncountable things such as Aggregate, Bitumen, Water, etc.

Collective: A rigid class that provides the principle of identity; while it has a homogenous internal structure in a way that all the members are perceived as part of a whole structure. An example can be a family if all the member of that family has the same role and responsibility.

Phase: An anti-rigid class that provides the principle of identity in which there are intrinsic properties that classify the instances of phase class such as Adult (age of a person as an intrinsic property).

Role: An anti-rigid class that provides the principle of identity in which there are relational contexts that define the instances of role class such as Married or Student.

Category: A rigid mixin that aggregates the essential properties of a variety of identity principles (kinds) such as Object or Device.

PhaseMixin: An anti-rigid class that aggregates essential properties of a variety of identity principles (phases) such as Living animal.

Mixin: A semi-rigid class that aggregates essential properties of a variety of identity principles. It has rigid behavior for some individuals and anti-rigid ones for other individuals.

Relator: A rigid sortal class that should be presented to show that a connection exists between two individuals such as Marriage, Investigation, Enrolment, etc.

Mode: A rigid class that is an intrinsic property for a particular type and has no value such as Disease, Ability, Intention, etc.

Quality: A rigid class that is an intrinsic property for a particular type and has a value such as Weight, Height, Colour, etc.

The mentioned stereotypes are the most important ones that were also used in this study.

Attribute

Aspects, properties, features or parameters that a class can have are called attributes. Similar to UML, an attribute can be divided based on its visibility such as + public, - private, and # protected attributes.

Relations

Ways in which a class can be related to another class in ontology are called relations. The types of relations used in OntoUML are the same as in UML. Below different kinds of relations are explained:

Generalization or Inheritance: This is a taxonomic relation that shows a parent-child relationship between classes. In generalization, the child will inherit properties (attributes) of the parent. There are several limitations in OntoUML for this type of relationship that should be considered when identifying a stereotype of a class (Guizzardi, 2005; Guizzardi et al., 2021, 2022):

- A kind **cannot** be a supertype of another kind
- A subkind **must** have **one** supertype with the principle of identity (e.g. kind)
- A subkind **cannot** be a supertype of a kind
- An anti-rigid type **must** have a supertype of a **specific** kind
- A sortal type **cannot** be a supertype of a non-sortal type
- An Anti-rigid type **cannot** be a supertype of a rigid type
- A category **can** be a supertype of several kinds

Association (→): When there is a rule and/or a reason for a relationship between two classes, a simple association can be used. It is represented by a solid line between two classifiers, an arrow, and a verb word (presenting a problem in reality). Also, each association has cardinality to show how instances of the first class can be associated with the instances of the second class.

Three types of simple association relations have been used in this study, Material, Mediation and Characterization (Guizzardi, 2009, 2011). When there is a relator (e.g. Marriage) in a class diagram, it connects two individuals, for instance, Husband (Role) and Wife (Role). The Marriage must have at least two mediation relations (one with Husband and one with Wife) because the relator (Marriage) provides the essential connection between the two individuals. Also, there will be a relation (material) between the two individuals (at least two individuals) of a relator. For instance, there is a material relation between Wife and Husband called “married to”. In addition to the

material and mediation, characterization relation can be used when there are mode and quality types. For example, Person as a Kind class can have a relation of characterization to a quality class called weight.

Composition/Aggregation (—♦ or —◊): When a class is part of another class, aggregate or composition can be used. When the whole is destroyed, there will be two conditions, the parts will be retained or destroyed as well. If the parts are destroyed, it is called composition and if they are retained, it is called aggregation.

MemberOf is a type of composition used in the OntoUML. In this relation, there is a collective as a whole and relates (MemberOf) to a kind or another collective as a part (Guizzardi, 2009, 2011; Guizzardi et al., 2022).

3.2.4. Implementing and Testing the Ontology

In this stage, it was essential to utilize a machine-readable language to effectively represent the ontology. In this regard, OWL was selected as it is a semantic ontological language. Among the various software options available for ontology representation, Protégé stood out for its reputation of being free, open-source, and user-friendly. It was utilized for the implementation of the pavement ontology. It is noteworthy that while this study aims to convert the reference ontology to an operational ontology, this implementation was only applied to select parts of the ontology as determined through consultation with the supervisors.

The first task in testing the ontology was verification. Based on the literature, the ontology taxonomy evaluation was used. In this method, a group of experts who have experience in ontological development in the domain checked the class hierarchy manually based on the three criteria of consistency (i.e. checking the circularity, partition and semantic errors), completeness (i.e. no missing concepts from the taxonomy) and redundancy (i.e. checking the repetition and definition of concepts)

(Gómez-Pérez, 2001; Uschold & Gruninger, 1996). In addition to the mentioned approach, Visual Paradigm, which is the software for representing the OntoUML, was used to check the consistency between the classes and attributes of the ontology. Also, Protégé software was used to check the consistency of the ontology. A number of reasoners in Protégé (i.e., Pellet, FACT ++ and HermiT) were used to check the relationships between different classes in pavement ontology. Based on the methods previously outlined, if any errors are identified within the pavement ontology, it is necessary to revise the class hierarchy in order to rectify them.

The next step in the process was to validate the ontology. Based on the literature, there are several methods for validating an ontology such as the gold standard, application-based evaluation, query and criteria-based evaluation (Taher et al., 2021). The gold standard approach can be used when there is an applicable ontology developed in a domain. For the pavement ontology, this method was not useful because of the lack of a benchmark for comparison. Also, the application-based evaluation could not be used since no applications were developed based on the pavement ontology. The most appropriate method for validating an ontology in the earlier design stage is criteria-based evaluation (Taher et al., 2021). To evaluate the pavement ontology, a criteria-based evaluation was conducted using an online survey. In this approach, several questions were formulated to gather feedback from experts and users of the ontology (Yu et al., 2007). The survey questions were designed in such way to assess the functional and non-functional requirements of end-users. The respondents were from the area of civil engineering, construction management, pavement engineering (different disciplines of design, construction, operation and maintenance), project management, information technology application in road construction, asphalt process

control, and ontology experts. The online survey will be analysed the adequacy of pavement ontology against the requirements defined in the first step.

As explained in the above paragraph, the method used for validation of the pavement ontology is criteria-based evaluation. As explained in the previous chapters, a survey has been prepared to assess the semantic representation of the taxonomies and relations. The focuses of the survey are on following criteria, accuracy, completeness, conciseness, consistency, comprehensiveness, clarity, user-friendliness, organizational fitness, extensibility, and scalability. In addition to these criteria, the ability of the ontology to be implemented (implementation) and capabilities of the developed ontology in comparison with PIM are also taken into account in the survey. Based on the criteria, a questionnaire has been prepared, as shown in Table 3.

Each question has a specific aim and has been formulated based on the criteria (requirements) in Chapter 3. Table 4 shows the relations between the criteria and questions and also the expected advantages captured by using the pavement ontology.

Table 3. Questions defined for the survey and main objective of each question

No	Questions
1	Name, organization name, area of expertise and years of experience.
2	Figure 1 shows the failure mode classification in the pavement ontology. To what extent do you agree that the mentioned figure capture the extensive/complete taxonomy in this domain? (Classification of failure mode)
3	Figure 2 shows the material (Figure 2a) and asphalt mix classification (Figure 2b) in the pavement ontology. To what extent do you agree that the mentioned figure capture the extensive/complete taxonomy in this domain? (Classification of pavement composition)
4	Figure 3 shows the road geometry classification in the pavement ontology. To what extent do you agree that the mentioned figure captures the extensive/complete taxonomy in this domain? (Classification of road geometry)
5	Figure 4 (a-e) shows the lifecycle activity classification in the pavement ontology. To what extent do you agree that the mentioned figure captures the extensive/complete taxonomy in this domain? (Classification of lifecycle activity)
6	Figure 5 shows the lifecycle resource classification in the pavement ontology. To what extent do you agree that the mentioned figure captures the extensive/complete taxonomy in this domain? (Classification of lifecycle resource)
7	Figure 6 shows the quality assessment classification in the pavement ontology. To what extent do you agree that the mentioned figure captures the extensive/complete taxonomy in this domain? (Classification of lifecycle assessment)
8	Figure 7 (a-c) shows the high-level structure of the ontology and the rest of the relations. To what extent do you agree that the concepts and relations mentioned are clear? (Clarity)
9	Based on the figures shown, to what extent do you agree that the concepts and relations of the pavement ontology are understandable and traceable? (User-friendliness)
10	To what extent do you agree that the developed ontology is to the point and free of redundancies? (Conciseness)

11	After checking the concepts and relations, To what extent do you agree that the pavement ontology captures the accurate information and knowledge in the domain? (Accuracy)
12	Figure 7(c) represents the relations between Cell and Failure mode and also Cell and Data collection classes. To what extent do you agree that the developed ontology can be used in decision-making systems? (Relation comprehensiveness)
13	Based on the figures mentioned earlier, to what extent do you agree that new concepts and relations can be easily added to the pavement ontology? (Extensibility)
14	To what extent do you agree that the developed ontology can be applied to your daily information management needs? (Applicability)
15	After checking the concepts and relations, To what extent do you agree that developed ontology can be scaled up and down to remain applicable to a variety of projects? (Scalability)
16	Based on considered concepts and relations, do you agree that pavement ontology can be compatible with the current technology and system used in the domain? (Organizational fitness)
17	To what extent do you agree that the developed ontology can be used as-is? (Implementation)
18	What is the rate of the developed ontology in comparison to PIM (Pavement Information Modelling) in terms of: Accuracy, Comprehensiveness, Clarity, Scalability and Extensibility. (PIM comparison)

*Figures mentioned in the table are the figure used for the survey and they are not the same figures used in the report.

Table 4. Relation between survey questions and expected advantages of pavement ontology

Expected advantages of pavement ontology	**Related questions in the survey**
Classifying the knowledge and information hierarchically and identifying the linking the relations between the concepts based on the expert idea	Q2: Classification of failure mode Q3: Classification of material and asphalt mix Q4: Classification of road geometry Q5: Classification of lifecycle activity Q6: Classification of lifecycle resource Q7: Classification of quality assessment Q8: Clarity of concepts and relations Q9: User-friendliness of pavement ontology Q10: Conciseness of pavement ontology Q11: Accuracy of concepts and relations
Easing the management of pavement lifecycle and information and facilitating the data exchange and interoperability between the fragmented systems	Q16: Organizational fitness of the representation Q14: Applicability of pavement ontology Q17: Implementation of pavement ontology Q18: PIM comparison
Enhancing the stakeholder's knowledge and information regarding the pavement lifecycle by providing structured and robust knowledge	Q12: Comprehensiveness of representation
Developing a standard approach for data structuring that has the capability to integrate data in the future	Q13: Extensibility of the ontology Q15: Scalability of the ontology

Another method for validating ontology is query-based evaluation. Query-based evaluation is an approach to finding correct data from a database. In this method, an actual or dummy database is required. The database should be developed based on ontology. Then, meaningful questions can be formulated to check how the database (created based on the ontology) can show the correct data. Finding the correct data in the database is possible by defining the right classes and relations in an ontology. If ontology is comprehensive, which can show meaningful relationships between the

classes, can satisfy this evaluation. This is the end of this chapter, the stakeholders and requirement analysis is explained in the next chapter.

Chapter 4. Stakeholders and Requirement Analysis

This chapter presents the stakeholders' analysis and requirement identification for the pavement ontology. As mentioned in the previous chapter, the first step was to define the goal of the stakeholders through several interviews and to identify the use case of the ontology for defining the competency questions. Next, the competency questions were extracted based on the use cases of the ontology. Finally, the goals and needs of the stakeholders were converted to structural requirements.

4.1. Stakeholders' Analysis

Stakeholder analysis has been conducted using semi-structured interviews (Schmidt, 2004). The goals of stakeholders are shown in

Table *5*.

Table 5. Stakeholder analysis

Stakeholders	**Stakeholder Goals**
Clients (Municipality, Rijkswaterstaat and Provinces)	• To enhance the interoperability of pavement lifecycle data • To have more insight into the behaviour of pavement lifecycle • To have an easy-to-use ontology • To have a future proof ontology
Contractors	• To enhance the interoperability of pavement lifecycle data • To have more insight into the behaviour of pavement lifecycle • To enhance the construction and maintenance of pavement • To have an easy-to-use ontology • To have a future proof ontology
Third parties (consultant/testing companies, research centres)	• To enhance the interoperability of pavement lifecycle data • To have more insight into the behaviour of pavement lifecycle

The main end-users of the ontology are contractors and clients. Contractors, as the main users who are involved in the main phases of the pavement lifecycle (design, construction, operation and maintenance), expressed a need to have more insight into the behaviour of pavement lifecycle and to enhance the construction and maintenance of pavement. Also, contractors wish to enhance the interoperability of pavement

lifecycle data to reduce the cost of data loss and misinterpretation. On the other side, clients are the evaluators of the road project. They assess pavement data provided by the contractors and monitor the pavement during the operation phase. By having an accurate approach for facilitating data exchange, not only does it benefit the contractors, but it also enhances knowledge and reduces interoperability issues for clients.

4.2. Competency Questions

By having several interviews with the end-users of the ontology (contractors, clients and third parties), the competency questions have been defined. Then, competency questions related to each intended use have been assigned. Based on the interviews, the pavement ontology will be used for formalizing knowledge about (1) the road geometry, (2) compositions (identifying material used), (3) deterioration (types of failure modes), (4) activities (variety of activities in the road pavement lifecycle), (5) resources (variety of resources used in the road pavement lifecycle), and (6) evaluation (measuring the quality of road pavement). Accordingly, the competency questions related to each of these use cases were formulated. The competency questions are presented in Table 6. It is worth mentioning that, as will be shown later, the six use cases constitute different sub-ontologies of the pavement ontology.

The competency questions are considered as a basis of the requirement for ontology. It is worth mentioning that due to the iterative process of ontology development, the mentioned competency questions have been revised during the phases of this ontological development and only the most updated questions are presented in Table 6.

Table 6. Competency questions

Group	nr	Questions

Pavement geometry	1	What are the largest and smallest geometry parts of a road?
	2	What is the BPS indication for every part of a road?
	3	What are the width and length of the lane segment?
	4	What are the size and location of a cell?
	5	What is the type of coordinate system used for the cell location?
	6	What are the initial temperature, the temperature at the first roller pass and last roller passes for a cell?
	7	How cell data can be converted to the lane segment?
Pavement composition	8	What is the width of the asphalt layer?
	9	What are the volumetric properties (target air void, density and max density) of the mix?
	10	What type of materials (aggregate, bitumen, recycle and additive) and their specifications (aggregate tests results, bitumen viscosity and additive and recycle used percentage) are used in the mix?
	11	What are the type, aggregate grading, code, DoP (Declaration of Performance), and elastic modulus of the mix?
	12	What are the max and min temperatures of asphalt production in the plant?
	13	What is the recommended temperature for asphalt mixing in the plant?
	14	What is the degree of compaction for the core mix?
	15	What are the stiffness, fatigue life, flow number, creep rate, moisture suitability resistance, dynamic modulus, resilient modulus, noise reduction, cracking resistance and indirect tensile strength of the mix?
Pavement deterioration	16	What are the properties (date and location) of failure mode measured in a survey?
	17	What are the distresses (crack, rutting, raveling, bleeding and pothole)?
	18	What are the levels of each failure mode (Rijkswaterstaat and CROW)?
	19	What is the area and percentage of fatigue?
	20	What are the length and crack depth of transverse and longitudinal cracks?
	21	What is the area and depth of the pothole?
	22	What is the bleeding level?
	23	What is the raveling level?
	24	What is the rut depth?
	25	What is the friction coefficient of the asphalt layer (dry and wet)?

	26	What is the texture depth of the asphalt layer?
Pavement activity	27	What are the contract and contractor properties such as ECI (Environmental Cost Indicator), guaranty period, contract type, etc. in the design phase?
	28	What are the target and final thicknesses of the pavement layer?
	29	What are the traffic condition parameters in the design phase such as freight traffic speed, different types of axle load, uncertainty factor for traffic, number of vehicles and trucks per day, etc.?
	30	What are the ranges for aggregate grading, density of aggregates, volumetric properties of aggregates, production and compaction temperatures, bitumen content, stiffness, air void, etc. that needs for the construction phase?
	31	What are the contract and contractor properties in the construction phase?
	32	What is the date of the construction activity?
	33	What are the properties (such as width, height, length, average speed, number of passes, etc.) of each construction activity?
	34	What are the start and end points, and times for each construction activity?
	35	What is the type of maintenance strategy?
	36	What are the contract and contractor properties in the maintenance phase?
	37	What type of equipment and material are used for the maintenance method?
	38	What is the weather condition during the maintenance activity?
	39	What is the type of laboratory test used and the properties of the lab test such as test date, location of the lab, type of the test, and the temperature of the test?
	40	What are the temperatures (core and surface), density, thickness, and GPS data of machines during the construction project?
	41	What type of monitoring method is used for the operation phase?
	42	How the effect of fire, flat tire, carcass, pollution, and extreme weather condition are considered in the measurement?
	43	What are the actual numbers of vehicles and trucks used on the road during the operation phase?
	44	What is the exact location of the core?
Pavement resource	45	What type of machine is used for the road construction project?
	46	What are the properties of each machine?
	47	What is the type of asphalt plant for asphalt manufacturing?

	48	What are the experience and age of the operator and workers?
Pavement evaluation	49	What type of parameters are used for evaluating the design, construction, and maintenance phases?
	50	What type of IRI is used?

4.3. Ontology Structural Requirement

As mentioned in the literature review, requirements should be derived from the stakeholder's goals. The requirements of the ontology are shown in Table 7. All requirements will be applied for the design of the ontology and used in the validation of the pavement ontology.

Table 7. List of requirements translated based on the INCOSE method

Stakeholder Goals	**Needs**	**Requirement for pavement ontology**
To enhance the interoperability of pavement lifecycle data	Prevent misinterpretation and miscommunication	Should consider the uniform and unified set of concepts and relations
To have more insight into the behavior of pavement lifecycle	Accuracy	Should include the expertise of the users in the correct fashion
	Completeness	Should consider most of the concepts and relations in the pavement domain
	Conciseness	Should prevent considering the irrelevant and redundant concepts and relations in the pavement domain
	Consistency	Should not include any contradictions in the concepts and relations
To enhance the construction and maintenance of pavement	Comprehensiveness	Should consider the relations between the design and construction with the maintenance
To have an easy-to-use ontology	Clarity	Should define, document and explain the class hierarchy
	User-friendliness	Concepts and relations Should be understandable and traceable by users
	Organizational fitness	Should comply with the technologies used by road users
To have a future proof ontology	Extensibility	Should be extendible by users under the condition of finding a new concept and relation
	Scalability	Should be applicable for use in different projects

For instance, one of the requirements defined is that the ontology should consider most of the concepts and relations in the domain. By considering all of the concepts and relations between them, the developed ontology will be a complete ontology

(needs) and then the stakeholders can explore more in the pavement domain by having more insight into the parameters which previously missed or neglected.

Chapter 5. Representing the Ontology

In this chapter, the high-level structure of the pavement ontology is first presented and then the sub-ontologies are explained. The competency questions related to each sub-ontology are shown (in terms of the question number) to indicate how the developed ontology is aligned with competency questions. But before staring to represent the ontology, the full picture of the ontology should be presented to clarify how the rest of the section will be explain. The pavement ontology is shown in Figure 6.

5.1. High-level Structure of Pavement Ontology

The top class in this ontology is called Road Infrastructure. Based on the objective of this EngD defined in Chapter 1, the ontology should be developed for the entire lifecycle of road pavement. Therefore, the scope of the pavement ontology developed in this research is the entire lifecycle. In this regard, the highest level of this ontology shows that each road infrastructure has its own lifecycle (Figure 5). The type of road infrastructure is a category since it has different individuals such as bridges and roads each of which can have its own typology. Also, Lifecycle is a mixin because it has some individuals such as resources (rigid ones) which are category and kind, and some individuals which are anti-rigid.

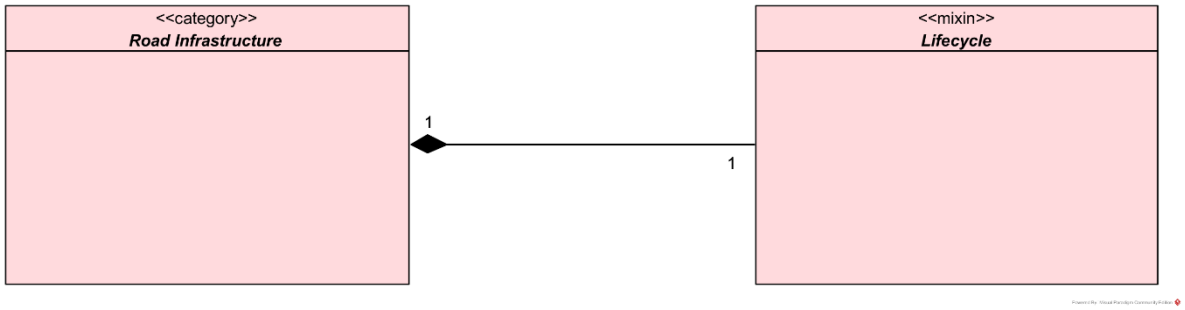


Figure 5. The highest level of pavement ontology.

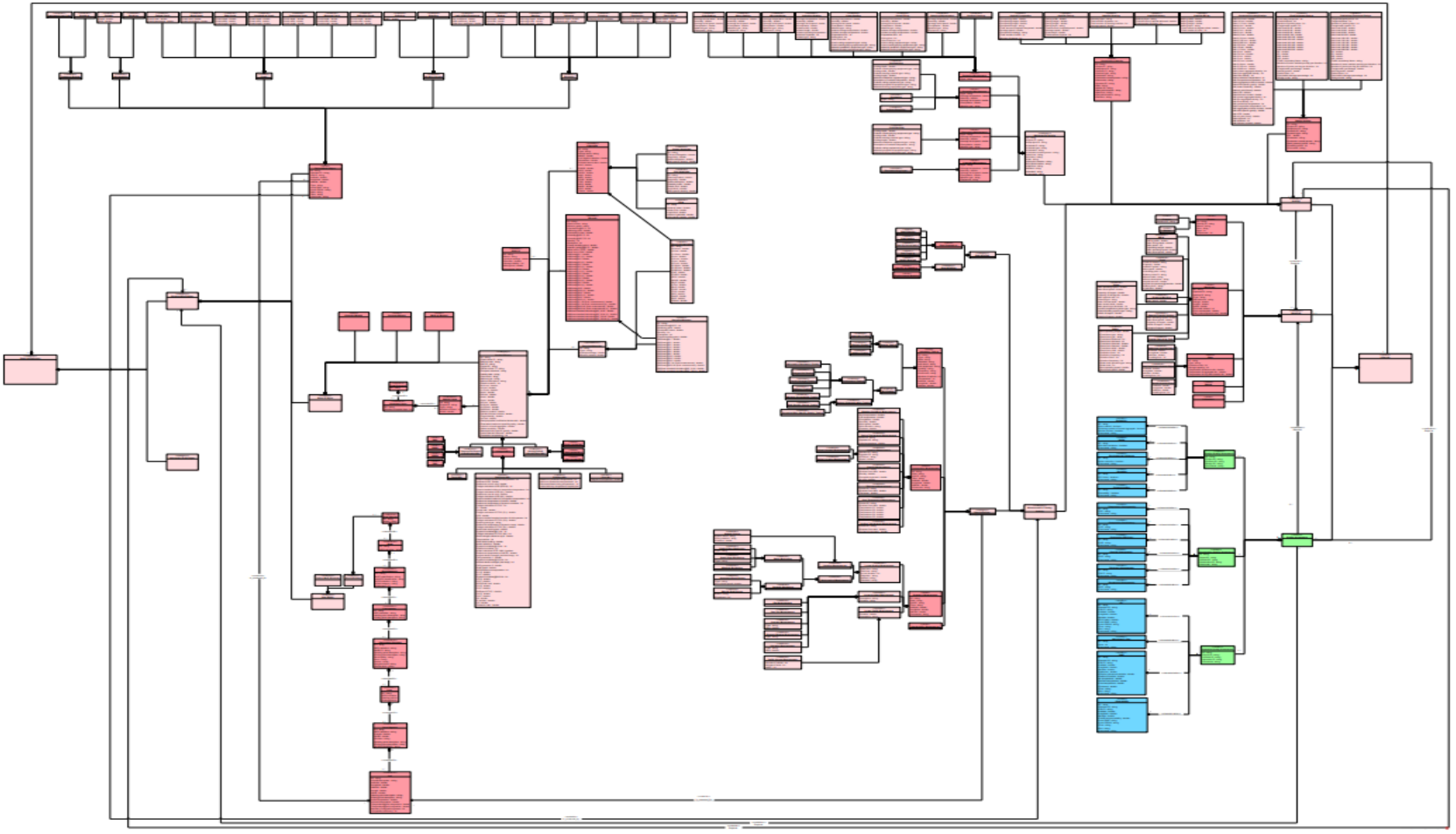


Figure 6. The complete picture of developed pavement ontology.

At the next level, the sub-classes of Road Infrastructure and Lifecycle are shown in Figure 7. Physical and Information Road Objects *“are”* Road Infrastructure (which is an object). Every Road Infrastructure has a physical part, which basically account for all tangible parts of the road. For instance, a road has different physical objects such as Material, Geometry, and Failure Mode Objects. Also, Lifecycle *“has”* at least one Activity, which represent all activities that are performed during different phases of the lifecycle. Resource (different resources used in the road lifecycle to improve the performance of the lifecycle such as people, machines, sensors, etc), and Quality Assessment (different types of quality assessment to evaluate the quality of each phase of the road lifecycle) are the other sub-classes of the Lifecycle class. Based on this high level decomposition, the Pavement Ontology is divided into six sub-ontologies, namely, deterioration, composition, geometry, activity, resource, and evaluation. The sub-ontologies and the relations between them (the big picture) are shown in Figure 6. The big picture can help the readers how ontology has been developed.

5.2. Pavement Geometry Sub Ontology

As shown in Figure 8, the Physical Road Object class and subsequently Geo Object class can be divided into two subclasses of Road Geometry and Failure Mode Geometry. The Geometry class try to capture different geometric components of the road Infrastructure based on the common classification standard in the Netherlands. The type of Road Geometry class is a category since it has different classes each of which has different kinds of identity principle. All subclasses of Road Geometry have are collective. They are all collective because there is a homogenous internal structure between them. Road Network is the top class and every road network consists of at least one Road (e.g. A1 or N325).

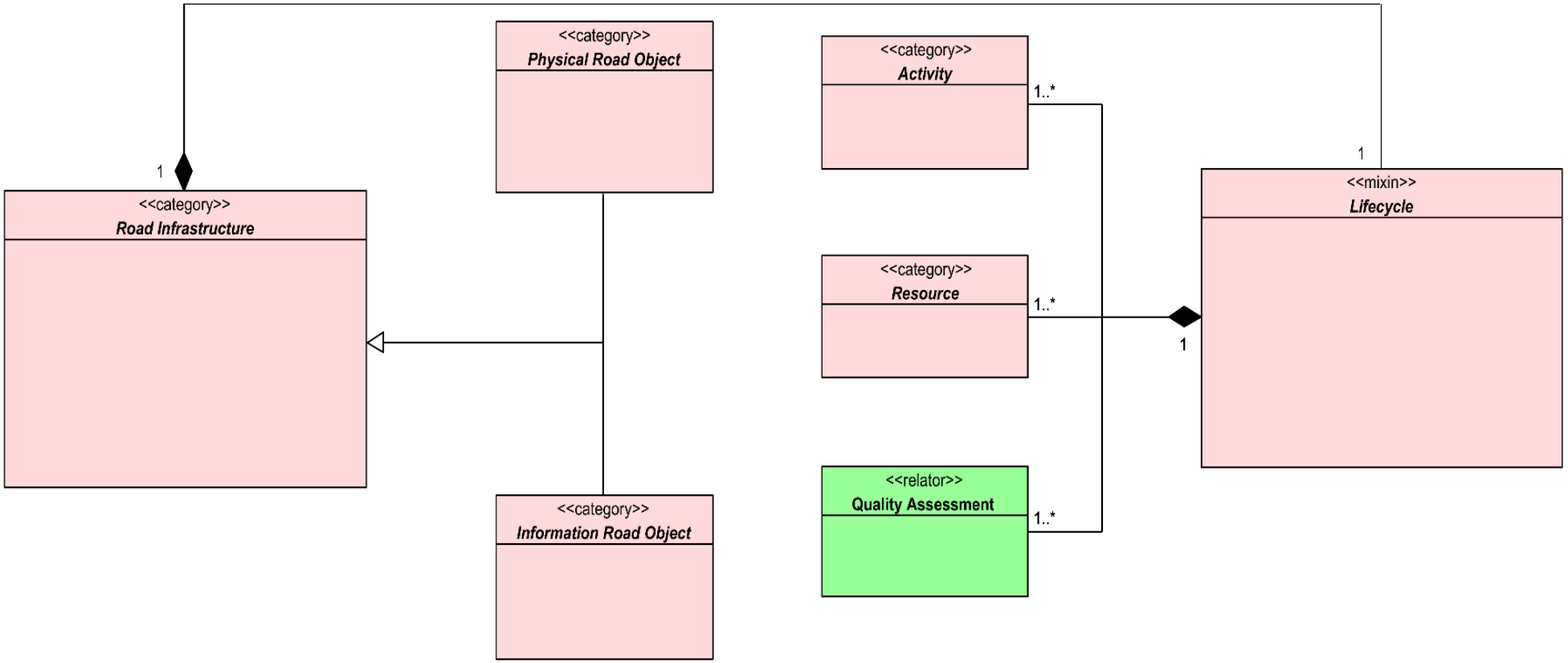


Figure 7. The second level of pavement ontology

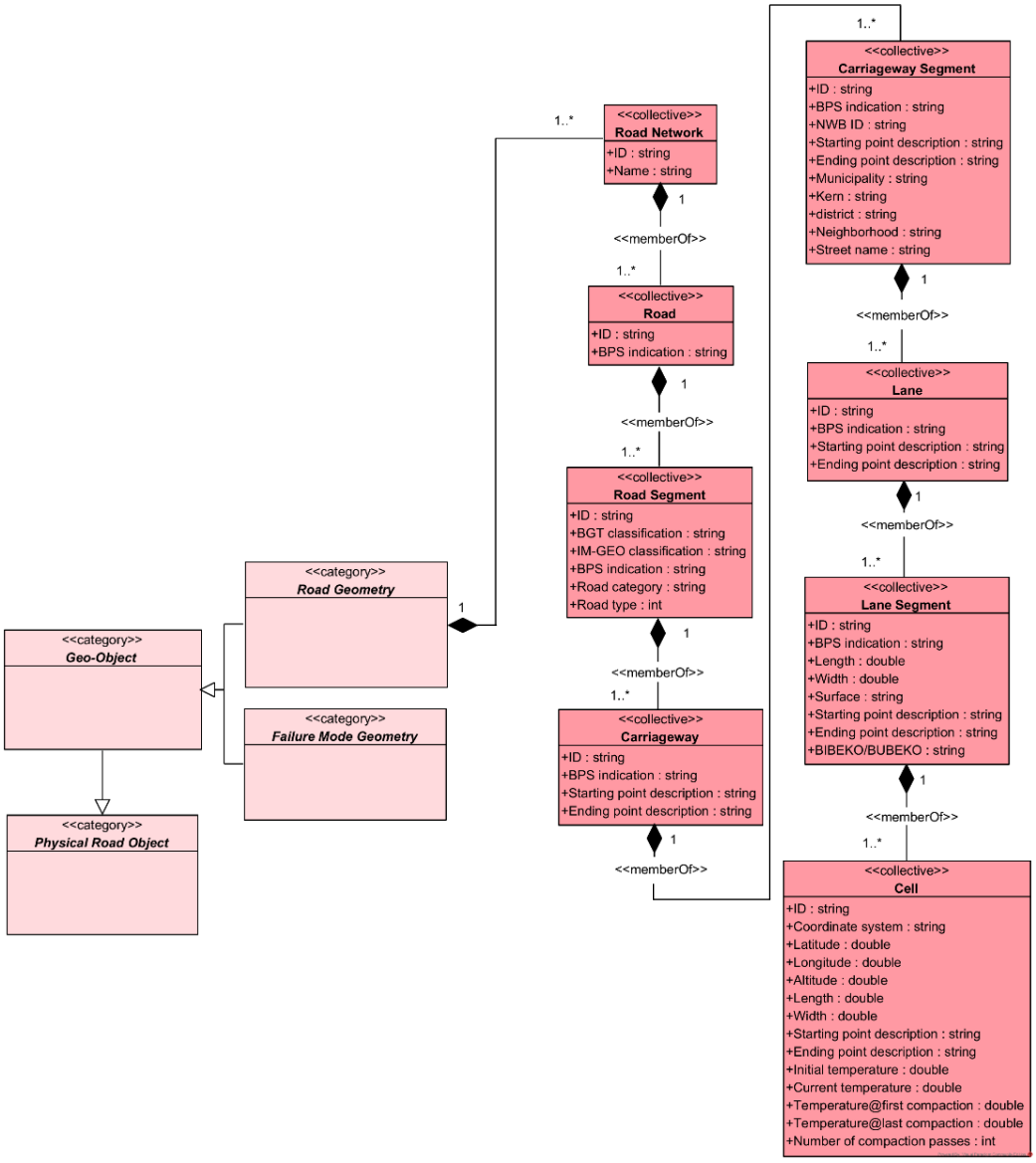


Figure 8. Sub ontology of Pavement Geometry

Every road consists of at least one Road Segment. This continues all the way down to a cell, which is the smallest part of road geometry. The relations used between the collective classes are MemberOf since, for instance, Road network is a collective as a whole and Road is a collective as part of Road Network. There is a sub ontology in PIM called “Ruimte”, this sub ontology has been extracted and used to make the main parts of road geometry; however, due to the importance of Cell, it has been added to this classification. The significance of cell has been demonstrated in the previous research of ASPARi research Unit (Makarov et al., 2020, 2021). The resolution of cell

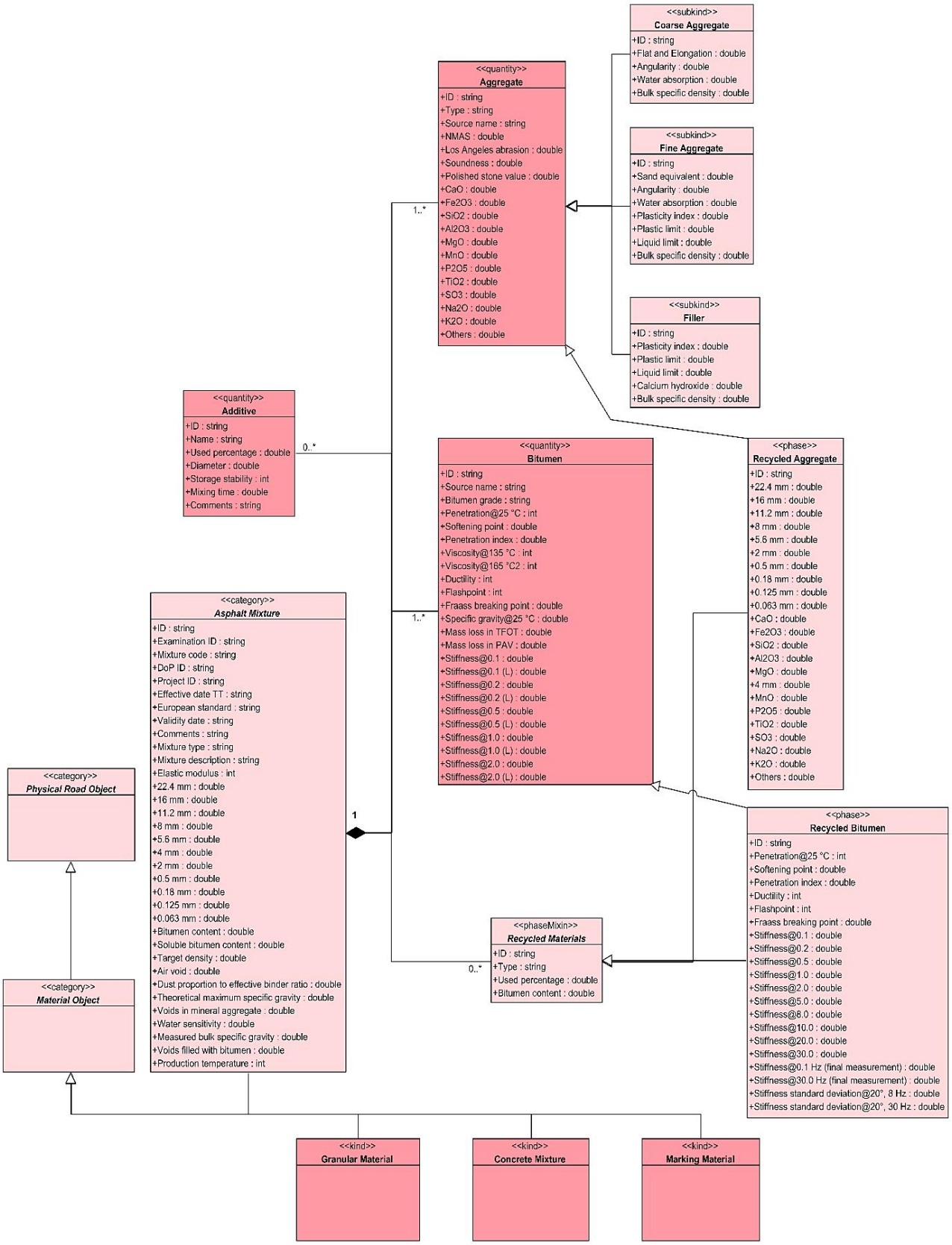
is important because all measurements during the construction work are conducted at the cell level.

Based on the classification, the largest and smallest part of a road geometry is Road Network and Cell (Q1), respectively. Every class in this sub ontology has a BPS (Beschrijvende Plaatsaanduiding Systematiek) indication as an attribute. BPS indication is a system that divided every part of a road based on a number and letter (Q2). Every Lane Segment has its length and width in reality and these two attributes have been considered in the Lane Segment class since most road construction projects are done for a lane segment and the length and width of a segment is important data to collect (Q3). There are some important attributes of a cell, such as size, location, different types of temperatures, etc that are the answers to Questions number 4 and 6. Another important attribute is the type of coordinate system used in for a cell (Q5). This is because there is a chance that different companies use different coordinate systems (such as Latitude and longitude, and Universal Transverse Mercator) and this data can help how they are integrating their data. The presented hierarchy and relations allow easy conversion (i.e., upscaling or downscaling) of data across different geometry scale (Q7). For instance, the data collected for a cell can be considered for its hosting lane segment because the size of a cell is explicit and the number of cells in each lane segment is also known. Thus, the average number of the data for all of the cells in a lane segment can be calculated and used for the lane segment.

5.3. Pavement Composition Sub Ontology

Another sub-class of Physical Road Object is Material Object. Every material used in the road should be shown in this class. Due to the scope of this project, only asphalt materials have been considered, however, there are some other materials such as

marking materials, concrete mixture and granular materials that are physical road object but they are not in the scope of this study. Figure 9 (a) and (b) shows the Material Object sub-ontology. It should be mentioned that for this sub-ontology, “PIM OTL Concrete” as the primary source and it has been complemented with additional (missing) data extracted from the available literature. For instance, aging is an attribute of bitumen and can happen because of oxygen absorption. Aging is a really important parameter since can initiate the condition for some other deterioration in the future of the asphalt. During production, the short-term aging and long-term aging of the bitumen should be evaluated and used as an attribute of the bitumen. If bitumen has susceptibility against aging, the bonding between the aggregate and bitumen will be fragile in the long-term and the asphalt pavement is prone to raveling, fatigue and cracks.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Coarse Aggregate
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+Flat and Elongation : double
+Angularity : double
+Water absorption : double
+Bulk specific density : double
<<quantity>>
Aggregate
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+Type : string
+Source name : string
+NMAS : double
+Los Angeles abrasion : double
+Soundness : double
+Polished stone value : double
+CaO : double
+Fe2O3 : double
+SiO2 : double
+Al2O3 : double
+MgO : double
+MnO : double
+P2O5 : double
+TiO2 : double
+SO3 : double
+Na2O : double
+K2O : double
+Others : double
<<subkind>>
Fine Aggregate
+ID : string
+Sand equivalent : double
+Angularity : double
+Water absorption : double
+Plasticity index : double
+Plastic limit : double
+Liquid limit : double
+Bulk specific density : double
<<subkind>>
Filler
+ID : string
+Plasticity index : double
+Plastic limit : double
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+Calcium hydroxide : double
+Bulk specific density : double
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Additive
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+Name : string
+Used percentage : double
+Diameter : double
+Storage stability : int
+Mixing time : double
+Comments : string
0..*
<<quantity>>
Bitumen
+ID : string
+Source name : string
+Bitumen grade : string
+Penetration@25 °C : int
+Softening point : double
+Penetration index : double
+Viscosity@135 °C : int
+Viscosity@165 °C2 : int
+Ductility : int
+Flashpoint : int
+Fraass breaking point : double
+Specific gravity@25 °C : double
+Mass loss in TFOT : double
+Mass loss in PAV : double
+Stiffness@0.1 : double
+Stiffness@0.1 (L) : double
+Stiffness@0.2 : double
+Stiffness@0.2 (L) : double
+Stiffness@0.5 : double
+Stiffness@0.5 (L) : double
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+Stiffness@1.0 (L) : double
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+Stiffness@2.0 (L) : double
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+11.2 mm : double
+8 mm : double
+5.6 mm : double
+2 mm : double
+0.5 mm : double
+0.18 mm : double
+0.125 mm : double
+0.063 mm : double
+CaO : double
+Fe2O3 : double
+SiO2 : double
+Al2O3 : double
+MgO : double
+4 mm : double
+MnO : double
+P2O5 : double
+TiO2 : double
+SO3 : double
+Na2O : double
+K2O : double
+Others : double
<<category>>
Asphalt Mixture
+ID : string
+Examination ID : string
+Mixture code : string
+DoP ID : string
+Project ID : string
+Effective date TT : string
+European standard : string
+Validity date : string
+Comments : string
+Mixture type : string
+Mixture description : string
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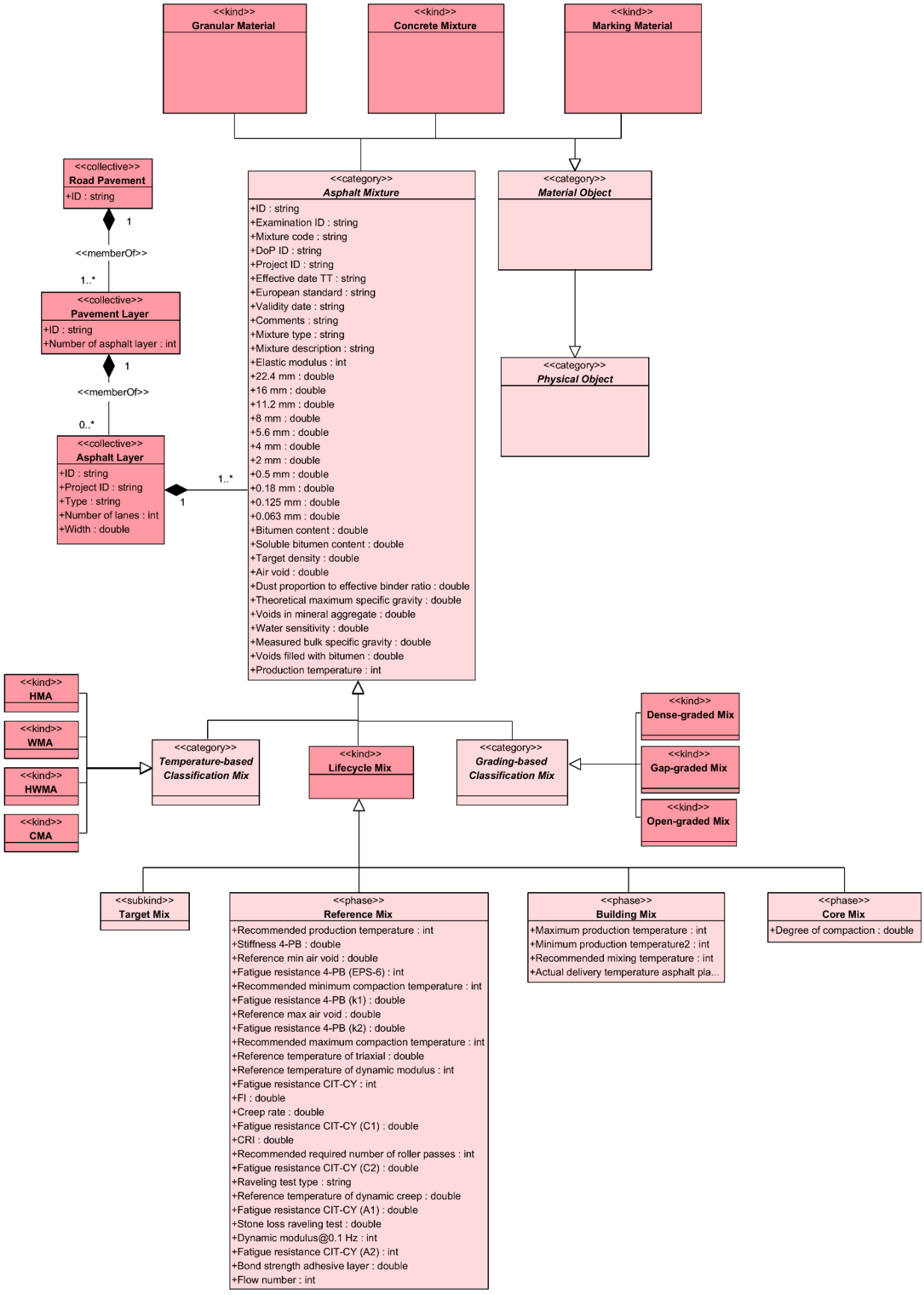
+16 mm : double
+11.2 mm : double
+8 mm : double
+5.6 mm : double
+4 mm : double
+2 mm : double
+0.5 mm : double
+0.18 mm : double
+0.125 mm : double
+0.063 mm : double
+Bitumen content : double
+Soluble bitumen content : double
+Target density : double
+Air void : double
+Dust proportion to effective binder ratio : double
+Theoretical maximum specific gravity : double
+Voids in mineral aggregate : double
+Water sensitivity : double
+Measured bulk specific gravity : double
+Voids filled with bitumen : double
+Production temperature : int
1..*
1
<<category>>
Physical Road Object
<<category>>
Material Object
<<phaseMixin>>
Recycled Materials
+ID : string
+Type : string
+Used percentage : double
+Bitumen content : double
0..*
<<phase>>
Recycled Bitumen
+ID : string
+Penetration@25 °C : int
+Softening point : double
+Penetration index : double
+Ductility : int
+Flashpoint : int
+Fraass breaking point : double
+Stiffness@0.1 : double
+Stiffness@0.2 : double
+Stiffness@0.5 : double
+Stiffness@1.0 : double
+Stiffness@2.0 : double
+Stiffness@5.0 : double
+Stiffness@8.0 : double
+Stiffness@10.0 : double
+Stiffness@20.0 : double
+Stiffness@30.0 : double
+Stiffness@0.1 Hz (final measurement) : double
+Stiffness@30.0 Hz (final measurement) : double
+Stiffness standard deviation@20°, 8 Hz : double
+Stiffness standard deviation@20°, 30 Hz : double
<<kind>>
Granular Material
<<kind>>
Concrete Mixture
<<kind>>
Marking Material

(a)



(b)

Figure 9. Pavement Composition sub ontology which is divided into two figures of (a) and (b) due to being more explicit for readers

As shown in Figure 9, Asphalt Mixture “is a” part of Material Object. Asphalt Mixture “has” different components such as Bitumen and Aggregate and the possibility of having Additive and Recycled Material. There are some other classifications such as different sizes of aggregate (Coarse, Fine, and Filler) and different Recycled Materials including Recycled Aggregate and Recycled Bitumen. For each Asphalt Layer, there must be at least one corresponding Asphalt Mixture. Additionally, a Pavement Layer may or may not contain an Asphalt Layer. This is because the Asphalt Layer is not the only layer used for the Pavement Layer and Concrete and Granular Layers can also be used (which is out of the scope of this study).

Asphalt Mixture can be classified in different ways. The first classification is based on the production temperature that divided the mixture into four different mixtures of Hot Mix Asphalt (HMA), Warm Mix Asphalt (WMA), Half Warm mix Asphalt (HWMA) and Cold Mix Asphalt (CMA) (Vaitkus et al., 2009). Asphalt mixture can also be classified in terms of the grading of aggregates into Dense-graded, Gap-graded (e.g., Stone Mastic Asphalt), and Open-graded (e.g., Porous Asphalt) (Garcia & Hansen, 2001). The last classification is based on the different phases that a mix goes through during the road lifecycle. According to the interviews, the mix that a client (asset manager) desires for its road, is called Target Mix. After finalizing the contract with a contractor, the contractor tries to use his historical data and laboratory tests to optimize the design of the asphalt, which is referred to as Reference Mix. Then, the information of the confirmed mix (after optimization by the contractor and confirmation by the client) will be sent to the plant for production. This mix is called Building Mix. Finally, the mix that is cored after the construction of a road is called Core Mix. The types of classes used in this sub ontology are explicit in Figure 8. It is worth mentioning that the type of

Aggregate, Bitumen and Additive are quantity since they are sortal, have their own principle of identity. and are uncountable.

The width of the asphalt layer has been considered in Asphalt Layer class (Q8). In addition to this, the number of lanes for an asphalt layer has also been considered as an attribute of this class. All of the volumetric properties of asphalt mix such as target density, air void, theoretical max specific gravity, measured bulk density, void filled with bitumen, and bitumen content have been added to the class of Asphalt Mixture (Q9). As mentioned earlier, all types of asphalt materials such as bitumen, different kind of aggregates, recycled materials, and additives are included in this sub ontology (Q10). Also, the properties of each material such as the physical and chemical properties of aggregates, volumetric properties and Atterberg limits of aggregates, source and grade of bitumen, classical bitumen test parameters (penetration, softening point, ductility, flashpoint, viscosity, etc), Superpave parameters (stiffness in Dynamic Shear Rheometers test) of bitumen, Fraass breaking point of bitumen, specific gravity of bitumen, name, used percentage, diameter, and storage stability of additive, etc have been considered as an attribute of Aggregate, Bitumen, Additive and Recycled Material classes (Q10). In addition to the mentioned parameters, aging, which is the oxidation of bitumen during its service life and can damage the asphalt mix, has also been considered in the Bitumen. This is achieved by dividing the stiffness of bitumen into short- and long-term measurements attributes of and also by calculating the mass loss of the bitumen after Thin Film Oven Test (TFOT) and Pressure Aging Vessel (PAV). The importance of the aging of asphalt mixes is confirmed by the literature (Sirin et al., 2018). The type of asphalt mixes has been considered by classifying the asphalt mix into different categories (such as HMA, WMA and CMA or Dense graded, Gap graded and Open graded mixes) and also by considering the attribute of the type in the Asphalt

Mixture class (Q11). Furthermore, the aggregate grading, code, DoP, elastic modulus, etc. of the mix have been added to the Asphalt Mixture classes (Q11). All parameters of Declaration of Performance (such as Water Sensitivity, Stiffness and Density of mixture), which is issued by an asphalt manufacturer, have also been added to increase the robustness of the proposed ontology. In the class of Building Mix, all the properties of this mix such as max and min production temperature and recommended mixing temperature have been added (Q12 &13). Additionally, the degree of compaction, which is the most important attribute of Core mix, is also incorporated (Q14). There are many performance parameters added to the Reference Mix class (Q15) such as fatigue resistance, stiffness (i.e., as per both 4-point bending flexural and indirect tensile strength tests), recommended min compaction temperature, reference min air void, creep rate, flow number, stone loss ravelling, shift factor healing, dynamic and resilient moduli, water-resistant (Tensile Strength Ratio), indirect tensile fatigue and tensile, rut depth, semi-circular bend peak load, Poisson's ratio, fracture energy, etc.

5.4. Pavement Deterioration Sub Ontology

The last sub-class of Physical Road Object is Failure Mode Object, which is shown in Figure 10. This sub-class has been added based on the literature (Coenen & Golroo, 2017; J. S. Miller et al., 2003; Monismith & Salam, 1973; Tamrakar, 2019; Zumrawi, 2015) and interviews with the Consultant and monitoring company in the road construction sector. The type of Failure Mode Object is kind since it has a principle of identity and rigidity. This class has five subclasses Distortion, Skiding Hazard, Crack, Disintegration and Treatment Distress, all of which are subkind. Then, each of these subontology has been divided into different classes based on the literature. For instance, different types of cracks such as Fatigue, Block, Edge, Transverse,

Longitudinal, Reflection and Slippage have been added. Since several properties are common to all failure modes, all the relations are designed as a generalization.

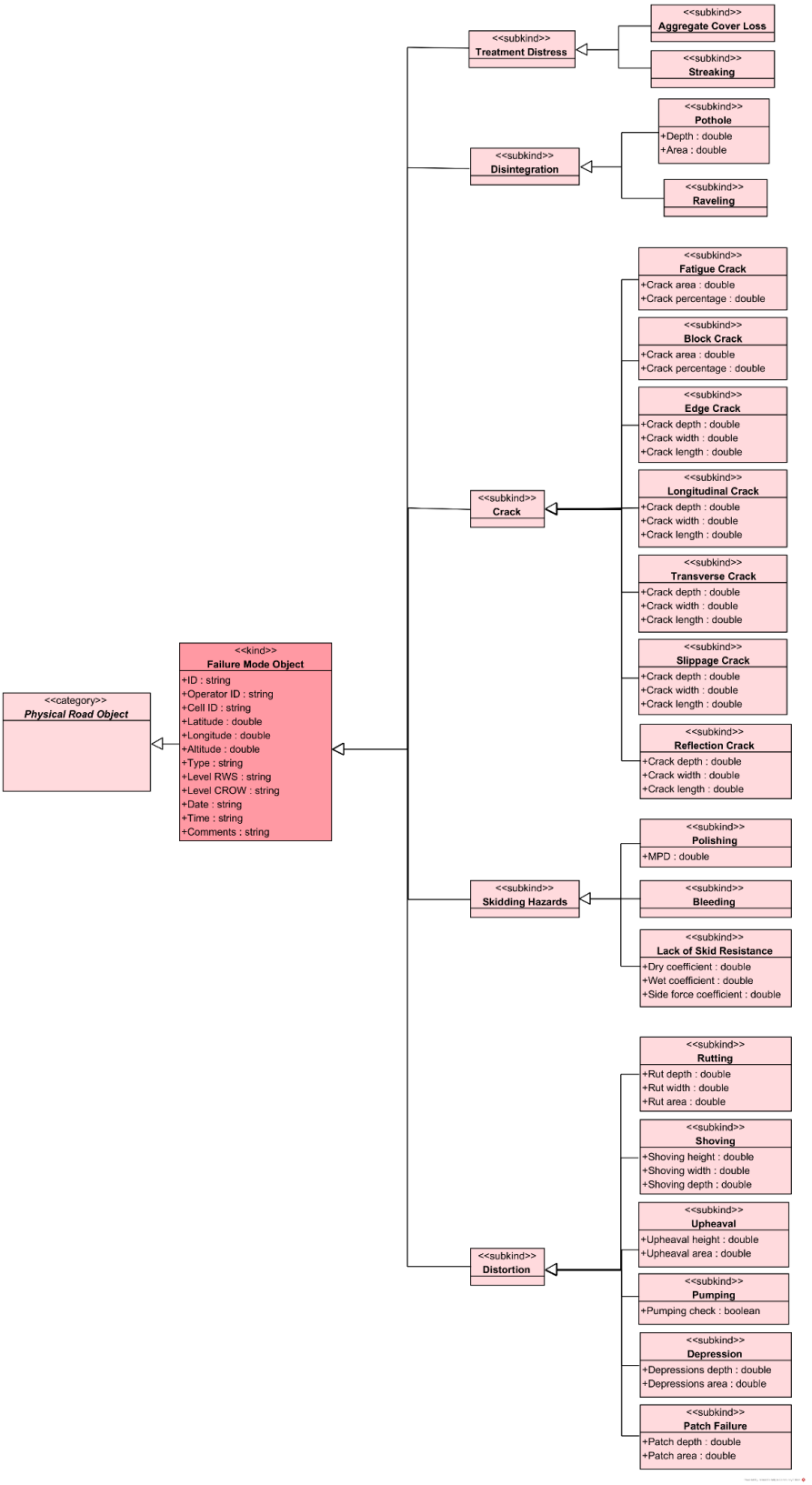


Figure 10. Sub ontology of Pavement Deterioration

The properties of failure mode such as date and location are defined in the Failure Mode Object class (Q16). In addition to these two attributes, the level of the failure mode (based on the classification of Rijkswaterstaat and CROW) has been also added to Failure Mode Object class (Q18). For each type of distress, separated classes have been considered and explained in the previous paragraph (Q17). The key parameters for measuring each failure mode such as area and percentage of fatigue (Q19), length and depth of different cracks (Q20), depth and area of a pothole (Q21), bleeding level (Q22), raveling level (Q23), rut depth (Q24), friction coefficient of dry and wet (Q25), texture depth (Q26), etc, have been extracted based on the literature and interviews. These parameters have been considered in each specific distress class and top class of Failure Mode.

5.5. Pavement Activity Sub Ontology

Activity is a subclass of Lifecycle and all of the activities performed in the lifecycle of a road are incorporated. To better show the developed sub ontology of Activity, the sub-classes of Activity should be first explained. Figure 11 shows that there are four different sub-classes of Design, Construction, Measurement & Testing, and Maintenance activities. To better explain the developed ontology, each activity will be described separately.

5.5.1. Design Activity

In Figure 12, the Design Activity has been divided into three different categories i. The first one is Preliminary Pavement Design. In this activity, the pavement is designed by the client or asset manager. The main reason is that the asset manager makes efforts to realize the preliminary condition of the road before the contractor accepts the road construction project. In this phase and the next phase of Design Activity (which is Final Pavement Design), “Ontwerpinstrumentarium Asfaltverhardingen (OIA)” software is

used. All parameters of the software have been considered in the Preliminary and Final Pavement Design.

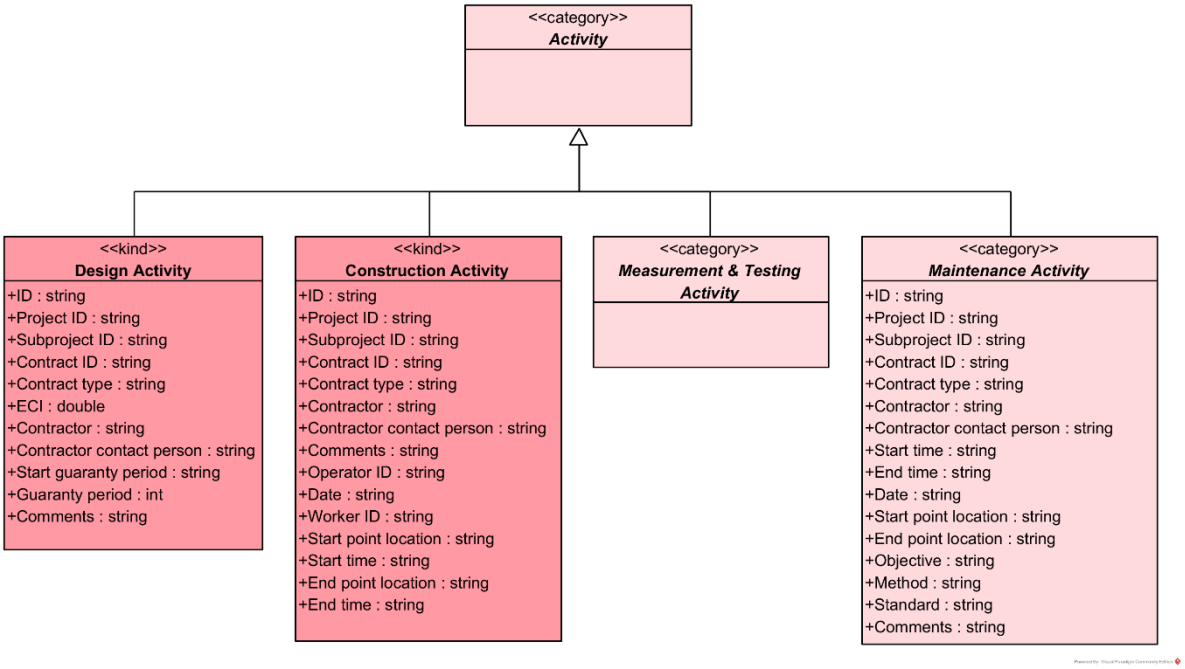


Figure 11. Sub-classes of Pavement Activity.

After finishing the Preliminary Pavement Design by the asset manager, a contractor receives the contract and checks the design, and tries to optimize the design based on the available historical data or new data obtained from laboratories. Then, the new design parameters (which are considered in the Final Pavement Design class) are checked by asset managers for confirmation. After finishing this phase, the design will be sent to the plant for the construction phase. However, parameters of the design should be converted to the parameters that can be implementable. For instance, the stiffness of the mix is defined as 10000 MPa in the Final Preliminary Design, whereas, the exact amount of 10000 MPa is improbable to achieve in plants. Therefore, a degree of tolerance is considered to ease the condition for the construction phase. In this case, the stiffness can be selected as a range of 9500 MPa to 10500 MPa. This phase is called the Construction-ready Design phase. In this phase, all parameters pertinent to the construction phase are changed to align with the practices and methods commonly

used by construction companies. The reason for using phase for the type of three different classes of Design Activity (OntoUML specification) is the mentioned intrinsic relation between them. It means that all of them follow the principle of identity of Design Activity, but there is an intrinsic change between them.

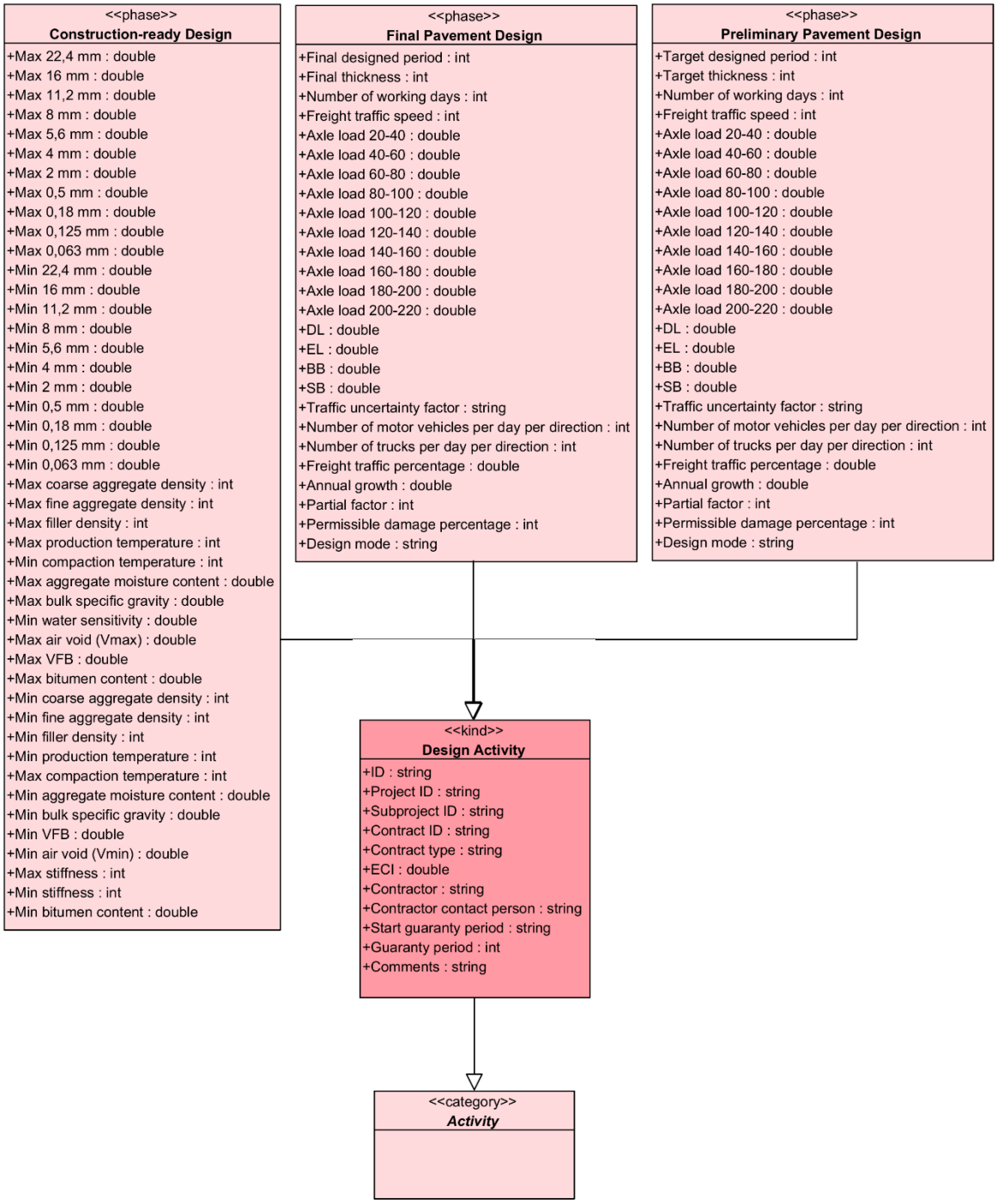


Figure 12. Design Activity class and its sub-classes.

One of the important properties that can affect road quality is the contract features and the contractor. The information regarding the contract such as type, ECI (Environmental Cost Indicator), guaranty period, start of the guaranty period, etc., are added to the class of Design Activity as attributes. Also, the information regarding the contractor such as name and the contact person are considered in this class as well (Q27). Two types of pavement thicknesses (target and final) are considered separately in the Preliminary and Final pavement Design (Q28). The traffic condition considered for different phases of the design are included in the classes (preliminary and final pavement design) and information such as axle load, uncertainty factor for traffic, number of vehicles and trucks per day, etc. are extracted from OIA software (Q29). All the ranges (max and min) needed for manufacturing the pavement in the construction phase (e.g., aggregate grading, density of aggregates, volumetric properties of aggregates, production and compaction temperatures, bitumen content, stiffness, air void, etc.) have been added as attributes to the class of Construction-ready Design (Q30).

5.5.2. Construction Activity

Figure 13 Shows Construction Activity and the sub-classes. Based on the interviews, all activities such as Milling, Cleaning, Delivery, Paving and Compaction for road construction and their properties need to be considered in the Pavement Ontology. The stereotypes used in this activity are similar to the Design Activity.

The information regarding the contract (type) and the contractor such as the name and contact person (Q31), date (Q32), start, end, and time (Q34) of each activity has been considered in the Construction Activity class. It is worth mentioning that these attributes have been added to the parent class and because of generalization relations they are inherited by sub-classes. Each specific construction activity has its own attribute. For

instance, milling has milling width, depth, length, layer, the total number of millers, the total amount of asphalt milled, etc (Q33). These attributes have been selected based on interviews with the construction companies.

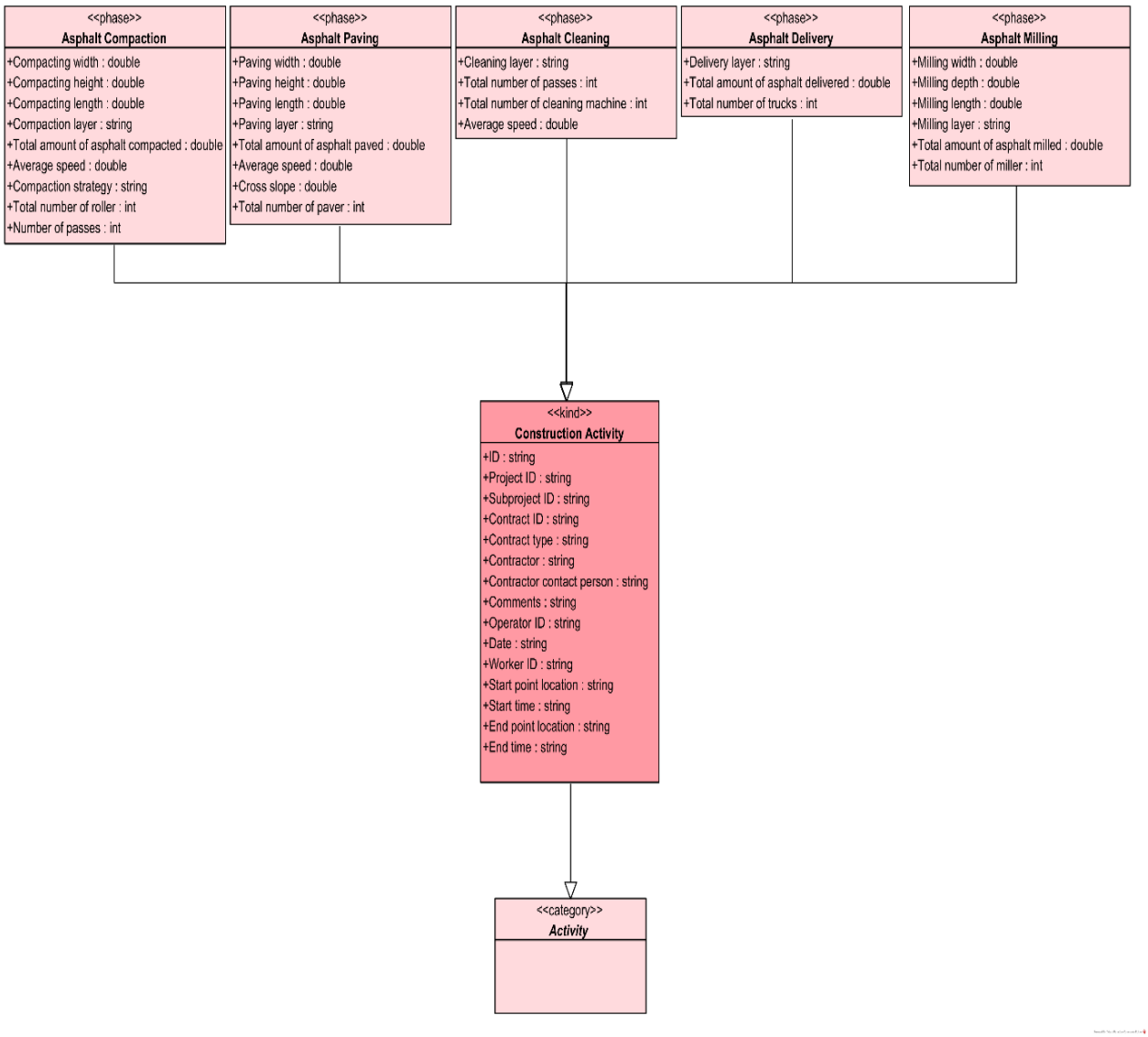


Figure 13. Construction Activity class and its sub-classes

5.5.3. Maintenance Activity

Figure 14 shows the Maintenance Activity class which represents different types of maintenance activities. There is no information for the maintenance phase in the PIM OTL. Therefore, all the required information has been obtained from the literature (Izeppi et al., 2015; Peterson, 1981; Y. Zhang et al., 2016).

There are four different types of pavement maintenance, namely, preventive, corrective, emergency, and contract. The differences between the first three types of maintenance are with respect to time and cost. It means that preventive maintenances are more cost-effective than corrective ones. The emergency and corrective maintenance are largely similar, however, they differ with respect to when they take place. Emergency maintenance should be done immediately because there commonly there are triggered by safety concerns about the road, such as large potholes. Nevertheless, if a failure mode does not pose an immediate danger but it has to be repaired in the future, then it is categorized as a corrective maintenance. The ontology has been developed in a way to be a robust and comprehensive ontology; therefore, relatively new maintenance methods used in the Netherlands are also added to this classification such as spraying rejuvenation (Y. Zhang et al., 2016) and induction healing (Apostolidis & Liu, 2017). The stereotype of each maintenance method has been selected as a subkind. The reason for this is twofold. First, there is no internal intrinsic change to define maintenance as a phase. Second, each maintenance gets the principle of identity from its parent class (the main types of maintenance such as Preventive, Corrective, Emergency and Contract).

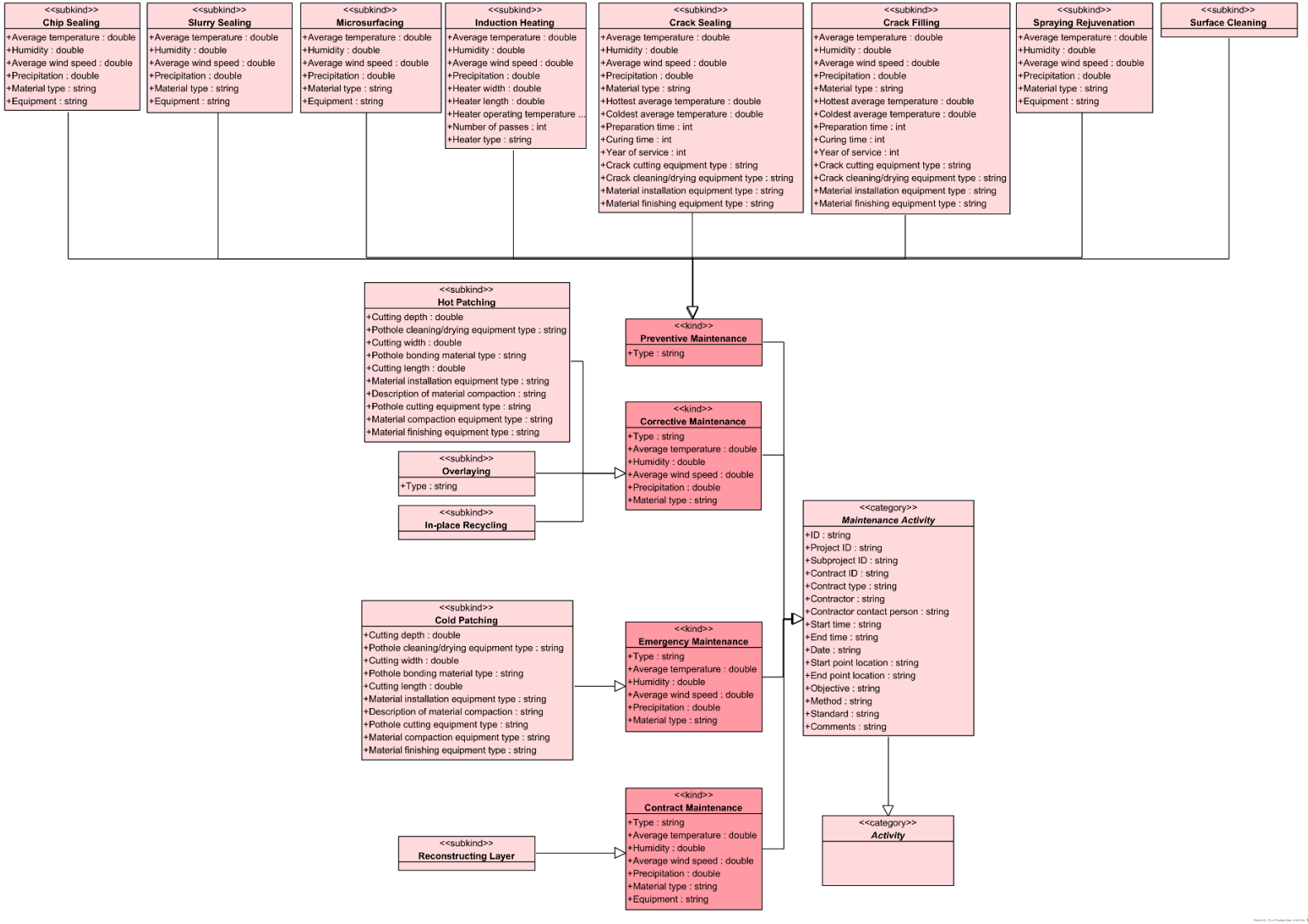


Figure 14. Maintenance Activity class and its sub-classes

Based on the classification used for the maintenance and also attributes considered in the Maintenance Activity class, the type, objective, and method of maintenance used are defined (Q35). The contract and contractor properties such as name, type and contact person are the attributes of Maintenance Activity (Q36). The equipment, material and weather condition have been considered as attributes of each specific class (Q37&38). In addition to the mentioned competency questions, there are many other parameters considered in the classes that are significant for the maintenance activity.

5.5.4. Measurement and Testing Activity

The last sub-class of activity, i.e., Measurement & Testing Activity, has been shown in Figure 15. All activities related to the testing and measuring of any type of data have been placed under this class. This class can be divided into two different classes of Data Collection and Data Analysis. Data analysis is a part of testing and measurement that analyze the data obtained by the Data Collection class. Data Collection is related to all the methods and measurements for collecting data such as laboratory testing, construction measurement (Process Quality improvement (PQi)), operation measurement, and sustainability measurement. All activities related to different asphalt tests have been extracted from the literature (Dave, 2015) and have been added to the Laboratory Testing class. This class can be divided into two classes, namely, Mix and Material Testing. Different types of asphalt materials such as aggregate, bitumen, and additive tests are placed under the Material Testing class. Mix Testing can be classified into two different types of mix tests, performance and mixture characterization testing. Each of these two classes has its own classification (Dave, 2015). It should be mentioned that because attributes are common between these classes, the generalization relation is used.

The pavement ontology also considers the potential link to sustainability assessment. The purpose to consider a Sustainability Measurement class is to indicate the potential of this ontology to be integrated with a Life Cycle Assessment (LCA) ontology, e.g., LCA-oriented semantic representation for the product life cycle (Y. Zhang et al., 2015). This is an example of LCA ontology, the process of producing a product and the interaction of the product with the environment are evaluated and the parameters have been extracted. However, since the integration of the Pavement Ontology with an LCA ontology is not in the scope of this study, it is considered a future work.

In the Construction Measurement class, all of the activities related to the PQi measurements have been considered. PQi methodology is a process cycle to help road contractor to improve the quality of construction by reducing the variability in the construction process. PQi includes the measurement of the weather condition, location of paving equipment (roller and paver), asphalt surface/core temperature, density, and thickness currently not part of PQI mainstream but will be added to the scope of PQi measurement in the future) during the road construction process. All of the measuring activities have been added separately as a sub-class of Construction Measurement. Furthermore, Operation Measurement is a type of measurement conducted after the road construction. This measurement is divided into different measurements of in-use quality, incident, and traffic. For each of mentioned categories, the related measuring strategies have been considered. For instance, In-use quality measurement is divided into invasive and non-invasive methods. As an Invasive method, asphalt coring is considered in the ontology as it is the most frequently used method. As for Non-invasive methods, static and dynamic monitoring methods have been considered (Shtayat et al., 2020). Each of the mentioned non-invasive measurements is then divided into different monitoring systems (Shtayat et al., 2020).

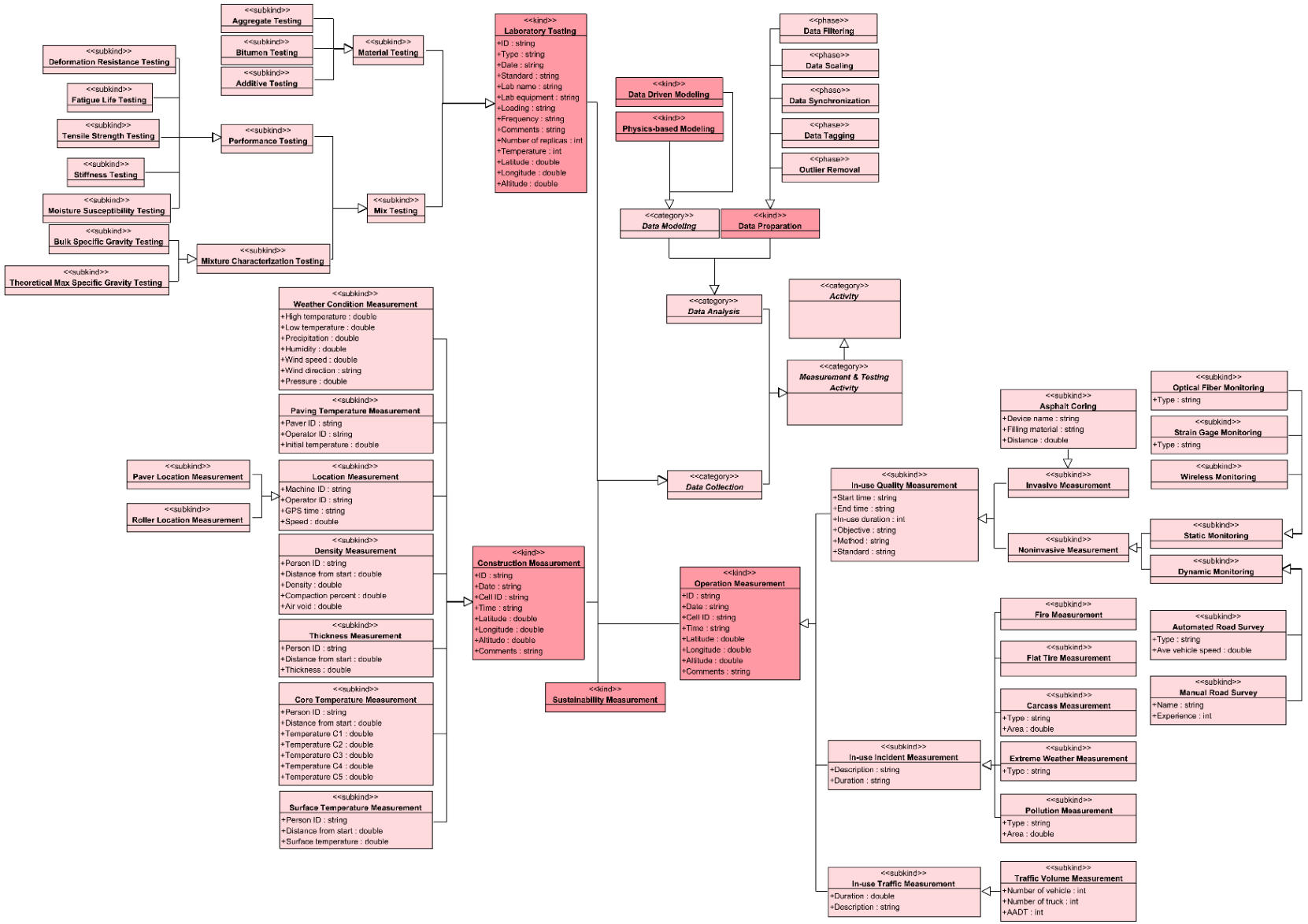


Figure 15. Measurement & Testing Activity class and its sub-classes.

Considering the mapping of the classes in this sub-ontology to the competency questions, it should be noted that all types of laboratory testing have been considered in Laboratory Testing class. For each test, the location of the lab, type of the test, and temperature of the test have been considered as attributes (Q39). PQi data have been added in the sub-classes of Construction Measurement class. For instance, the temperatures C1 to C5 show the core temperature of five different channels used in thermologgers (Q40). The classification of different monitoring has been explained in the above paragraphs (Q41). There is a class called In-use Incident Measurement that encapsulates all incidents such as Fire, Flat tire, Carcass, Pollution, and Extreme Weather (Q42). Based on the attributes and classification, the effect of these incidents in the operation phase is investigated. Number of trucks and vehicles used during the in-use phase are attributes of Traffic Volume Measurement class (Q43). Asphalt coring is an activity that produce different cores. This activity has a location that defines the location of the core. This attribute is obtained from the parent class (Q44).

5.6. Pavement Resource Sub Ontology

Resource is another sub-class of Lifecycle. Figure 16 depicts the structure of this sub-ontology. Person, Machine, Plant, laboratory, and Sensor “are part” of Resource. The stereotype of Resource is a category since it has different kinds as sub-classes. Person is kind and the sub-class of Person, Operator, and Worker are roles. Roller, Paver, Miller, Truck, Cleaning Machine, Material Transferring Vehicle, and Asphalt recycling Train “are part” of Machine class. All of them are sub-kinds of Machinery class as well. There are three different plants Stationary Asphalt Plant (fixed in a place), Semi-stationary Asphalt Plant (plant is transferred and reassembled on the job site), and Mobile Asphalt Plant (mounted on a chassis and can be transferred with road construction site) (Dos Santos et al., 2020). The other classes such as Sensor and

Laboratory have been just considered to be used in the future. Now, both of the classes do not have any attributes. It should be mentioned that the attributes of Machinery have been extracted from the Wirtgen Group website. All of the machines used in road construction are available on this website and the information can be obtained by the type of the machine.

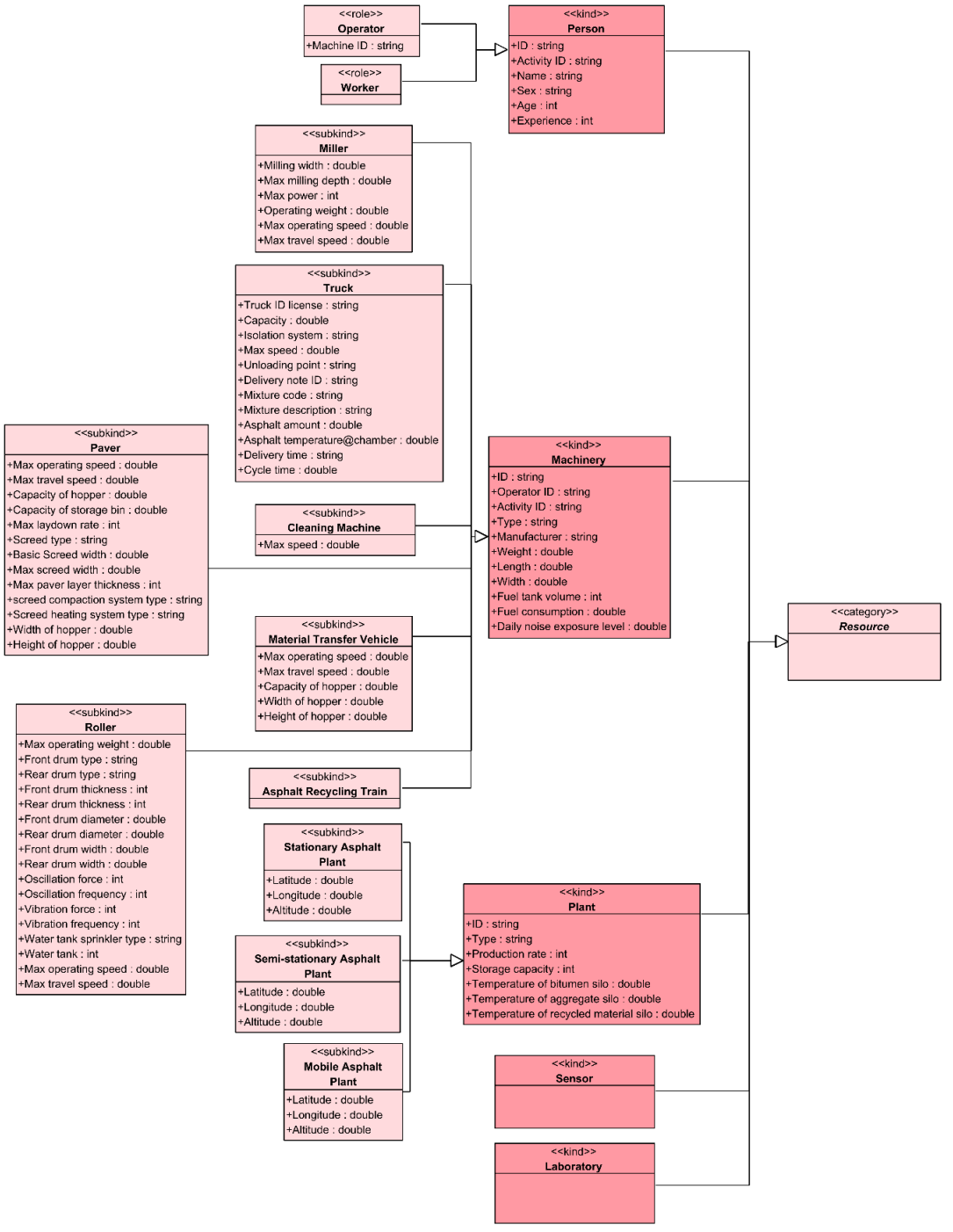


Figure 16. Sub ontology of Pavement Resource.

Based on the classification used in Resource and Machine classes, the type of each machine with the properties is explicit in the ontology (Q45&46). Three types of asphalt plants have been identified by their properties (Q47). In the class of Person, there are some attributes such as experience and age of the person. These attributes are shared with the child classes of Operators and Workers (Q48).

5.7. Pavement Evaluation Sub Ontology

The last sub-ontology is Pavement Evaluation which evaluates the quality of pavement according to the specific parameters in different phases. Figure 17 depicts the last sub-ontology developed in this project. The stereotype of Quality Assessment is a relator and it “has” three different relators as sub-class, namely, Design, Construction, and Operation Quality Assessments. The pattern for the realtor class is explained in the next chapter where the remaining relations are described. Each of the assessment sub-ontologies has its parameters to be used for evaluating each phase. For instance, Reliability (indicators that show whether or not the design considered specific functions such as suitability of new technique and material used in the design, acceptable polishing number for coarse aggregates, etc.), Safety (indicators that show whether or not the design considered safety functions such as skid resistance), Environmental Nuisance (indicators can show whether or not the design considered environmental functions such as reducing noise), Durability (indicators that show whether or not the design considered drapability functions such as ECI), and Future-proofing (indicators that show whether or not the design considered functions for future-proofing such as reusability of material) are the sub-classes of the Design Quality Assessment. The relations between the Design Quality Assessment and each of the mentioned parameters are Characterization since it is a relation between a bearer type and its

feature. It is worth mentioning that features of Design Quality Assessment have been extracted from “Eisen E&C (Bovenbouw)” of Rijkswaterstaat.

The features of Construction Quality Assessment have been obtained from the final results of PQi measurement. As mentioned earlier in the explanation of PQi measurement, the objective of PQi measurement is to reduce variability in the construction process. For example, one of the variability is inhomogeneity of asphalt temperature in paving process which is caused by problems in supply chain or stops in the paving process. This variability has been considered temperature homogeneity. There are some other indicators in this classification such as compaction consistency, compaction efficiency, density and thickness and roughness homogeneity. Finally, the features of Operation Quality Assessment have been obtained based on several interviews with asset managers (Rijkswaterstaat, provinces, and municipalities). The features, whose values are numbers, have been categorized as quality and the others are mode. The features are IRI (International Roughness Index), maintenance year (which is an indicator formulated based on all of the deterioration located in the road), FWD (Falling Weight Deflectometer) and permeability (which is one indicator specially for the porous asphalt to check the permeability of the mix against water drainage).

The first question (Q49) was explained in the above paragraph. The type of IRI used in the ontology is IRI10 (Q50). This is the IRI measured for each 10 m of road and the results are more accurate compared to IRI100.

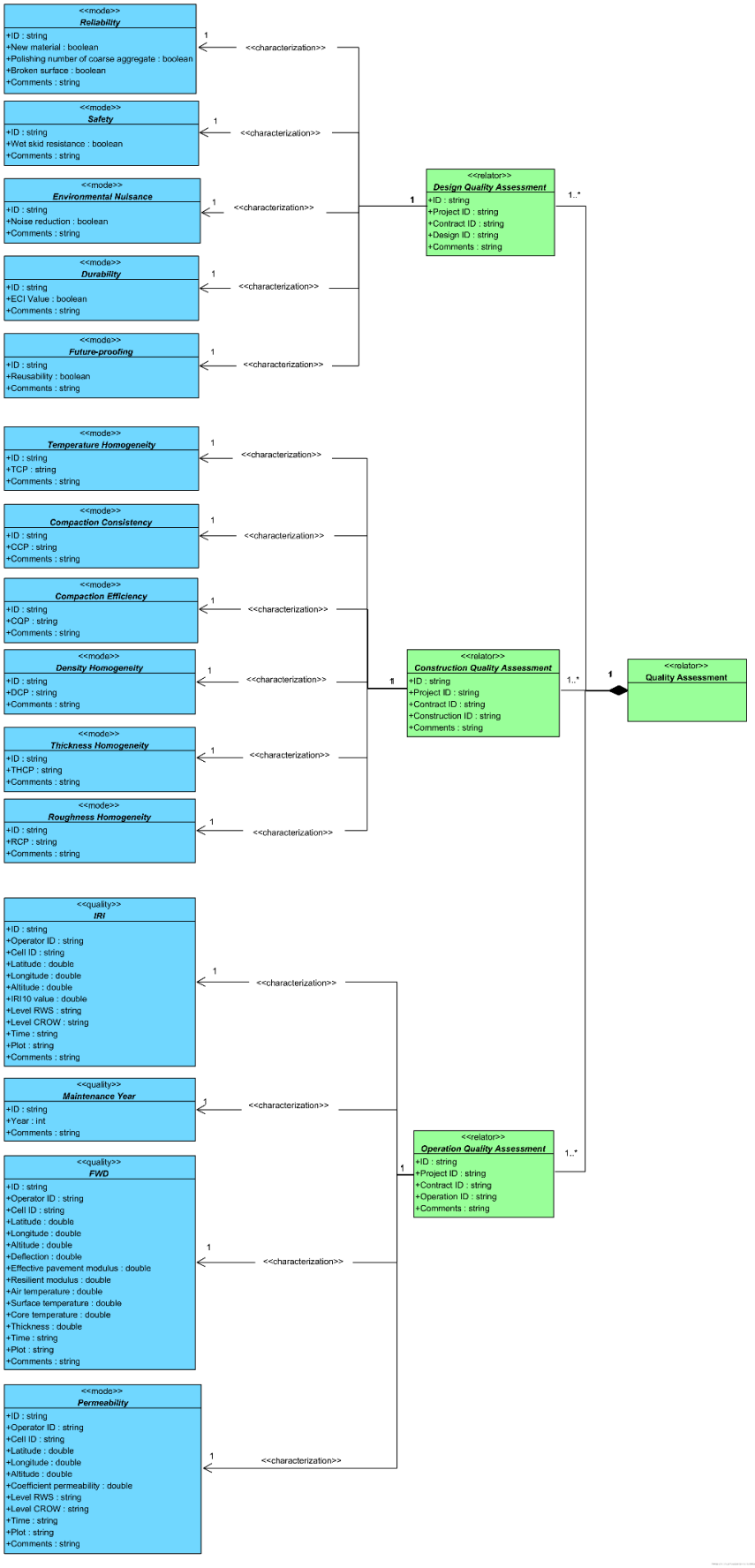


Figure 17. Sub ontology of Pavement Evaluation

5.8. Other Relations and Patterns

In addition to the relations shown in the previous sections, some important relations are depicted in Figure 18.

The first relation is Cell relations. One of the important results of the interviews is that all the measurement data should be collected at a cell level. Therefore, Failure Mode parameters and Data Collection (which consists of different measurements) have been connected to the Cell by Material relations (association) of ”Is_measured _for”. Based on these relations, every failure mode object or data collection is ascribed to at least one cell. In addition to this, the attribute of Cell ID has been assigned for each parameter measured in these two classes (Failure Mode Object and Data Collection). Another material relation has been used for the Failure mode Object class. This association relation showed that the failure mode “Is_measured_by” the class of Measured & Testing Activity (this class consists of different methods for the evaluation of the failure mode such as dynamic and static monitoring). It also shows that every failure mode should be measured by one measurement and testing activity.

There are two association relations for the Activity class. The first one showed that one activity “Requires” at least one Resource to be performed. For instance, one of the sub-classes of the Activity class is Construction Activity, which needs several machines (Resource) such as a paver, roller, and truck. Another Material relation of Activity is that one activity “Requires” at least one Physical Road Object such as asphalt material Since an activity needs to be implemented on material, this relation is captured in the ontology.

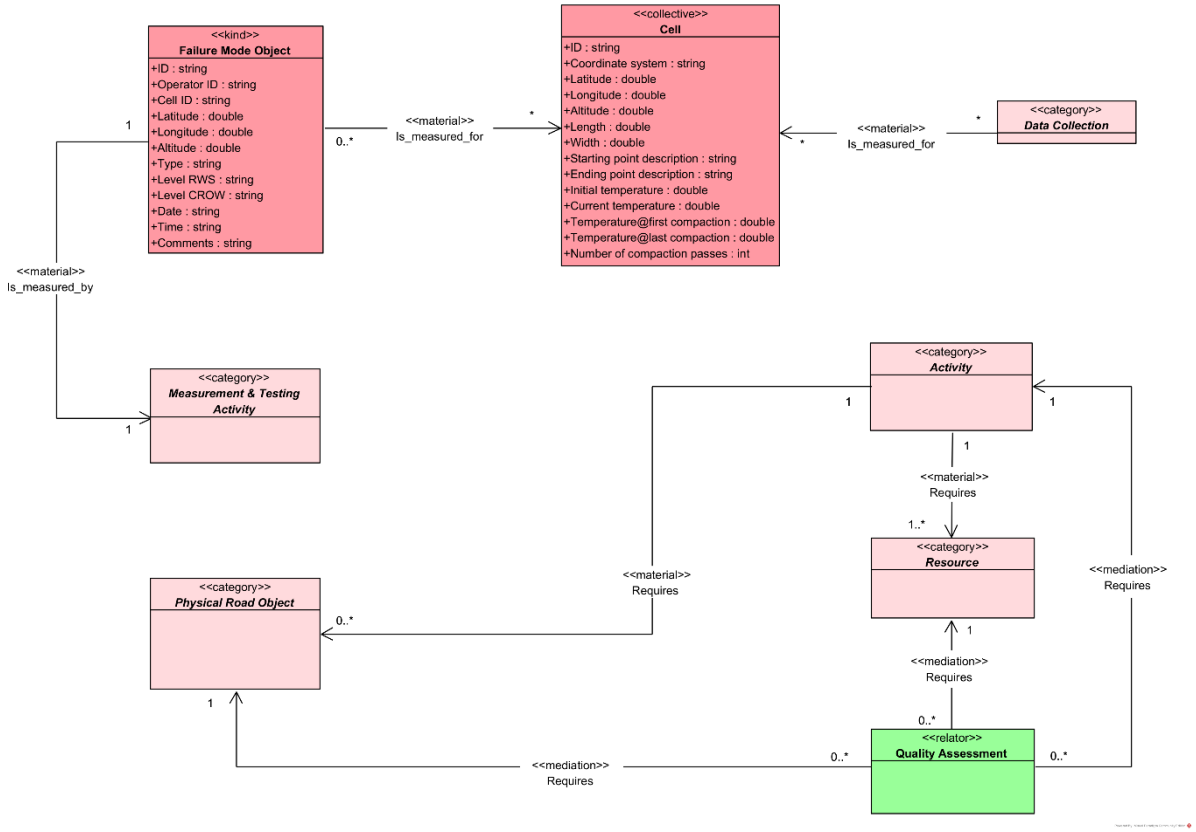


Figure 18. Other relations and patterns

One pattern, which has been used in this ontology, is the relator pattern. The relator is Assessment and for implementing the Quality Assessment, three Mediation relations (association) are required. The Assessment “Requires” to evaluate the process (activity), resources (e.g. the location machines for obtaining the compaction consistency), and physical object (evaluates the material condition). Thus, at least one of three classes should be available for the assessment to be performed.

To sum up, the entire developed ontology has been shown and compared with the related competency questions. In the next chapter, the Implementation and validation of the ontology are presented.

Chapter 6. Ontology Implementation and Testing

This chapter presents the implementation and testing of the pavement ontology. The first step is to verify the ontology based on the criteria of consistency, completeness and redundancy. Then, the implementation and testing of the ontology is explained. Next, the pavement ontology is validated using query and criteria-based evaluation methods.

6.1. Ontology Verification

The first step of testing is ontology verification. As mentioned in Chapter 3, experts in a domain checked the class hierarchy based on the three criteria of consistency (i.e. checking the circularity, partition and semantic errors), completeness (i.e. no missing concepts from the taxonomy) and redundancy (i.e. checking the repetition and definition of concepts) (Gómez-Pérez, 2001; Uschold & Gruninger, 1996). Based on the evaluation, all of the errors in the ontology taxonomy have been revised and there are no errors in the class hierarchy. At the end of this phase, all of the experts rated the ontology ten out of ten in the terms mentioned earlier.

In addition to the mentioned approach, Visual Paradigm software is used to check the syntax errors in the taxonomy. If the wrong type of class or relations is used in the ontology, it will show as a syntax error after checking the model in this software. The final result of ontology proves no syntax error (Figure 19).

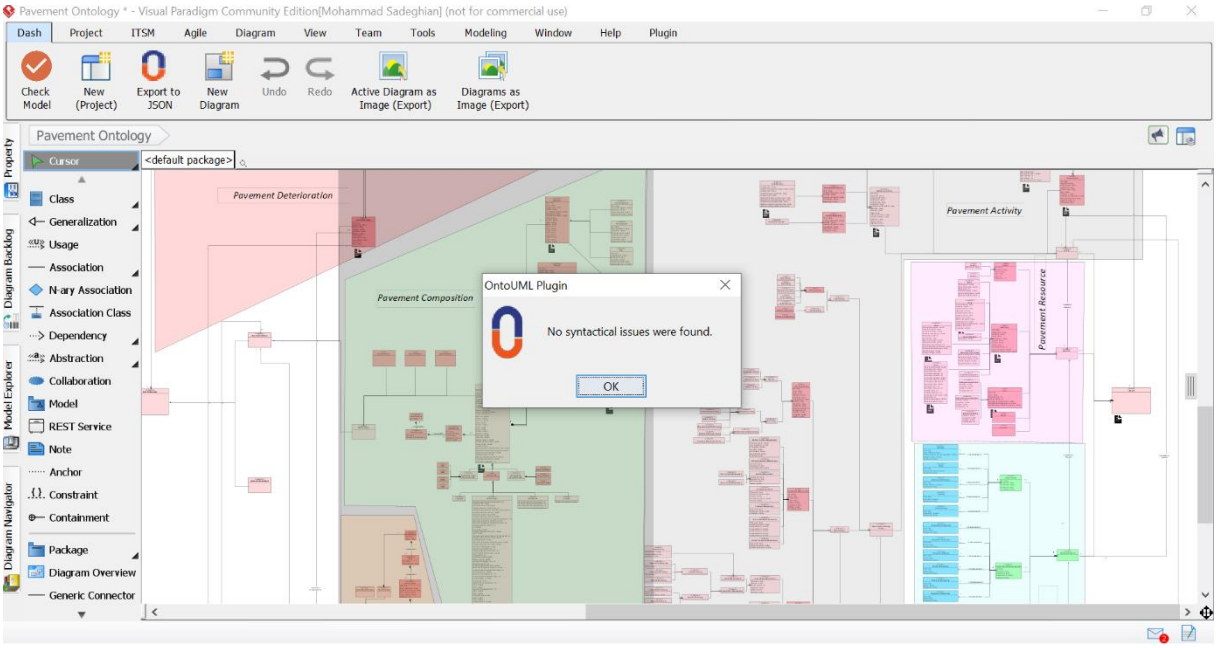


Figure 19. The result of checking model by Visual Paradigm software.

Also, Protégé software can check the ontology based on the consistency criterion. There are some logic reasoners in Protégé such as Pellet, FACT ++ and HermiT. They have been used to check the relationships between different classes in pavement ontology. If the type of the relations used or the semantics used in the class and relations are not correct, the reasoners cannot be run. Since, high-level structure, geometry, deterioration and construction measurement (PQi measurement) have been imported to Protégé software, the consistency between these parts of the ontology has been checked using the mentioned reasoners. It should be highlighted that only small parts of the ontology have been imported for the implementation and query-based evaluation (next section). The reason is that by using OntoUML as a language for presenting the ontology, there are several errors occurred during the import of ontology from Visual Paradigm Software to Protégé. So, due to the fact that complete implementation of the ontology was not in the scope of this study, only some parts of the ontology have been imported. Based on the mentioned methods, the ontology has

been verified. The last verification is required since query-based evaluation can be used only when the reasoner can be run precisely.

6.2. Ontology Validation

The pavement ontology has been validated based on two different approaches. The first approach is evaluating the ontology by making a query (query-based evaluation) and the second approach is validating the ontology based on the experts' idea (criteria-based evaluation). In the next sections, the results from these two approaches are presented.

6.2.1. Query-based evaluation

The implemented ontology has been processed by Protégé software. As mentioned earlier, some parts of the ontology (high-level structure, geometry, deterioration and construction measurement) have been imported to Protégé software. In general, making a query is a request for data results from the available database. For this purpose, DL query plugin has been used. In the DL query plugin, developers have this opportunity to create human-understandable syntax queries.

Making a query is applicable when there is a database. Thus, either an actual database has to be used or a random/hypothetical database should be created for this purpose. Since no actual databases were used in the Pavement Ontology, a hypothetical database was created. Protégé software has the capability of defining instances for the classes. Therefore, several instances have been created for imported ontology. As shown in geometry sub ontology, Cell is the smallest part of the road geometry. Ten different cell instances have been created. Also, because the objective of the query is to show the meaningful relations between the phases of the lifecycle, the other instances are reveling level (parameters of failure mode and operation phase of

lifecycle) and compaction efficiency (parameter of PQi measurement and construction phase).

Needless to say that deficient construction process such as compacting the road pavement outside the temperature window or not reaching the target number of roller passes can reduce the quality of asphalt. The area with such deficiencies can be more prone to failure in the future. The scenario for this query is extracted from this fact. Therefore, the scenario is to check whether or not less compaction efficiency (i.e., not having appropriate compaction inside the temperature window) can induce serious raveling deterioration (raveling levels of 3 or 4).

The scenario assumes that the compaction efficiency and raveling of the road are stored in different databases structured according to the proposed ontology. Table 8 shows the hypothetical data created for this scenario.

Table 8. Instances created for the query-based evaluation

Cell No	Ravelling Level
1	4
2	2
3	1
4	2
5	3
6	3
7	4
8	3
9	2
10	1

Cell No	Compaction Efficiency (%)
1	42
2	67
3	70
4	62
5	50
6	58
7	41
8	59
9	62
10	75

The query asks for “the cell number that has compaction efficiencies of 41 and 42 and the raveling level of 4”. Based on the relations defined between the important parts of the ontology, meaningful results are represented. Based on the results shown in Figure 20, cell numbers 1 and 7 have compaction efficiencies of 41 and 42 percentages and also raveling level of 4. This means that based on the complete taxonomy and comprehensive relations defined between the different phases of the lifecycle, several

meaningful queries can be made from the results in the future database and the ontology can be used to increase the quality of the pavement lifecycle.

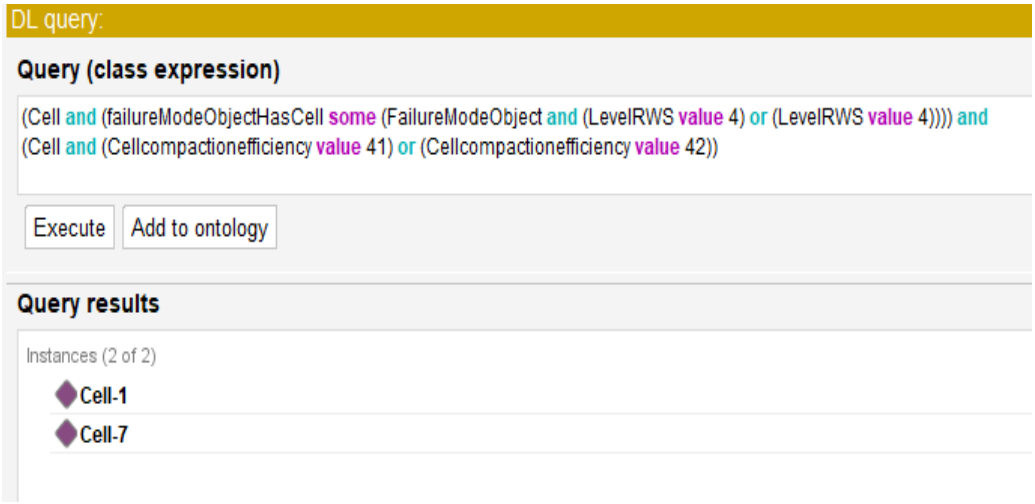


Figure 20. The result of making a query from Protege software.

6.2.2. Criteria-based evaluation

It had been planned to have a physical workshop and explained the ontology to the experts and then, asked them to rate the ontology based on the questions. However, it was difficult to find one date and time when most of the experts can participate. Therefore, an online survey has been held instead of a physical workshop. 24 experts have rated the ontology. The profile of the experts is shown in Table 9.

Table 9. The respondents' profiles

Number of respondents	Area of expertise	Years of experience (total)
2	Road design	40
6	Road construction	112
2	Road Maintenance	19
2	Road testing	17
4	Asset management	72
4	Information modeling	25
4	Ontology researcher	17

The distribution of responses is shown in Table 10 and Table 11. Table 10 shows the responses for questions 2 to 17 and because the question 18 is about the comparison of the developed ontology with PIM, it has shown in a different table (Table 11).

Table 10. Distribution responses for Questions 2 to 17

Q. No.	Type	Result				
		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
2	Classification of failure mode	28%	52%	20%	0%	0%
3	Classification of pavement composition	24%	56%	20%	0%	0%
4	Classification of road geometry	32%	40%	20%	4%	4%
5	Classification of lifecycle activity	16%	48%	28%	8%	0%
6	Classification of lifecycle resource	8%	44%	44%	4%	0%
7	Classification of lifecycle assessment	16%	44%	40%	0%	0%
8	Clarity	12%	40%	44%	4%	0%
9	User-friendliness	20%	60%	16%	4%	0%
10	Conciseness	20%	40%	40%	0%	0%
11	Accuracy	28%	44%	28%	0%	0%
12	Relation comprehensiveness	13%	29%	54%	4%	0%
13	Extensibility	29%	46%	25%	0%	0%
14	Applicability	32%	41%	9%	18%	0%
15	Scalability	32%	41%	27%	0%	0%
16	Organizational fitness	23%	45%	32%	0%	0%
17	Implementation	18%	41%	27%	14%	0%

Table 11. Distribution responses for Question 18

Q. No.	Type	Result				
		Much better	Better	Neutral	Worse	Much worse
18	PIM comparison-Accuracy	0%	9.1%	86.4%	4.5%	0%
	PIM comparison-Comprehensiveness	0%	13.6%	81.6%	4.5%	0%
	PIM comparison-Clarity	4.5%	13.6%	72.7%	9.1%	0%
	PIM comparison-Scalability	13.6%	4.5%	81.8%	0%	0%
	PIM comparison-Extensibility	9.1%	13.6%	77.3%	0%	0%

Questions 2, 3, 4, 5, 6 and 7 show the classification of failure mode, pavement composition, road geometry, lifecycle activity, resource and assessment. Around 70 percent of respondents agreed that the classifications used for these sub ontologies are extensive. The majority of the rest are neutral about these parts. The reason for this is the difference between the expertise of the respondents and the scope of the question. This has been mentioned frequently in the comments by the respondents. The same pattern happens for the other questions as well. However, there are three questions that need to be examined precisely. Question 12 (relation comprehensiveness) showed the importance of cell as the smallest part of the road and indicated that every measurement during the lifecycle of pavement should be done for cell instead of lane segment, for example, measuring the depth of a crack should

be done for cell. However, 54% of the respondents were neutral and mentioned that they have difficulty understanding this relation since and cell might not be an efficient option. For instance, they stated that a crack can be and should be measured for a wider context (such as lane segment) than cell. It seems the respondents missed the point. Going to the level of detail of the cell does not mean that they need to collect all measurement data at this level. It means regardless of the resolution of the data collection, it has to be stored and structured at the cell level. In the example mentioned, the crack measurement can very well be at the lane segment level. But, it means all the cells involved in that segment would have the same (scalded) data for cracks.

Questions 14 and 17 (applicability) and (implementation) are two questions with higher percentages of disagreement (18% and 14% respectively). The comments on these two questions clarified that the disagreed respondents are afraid that too many works need to be done for application and implementation since the developed ontology has not followed NEN 2660. NEN 2660 is standard for information modeling of built environments. The developed pavement ontology has not followed NEN due to a reason. The ontologies are developed with the standard should follow a bottom-up approach. It means that the ontology should be developed based on the current data that can be measured and collected. However, there are some important data in the lifecycle that cannot be measured or collected right now and they have a significant effect on the lifecycle such as the density of the entire road (not only one point in each 100-meter) after compaction. In this study, the objective was to develop a comprehensive ontology; therefore, top-down approach has been selected to develop the comprehensive and future-proof ontology.

The last questions are the comparison between the developed ontology and PIM. The most important point is that most of the respondents mentioned that they are neutral

when they compared the developed ontology. This is significantly important because most of the respondents who were just users of PIM were neutral but if we separate the PIM developer teams that consist of experts in the road construction sector and also ontology developers clearly stated the robustness of the ontology against PIM in accuracy, comprehensibility, scalability, extensibility and clarity criteria.

To sum up, the evaluation chapter showed the effectiveness of SABiO in developing this ontology. Also, it indicated that the pavement ontology is capable to give a clear, comprehensive and accurate understanding of concepts and relations in the domain. Furthermore, the respondents showed that ontology can be favorably used for the application in integrating and exchanging different data in the road sector.

Chapter 7. Discussions and Conclusions

7.1. Project Summary

This design research tried to address a widespread fragmentation within the industry both across different players, e.g., clients and contractors, and across different phases, e.g., design and construction. This causes considerable rework, information loss, and inability to perform correlational analysis to identify hidden relationships between different decision variables and long-term pavement quality indicators. To this end, a comprehensive ontological model was developed for pavement projects considering the entire lifecycle in order to establish a more consistent structure for data collection, storage, and management. This ontology can be used to improve interoperability between fragmented systems used in the current practice. To achieve this objective, the main stakeholders of the project were identified and their requirements were considered.

After identifying the requirements (structural and functional), the concepts and relations of the pavement lifecycle have been extracted based on the functional requirements (competency questions). Then, the concepts and relations have been represented by using OntoUML conceptual language modeling.

Finally, the represented ontology has been verified and validated. For this purpose, an expert checked the taxonomy based on the criteria of consistency, completeness and redundancy. Then, the verified ontology has been validated by using two approaches, query- and criteria-based evaluation. The results indicated that the pavement ontology is capable to give a clear, comprehensive and accurate understanding of concepts and relations in the domain.

7.2. Discussions

The ontology developed in this study was designed for widespread use in the pavement lifecycle. Contractors and clients are the two main users of this ontology. Also, the ontology was developed to consider the needs of third parties in the Netherlands. Different third parties such as road testing and monitoring companies, research centers, consultant companies, etc. can use the ontology to structure their data management.

The developed ontology can be used for theoretical and fundamental research on the behavior of asphalt pavement. That means the complex correlations that can be better studied that are in play between different phases of the asphalt pavement lifecycle.

Since Digital Twin (DT) is becoming a major buzzword in the industry, it should be noted that the gateway to successful DT implementation in the pavement sector is ontology. It is through the use of ontology that true network-level representation and analysis can be made. DT requires cross-phase, cross-player, and cross-industry data exchange. This cannot be achieved without ontology.

The method used for developing this ontology proved to have significant effects on the future of data management in the Netherlands. Based on the results of the online survey, due to the comprehensive and complete taxonomy of the pavement ontology, road stakeholders are willing to use the ontology to identify their missing data. In general, the ontology can act as a reference for the users to identify important data and improve contractors' and asset managers' databases. But, it is worth mentioning that using this ontology does not mean that contractors should use the same databases or systems. Existing data management systems can still be used. The use of ontology in many cases can be facilitated by simple tweaking or middleware/data translators.

Also, the ontology can be used to align the different contractors in the Netherlands. Due to the results of interviews, it was confirmed that the level of the contractors is not the same. There are some big companies with advanced technologies and the ability to collect and store data with accurate resolution. On the other hand, there are some small companies that have not invested in advanced technologies. These companies tend to save the data based on their current approaches. For improving the quality of the entire Dutch road network, all the parties in the road construction sector need to have a better understanding of the pavement behavior throughout its lifecycle. To elaborate, companies (small and big companies) have different understandings and the data collected and stored by them is not consistent, and cannot be used to evaluate the entire Dutch road network. To better investigate pavement behavior, the developed reference ontology can help them to realize the important data and pave the way to change the approach of companies (approach regarding the data storage and exchange) for aligning in one direction which is having a database which consists of all important data in the entire pavement lifecycle. Therefore, the first step for each party involved in the pavement lifecycle is to check the relations and find the important data in this developed ontology, Then, the comparison between the important data defined by the ontology and the database stored by the parties can help them to develop a more robust database for the future.

Also, PIM has limited scope and it has not developed to be comprehensive and complete (it is not a future-proof ontology). First, the ontology can be used to complete the PIM data structure since there are some important data that are missing in the PIM and they have significant effects on the pavement lifecycle such as aging. Furthermore, PIM has only focused on the information of as-built pavement (not entire phase of

pavement lifecycle) and if there will be any extension for the future of PIM scope, the developed ontology can be a reference.

7.3. Conclusions and Future Work

By revisiting the objective of this design project, it can be concluded that the developed ontology is indeed a comprehensive ontology for the entire lifecycle. All of the competency questions (50 questions) have been answered and shown in chapter 5. This means that all of the functional requirements determined for the project have been taken into account. The structural requirements identified have been checked by the expert idea in the validation of the ontology (criteria-based evaluation) and it showed promising results.

Although this project showed the potential of ontological development in the pavement lifecycle, still there is much room for improvement and future work. First, implementing the ontology has been done only for small parts of the ontology due to the limited time. Fully implementing the ontology with one machine-readable language such as OWL is required for the future. Also, due to the scope of the research, only asphalt material has been considered as the main material used in the road infrastructure; however, different types of granular, concrete and composite materials are used in the pavement structure.

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Appendix

Since the Appendix of the project is quite long, it has been prepared in a separate file.

Samenvatting

Ontologische modellering (ook wel semantische modellering genoemd) is gebruikt om het probleem van interoperabiliteit en informatiestructuur in verschillende domeinen aan te pakken. De levenscyclus van wegverhardingen is een valide voorbeeld dat lijdt onder verschillende problemen van data-interoperabiliteit en -integratie. Momenteel wordt informatie over de levenscyclus van wegverhardingen verzameld over een lange periode en door verschillende partijen die verschillende systemen gebruiken. De versnippering van informatie en het ontbreken van een gestructureerd informatiesysteem maakt het beheer van verhardingen vatbaar voor aanzienlijk herwerk, informatieverlies, beoordelingsfouten, verkeerde interpretatie van de informatie, enz. Om uit te werken, waardevolle data over het bouwproces worden zelden overgedragen aan de volgende fasen van de levenscyclus van de wegverharding. Hetzelfde geldt voor de meeste IT-systemen (Information Technology) die zijn ontwikkeld om het ontwerp en onderhoud van trottoirs te ondersteunen. Het gebrek aan interoperabiliteit, d.w.z. naadloze uitwisseling van data tussen systemen, kan leiden tot schade en verlies van data, evenals toename van de kosten en tijd voor verschillende partijen. Daarom maakt de afwezigheid van een gestructureerd informatiesysteem het moeilijk om de levenscyclusimpact van verschillende beslissingen in verschillende fasen van het wegdekleven op de algehele kwaliteit van het wegdek te onderzoeken. Dit komt omdat dit type onderzoek statistische correlatieanalyse vereist op een database die homogeen en gestructureerd is.

Het ontbreken van een dergelijke ontologie heeft bijgedragen tot een wijdverspreide versnippering binnen de industrie, zowel over verschillende spelers, bijvoorbeeld opdrachtgevers en aannemers, als over verschillende fasen, bijvoorbeeld ontwerp en constructie. Dit veroorzaakt veel herwerk, informatieverlies en het onvermogen om

correlationele analyses uit te voeren om verborgen verbanden tussen verschillende beslissingsvariabelen en indicatoren voor de kwaliteit van het wegdek op de lange termijn te identificeren. Daarom is het hoofddoel van deze studie het ontwikkelen van een alomvattend ontologisch model voor wegverhardingsprojecten waarbij rekening wordt gehouden met de gehele levenscyclus om een meer consistente structuur voor dataverzameling, -opslag en -beheer tot stand te brengen. Deze ontologie kan worden gebruikt om de interoperabiliteit tussen gefragmenteerde systemen die in de huidige praktijk worden gebruikt, te verbeteren.

SABiO is een systematische aanpak voor het bouwen van ontologieën die wordt gebruikt voor het ontwikkelen van de ontologie. In de eerste fase van deze ontwikkeling zijn ongeveer 20 interviews gehouden om behoeften en doelen te bepalen en vervolgens de vereisten voor de ontologie. In de volgende fase zijn de concepten en relaties van de verhardingsontologie geïdentificeerd. Voor het weergeven van de ontologie is OntoUML gebruikt als conceptuele modelleringstaal en de ontologie is weergegeven in Visual Paradigm-software. De weergegeven ontologie is geïmplementeerd en getest met behulp van experts (waardering op basis van criteria) en de evaluatie op basis van “query-gebaseerde” vragen.

De resultaten gaven aan dat de wegverhardingsontologie in staat is om een duidelijk, alomvattend en nauwkeurig begrip te geven van concepten en relaties in het domein. Bovendien toonden de respondenten aan dat ontologie gunstig kan worden gebruikt voor de toepassing bij het integreren en uitwisselen van verschillende data in de wegenbouw sector.

De ontwikkelde ontologie kan gebruikt worden om datamanagement in de levenscyclus van verhardingen te structureren. De belanghebbenden van de levenscyclus van wegverhardingen kunnen ontologie gebruiken om de belangrijke

data te identificeren en hun huidige benadering van opslag van dataverzameling te verbeteren.

DEVELOP AN ONTOLOGY FOR PAVEMENT LIFECYCLE MANAGEMENT

EngD Thesis Appendix

in the Department of Civil Engineering
21 June 2023

by

Mohammad Sadeghian

born on the 26th August 1994
in Tehran, Iran

This EngD Thesis has been approved by:

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Type:	Final Thesis for the degree of Engineering Doctorate
Project:	Develop an Ontology for Pavement Lifecycle Management
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Appendix I

Table. Similarities between SABiO and design science approach.

Number	SABiO	Design science engineering
1	Knowledge acquisition process	Knowledge context
2	Ontology purpose identification	Social context
3	Requirements elicitation	Requirement engineering
4	Testing the ontology	Treatment validation
5	Iterative process	Iterative process

Appendix II

Table. Interviewee information for identifying ontology concepts and relations.

No.	Interviewee Name	Interviewee Company	Interviewee Position
1	Denis Makarov	Boskalis	Advisor
2	Berwich Sluer	Boskalis	Research and quality manager
3	Jasper Keizer	KWS	Research project leader and road advisor
4	Simon Jorritsma	KWS	Durability advisor
5	Joost Alleman	KWS	Road engineer
6	Daan Heijster	KWS	Road advisor
7	Allart Bosch	Volker Infra Asset Management	Maintenance engineer
8	Wouter Heijsser	Heijmans Infra B.V.	Program manager of asphalt paving
9	Lorenzo van Wijngaarden	Heijmans Infra B.V.	Asphalt technologist
10	Martijn van Lieshout	Heijmans Infra B.V.	Maintenance engineer
11	René Mevissen	Heijmans Infra B.V.	Design & Delivery Coordinator
12	Joost van Pelt	Heijmans Infra B.V.	Pavement designer
13	Annemieke Vogel	Heijmans Infra B.V.	Product owner and data architect
14	Wouter Bosch	Bam	Maintenance Manager
15	Johan Eijzinga	Bam	Maintenance Manager
16	Maurits Koenders	Dusseldorp	Pavement designer
17	André Houtepen	Gemeente Rotterdam	Advisor of paving and road construction materials
18	Sylvia Drok	Rijkswaterstaat	Road construction advisor
19	Rutger Krans	Rijkswaterstaat	Program manager of road maintenance
20	Bram Vreugdenhil	Rijkswaterstaat	Technical Manager at Rijkswaterstaat

21	Redmer Kronemeijer	CROW	Data architect
22	Rik Opgenoort	CROW	Data architect

Appendix III

Table. Items name, type, description, source and lifecycle phase of composition sub-ontology.

Item name	Type of item	Description of item	Source of item (applications or literature)	Life cycle phase
Road Pavement	Class	Road pavement is the structure of a road and is a superclass for all of the terms	PIM	
Pavement Layer	Class	Pavement is composed of different layers	PIM	
Asphalt Layer	Class	One type of pavement layer is the asphalt layer	PIM	
Asphalt Mixture	Class	The composition of the asphalt materials makes the asphalt mixture; the mixture is the actual asphalt mix that is used for constructing a new construction project	PIM	
Aggregate	Class	Aggregate is one type of asphalt material that is used for asphalt mixture production	PIM	
Coarse Aggregate	Class	Coarse aggregate is one type of aggregate	PIM	
Fine Aggregate	Class	Fine aggregate is one type of aggregate	PIM	
Filler	Class	Filler is one type of aggregate	PIM	
Bitumen	Class	Bitumen is one type of asphalt material that is used for asphalt mixture production	PIM	
Additive	Class	Additive is one type of asphalt material that is used for asphalt mixture production	PIM	
Recycled Materials	Class	Recycled material is one type of asphalt material that is used for asphalt mixture production	PIM	
Recycled Bitumen	Class	Recycled bitumen is the old bitumen of the recycled materials	PIM	
Recycled Aggregate	Class	Recycled aggregate is the old aggregate of the recycled materials	PIM	
Temperature-based Classification	Class	Classifying the asphalt mixture based on the production temperature	Literature	
Grading-based Classification	Class	Classifying the asphalt mixture based on the mix gradation	Literature	
HMA	Class	Hot Mix Asphalt is one type of asphalt Mixture that is produced at temperature of 140-180 °C	Literature	
WMA	Class	Warm Mix Asphalt is one type of asphalt Mixture that is produced at temperature of 100-140 °C	Literature	

HWMA		Class	Half Warm Mix Asphalt is one type of asphalt Mixture that is produced at temperature of 60-100 °C	Literature	
CMA		Class	Cold Mix Asphalt is one type of asphalt Mixture that is produced at ambient temperatures	Literature	
Dense-graded Mix		Class	Dense-graded Mix is a well-graded mix	Literature	
Gap-graded Mix		Class	Gap-graded Mix is designed to max deformation resistance and durability	Literature	
Open-graded Mix		Class	Open-graded Mix is designed to be water permeable	Literature	
Class name	**Attribute of the class**	**Type of attribute**	**Description of attribute**	**Source of attribute (applications or literature)**	**Life cycle phase**
Asphalt Layer	ID	String	Unique identifier (code) for the asphalt layer	PIM	
Asphalt Layer	Project ID	String	Unique identifier (code) for the project	PIM	
Asphalt Layer	Type	String	The type of asphalt layer which can be surface, binder and base layer	OIA	
Asphalt Layer	Number of lanes	Integer	Number of lanes per direction	OIA	
Asphalt Layer	Width (m)	Double	The width of each lane	OIA	
Aggregate	ID	String	Unique identifier (code) for the aggregate	PIM	
Aggregate	Type	String	Type of aggregate used for road construction project	Literature	
Aggregate	Source name	String	The source name of aggregate used for road construction project	Literature	
Aggregate	Nominal Maximum Aggregate Size (NMAS)	Double	Nominal Maximum Aggregate Size (NMAS) used for road construction project	PIM	
Aggregate	Los Angeles abrasion (%)	Double	Los Angeles abrasion which is used for aggregate toughness and abrasion resistance measurement	PIM	
Aggregate	Soundness (%)	Double	The durability of aggregate against the weather is measured by soundness test	Literature	
Aggregate	Polished stone value (%)	Double	The resistance against the polishing of vehicle tyre	Literature	
Aggregate	CaO (%)	Double	The oxide content of CaO in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	Fe2O3 (%)	Double	The oxide content of Fe2O3 in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	SiO2 (%)	Double	The oxide content of SiO2 in aggregate, XRF(X-Ray Fluorescence) test	Literature	

Aggregate	Al2O3 (%)	Double	The oxide content of Al2O3 in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	MgO (%)	Double	The oxide content of MgO in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	MnO (%)	Double	The oxide content of MnO in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	P2O5 (%)	Double	The oxide content of P2O5 in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	TiO2 (%)	Double	The oxide content of TiO2 in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	SO3 (%)	Double	The oxide content of SO3 in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	Na2O (%)	Double	The oxide content of Na2O in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	K2O (%)	Double	The oxide content of K2O in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Aggregate	Others (%)	Double	The oxide content of others in aggregate, XRF(X-Ray Fluorescence) test	Literature	
Coarse Aggregate	ID	String	Unique identifier (code) for the coarse aggregate	PIM	
Coarse Aggregate	Flat and Elongation (FE)	Double	FE measures the dimension ratio of the coarse aggregate	Literature	
Coarse Aggregate	Angularity (%)	Double	The test measures the angularity of the coarse aggregate	Literature	
Coarse Aggregate	Water absorption (%)	Double	The test measures the water absorption of the coarse aggregate	Literature	
Coarse Aggregate	Bulk specific density (g/cm3)	Double	Bulk specific density of coarse aggregate	PIM	
Fine Aggregate	ID	String	Unique identifier (code) for the fine aggregate	PIM	
Fine Aggregate	Angularity (%)	Double	The test measures the angularity of the fine aggregate	Literature	
Fine Aggregate	Sand equivalent	Double	The ratio of sand reading to clay reading	Literature	
Fine Aggregate	Water absorption (%)	Double	The test measures the water absorption of the fine aggregate	Literature	
Fine Aggregate	Plasticity index	Double	The plasticity index of fine aggregate	Literature	
Fine Aggregate	Plastic limit	Double	The plasticity limit (PL) of fine aggregate	Literature	

Fine Aggregate	Liquid limit	Double	The liquid limit (LL) of fine aggregate	Literature	
Fine Aggregate	Bulk specific density (g/cm3)	Double	Bulk specific density of fine aggregate	PIM	
Filler	ID	String	Unique identifier (code) for the filler	PIM	
Filler	Plasticity index	Double	The plasticity index of the filler	Literature	
Filler	Plastic limit	Double	The plasticity limit (PL) of filler	Literature	
Filler	Liquid limit	Double	The liquid limit (LL) of filler	Literature	
Filler	Bulk specific density (g/cm3)	Double	Bulk specific density of the filler	PIM	
Filler	Calcium hydroxide	Double	The measured content of calcium hydroxide in filler	PIM	
Bitumen	ID	String	Unique identifier (code) for the bitumen	PIM	
Bitumen	Source name	String	The source name of bitumen used for road construction project	Literature	
Bitumen	Bitumen grade	String	The PG grading of the bitumen	PIM	
Bitumen	Penetration@25 °C (0.1mm)	Integer	The test measures the hardness or softness of used bitumen for road construction project	PIM	
Bitumen	Softening point (°C)	Double	Softening point is a temperature at that bitumen softens (bitumen)	PIM	
Bitumen	Penetration index	Double	PI measures the behavior of bitumen against the variation in temperature	PIM	
Bitumen	Viscosity@135 °C (centistokes)	Integer	The viscosity of bitumen at 135 °C	Literature	
Bitumen	Viscosity@165 °C (centistokes)	Integer	The viscosity of bitumen at 165 °C	Literature	
Bitumen	Ductility (cm)	Integer	Ductility is a feature that evaluates the elongation of the bitumen under traffic condition	PIM	
Bitumen	Flashpoint (°C)	Integer	A temperature at which bitumen ignites	PIM	
Bitumen	Fraass breaking point (°C)	Double	A temperature at which bitumen becomes brittle	Literature	
Bitumen	Specific gravity@25 °C (g/cm3)	Double	Specific gravity of bitumen at 25 °C	PIM	
Bitumen	Mass loss in TFOT (%)	Double	The amount of mass loss after applying the short-term aging on a sample in Thin Film Oven Test (TFOT)	Literature	

Bitumen	Mass loss in PAV (%)	Double	The amount of mass loss after applying the Long-term aging on a sample in Pressure Aging Vessel (PAV)	Literature	
Bitumen	Stiffness@0.1 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	PIM	
Bitumen	Stiffness@0.2 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.2 Hz	PIM	
Bitumen	Stiffness@0.5 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.5 Hz	PIM	
Bitumen	Stiffness@1.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 1.0 Hz	PIM	
Bitumen	Stiffness@2.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 2.0 Hz	PIM	
Bitumen	Stiffness@5.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 5.0 Hz	PIM	
Bitumen	Stiffness@8.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	PIM	
Bitumen	Stiffness@10.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 10.0 Hz	PIM	
Bitumen	Stiffness@20.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 20.0 Hz	PIM	
Bitumen	Stiffness@30.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	PIM	
Bitumen	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	PIM	
Bitumen	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	PIM	
Bitumen	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	PIM	
Bitumen	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	PIM	
Bitumen	Stiffness@0.1 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	
Bitumen	Stiffness@0.2 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	
Bitumen	Stiffness@0.5 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	
Bitumen	Stiffness@1.0 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	
Bitumen	Stiffness@2.0 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	
Bitumen	Stiffness@5.0Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	

Bitumen	Stiffness@8.0Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	
Bitumen	Stiffness@10.0 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	
Bitumen	Stiffness@20.0 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	
Bitumen	Stiffness@30.0 Hz	Double	The stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Bitumen	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	
Bitumen	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Bitumen	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	
Bitumen	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a short-term aged bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Bitumen	Stiffness@0.1 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	
Bitumen	Stiffness@0.2 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	
Bitumen	Stiffness@0.5 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	
Bitumen	Stiffness@1.0 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	
Bitumen	Stiffness@2.0 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	
Bitumen	Stiffness@5.0Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	
Bitumen	Stiffness@8.0Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	
Bitumen	Stiffness@10.0 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	
Bitumen	Stiffness@20.0 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	
Bitumen	Stiffness@30.0 Hz	Double	The stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	

Bitumen	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	
Bitumen	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Bitumen	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	
Bitumen	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a long-term aged bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Additive	ID	String	Unique identifier (code) for the additive	PIM	
Additive	Name	String	The name (type) of used additive	PIM	
Additive	Used percentage (%)	Double	The amount of additive used in asphalt mixture	PIM	
Additive	Diameter (mm)	Double	The diameter of additive used in asphalt mixture	Literature	
Additive	Comments	String	Remarks associated with an additive added to the asphalt mixture	Literature	
Recycled Materials	ID	String	Unique identifier (code) for the recycled material	PIM	
Recycled Materials	Type	String	Type of recycled material used in the road construction project	Literature	
Recycled Materials	Used percentage (%)	Double	The amount of recycled materials used in the asphalt mixture	PIM	
Recycled Materials	Bitumen content (%)	Double	The content of old-aged bitumen in recycled materials	Literature	
Recycled Bitumen	ID	String	Unique identifier (code) for the recycled bitumen	Literature	
Recycled Bitumen	Penetration@25 °C	Integer	Softening point is a temperature at that bitumen softens (old-aged bitumen in recycled materials)	Literature	
Recycled Bitumen	Softening point (°C)	Double	Softening point is a temperature at that bitumen softens (old-aged bitumen in recycled materials)	Literature	
Recycled Bitumen	Penetration index	Double	PI measures the behavior of old-aged bitumen against the variation in temperature	Literature	
Recycled Bitumen	Ductility (cm)	Integer	Ductility is a feature that evaluates the elongation of the old-aged bitumen (recycled materials) under traffic condition	Literature	

Recycled Bitumen	Flashpoint (°C)	Integer	A temperature at which old-aged bitumen ignites	Literature	
Recycled Bitumen	Fraass breaking point (°C)	Double	A temperature at which old-aged bitumen becomes brittle	Literature	
Recycled Bitumen	Stiffness@0.1 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	
Recycled Bitumen	Stiffness@0.2 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	
Recycled Bitumen	Stiffness@0.5 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	
Recycled Bitumen	Stiffness@1.0 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	
Recycled Bitumen	Stiffness@2.0 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	
Recycled Bitumen	Stiffness@5.0Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	
Recycled Bitumen	Stiffness@8.0Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	
Recycled Bitumen	Stiffness@10.0 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	
Recycled Bitumen	Stiffness@20.0 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	
Recycled Bitumen	Stiffness@30.0 Hz	Double	The stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Recycled Bitumen	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	
Recycled Bitumen	Stiffness@30.0 Hz (final measurement)	Double	The final measurment of the stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Recycled Bitumen	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	
Recycled Bitumen	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a recycled bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	
Recycled Aggregate	ID	String	Unique identifier (code) for the recycled aggregate	Literature	

Recycled Aggregate	22,4 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 22.4 mm	Literature	
Recycled Aggregate	16 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 16 mm	Literature	
Recycled Aggregate	11,2 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 11.2 mm	Literature	
Recycled Aggregate	8 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 8 mm	Literature	
Recycled Aggregate	5,6 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 5.6 mm	Literature	
Recycled Aggregate	4 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 4 mm	Literature	
Recycled Aggregate	2 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 2 mm	Literature	
Recycled Aggregate	0,5 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 500 µm	Literature	
Recycled Aggregate	0,18 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 180 µm	Literature	
Recycled Aggregate	0,125 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 125 µm	Literature	
Recycled Aggregate	0,063 mm (%)	Double	The mass fraction of the recycled aggregate through sieve size 63 µm	Literature	
Recycled Aggregate	CaO (%)	Double	The oxide content of CaO in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	Fe2O3 (%)	Double	The oxide content of Fe2O3 in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	SiO2 (%)	Double	The oxide content of SiO2 in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	Al2O3 (%)	Double	The oxide content of Al2O3 in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	MgO (%)	Double	The oxide content of MgO in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	MnO (%)	Double	The oxide content of MnO in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	P2O5 (%)	Double	The oxide content of P2O5 in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	

Recycled Aggregate	TiO2 (%)	Double	The oxide content of TiO2 in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	SO3 (%)	Double	The oxide content of SO3 in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	Na2O (%)	Double	The oxide content of Na2O in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	K2O (%)	Double	The oxide content of K2O in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Recycled Aggregate	Others (%)	Double	The oxide content of others in recycled aggregate, XRF(X-Ray Fluorescence) test	Literature	
Asphalt Mixture	ID	String	Unique identification (code) in PIM for an asphalt mixture	PIM	
Asphalt Mixture	Project ID	String	Unique identification (code) for the project	Literature	
Asphalt Mixture	Mixture Code	String	Unique code for the designation of an asphalt mixture	PIM	
Asphalt Mixture	European standard	String	European standard code for an asphalt mixture	PIM	
Asphalt Mixture	Examination ID	String	Unique identifier (code) of a mixture type in the examination report	PIM	
Asphalt Mixture	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of a mixture (Declaration of Performance)	PIM	
Asphalt Mixture	Effective date TT	String	A date that mixture tests are completed	PIM	
Asphalt Mixture	Validity date	String	A date that the validity of the mixture tests is expired	PIM	
Asphalt Mixture	Comments	String	Remarks associated with an asphalt mixture	PIM	
Asphalt Mixture	Mixture type	String	Asphalt mix type	Literature	
Asphalt Mixture	Mixture description	String	Description of an asphalt mixture	Literature	
Asphalt Mixture	E (MPa)	Integer	Young's modulus which defines how a material can deform (Ratio of tensile stress to tensile strain)	OIA	

Asphalt Mixture	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	PIM	
Asphalt Mixture	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	PIM	
Asphalt Mixture	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	PIM	
Asphalt Mixture	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	PIM	
Asphalt Mixture	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	PIM	
Asphalt Mixture	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	PIM	
Asphalt Mixture	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	PIM	
Asphalt Mixture	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	PIM	
Asphalt Mixture	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	PIM	
Asphalt Mixture	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	PIM	
Asphalt Mixture	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	PIM	
Asphalt Mixture	Bitumen content (%)	Double	The optimum bitumen content	PIM	
Asphalt Mixture	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
Asphalt Mixture	Production temperature (°C)	Integer	The temperature recommended for the production of asphalt mixture	Literature	
Asphalt Mixture	Target density (kg/m3)	Double	The target density	PIM	
Asphalt Mixture	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of an asphalt mixture	PIM	
Asphalt Mixture	Measured bulk specific gravity (kg/m3)	Double	The density of the mixture determined by the test	PIM	
Asphalt Mixture	Air void (%)	Double	The amount of air void in the asphalt mixture	PIM	

Asphalt Mixture	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	
Asphalt Mixture	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
Asphalt Mixture	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	
Asphalt Mixture	Water sensitivity (TSR) (%)	Double	The sensitivity of an asphalt mixture to the action of moisture (ratio of conditioned ITS to dry ITS)	PIM	
HMA	ID	String	Unique identification (code) in PIM for HMA	Literature	
HMA	Project ID	String	Unique identification (code) for the project	Literature	
HMA	Mixture Code	String	Unique code for the designation of HMA	Literature	
HMA	European standard	String	European standard code for HMA	Literature	
HMA	Examination ID	String	Unique identifier (code) of HMA in the examination report	Literature	
HMA	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of HMA (Declaration of Performance)	Literature	
HMA	Effective date TT	String	A date that HMA tests are completed	Literature	
HMA	Validity date	String	A date that the validity of HMA tests is expired	Literature	
HMA	E (MPa)	Integer	Young's modulus which defines how a material can deform (Ratio of tensile stress to tensile strain)	Literature	
HMA	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	
HMA	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	
HMA	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	
HMA	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	
HMA	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	
HMA	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	
HMA	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	
HMA	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	
HMA	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	
HMA	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	

HMA	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	
HMA	Bitumen content (%)	Double	The optimum bitumen content	Literature	
HMA	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
HMA	Production temperature (°C)	Integer	The temperature recommended for the production of HMA	Literature	
HMA	Target density (kg/m3)	Double	The target density	Literature	
HMA	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of HMA	Literature	
HMA	Measured bulk specific gravity (kg/m3)	Double	The density of HMA determined by the test	Literature	
HMA	Air void (%)	Double	The amount of air void in HMA	Literature	
HMA	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	
HMA	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
HMA	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	
HMA	Water sensitivity (TSR) (%)	Double	The sensitivity of HMA to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	
HMA	Comments	String	Remarks associated with HMA	Literature	
WMA	ID	String	Unique identification (code) in PIM for WMA	Literature	
WMA	Project ID	String	Unique identification (code) for the project	Literature	
WMA	Mixture Code	String	Unique code for the designation of WMA	Literature	
WMA	European standard	String	European standard code for WMA	Literature	
WMA	Examination ID	String	Unique identifier (code) of WMA in the examination report	Literature	
WMA	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of WMA (Declaration of Performance)	Literature	
WMA	Effective date TT	String	A date that WMA tests are completed	Literature	
WMA	Validity date	String	A date that the validity of WMA tests is expired	Literature	

WMA	E (MPa)	Integer	Young's modulus which defines how a material can deform (Ratio of tensile stress to tensile strain)	Literature	
WMA	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	
WMA	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	
WMA	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	
WMA	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	
WMA	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	
WMA	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	
WMA	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	
WMA	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	
WMA	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	
WMA	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	
WMA	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	
WMA	Bitumen content (%)	Double	The optimum bitumen content	Literature	
WMA	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
WMA	Production temperature (°C)	Integer	The temperature recommended for the production of WMA	Literature	
WMA	Target density (kg/m3)	Double	The target density	Literature	
WMA	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of WMA	Literature	
WMA	Measured bulk specific gravity (kg/m3)	Double	The density of WMA determined by the test	Literature	
WMA	Air void (%)	Double	The amount of air void in WMA	Literature	
WMA	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	
WMA	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
WMA	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	

WMA	Water sensitivity (TSR) (%)	Double	The sensitivity of WMA to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	
WMA	Comments	String	Remarks associated with WMA	Literature	
HWMA	ID	String	Unique identification (code) in PIM for HWMA	Literature	
HWMA	Project ID	String	Unique identification (code) for the project	Literature	
HWMA	Mixture Code	String	Unique code for the designation of HWMA	Literature	
HWMA	European standard	String	European standard code for HWMA	Literature	
HWMA	Examination ID	String	Unique identifier (code) of HWMA in the examination report	Literature	
HWMA	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of HWMA (Declaration of Performance)	Literature	
HWMA	Effective date TT	String	A date that HWMA tests are completed	Literature	
HWMA	Validity date	String	A date that the validity of HWMA tests is expired	Literature	
HWMA	E (MPa)	Integer	Young's modulus which defines how a material can deform (Ratio of tensile stress to tensile strain)	Literature	
HWMA	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	
HWMA	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	
HWMA	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	
HWMA	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	
HWMA	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	
HWMA	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	
HWMA	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	
HWMA	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	
HWMA	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	
HWMA	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	
HWMA	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	
HWMA	Bitumen content (%)	Double	The optimum bitumen content	Literature	
HWMA	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
HWMA	Production temperature (°C)	Integer	The temperature recommended for the production of HWMA	Literature	

HWMA	Target density (kg/m3)	Double	The target density	Literature	
HWMA	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of HWMA	Literature	
HWMA	Measured bulk specific gravity (kg/m3)	Double	The density of HWMA determined by test	Literature	
HWMA	Air void (%)	Double	The amount of air void in HWMA	Literature	
HWMA	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	
HWMA	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
HWMA	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	
HWMA	Water sensitivity (TSR) (%)	Double	The sensitivity of HWMA to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	
HWMA	Comments	String	Remarks associated with HWMA	Literature	
CMA	ID	String	Unique identification (code) in PIM for CMA	Literature	
CMA	Project ID	String	Unique identification (code) for the project	Literature	
CMA	Mixture Code	String	Unique code for the designation of CMA	Literature	
CMA	European standard	String	European standard code for CMA	Literature	
CMA	Examination ID	String	Unique identifier (code) of CMA in the examination report	Literature	
CMA	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of CMA (Declaration of Performance)	Literature	
CMA	Effective date TT	String	A date that CMA tests are completed	Literature	
CMA	Validity date	String	A date that validity of CMA tests is expired	Literature	
CMA	E (MPa)	Integer	Young's modulus which defines how material can deform (Ratio of tensile stress to tensile strain)	Literature	
CMA	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	
CMA	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	
CMA	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	
CMA	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	

CMA	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	
CMA	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	
CMA	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	
CMA	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	
CMA	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	
CMA	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	
CMA	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	
CMA	Bitumen content (%)	Double	The optimum bitumen content	Literature	
CMA	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
CMA	Production temperature (°C)	Integer	The temperature recommended for the production of CMA	Literature	
CMA	Target density (kg/m3)	Double	The target density	Literature	
CMA	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of CMA	Literature	
CMA	Measured bulk specific gravity (kg/m3)	Double	The density of CMA determined by test	Literature	
CMA	Air void (%)	Double	The amount of air void in CMA	Literature	
CMA	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	
CMA	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
CMA	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	
CMA	Water sensitivity (TSR) (%)	Double	The sensitivity of CMA to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	
CMA	Comments	String	Remarks associated with CMA	Literature	
Dense-graded Mix	ID	String	Unique identification (code) in PIM for dense-graded mix	Literature	

Dense-graded Mix	Project ID	String	Unique identification (code) for the project	Literature	
Dense-graded Mix	Mixture Code	String	Unique code for the designation of dense-graded mix	Literature	
Dense-graded Mix	European standard	String	European standard code for dense-graded mix	Literature	
Dense-graded Mix	Examination ID	String	Unique identifier (code) of dense-graded mix in the examination report	Literature	
Dense-graded Mix	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of dense-graded mix (Declaration of Performance)	Literature	
Dense-graded Mix	Effective date TT	String	A date that dense-graded mix tests are completed	Literature	
Dense-graded Mix	Validity date	String	A date that validity of dense-graded mix tests is expired	Literature	
Dense-graded Mix	E (MPa)	Integer	Young's modulus which defines how material can deform (Ratio of tensile stress to tensile strain)	Literature	
Dense-graded Mix	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	
Dense-graded Mix	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	
Dense-graded Mix	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	
Dense-graded Mix	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	

Dense-graded Mix	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	
Dense-graded Mix	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	
Dense-graded Mix	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	
Dense-graded Mix	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	
Dense-graded Mix	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	
Dense-graded Mix	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	
Dense-graded Mix	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	
Dense-graded Mix	Bitumen content (%)	Double	The optimum bitumen content	Literature	
Dense-graded Mix	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
Dense-graded Mix	Production temperature (°C)	Integer	The temperature recommended for the production of dense-graded mix	Literature	
Dense-graded Mix	Target density (kg/m3)	Double	The target density	Literature	
Dense-graded Mix	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of dense-graded mix	Literature	

Dense-graded Mix	Measured bulk specific gravity (kg/m3)	Double	The density of dense-graded mix determined by test	Literature	
Dense-graded Mix	Air void (%)	Double	The amount of air void in dense-graded mix	Literature	
Dense-graded Mix	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	
Dense-graded Mix	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
Dense-graded Mix	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	
Dense-graded Mix	Water sensitivity (TSR) (%)	Double	The sensitivity of dense-graded mix to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	
Dense-graded Mix	Comments	String	Remarks associated with dense-graded mix	Literature	
Gap-graded Mix	ID	String	Unique identification (code) in PIM for gap-graded mix	Literature	
Gap-graded Mix	Project ID	String	Unique identification (code) for the project	Literature	
Gap-graded Mix	Mixture Code	String	Unique code for the designation of gap-graded mix	Literature	
Gap-graded Mix	European standard	String	European standard code for gap-graded mix	Literature	

Gap-graded Mix	Examination ID	String	Unique identifier (code) of gap-graded mix in the examination report	Literature	
Gap-graded Mix	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of gap-graded mix (Declaration of Performance)	Literature	
Gap-graded Mix	Effective date TT	String	A date that gap-graded mix tests are completed	Literature	
Gap-graded Mix	Validity date	String	A date that validity of gap-graded mix tests is expired	Literature	
Gap-graded Mix	E (MPa)	Integer	Young's modulus which defines how material can deform (Ratio of tensile stress to tensile strain)	Literature	
Gap-graded Mix	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	
Gap-graded Mix	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	
Gap-graded Mix	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	
Gap-graded Mix	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	
Gap-graded Mix	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	
Gap-graded Mix	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	
Gap-graded Mix	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	

Gap-graded Mix	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	
Gap-graded Mix	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	
Gap-graded Mix	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	
Gap-graded Mix	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	
Gap-graded Mix	Bitumen content (%)	Double	The optimum bitumen content	Literature	
Gap-graded Mix	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
Gap-graded Mix	Production temperature (°C)	Integer	The temperature recommended for the production of gap-graded mix	Literature	
Gap-graded Mix	Target density (kg/m3)	Double	The target density	Literature	
Gap-graded Mix	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of gap-graded mix	Literature	
Gap-graded Mix	Measured bulk specific gravity (kg/m3)	Double	The density of gap-graded mix determined by test	Literature	
Gap-graded Mix	Air void (%)	Double	The amount of air void in gap-graded mix	Literature	
Gap-graded Mix	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	

Gap-graded Mix	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
Gap-graded Mix	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	
Gap-graded Mix	Water sensitivity (TSR) (%)	Double	The sensitivity of gap-graded mix to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	
Gap-graded Mix	Comments	String	Remarks associated with gap-graded mix	Literature	
Open-graded Mix	ID	String	Unique identification (code) in PIM for open-graded mix	Literature	
Open-graded Mix	Project ID	String	Unique identification (code) for the project	Literature	
Open-graded Mix	Mixture Code	String	Unique code for the designation of open-graded mix	Literature	
Open-graded Mix	European standard	String	European standard code for open-graded mix	Literature	
Open-graded Mix	Examination ID	String	Unique identifier (code) of open-graded mix in the examination report	Literature	
Open-graded Mix	DoP ID	String	Unique identifier (code) of the CE declaration for the performance of open-graded mix (Declaration of Performance)	Literature	
Open-graded Mix	Effective date TT	String	A date that open-graded mix tests are completed	Literature	

Open-graded Mix	Validity date	String	A date that validity of open-graded mix tests is expired	Literature	
Open-graded Mix	E (MPa)	Integer	Young's modulus which defines how material can deform (Ratio of tensile stress to tensile strain)	Literature	
Open-graded Mix	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	
Open-graded Mix	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	
Open-graded Mix	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	
Open-graded Mix	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	
Open-graded Mix	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	
Open-graded Mix	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	
Open-graded Mix	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	
Open-graded Mix	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	
Open-graded Mix	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	
Open-graded Mix	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	

Open-graded Mix	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	
Open-graded Mix	Bitumen content (%)	Double	The optimum bitumen content	Literature	
Open-graded Mix	Soluble bitumen content (%)	Double	The soluble bitumen content	Literature	
Open-graded Mix	Production temperature (°C)	Integer	The temperature recommended for the production of open-graded mix	Literature	
Open-graded Mix	Target density (kg/m3)	Double	The target density	Literature	
Open-graded Mix	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of open-graded mix	Literature	
Open-graded Mix	Measured bulk specific gravity (kg/m3)	Double	The density of open-graded mix determined by test	Literature	
Open-graded Mix	Air void (%)	Double	The amount of air void in open-graded mix	Literature	
Open-graded Mix	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	
Open-graded Mix	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	
Open-graded Mix	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	
Open-graded Mix	Water sensitivity (TSR) (%)	Double	The sensitivity of open-graded mix to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	

Open-graded Mix	Comments	String	Remarks associated with open-graded mix	Literature	

Table. Items name, type, description, source and lifecycle phase of geometry sub-ontology.

Item name		**Type of item**	**Description of item**	**Source of item (applications or literature)**	**Life cycle phase**
Road Geometry		Class	Arrangement and dimension of road visible property	PIM	
Road Network		Class	All types of roads in a country are a part of the road network	PIM	
Road		Class	Collection of road segments managed by the same road authority and known under the same number	PIM	
Road Segment		Class	Road segment is a connection between two intersections and it has a number that may vary from moment to moment	PIM	
Carriageway		Class	One side of a road on which traffic travelling in opposite directions is separated by a barrier	PIM	
Carriageway segment		Class	One side of a road on which homogeneous traffic travelling in opposite directions is separated by a barrier	PIM	
Lane		Class	One lane on one side of a road on which traffic travelling in opposite directions is separated by a barrier	PIM	
Lane Segment		Class	A segment of one lane on one side of a road on which traffic travelling in opposite directions is separated by a barrier	PIM	
Cell		Class	A cell is the smallest part of lane segment	Literature	
Class name	**Attribute of the class**	**Type of attribute**	**Description of attribute**	**Source of attribute (applications or literature)**	**Life cycle phase**
Road network	ID	String	Unique identifier (code) for the road network	PIM	
Road network	Name	String	The name of the road network, for example, the Netherlands	PIM	
Road	ID	String	Unique identifier (code) for the road	PIM	
Road	BPS indication	String	The BPS indication	PIM	

Road Segment	ID	String	Unique identifier (code) for the road segment	PIM	
Road Segment	BGT Classification	String	The classification of the road segment based on the BGT	PIM	
Road Segment	IM-GEO classification	String	The classification of the road segment based on the IM-GEO	PIM	
Road Segment	BPS indication	String	The BPS indication	PIM	
Road Segment	Road category	String	The category of the road (design: flow road, GBOW, ETW, etc.)	PIM	
Road Segment	Road type	Integer	The type of road based on the CROW management system, type 1 to7	PIM	
Carriageway	ID	String	Unique identifier (code) for the carriageway	PIM	
Carriageway	BPS indication	String	The BPS indication	PIM	
Carriageway	Starting point description	String	The description regarding the start point of this carriageway	PIM	
Carriageway	Ending point description	String	The description regarding the endpoint of this carriageway	PIM	
Carriageway segment	ID	String	Unique identifier (code) for the carriageway segment	PIM	
Carriageway segment	BPS indication	String	The BPS indication	PIM	
Carriageway segment	NWB ID	String	NWB ID for the carriageway segment	PIM	
Carriageway segment	Starting point description	String	The description regarding the start point of this carriageway segment	PIM	
Carriageway segment	Ending point description	String	The description regarding the endpoint of this carriageway segment	PIM	
Carriageway segment	Municipality	String	The municipality name to which the carriageway segment belongs	PIM	
Carriageway segment	Kern	String	The kern name which carriageway segment belongs	PIM	

Carriageway segment	District	String	The district name to which the carriageway segment belongs	PIM	
Carriageway segment	Neighbourhood	String	The neighbourhood name to which the carriageway segment belongs	PIM	
Carriageway segment	Street name	String	The street name to which the carriageway segment belongs	PIM	
Lane	ID	String	Unique identifier (code) for the lane	PIM	
Lane	BPS indication	String	The BPS indication	PIM	
Lane	Starting point description	String	The description regarding the start point of this lane	PIM	
Lane	Ending point description	String	The description regarding the endpoint of this lane	PIM	
Lane Segment	ID	String	Unique identifier (code) for the lane segment	PIM	
Lane Segment	BPS indication	String	The BPS indication	PIM	
Lane Segment	Length	Double	The length of the lane segment	PIM	
Lane Segment	Width	Double	The width of the lane segment	PIM	
Lane Segment	Surface	String	The surface of the lane segment	PIM	
Lane Segment	Starting point description	String	The description regarding the start point of this lane segment	PIM	
Lane Segment	Ending point description	String	The description regarding the endpoint of this lane segment	PIM	
Lane Segment	BIBEKO/BUBEKO	String	Within the built-up area or outside the built-up area	PIM	
Cell	ID	String	Unique identifier (code) for the cell	Literature	
Cell	Coordinate System	String	The type of coordinate system used for measuring the location of cell	Literature	

Cell	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (centroid)	Literature	
Cell	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (centroid)	Literature	
Cell	Altitude	Double	Vertical direction between a reference datum and a point (centroid)	Literature	
Cell	Length	Double	The length of the cell	Literature	
Cell	Width	Double	The width of the cell	Literature	
Cell	Starting point description	String	The description regarding the start point of this cell	Literature	
Cell	Ending point description	String	The description regarding the endpoint of this cell	Literature	
Cell	Initial Temperature	Double	Initial temperature of the cell after paving is defined by the paving temperature	Literature	
Cell	Current Temperature	Double	The current temperature of the cell that is defined by surface temperature	Literature	
Cell	Temperature@First Compaction	Double	Temperature of the cell at the first roller passe (core temperature)	Literature	
Cell	Temperature@Last Compaction	Double	Temperature of the cell at the end roller passe (core temperature)	Literature	
Cell	Number of Compaction Passes	Integer	Total number of compaction passes from the cell	Literature	

Table. Items name, type, description, source and lifecycle phase of activity and resource sub-ontologies.

Item name	**Type of item**	**Description of item**	**Source of item (applications or literature)**	**Life cycle phase**
Road Infrastructure	Class	Every physical objects of the road such as road itself and other objects on the road		
Lifecycle	Class	The series that pavement changes during its life	Literature	
Design Activity	Class	Design is the first phase of the pavement lifecycle which focuses on determining the thickness, mix design, etc of the pavement	Literature	Design
Construction Activity	Class	Construction is one of the phases of the pavement lifecycle which pavement is paved and compacted	Literature	Construction

Measurement & Testing Activity	Class	Measurement and testing is included in pavement lifecycle in which pavement condition is examined	Literature	Operation
Maintenance Activity	Class	Maintenance is the last phase of pavement which certain methods are applied to increase the life of the pavement	Literature	Maintenance
Pavement Design	Class	The most important task is pavement design in the design phase	Literature	Design
Preliminary Pavement Design	Class	Preliminary Pavement Design is a step that client designs the pavement and sends the information to contractors, mostly focusing on contract parameters and calculated based on the target mix properties	Literature	Design
Final Pavement Design	Class	Final Pavement Design is determined after consultant between the client and contractor and calculated based on the reference mix properties	Literature	Design
Construction-ready Design	Class	Construction-ready design is a step in which design parameters have been confirmed but should be adjusted for being used in the manufacturing and construction phases	Literature	Design
Stationary Asphalt Plant	Class	Stationary asphalt plant is a type of asphalt plant that the operation site fixed in a place	Literature	Construction
Semi-stationary Asphalt Plant	Class	Semi-stationary asphalt plant is installed on some trailers and is reassembled in a job site	Literature	Construction
Mobile Asphalt Plant	Class	Mobile asphalt plant is mounted on a chassis and can be transferred to road construction site	Literature	Construction
Machinery	Class	There are several types of equipment used for the construction of the asphalt pavement	Literature	Construction
Person	Class	There are several types of laborers worked on a pavement construction project	Literature	Construction
Operator	Class	Operator is the driver of roller, paver, truck, etc	Literature	Construction
Worker	Class	Worker is a person who is performing other tasks besides driving equipment during the road construction project	Literature	Construction
Truck	Class	Truck can be used for the transportation of the asphalt to or in the job site	Literature	Construction
Roller	Class	Roller is the equipment used for the compaction of the asphalt mixture	Literature	Construction
Paver	Class	Paver is the vehicle used for the paving process of the asphalt mixture	Literature	Construction
Miller	Class	The old surface of the asphalt mixture can be removed by millers	Literature	Construction
Material Transfer Vehicle	Class	Material Transfer Vehicle (MTV) is a machine to transfer material (asphalt) in the job site between truck and paver	Literature	Construction
Cleaning Machine	Class	Cleaning machine cleans the road surface before paving takes place	Literature	Construction
Asphalt Milling	Class	The process of milling asphalt mixture from the surface of road	Literature	Construction
Asphalt Delivery	Class	The process of asphalt transportation in and from job site	Literature	Construction
Asphalt Cleaning	Class	The process of cleaning the surface of road	Literature	Construction

Asphalt Paving	Class	The process of paving the asphalt mixture	Literature	Construction
Asphalt Compaction	Class	The process of compacting the asphalt mixture	Literature	Construction
Preventive Maintenance	Class	One type of maintenance that can increase the service life of the asphalt pavement in a cost-effective way	Literature	Maintenance
Cleaning	Class	Cleaning the surface of asphalt pavement (especially porous asphalt) to prevent the clogged of water	Literature	Maintenance
Spraying Rejuvenation	Class	Spraying rejuvenator can soften the bitumen and prevent aging, thus the unaged bitumen is more resistant to raveling	Literature	Maintenance
Crack Filling	Class	Crack Filling is one type of preventive maintenance that should be used for non-working cracks (cracks whose movements are less than 3 mm annually)	Literature	Maintenance
Crack Sealing	Class	Crack sealing is one type of preventive maintenance that should be used for working cracks (cracks whose movements are more than 3 mm annually)	Literature	Maintenance
Induction Heating	Class	Induction heating is one type of preventive maintenance that heat the asphalt to be healed by bitumen	Literature	Maintenance
Microsurfacing	Class	Microsurfacing is one type of preventive maintenance that is made by asphalt emulsion with finely aggregate to extend the life of the pavement (breaking is rely on the chemical additive in the emulsion)	Literature	Maintenance
Slurry Sealing	Class	Slurry sealing is one type of preventive maintenance that is made by asphalt emulsion with finely aggregate to extend the life of the pavement (breaking relies on the sun and amount of water i.e. no chemical additive)	Literature	Maintenance
Chip Sealing	Class	Chip sealing is one type of preventive maintenance that is made by asphalt emulsion or polymer or crumbed rubber bitumen with finely aggregate to extend the life of the pavement	Literature	Maintenance
Corrective Maintenance	Class	One type of maintenance that can increase the service life of the asphalt pavement (repairing the asphalt pavement) that is more costly	Literature	Maintenance
Hot Patching	Class	Hot Patching is one type of corrective maintenance that is used to fill the pothole mostly made by hot mix asphalt	Literature	Maintenance
Structural Overlays	Class	Structural overlay is one type of corrective maintenance that is made with bitumen and aggregate to protect the pavement	Literature	Maintenance
Emergency Maintenance	Class	One type of maintenance that should be performed immediately because of an emergency situation such as severe pothole and blowout, in the future, this maintenance will be replaced with the corrective maintenance	Literature	Maintenance
Cold Patching	Class	Cold patching is one type of emergency maintenance that is used to fill the pothole mostly made by cold mix asphalt	Literature	Maintenance

Contract Maintenance		Class	One type of maintenance that is performed mostly by contractors and it is only because of the contract	Literature	Maintenance
Reconstructing Layer		Class	Reconstructing layer is one type of contract maintenance in that the entire layer is reconstructed	Literature	Maintenance
Class name	**Attribute of the class**	**Type of attribute**	**Description of attribute**	**Source of attribute (applications or literature)**	**Life cycle phase**
Design Activity	ID	String	Unique identifier (code) of the design	PIM	Design
Design Activity	Project ID	String	Unique identifier (code) of the project	PIM	Design
Design Activity	Subproject ID	String	Unique identifier (code) in PIM of the subproject	PIM	Design
Design Activity	Contract ID	String	Contract ID	PIM	Design
Design Activity	Contract Type	String	The type of Contact	Literature	Design
Design Activity	Comments	String	Remarks associated with the contract	Literature	Design
Design Activity	ECI (Euro)	Double	Environmental Cost Indicator (ECI) is known as Milieu Kosten Indicator (MKI)	Literature	Design
Design Activity	Contractor	String	Contractor's company name	PIM	Design
Design Activity	Contractor Contact Person	String	Contact person for the project at the contractor	PIM	Design
Design Activity	Start Guaranty Period	String	Start date of the guaranty period	PIM	Design
Design Activity	Guaranty Period	Integer	The duration of guarantee period in years	Literature	Design
Preliminary Pavement Design	ID	String	Unique identifier (code) of the preliminary design	Literature	Design

Preliminary Pavement Design	Target Designed Period	Integer	The target design period for the road pavement based on the properties of target mix	OIA	Design
Preliminary Pavement Design	Target thickness (mm)	Integer	The target thickness of the asphalt layer based on the properties of target mix	OIA	Design
Preliminary Pavement Design	Number of working days	Integer	Target number of working days per year	OIA	Design
Preliminary Pavement Design	Freight traffic speed (km/h)	Integer	The target speed for the freight traffic	OIA	Design
Preliminary Pavement Design	Axle Load 20-40 (%)	Double	The percent of axle load in the spectrum of 20-40 (preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 40-60 (%)	Double	The percent of axle load in the spectrum of 40-60 (preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 60-80 (%)	Double	The percent of axle load in the spectrum of 60-80(preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 80-100 (%)	Double	The percent of axle load in the spectrum of 80-100 (preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 100-120 (%)	Double	The percent of axle load in the spectrum of 100-120 (preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 120-140 (%)	Double	The percent of axle load in the spectrum of 120-140 (preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 140-160 (%)	Double	The percent of axle load in the spectrum of 140-160 (preliminary design)	OIA	Design

Preliminary Pavement Design	Axle Load 160-180 (%)	Double	The percent of axle load in the spectrum of 160-180 (preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 180-200 (%)	Double	The percent of axle load in the spectrum of 180-200 (preliminary design)	OIA	Design
Preliminary Pavement Design	Axle Load 200-220 (%)	Double	The percent of axle load in the spectrum of 200-220 (preliminary design)	OIA	Design
Preliminary Pavement Design	DL (%)	Double	Percent distribution of single air tire (preliminary design)	OIA	Design
Preliminary Pavement Design	EL (%)	Double	Percent distribution of double air tire (preliminary design)	OIA	Design
Preliminary Pavement Design	BB (%)	Double	Percent distribution of broadband tire (preliminary design)	OIA	Design
Preliminary Pavement Design	SB (%)	Double	Percent distribution of super broadband tire (preliminary design)	OIA	Design
Preliminary Pavement Design	Traffic uncertainty factor	String	The factor which shows the uncertainty in the traffic load (preliminary design)	OIA	Design
Preliminary Pavement Design	Number of motor vehicles per day per direction	Integer	Number of motor vehicles per day per direction (preliminary design)	OIA	Design
Preliminary Pavement Design	Number of trucks per day per direction	Integer	Number of trucks per day per direction (preliminary design)	OIA	Design
Preliminary Pavement Design	Freight traffic	Double	The percentage regarding the freight traffic (preliminary design)	OIA	Design

	percentage (%)				
Preliminary Pavement Design	Annual growth (%)	Double	The percentage of growth in traffic annually (preliminary design)	OIA	Design
Preliminary Pavement Design	Partial factor (%)	Integer	The percent of reliability which is defined by the partial factor (preliminary design)	OIA	Design
Preliminary Pavement Design	Permissible damage percentage (%)	Integer	The percentage of road length over which initiation of fatigue cracks may have arisen during the first reinforcement of asphalt pavements (preliminary design)	OIA	Design
Preliminary Pavement Design	Design mode	String	The design model used for designing the asphalt pavement (preliminary design)	OIA	Design
Target Mix Design	ID	String	Unique identifier (code) of the target mix design	Literature	Design
Target Mix Design	Mixture type	String	Asphalt mix type (target mix)	Literature	Design
Target Mix Design	Mixture description	String	Description of a target mixture	Literature	Design
Target Mix Design	E (MPa)	Integer	Young's modulus which defines how material can deform (Ratio of tensile stress to tensile strain) for target mix	OIA	Design
Target Mix Design	22,4 mm (%)	Double	The mass fraction of the target aggregate through sieve size 22.4 mm	PIM	Design
Target Mix Design	16 mm (%)	Double	The mass fraction of the target aggregate through sieve size 16 mm	PIM	Design
Target Mix Design	11,2 mm (%)	Double	The mass fraction of the target aggregate through sieve size 11.2 mm	PIM	Design
Target Mix Design	8 mm (%)	Double	The mass fraction of the target aggregate through sieve size 8 mm	PIM	Design
Target Mix Design	5,6 mm (%)	Double	The mass fraction of the target aggregate through sieve size 5.6 mm	PIM	Design
Target Mix Design	4 mm (%)	Double	The mass fraction of the target aggregate through sieve size 4 mm	PIM	Design

Target Mix Design	2 mm (%)	Double	The mass fraction of the target aggregate through sieve size 2 mm	PIM	Design
Target Mix Design	0,5 mm (%)	Double	The mass fraction of the target aggregate through sieve size 500 µm	PIM	Design
Target Mix Design	0,18 mm (%)	Double	The mass fraction of the target aggregate through sieve size 180 µm	PIM	Design
Target Mix Design	0,125 mm (%)	Double	The mass fraction of the target aggregate through sieve size 125 µm	PIM	Design
Target Mix Design	0,063 mm (%)	Double	The mass fraction of the target aggregate through sieve size 63 µm	PIM	Design
Target Mix Design	Bitumen grade	String	The PG grading of the bitumen in target mixture	PIM	Design
Target Mix Design	Bitumen content (%)	Double	The optimum bitumen content in target mixture	PIM	Design
Target Mix Design	Soluble bitumen content (%)	Double	The soluble bitumen content in target mixture	PIM	Design
Target Mix Design	Target air void (%)	Double	The target air void in target mixture	Literature	Design
Target Mix Design	Target density (kg/m3)	Double	The target density of the target mixture	PIM	Design
Final Pavement Design	ID	String	Unique identifier (code) of the final design	Literature	Design
Final Pavement Design	Final Designed Period	Integer	The final design period for the road pavement based on the properties of the reference mix	OIA	Design
Final Pavement Design	Final thickness (mm)	Integer	The final thickness of the asphalt layer which received based on the properties of the reference mix	OIA	Design
Final Pavement Design	Number of working days	Integer	Final number of working days per year	OIA	Design

Final Pavement Design	Freight traffic speed (km/h)	Integer	The Final speed for the freight traffic	OIA	Design
Final Pavement Design	Axle Load 20-40 (%)	Double	The percent of axle load in the spectrum of 20-40 (final design)	OIA	Design
Final Pavement Design	Axle Load 40-60 (%)	Double	The percent of axle load in the spectrum of 40-60 (final design)	OIA	Design
Final Pavement Design	Axle Load 60-80 (%)	Double	The percent of axle load in the spectrum of 60-80 (final design)	OIA	Design
Final Pavement Design	Axle Load 80-100 (%)	Double	The percent of axle load in the spectrum of 80-100 (final design)	OIA	Design
Final Pavement Design	Axle Load 100-120 (%)	Double	The percent of axle load in the spectrum of 100-120 (final design)	OIA	Design
Final Pavement Design	Axle Load 120-140 (%)	Double	The percent of axle load in the spectrum of 120-140 (final design)	OIA	Design
Final Pavement Design	Axle Load 140-160 (%)	Double	The percent of axle load in the spectrum of 140-160 (final design)	OIA	Design
Final Pavement Design	Axle Load 160-180 (%)	Double	The percent of axle load in the spectrum of 160-180 (final design)	OIA	Design
Final Pavement Design	Axle Load 180-200 (%)	Double	The percent of axle load in the spectrum of 180-200 (final design)	OIA	Design
Final Pavement Design	Axle Load 200-220 (%)	Double	The percent of axle load in the spectrum of 200-220 (final design)	OIA	Design

Final Pavement Design	DL (%)	Double	Percent distribution of single air tire (final design)	OIA	Design
Final Pavement Design	EL (%)	Double	Percent distribution of double air tire (final design)	OIA	Design
Final Pavement Design	BB (%)	Double	Percent distribution of broadband tire (final design)	OIA	Design
Final Pavement Design	SB (%)	Double	Percent distribution of super broadband tire (final design)	OIA	Design
Final Pavement Design	Traffic uncertainty factor	String	The factor which shows the uncertainty in the traffic load (final design)	OIA	Design
Final Pavement Design	Number of motor vehicles per day per direction	Integer	Number of motor vehicles per day per direction (final design)	OIA	Design
Final Pavement Design	Number of trucks per day per direction	Integer	Number of trucks per day per direction (final design)	OIA	Design
Final Pavement Design	Freight traffic percentage (%)	Double	The percentage regarding the freight traffic (final design)	OIA	Design
Final Pavement Design	Annual growth (%)	Double	The percentage of growth in traffic annually (final design)	OIA	Design
Final Pavement Design	Partial factor (%)	Integer	The percent of reliability which is defined by the partial factor (final design)	OIA	Design

Final Pavement Design	Permissible damage percentage (%)	Integer	The percentage of road length over which initiation of fatigue cracks may have arisen during the first reinforcement of asphalt pavements (final design)	OIA	Design
Final Pavement Design	Design mode	String	The design model used for designing the asphalt pavement (final design)	OIA	Design
Reference Mix Design	ID	String	Unique identifier (code) of the reference mix design	Literature	Design
Reference Mix Design	Mixture type	String	Asphalt mix type (reference mix)	Literature	Design
Reference Mix Design	Mixture description	String	Description of a reference mixture	Literature	Design
Reference Mix Design	E (MPa)	Integer	Young's modulus which defines how material can deform (Ratio of tensile stress to tensile strain) for reference mix	OIA	Design
Reference Mix Design	22,4 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 22.4 mm	PIM	Design
Reference Mix Design	16 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 16 mm	PIM	Design
Reference Mix Design	11,2 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 11.2 mm	PIM	Design
Reference Mix Design	8 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 8 mm	PIM	Design
Reference Mix Design	5,6 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 5.6 mm	PIM	Design
Reference Mix Design	4 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 4 mm	PIM	Design
Reference Mix Design	2 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 2 mm	PIM	Design
Reference Mix Design	0,5 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 500 µm	PIM	Design
Reference Mix Design	0,18 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 180 µm	PIM	Design
Reference Mix Design	0,125 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 125 µm	PIM	Design

Reference Mix Design	0,063 mm (%)	Double	The mass fraction of the reference aggregate through sieve size 63 µm	PIM	Design
Reference Mix Design	Bitumen grade	String	The PG grading of the bitumen in reference mixture	Literature	Design
Reference Mix Design	Bitumen content (%)	Double	The optimum bitumen content in reference mixture	PIM	Design
Reference Mix Design	Bitumen correction (%)	Double	The revised bitumen content in reference mixture	PIM	Design
Reference Mix Design	Soluble bitumen content (%)	Double	The soluble bitumen content in reference mixture	Literature	Design
Reference Mix Design	Recommended production temperature (°C)	Integer	The temperature recommended for the production of reference mixture	Literature	Design
Reference Mix Design	Recommended minimum compaction temperature (°C)	Integer	The min temperature recommended for the compaction of reference mixture	PIM	Design
Reference Mix Design	Recommended maximum compaction temperature (°C)	Integer	The max temperature recommended for the compaction of reference mixture	PIM	Design
Reference Mix Design	Recommended required number of roller passes	Integer	The number of roller passes recommended for the compaction of reference mixture	PIM	Design

Reference Mix Design	Target density (kg/m3)	Double	The target density of the reference mixture	PIM	Design
Reference Mix Design	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of a reference mixture	PIM	Design
Reference Mix Design	Measured bulk specific gravity (kg/m3)	Double	The density of a reference mixture determined by test	PIM	Design
Reference Mix Design	Reference min air void (Vmin) (%)	Double	The minimum amount of hollow space in a reference mixture	PIM	Design
Reference Mix Design	Reference max air void (Vmax) (%)	Double	The maximum amount of hollow space in a reference mixture	PIM	Design
Reference Mix Design	Reference air void (%)	Double	The calculated amount of air void in a reference mixture based on measured bulk density and theoretical maximum specific density	PIM	Design
Reference Mix Design	Voids in mineral aggregate (%)	Double	The extent of intergranular void area among the combination particles of the compacted paving mixture	Literature	Design
Reference Mix Design	Voids filled with bitumen (%)	Double	The volume of space between the asphalt binder and the aggregate measured for the compacted paving mixture	Literature	Design
Reference Mix Design	Dust proportion to effective binder ratio (DP) (%)	Double	The Ratio of passing the No. 200 sieve of the gradation (filler) to the percent of effective asphalt binder	Literature	Design

Reference Mix Design	Water sensitivity (TSR) (%)	Double	The sensitivity of an asphalt mixture to the action of moisture (ratio of conditioned ITS to dry ITS)	PIM	Design
Reference Mix Design	Reference temperature of dynamic modulus (°C)	Integer	A reference temperature that the dynamic modulus test is conducted	Literature	Design
Reference Mix Design	Dynamic modulus@ 0.1 Hz (MPa)	Integer	Dynamic modulus of a mixture at the reference temperature and 0.1 Hz	Literature	Design
Reference Mix Design	Dynamic modulus@ 1.0 Hz (MPa)	Integer	Dynamic modulus of a mixture at the reference temperature and 1.0 Hz	Literature	Design
Reference Mix Design	Dynamic modulus@ 10.0 Hz (MPa)	Integer	Dynamic modulus of a mixture at the reference temperature and 10.0 Hz	Literature	Design
Reference Mix Design	Dynamic modulus@ 20.0 Hz (MPa)	Integer	Dynamic modulus of a mixture at the reference temperature and 20.0 Hz	Literature	Design
Reference Mix Design	Stiffness 4-PB (MPa)	Double	The stiffness modulus of an asphalt mixture measured in the four-point bending test	PIM	Design
Reference Mix Design	Fatigue resistance 4-PB (EPS-6)	Integer	The fatigue resistance of an asphalt mixture measured in the four-point bending test expressed in the elongation at 1E+06 load repetitions	PIM	Design
Reference Mix Design	Fatigue resistance 4-PB (k1)	Double	The intercept of the fatigue characteristic (Wohler) of an asphalt mixture measured in the four-point bending test	PIM	Design

Reference Mix Design	Fatigue resistance 4-PB (k2)	Double	The slope of the fatigue characteristic (Wohler) of an asphalt mixture measured in the four-point bending test	PIM	Design
Reference Mix Design	Reference temperature of triaxial (°C)	Double	A reference temperature that the triaxial test is conducted	Literature	Design
Reference Mix Design	Creep rate (µstrain/load cycle)	Double	The deformation resistance of an asphalt mixture measured in the triaxial test	PIM	Design
Reference Mix Design	Reference temperature of dynamic creep (°C)	Double	A reference temperature that the dynamic creep test is conducted	Literature	Design
Reference Mix Design	Flow number	Integer	The number of cycles when the tangent slope of the permanent strain vs loading cycle curve dramatically increases in the dynamic creep test	Literature	Design
Reference Mix Design	Reference temperature of HWTD (°C)	Double	A reference temperature that the Hamburg Wheel-Track Device (HWTD) test is conducted	Literature	Design
Reference Mix Design	Ruth Depth (mm)	Double	The rutting depth under the wheel of Hamburg Wheel-Track Device (HWTD) test in 10000 cycles	Literature	Design
Reference Mix Design	Stiffness CIT-CY (MPa)	Double	The stiffness modulus of an asphalt mixture measured in the four-point bending test	PIM	Design
Reference Mix Design	Fatigue resistance CIT-CY	Integer	The fatigue resistance of an asphalt mixture measured in the cyclic indirect tensile test	Literature	Design
Reference Mix Design	Fatigue resistance CIT-CY (C1)	Double	The intercept of the fatigue characteristic (exponential) of an asphalt mixture measured in the cyclic indirect tensile test	PIM	Design
Reference Mix Design	Fatigue resistance CIT-CY (C2)	Double	The slope of the fatigue characteristic (exponential) of an asphalt mixture measured in the cyclic indirect tensile test	PIM	Design

Reference Mix Design	Fatigue resistance CIT-CY (A1)	Double	The intercept of the fatigue characteristic (logarithmic) of an asphalt mixture measured in the cyclic indirect tensile test	PIM	Design
Reference Mix Design	Fatigue resistance CIT-CY (A2)	Double	The slope of the fatigue characteristic (logarithmic) of an asphalt mixture measured in the cyclic indirect tensile test	PIM	Design
Reference Mix Design	Shift factor healing	Double	Correction factor for the number of permissible axle load cycles on a mixture as a result of the self-healing capacity	PIM	Design
Reference Mix Design	Resilient modulus (MPa)	Integer	The ratio of the applied peak stress to the recoverable strain in the resilient modulus test	Literature	Design
Reference Mix Design	Indirect tensile strength, ambient temp (kPa)	Integer	Indirect tensile strength when a mixture is subjected to were subjected to loading from a diagonal direction at a constant load rate and ambient temperature	Literature	Design
Reference Mix Design	Indirect tensile strength, low temp (kPa)	Integer	Indirect tensile strength when a mixture is subjected to were subjected to loading from a diagonal direction at a constant load rate and low temperature	Literature	Design
Reference Mix Design	SCB-Reference temperature (°C)	Integer	A reference temperature that the SemiCircular Bending (SCB) test is conducted	Literature	Design
Reference Mix Design	SCB-Peak load (kN)	Double	Peak load which is an indicating failure strength in SCB test	Literature	Design
Reference Mix Design	Gf (j/m2)	Double	Fracture energy which shows the total dissipated energy during crack formation in SCB test	Literature	Design
Reference Mix Design	FI (kN/mm)	Double	Flexibility index which shows the potential of mixtures for development of cracking-related damage in SCB test	Literature	Design
Reference Mix Design	CRI	Double	Cracking resistance index which is the ratio of fracture energy and peak load in SCB test	Literature	Design
Reference Mix Design	Raveling test type	String	The type of raveling test used to determine the raveling resistance of a mixture	PIM	Design

Reference Mix Design	Stone loss raveling test (%)	Double	The measured stone loss of a mixture in the raveling test	PIM	Design
Reference Mix Design	Bond strength adhesive layer	Double	The bond strength of an adhesive layer between two asphalt layers	PIM	Design
Reference Mix Design	Noise reduction	Double	The measured noise reduction of an asphalt surface layer	PIM	Design
Reference Mix Design	Water-resistance RTD 1009	Boolean	The indication of whether an asphalt mixture is watertight (yes/no) following RTD 1009 (Rijkswaterstaat Technical Documentation)	PIM	Design
Reference Mix Design	FAP parameter 1	Double	The measured frictional resistance of an asphalt mixture (absolute) based on the Friction After Polishing test	PIM	Design
Reference Mix Design	FAP parameter 2	Double	The measured frictional resistance of an asphalt mixture (relative) the Friction After Polishing test	PIM	Design
Reference Mix Design	C1	Double	Material constant C1 is the stiffness characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C2	Double	Material constant C2 is the stiffness characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C3	Double	Material constant C3 is the stiffness characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C4	Double	Material constant C4 is the stiffness characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C number [°K]	Double	Material constant C number is the stiffness characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C1	Double	Material constant C1 is the fatigue characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C2	Double	Material constant C2 is the fatigue characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C3	Double	Material constant C3 is the fatigue characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	C4	Double	Material constant C4 is the fatigue characteristic of an asphalt mixture	OIA	Design

Reference Mix Design	C5	Double	Material constant C5 is the fatigue characteristic of an asphalt mixture	OIA	Design
Reference Mix Design	Poisson's ratio	Double	Poisson's ratio of a reference asphalt mix	OIA	Design
Construction-ready Design	ID	String	Unique identifier (code) of the construction-ready design	Literature	Design
Construction-ready Design	Max 22,4 mm (%)	Double	The max mass fraction of the aggregate through sieve size 22.4 mm	Literature	Design
Construction-ready Design	Max 16 mm (%)	Double	The max mass fraction of the aggregate through sieve size 16 mm	Literature	Design
Construction-ready Design	Max 11,2 mm (%)	Double	The max mass fraction of the aggregate through sieve size 11.2 mm	Literature	Design
Construction-ready Design	Max 8 mm (%)	Double	The max mass fraction of the aggregate through sieve size 8 mm	Literature	Design
Construction-ready Design	Max 5,6 mm (%)	Double	The max mass fraction of the aggregate through sieve size 5.6 mm	Literature	Design
Construction-ready Design	Max 4 mm (%)	Double	The max mass fraction of the aggregate through sieve size 4 mm	Literature	Design
Construction-ready Design	Max 2 mm (%)	Double	The max mass fraction of the aggregate through sieve size 2 mm	Literature	Design
Construction-ready Design	Max 0,5 mm (%)	Double	The max mass fraction of the aggregate through sieve size 500 µm	Literature	Design
Construction-ready Design	Max 0,18 mm (%)	Double	The max mass fraction of the aggregate through sieve size 180 µm	Literature	Design

Construction-ready Design	Max 0,125 mm (%)	Double	The max mass fraction of the aggregate through sieve size 125 µm	Literature	Design
Construction-ready Design	Max 0,063 mm (%)	Double	The max mass fraction of the aggregate through sieve size 63 µm	Literature	Design
Construction-ready Design	Min 22,4 mm (%)	Double	The min mass fraction of the aggregate through sieve size 22.4 mm	Literature	Design
Construction-ready Design	Min 16 mm (%)	Double	The min mass fraction of the aggregate through sieve size 16 mm	Literature	Design
Construction-ready Design	Min 11,2 mm (%)	Double	The min mass fraction of the aggregate through sieve size 11.2 mm	Literature	Design
Construction-ready Design	Min 8 mm (%)	Double	The min mass fraction of the aggregate through sieve size 8 mm	Literature	Design
Construction-ready Design	Min 5,6 mm (%)	Double	The min mass fraction of the aggregate through sieve size 5.6 mm	Literature	Design
Construction-ready Design	Min 4 mm (%)	Double	The min mass fraction of the aggregate through sieve size 4 mm	Literature	Design
Construction-ready Design	Min 2 mm (%)	Double	The min mass fraction of the aggregate through sieve size 2 mm	Literature	Design
Construction-ready Design	Min 0,5 mm (%)	Double	The min mass fraction of the aggregate through sieve size 500 µm	Literature	Design
Construction-ready Design	Min 0,18 mm (%)	Double	The min mass fraction of the aggregate through sieve size 180 µm	Literature	Design
Construction-ready Design	Min 0,125 mm (%)	Double	The min mass fraction of the aggregate through sieve size 125 µm	Literature	Design

Construction-ready Design	Min 0,063 mm (%)	Double	The min mass fraction of the aggregate through sieve size 63 µm	Literature	Design
Construction-ready Design	Max additive density	Integer	Max density of additive that can be adequate for the mix	Literature	Design
Construction-ready Design	Min additive density	Integer	Min density of additive that can be adequate for the mix	Literature	Design
Construction-ready Design	Max coarse aggregate density (kg/m3)	Integer	Max density of coarse aggregate that can be adequate for the mix	Literature	Design
Construction-ready Design	Min coarse aggregate density (kg/m3)	Integer	Min density of coarse aggregate that can be adequate for the mix	Literature	Design
Construction-ready Design	Max fine aggregate density (kg/m3)	Integer	Max density of fine aggregate that can be adequate for the mix	Literature	Design
Construction-ready Design	Min fine aggregate density (kg/m3)	Integer	Min density of fine aggregate that can be adequate for the mix	Literature	Design
Construction-ready Design	Max filler density (kg/m3)	Integer	Max density of filler that can be adequate for the mix	Literature	Design
Construction-ready Design	Min filler density (kg/m3)	Integer	Min density of filler that can be adequate for the mix	Literature	Design
Construction-ready Design	Max aggregate moisture content	Double	Max moisture content of aggregate that can be adequate for the mix	Literature	Design

Construction-ready Design	Min aggregate moisture content	Double	Min moisture content of aggregate that can be adequate for the mix	Literature	Design
Construction-ready Design	Max bitumen content (%)	Double	The max bitumen content that can be adequate for the mix	Literature	Design
Construction-ready Design	Min bitumen content (%)	Double	The min bitumen content that can be adequate for the mix	Literature	Design
Construction-ready Design	Max production temperature (°C)	Integer	The max temperature recommended for the production of mixture	Literature	Design
Construction-ready Design	Min production temperature (°C)	Integer	The temperature recommended for the production of mixture	Literature	Design
Construction-ready Design	Minimum compaction temperature (°C)	Integer	The min temperature recommended for the compaction of mixture	PIM	Design
Construction-ready Design	Maximum compaction temperature (°C)	Integer	The max temperature recommended for the compaction of mixture	PIM	Design
Construction-ready Design	Max bulk specific gravity (kg/m3)	Double	The max density that can be adequate for the mix	PIM	Design
Construction-ready Design	Min bulk specific gravity (kg/m3)	Double	The min density that can be adequate for the mix	PIM	Design

Construction-ready Design	Min air void (Vmin) (%)	Double	The minimum amount of hollow space that can be adequate for the mix	PIM	Design
Construction-ready Design	Max air void (Vmax) (%)	Double	The maximum amount of hollow space that can be adequate for the mix	PIM	Design
Construction-ready Design	Min water sensitivity (TSR) (%)	Double	The min sensitivity of an asphalt mixture to the action of moisture (ratio of conditioned ITS to dry ITS)	PIM	Design
Construction-ready Design	Max VFB (%)	Double	The max void that can be filled by bitumen	PIM	Design
Construction-ready Design	Min VFB (%)	Double	The mix void that can be filled by bitumen	PIM	Design
Construction-ready Design	Max stiffness (MPa)	Integer	The max stiffness that can be adequate for the mix	PIM	Design
Construction-ready Design	Min stiffness (MPa)	Integer	The min stiffness that can be adequate for the mix	PIM	Design
Construction Activity	ID	String	Unique identifier (code) of the construction	Literature	Construction
Construction Activity	Project ID	String	Unique identifier (code) of the project	Literature	Construction
Construction Activity	Subproject ID	String	Unique identifier (code) in PIM of a subproject	Literature	Construction
Construction Activity	Contract ID	String	Contract ID	Literature	Construction
Construction Activity	Contract Type	String	The type of Contact	Literature	Construction
Construction Activity	Comments	String	Remarks associated with the contract	Literature	Construction
Construction Activity	Contractor	String	Contractor's company name	Literature	Construction

Construction Activity	Contractor Contact Person	String	Contact person for the project at the contractor	Literature	Construction
Building Mixture	ID	String	Unique identifier (code) of the building mix	Literature	Construction
Building Mixture	Building mixture name	String	Description or name of a building mixture	PIM	Construction
Building Mixture	Building mixture code	String	Unique code for designating a building mixture	PIM	Construction
Building Mixture	Target density (kg/m3)	Double	The target density of the building mixture	Literature	Construction
Building Mixture	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density of a building mixture	Literature	Construction
Building Mixture	Maximum production temperature (°C)	Integer	The maximum temperature allowed for the production of a mixture	PIM	Construction
Building Mixture	Minimum production temperature (°C)	Integer	The minimum temperature allowed for the production of a mixture	PIM	Construction
Building Mixture	Recommended mixing temperature (°C)	Integer	The recommended temperature for the production of an asphalt mixture	PIM	Construction
Building Mixture	Actual delivery temperatur	Double	The measured delivery temperature of a mixture when loading into the truck takes place	PIM	Construction

	e asphalt plant (°C)				
Building Mixture	22,4 mm (%)	Double	The mass fraction of the building aggregate through sieve size 22.4 mm	PIM	Construction
Building Mixture	16 mm (%)	Double	The mass fraction of the building aggregate through sieve size 16 mm	PIM	Construction
Building Mixture	11,2 mm (%)	Double	The mass fraction of the building aggregate through sieve size 11.2 mm	PIM	Construction
Building Mixture	8 mm (%)	Double	The mass fraction of the building aggregate through sieve size 8 mm	PIM	Construction
Building Mixture	5,6 mm (%)	Double	The mass fraction of the building aggregate through sieve size 5.6 mm	PIM	Construction
Building Mixture	4 mm (%)	Double	The mass fraction of the building aggregate through sieve size 4 mm	PIM	Construction
Building Mixture	2 mm (%)	Double	The mass fraction of the building aggregate through sieve size 2 mm	PIM	Construction
Building Mixture	0,5 mm (%)	Double	The mass fraction of the building aggregate through sieve size 500 µm	PIM	Construction
Building Mixture	0,18 mm (%)	Double	The mass fraction of the building aggregate through sieve size 180 µm	PIM	Construction
Building Mixture	0,125 mm (%)	Double	The mass fraction of the building aggregate through sieve size 125 µm	PIM	Construction
Building Mixture	0,063 mm (%)	Double	The mass fraction of the building aggregate through sieve size 63 µm	PIM	Construction
Building Mixture	Bitumen content (%)	Double	The optimum bitumen content in building mixture	Literature	Construction
Building Mixture	Soluble bitumen content (%)	Double	The soluble bitumen content in building mixture	Literature	Construction
Building Mixture	Number of passes@target density	Integer	The number of passes (rollers passes) when the asphalt reaches to target density	PQi	Construction
Stationary Asphalt Plant	ID	String	Unique identifier (code) of the stationary asphalt plant	Literature	Construction

Stationary Asphalt Plant	Type	String	The type of asphalt plant for mixing asphalt such as batch, drum, etc	Literature	Construction
Stationary Asphalt Plant	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (location)	Literature	Construction
Stationary Asphalt Plant	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (location)	Literature	Construction
Stationary Asphalt Plant	Altitude	Double	Vertical direction between a reference datum and a point (location)	Literature	Construction
Stationary Asphalt Plant	Production Rate (ton/hr)	Integer	The amount of asphalt that can be produced by the plant in an hour	Literature	Construction
Stationary Asphalt Plant	Storage Capacity (ton)	Integer	The total amount of storage capacity that can be saved by the asphalt plant	Literature	Construction
Stationary Asphalt Plant	Temperature of Bitumen silo (°C)	Double	The average temperature for the silo of bitumen	Literature	Construction
Stationary Asphalt Plant	Temperature of Aggregate silo (°C)	Double	The average temperature for the silo of aggregate	Literature	Construction
Stationary Asphalt Plant	Temperature of Recycled Material silo (°C)	Double	The average temperature for the silo of recycled materials	Literature	Construction
Stationary Asphalt Plant	Loading time (min)	Integer	The time which takes to fill one truck	Literature	Construction

Semi-stationary Asphalt Plant	ID	String	Unique identifier (code) of the semi-stationary asphalt plant	Literature	Construction
Semi-stationary Asphalt Plant	Type	String	The type of asphalt plant for mixing asphalt such as batch, drum, etc	Literature	Construction
Semi-stationary Asphalt Plant	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (location)	Literature	Construction
Semi-stationary Asphalt Plant	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (location)	Literature	Construction
Semi-stationary Asphalt Plant	Altitude	Double	Vertical direction between a reference datum and a point (location)	Literature	Construction
Semi-stationary Asphalt Plant	Production Rate (ton/hr)	Integer	The amount of asphalt that can be produced by the plant in an hour	Literature	Construction
Semi-stationary Asphalt Plant	Storage Capacity (ton)	Integer	The total amount of storage capacity that can be saved by the asphalt plant	Literature	Construction
Semi-stationary Asphalt Plant	Temperature of Bitumen silo (°C)	Double	The average temperature for the silo of bitumen	Literature	Construction
Semi-stationary Asphalt Plant	Temperature of Aggregate silo (°C)	Double	The average temperature for the silo of aggregate	Literature	Construction

Semi-stationary Asphalt Plant	Temperature of Recycled Material silo (°C)	Double	The average temperature for the silo of recycled materials	Literature	Construction
Semi-stationary Asphalt Plant	Loading time (min)	Integer	The time which takes to fill one truck	Literature	Construction
Mobile Asphalt Plant	ID	String	Unique identifier (code) of the mobile asphalt plant	Literature	Construction
Mobile Asphalt Plant	Type	String	The type of asphalt plant for mixing asphalt such as batch, drum, etc	Literature	Construction
Mobile Asphalt Plant	Production Rate (ton/hr)	Integer	The amount of asphalt that can be produced by the plant in an hour	Literature	Construction
Mobile Asphalt Plant	Storage Capacity (ton)	Integer	The total amount of storage capacity that can be saved by the asphalt plant	Literature	Construction
Mobile Asphalt Plant	Temperature of Bitumen silo (°C)	Double	The average temperature for the silo of bitumen	Literature	Construction
Mobile Asphalt Plant	Temperature of Aggregate silo (°C)	Double	The average temperature for the silo of aggregate	Literature	Construction
Mobile Asphalt Plant	Temperature of Recycled Material silo (°C)	Double	The average temperature for the silo of recycled materials	Literature	Construction

Mobile Asphalt Plant	Loading time (min)	Integer	The time which takes to fill one truck	Literature	Construction
Operator	ID	String	Unique identifier (code) of the operator	Literature	Construction
Operator	Equipment ID	String	Unique identifier (code) of equipment that the operator operates	Literature	Construction
Operator	Operator Name	String	The name of the operator	Literature	Construction
Operator	Operator Sex	String	The sex of operator	Literature	Construction
Operator	Operator Age	Integer	The age of operator	Literature	Construction
Operator	Operator Experience	Integer	The experience of operator in years	Literature	Construction
Worker	ID	String	Unique identifier (code) of the worker	Literature	Construction
Worker	Activity ID	String	Unique identifier (code) of activity that the worker performs	Literature	Construction
Worker	Worker Name	String	The name of the worker	Literature	Construction
Worker	Worker Sex	String	The sex of worker	Literature	Construction
Worker	Worker Age	Integer	The age of worker	Literature	Construction
Worker	Worker Experience	Integer	The experience of worker in years	Literature	Construction
Truck	ID	String	Unique identifier (code) of the truck	Literature	Construction
Truck	Type	String	The type of truck used for the asphalt transportation	Literature	Construction
Truck	Manufacturer	String	The name of company that makes the truck	Literature	Construction
Truck	Truck ID License	String	The license plate of the truck that transports the asphalt	WINWEIGH - PIM	Construction
Truck	Capacity (ton)	Double	The total capacity of truck	Literature	Construction

Truck	Weight (ton)	Double	The weight of truck when it is empty	Literature	Construction
Truck	Length (m)	Double	The length of truck	Literature	Construction
Truck	Width (m)	Double	The width of truck	Literature	Construction
Truck	Isolation System	String	The description regarding the type of isolation system used for the truck	Literature	Construction
Truck	Fuel tank (l)	Integer	The volume of tank filling with the fuel	Literature	Construction
Truck	Fuel Consumption (l/100km)	Double	The amount of fuel consumption in liters per 100 km	Literature	Construction
Truck	Daily noise exposure level (dB)	Double	The amount of noise produced by the vehicle per 8 hours in a day (daily work)	Literature	Construction
Truck	Max Speed (km/h)	Double	The maximum speed of the vehicle	Literature	Construction
Truck	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Truck	Unloading point	String	The GPS location where the truck unloads the asphalt mix (specific for each truck)	PIM	Construction
Truck	Delivery note ID	String	Unique identifier of an asphalt freight delivery note	WINWEIGH - PIM	Construction
Truck	Mixture Code	String	The unique mixture code of the asphalt mixture delivered	WINWEIGH - PIM	Construction
Truck	Mixture description	String	The description of the delivered asphalt mixture	WINWEIGH - PIM	Construction
Truck	Asphalt Amount	Double	The amount of asphalt mixture in the truck	WITOS	Construction
Truck	Asphalt temperature@Chamber (°C)	Double	The temperature of asphalt mortar measured in the worm chamber of the asphalt spreading machine	WITOS	Construction
Truck	Delivery Time	String	The time at which the truck arrived at the job site (specific for each truck)	Literature	Construction
Truck	Cycle Time (min)	Double	The time duration takes for each truck to reach the job site from the starting point (plant)	Literature	Construction

Miller	ID	String	Unique identifier (code) of the miller	Literature	Construction
Miller	Type	String	The type of miller used for the asphalt milling	Literature	Construction
Miller	Manufacturer	String	The name of the company makes the miller	Literature	Construction
Miller	Milling Width (m)	Double	The width of road that can be milled by the miller	Literature	Construction
Miller	Max Milling Depth (mm)	Double	The max depth of the road that can be milled by the miller	Literature	Construction
Miller	Max Power (hp)	Integer	The max power of the miller used for the project	Literature	Construction
Miller	Operating Weight (ton)	Double	The weight of the miller while it is operating	Literature	Construction
Miller	Fuel tank (l)	Integer	The volume of tank filling with the fuel	Literature	Construction
Miller	Fuel Consumption (l/100km)	Double	The amount of fuel consumption in liter per 100 km	Literature	Construction
Miller	Daily noise exposure level (dB)	Double	The amount of noise produced by the vehicle per 8 hours in a day (daily work)	Literature	Construction
Miller	Max Operating Speed (m/min)	Double	The maximum speed that can be used for operating phase	Literature	Construction
Miller	Max Travel Speed (km/h)	Double	The maximum speed that can be used for traveling phase (not operating phase)	Literature	Construction
Miller	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Cleaning Machine	ID	String	Unique identifier (code) of the cleaning machine	Literature	Construction

Cleaning Machine	Type	String	The type of cleaning machine used for the asphalt cleaning	Literature	Construction
Cleaning Machine	Manufacturer	String	The name of company that makes the cleaning machine	Literature	Construction
Cleaning Machine	Weight (ton)	Double	The weight of cleaning machine	Literature	Construction
Cleaning Machine	Length (m)	Double	The length of cleaning machine	Literature	Construction
Cleaning Machine	Width (m)	Double	The width of cleaning machine	Literature	Construction
Cleaning Machine	Fuel tank (l)	Integer	The volume of tank filling with the fuel	Literature	Construction
Cleaning Machine	Fuel Consumption (l/100km)	Double	The amount of fuel consumption in liters per 100 km	Literature	Construction
Cleaning Machine	Daily noise exposure level (dB)	Double	The amount of noise produced by the vehicle per 8 hours in a day (daily work)	Literature	Construction
Cleaning Machine	Max Speed (km/h)	Double	The maximum speed of the vehicle	Literature	Construction
Cleaning Machine	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Material Transfer Vehicle	ID	String	Unique identifier (code) of the material transfer vehicle	Literature	Construction
Material Transfer Vehicle	Type	String	The type of material transfer vehicle used in job site such as feeder, shuttle buggy, etc	Literature	Construction
Material Transfer Vehicle	Manufacturer	String	The name of company makes the MTV	Literature	Construction
Material Transfer Vehicle	Weight (ton)	Double	The weight of material transfer vehicle	Literature	Construction

Material Transfer Vehicle	Length (m)	Double	The length of material transfer vehicle	Literature	Construction
Material Transfer Vehicle	Width (m)	Double	The width of material transfer vehicle	Literature	Construction
Material Transfer Vehicle	Fuel tank (l)	Integer	The volume of tank filling with the fuel	Literature	Construction
Material Transfer Vehicle	Fuel Consumption (l/100km)	Double	The amount of fuel consumption in liters per 100 km	Literature	Construction
Material Transfer Vehicle	Daily noise exposure level (dB)	Double	The amount of noise produced by the vehicle per 8 hours in a day (daily work)	Literature	Construction
Material Transfer Vehicle	Max Operating Speed (m/min)	Double	The maximum speed that can be used for operating phase	Literature	Construction
Material Transfer Vehicle	Max Travel Speed (km/h)	Double	The maximum speed that can be used for traveling phase (not operating phase)	Literature	Construction
Material Transfer Vehicle	Capacity of Hopper (ton)	Double	The capacity of hopper that can be filler with asphalt mixture	Literature	Construction
Material Transfer Vehicle	Width of Hopper (m)	Double	The width of hopper	Literature	Construction
Material Transfer Vehicle	Height of Hopper (m)	Double	The height of hopper	Literature	Construction
Material Transfer Vehicle	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction

Paver	ID	String	Unique identifier (code) of the paver	Literature	Construction
Paver	Type	String	The type of paver used in job site	Literature	Construction
Paver	Manufacturer	String	The name of company that makes the paver	Literature	Construction
Paver	Weight (ton)	Double	The weight of paver	Literature	Construction
Paver	Length (m)	Double	The length of paver	Literature	Construction
Paver	Width (m)	Double	The width of paver	Literature	Construction
Paver	Fuel tank (l)	Integer	The volume of tank filling with the fuel	Literature	Construction
Paver	Fuel Consumption (l/100km)	Double	The amount of fuel consumption in liters per 100 km	Literature	Construction
Paver	Daily noise exposure level (dB)	Double	The amount of noise produced by the vehicle per 8 hours in a day (daily work)	Literature	Construction
Paver	Max Operating Speed (m/min)	Double	The maximum speed that can be used for operating phase	Literature	Construction
Paver	Max Travel Speed (km/h)	Double	The maximum speed that can be used for traveling phase (not operating phase)	Literature	Construction
Paver	Capacity of Hopper (ton)	Double	The capacity of hopper that can be filler with asphalt mixture	Literature	Construction
Paver	Width of Hopper (m)	Double	The width of hopper	Literature	Construction
Paver	Height of Hopper (m)	Double	The height of hopper	Literature	Construction
Paver	Capacity of Storage Bin (ton)	Double	The capacity of storage bin that can be filler with asphalt mixture	Literature	Construction
Paver	Max Laydown	Integer	The maximum amount of asphalt that can be paved by the paver	Literature	Construction

	Rate (ton/h)				
Paver	Screed Type	String	The type of screed used for the paving process	Literature	Construction
Paver	Basic Screed Width (m)	Double	The basic width of screed	Literature	Construction
Paver	Max Screed Width (m)	Double	The maximum width of screed	Literature	Construction
Paver	Max Paver Layer Thickness (mm)	Integer	The maximum thickness that can be paved by the screed	Literature	Construction
Paver	Screed Compactio n System Type	String	The type of compaction system used for the screed	Literature	Construction
Paver	Screed Heating System Type	String	The type of heating system used for the screed	Literature	Construction
Paver	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Roller	ID	String	Unique identifier (code) of the roller	Literature	Construction
Roller	Type	String	The type of roller used in job site such as tandem, pneumatic, 3 drum rollers	Literature	Construction
Roller	Manufactur er	String	The name of company that makes the roller	Literature	Construction
Roller	Weight (ton)	Double	The weight of roller	Literature	Construction
Roller	Max Operating Weight (ton)	Double	The maximum weight of roller during the operation	Literature	Construction
Roller	Length (m)	Double	The length of roller	Literature	Construction
Roller	Width (m)	Double	The width of roller	Literature	Construction

Roller	Front Drum Type	String	The type of front drum	Literature	Construction
Roller	Rear Drum Type	String	The type of rear drum	Literature	Construction
Roller	Front Drum Thickness (mm)	Integer	The thickness of the front drum	Literature	Construction
Roller	Rear Drum Thickness (mm)	Integer	The thickness of the rear drum	Literature	Construction
Roller	Front Drum Diameter (m)	Double	The diameter of the front drum	Literature	Construction
Roller	Rear Drum Diameter (m)	Double	The diameter of the rear drum	Literature	Construction
Roller	Front Drum Width (m)	Double	The width of the front drum	Literature	Construction
Roller	Rear Drum Width (m)	Double	The width of the rear drum	Literature	Construction
Roller	Oscillation Force (kN)	Integer	The oscillation force used by the roller	Literature	Construction
Roller	Oscillation Frequency (Hz)	Integer	The frequency of the oscillation used by the roller	Literature	Construction
Roller	Vibration Force (kN)	Integer	The Vibration force used by the roller	Literature	Construction
Roller	Vibration Frequency (Hz)	Integer	The frequency of the Vibration used by the roller	Literature	Construction
Roller	Fuel tank (l)	Integer	The volume of tank filling with the fuel	Literature	Construction
Roller	Fuel Consumption (l/100km)	Double	The amount of fuel consumption in liters per 100 km	Literature	Construction

Roller	Water Tank Sprinkler Type	String	The type of water tank sprinkler	Literature	Construction
Roller	Water tank (l)	Integer	The volume of the water tank	Literature	Construction
Roller	Daily noise exposure level (dB)	Double	The amount of noise produced by the vehicle per 8 hours in a day (daily work)	Literature	Construction
Roller	Max Operating Speed (m/min)	Double	The maximum speed that can be used for operating phase	Literature	Construction
Roller	Max Travel Speed (km/h)	Double	The maximum speed that can be used for traveling phase (not operating phase)	Literature	Construction
Roller	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Asphalt Milling	ID	String	Unique identifier (code) for the milling activity	Literature	Construction
Asphalt Milling	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Asphalt Milling	Worker ID	String	Unique identifier (code) of the worker	Literature	Construction
Asphalt Milling	Start Time	String	The time that milling is started	Literature	Construction
Asphalt Milling	End Time	String	The time that milling is ended	Literature	Construction
Asphalt Milling	Date	String	The date of milling	Literature	Construction
Asphalt Milling	Start Point Location	String	The GPS location of starting point	Literature	Construction
Asphalt Milling	End Point Location	String	The GPS location of ending point	Literature	Construction
Asphalt Milling	Milling Width (m)	Double	The width of milling	Literature	Construction

Asphalt Milling	Milling Depth (mm)	Double	The depth of milling	Literature	Construction
Asphalt Milling	Milling Length (km)	Double	The length of milling	Literature	Construction
Asphalt Milling	Milling Layer	String	The layer where milling is performed such surface, binder or base layer	Literature	Construction
Asphalt Milling	Total Amount of Asphalt Milled (m3)	Double	The total amount of asphalt miller by miller	Literature	Construction
Asphalt Milling	Total Number of Miller	Integer	The total number of miller used for the milling activity	Literature	Construction
Asphalt Milling	Comments	String	Remarks associated with the milling	Literature	Construction
Asphalt Delivery	ID	String	Unique identifier (code) for the delivery activity	Literature	Construction
Asphalt Delivery	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Asphalt Delivery	Worker ID	String	Unique identifier (code) of the worker	Literature	Construction
Asphalt Delivery	Start Time	String	The time that delivery is started (First truck leaves the plant)	Literature	Construction
Asphalt Delivery	End Time	String	The time that delivery ends (the last truck unloads the asphalt)	Literature	Construction
Asphalt Delivery	Date	String	The date of delivery	Literature	Construction
Asphalt Delivery	Start Point Location	String	The GPS location of starting point (might be the plant)	Literature	Construction
Asphalt Delivery	End Point Location	String	The GPS location of ending point (job site location)	Literature	Construction
Asphalt Delivery	Delivery Layer	String	The layer that delivery is performed for such surface, binder or base layer	Literature	Construction

Asphalt Delivery	Total Amount of Asphalt Milled (m3)	Double	The total amount of asphalt delivered by trucks	Literature	Construction
Asphalt Delivery	Total Number of Trucks	Integer	The total number of trucks used for the delivery activity	Literature	Construction
Asphalt Delivery	Comments	String	Remarks associated with the delivery	Literature	Construction
Asphalt Cleaning	ID	String	Unique identifier (code) for the cleaning activity	Literature	Construction
Asphalt Cleaning	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Asphalt Cleaning	Worker ID	String	Unique identifier (code) of the worker	Literature	Construction
Asphalt Cleaning	Start Time	String	The time that cleaning is started	Literature	Construction
Asphalt Cleaning	End Time	String	The time that cleaning is ended	Literature	Construction
Asphalt Cleaning	Date	String	The date of cleaning	Literature	Construction
Asphalt Cleaning	Start Point Location	String	The GPS location of starting point	Literature	Construction
Asphalt Cleaning	End Point Location	String	The GPS location of ending point	Literature	Construction
Asphalt Cleaning	Cleaning Layer	String	The layer that cleaning is performed for such surface, binder or base layer	Literature	Construction
Asphalt Cleaning	Total Number of Cleaning Machine	Integer	The total number of cleaning machines used for the cleaning activity	Literature	Construction
Asphalt Cleaning	Total Number of Passes	Integer	The total number of passes that is taken place for cleaning the layer	Literature	Construction

Asphalt Cleaning	Average Speed (km/h)	Double	The average speed of the vehicle used for cleaning activity	Literature	Construction
Asphalt Cleaning	Comments	String	Remarks associated with the cleaning	Literature	Construction
Asphalt Paving	ID	String	Unique identifier (code) for the paving activity	Literature	Construction
Asphalt Paving	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Asphalt Paving	Worker ID	String	Unique identifier (code) of the worker	Literature	Construction
Asphalt Paving	Start Time	String	The time that paving is started	Literature	Construction
Asphalt Paving	End Time	String	The time that paving is ended	Literature	Construction
Asphalt Paving	Date	String	The date of paving	Literature	Construction
Asphalt Paving	Start Point Location	String	The GPS location of starting point	Literature	Construction
Asphalt Paving	End Point Location	String	The GPS location of ending point	Literature	Construction
Asphalt Paving	Paving Layer	String	The layer that paving is performed for such surface, binder or base layer	Literature	Construction
Asphalt Paving	Total Number of Paver	Integer	The total number of paving machines used for the paving activity	Literature	Construction
Asphalt Paving	Average Speed (km/h)	Double	The average speed of the vehicle used for paving activity	Literature	Construction
Asphalt Paving	Paving Width (m)	Double	The width of paving	Literature	Construction
Asphalt Paving	Paving Height (mm)	Double	The height of paving	Literature	Construction

Asphalt Paving	Paving Length (km)	Double	The length of paving	Literature	Construction
Asphalt Paving	Total Amount of Asphalt Paved (m3)	Double	The total amount of asphalt paved by paver	Literature	Construction
Asphalt Paving	Cross Slope (%)	Double	The cross slope considered for the paving activity	Literature	Construction
Asphalt Paving	Comments	String	Remarks associated with the paving	Literature	Construction
Asphalt Compaction	ID	String	Unique identifier (code) for the compacting activity	Literature	Construction
Asphalt Compaction	Operator ID	String	Unique identifier (code) of the operator	Literature	Construction
Asphalt Compaction	Worker ID	String	Unique identifier (code) of the worker	Literature	Construction
Asphalt Compaction	Start Time	String	The time that compaction is started	Literature	Construction
Asphalt Compaction	End Time	String	The time that compaction is ended	Literature	Construction
Asphalt Compaction	Date	String	The date of compaction	Literature	Construction
Asphalt Compaction	Start Point Location	String	The GPS location of starting point	Literature	Construction
Asphalt Compaction	End Point Location	String	The GPS location of ending point	Literature	Construction
Asphalt Compaction	Compactio n Layer	String	The layer that compaction is performed for such surface, binder or base layer	Literature	Construction
Asphalt Compaction	Total Number of Roller	Integer	The total number of compacting machines used for the compaction activity	Literature	Construction
Asphalt Compaction	Average Speed (km/h)	Double	The average speed of the vehicle used for compaction activity	Literature	Construction

Asphalt Compaction	Compacting Width (m)	Double	The width of the road which is compacted	Literature	Construction
Asphalt Compaction	Compacting Height (mm)	Double	The height of road which is compacted	Literature	Construction
Asphalt Compaction	Compacting Length (km)	Double	The length of road which is compacted	Literature	Construction
Asphalt Compaction	Total Amount of Asphalt Compacted (m3)	Double	The total amount of asphalt compacted by roller	Literature	Construction
Asphalt Compaction	Compactio n Strategy	String	The description regarding the compaction strategy such as the priorities of roller and method for compacting	Literature	Construction
Asphalt Compaction	Number of Passes	Integer	The number of passes that is taken place for compacting the layer	Literature	Construction
Asphalt Compaction	Comments	String	Remarks associated with the compaction	Literature	Construction
Measureme nt & Testing Activity	ID	String	Unique identifier (code) of the operation	Literature	Operation
Measureme nt & Testing Activity	Project ID	String	Unique identifier (code) of the project	Literature	Operation
Measureme nt & Testing Activity	Subproject ID	String	Unique identifier (code) in PIM of a subproject	Literature	Operation
Measureme nt & Testing Activity	Contract ID	String	Contract ID	Literature	Operation
Measureme nt & Testing Activity	Contract Type	String	The type of Contact	Literature	Operation

Measurement & Testing Activity	Comments	String	Remarks associated with the contract	Literature	Operation
Measurement & Testing Activity	Contractor	String	Contractor's company name (for operation process)	Literature	Operation
Measurement & Testing Activity	Contractor Contact Person	String	Contact person for the project at the contractor (for operation process)	Literature	Operation
Maintenance Activity	ID	String	Unique identifier (code) of the maintenance	Literature	Maintenance
Maintenance Activity	Project ID	String	Unique identifier (code) of the project	Literature	Maintenance
Maintenance Activity	Subproject ID	String	Unique identifier (code) in PIM of a subproject	Literature	Maintenance
Maintenance Activity	Contract ID	String	Contract ID	Literature	Maintenance
Maintenance Activity	Contract Type	String	The type of Contact	Literature	Maintenance
Maintenance Activity	Comments	String	Remarks associated with the contract	Literature	Maintenance
Maintenance Activity	Contractor	String	Contractor's company name (for maintenance process)	Literature	Maintenance
Maintenance Activity	Contractor Contact Person	String	Contact person for the project at the contractor (for maintenance process)	Literature	Maintenance
Cleaning	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Cleaning	Start Time	String	The time that the task is started	Literature	Maintenance
Cleaning	End Time	String	The time that the task is started	Literature	Maintenance

Cleaning	Date	String	The date that the task is taken place	Literature	Maintenance
Cleaning	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Cleaning	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Cleaning	Objective	String	The objective that the cleaning starts for	Literature	Maintenance
Cleaning	Method	String	The description of the method used for the cleaning	Literature	Maintenance
Cleaning	Standard	String	The standard used for the cleaning	Literature	Maintenance
Cleaning	Contractor	String	The name of the contractor that performing the cleaning	Literature	Maintenance
Cleaning	Comments	String	Remarks associated with the cleaning	Literature	Maintenance
Spraying Rejuvenation	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Spraying Rejuvenation	Start Time	String	The time that the task is started	Literature	Maintenance
Spraying Rejuvenation	End Time	String	The time that the task is started	Literature	Maintenance
Spraying Rejuvenation	Date	String	The date that the task is taken place	Literature	Maintenance
Spraying Rejuvenation	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Spraying Rejuvenation	End Point Location	String	The GPS location of ending point	Literature	Maintenance

Spraying Rejuvenation	Objective	String	The objective that the spraying starts for	Literature	Maintenance
Spraying Rejuvenation	Method	String	The description of the method used for the spraying	Literature	Maintenance
Spraying Rejuvenation	Standard	String	The standard used for the spraying	Literature	Maintenance
Spraying Rejuvenation	Contractor	String	The name of the contractor that performing the spraying	Literature	Maintenance
Spraying Rejuvenation	Average Temperature (°C)	Double	The average temperature in a day that spraying is taken place	Literature	Maintenance
Spraying Rejuvenation	Humidity (%)	Double	The humidity on a day that spraying is taking place	Literature	Maintenance
Spraying Rejuvenation	Average Wind Speed (km/h)	Double	The average wind speed in a day that spraying takes place	Literature	Maintenance
Spraying Rejuvenation	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that spraying is taken place	Literature	Maintenance
Spraying Rejuvenation	Material Type	String	The type of rejuvenation used for the project	Literature	Maintenance
Spraying Rejuvenation	Bitumen Content (%)	Double	The content of bitumen used	Literature	Maintenance
Spraying Rejuvenation	Softening Point (°C)	Double	The softening point of the material	Literature	Maintenance

Spraying Rejuvenation	Stiffness@0.1 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@0.2 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@0.5 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@1.0 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@2.0 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@5.0Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@8.0Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@10.0 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@20.0 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@30.0 Hz	Double	The stiffness of a material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a material measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance

Spraying Rejuvenation	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a material measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Spraying Rejuvenation	Equipment	String	The equipment used for spraying the rejuvenation	Literature	Maintenance
Spraying Rejuvenation	Comments	String	Remarks associated with the spraying	Literature	Maintenance
Crack Filling	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Crack Filling	Start Time	String	The time that the task is started	Literature	Maintenance
Crack Filling	End Time	String	The time that the task is started	Literature	Maintenance
Crack Filling	Date	String	The date that the task is taken place	Literature	Maintenance
Crack Filling	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Crack Filling	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Crack Filling	Objective	String	The objective that the crack filling starts for	Literature	Maintenance
Crack Filling	Method	String	The description of the method used for the crack filling	Literature	Maintenance

Crack Filling	Standard	String	The standard used for the crack filling	Literature	Maintenance
Crack Filling	Contractor	String	The name of the contractor that performing the crack filling	Literature	Maintenance
Crack Filling	Operator Sex	String	The sex of operator	Literature	Maintenance
Crack Filling	Operator Age	Integer	The age of operator	Literature	Maintenance
Crack Filling	Operator Experience	Integer	The experience of operator in years	Literature	Maintenance
Crack Filling	Hottest Average Temperature (°C)	Double	The average hottest temperature in the location of crack filling annually	Literature	Maintenance
Crack Filling	Coldest Average Temperature (°C)	Double	The average coldest temperature in the location of crack filling annually	Literature	Maintenance
Crack Filling	Average Temperature (°C)	Double	The average temperature in a day that crack filling is taken place	Literature	Maintenance
Crack Filling	Humidity (%)	Double	The humidity in a day that crack filling takes place	Literature	Maintenance
Crack Filling	Average Wind Speed (km/h)	Double	The average wind speed in a day that crack filling is taken place	Literature	Maintenance
Crack Filling	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that crack filling is taken place	Literature	Maintenance
Crack Filling	Material Type	String	The type of material used for crack filling	Literature	Maintenance
Crack Filling	Preperation Time (min)	Integer	The preparation time for the material used for crack filling	Literature	Maintenance
Crack Filling	Curing Time (day)	Integer	The curing time for the material used for crack filling	Literature	Maintenance

Crack Filling	Cone Penetration @25°C (dmm)	Double	The amount of penetration in cone penetration test at temperature of 25 °C	Literature	Maintenance
Crack Filling	Cone Penetration @4°C (dmm)	Double	The amount of penetration in cone penetration test at temperature of 4 °C	Literature	Maintenance
Crack Filling	Cone Penetration -18°C (dmm)	Double	The amount of penetration in cone penetration test at temperature of -18 °C	Literature	Maintenance
Crack Filling	Resilience @25°C (%)	Double	The percent of recovery in resilient test at 25 °C	Literature	Maintenance
Crack Filling	Softening Point (°C)	Double	The softening point of the material	Literature	Maintenance
Crack Filling	Extrusion Rate (mL/min)	Double	The amount of extrusion rate in ml per min	Literature	Maintenance
Crack Filling	Tensile stress@150 % strain@23° C (kPa)	Double	The tensile stress when strain is 150 % and at 23 °C	Literature	Maintenance
Crack Filling	Tack-Free Time (h)	Double	The tack-free time for the material used in hour	Literature	Maintenance
Crack Filling	Stiffness@0 .1 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Crack Filling	Stiffness@0 .2 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Crack Filling	Stiffness@0 .5 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Crack Filling	Stiffness@1 .0 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Crack Filling	Stiffness@2 .0 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance

Crack Filling	Stiffness@5.0Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Crack Filling	Stiffness@8.0Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Crack Filling	Stiffness@10.0 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Crack Filling	Stiffness@20.0 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Crack Filling	Stiffness@30.0 Hz	Double	The stiffness of a crack filling material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Crack Filling	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a crack filling material measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Crack Filling	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a crack filling material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Crack Filling	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a crack filling material measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Crack Filling	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a crack filling material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Crack Filling	Bonding	String	The pass or fail value in the bonding test based on the EN standard	Literature	Maintenance
Crack Filling	Hardness	Integer	The amount of hardness in the hardness test based on the EN standard	Literature	Maintenance
Crack Filling	Flow@60°C (mm)	Double	The flow amount (mm) for the materials at 60°C	Literature	Maintenance
Crack Filling	Year of Service (year)	Integer	The years that the material can be in service	Literature	Maintenance

Crack Filling	Crack Cutting Equipment Type	String	The type of equipment used for crack cutting	Literature	Maintenance
Crack Filling	Crack Cleaning/Drying Equipment Type	String	The type of equipment used for crack cleaning/drying	Literature	Maintenance
Crack Filling	Material Installation Equipment Type	String	The type of equipment used for material installation	Literature	Maintenance
Crack Filling	Material Finishing Equipment Type	String	The type of equipment used for material finishing	Literature	Maintenance
Crack Filling	Comments	String	Remarks associated with the crack filling	Literature	Maintenance
Crack Sealing	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Crack Sealing	Start Time	String	The time that the task is started	Literature	Maintenance
Crack Sealing	End Time	String	The time that the task is started	Literature	Maintenance
Crack Sealing	Date	String	The date that the task is taken place	Literature	Maintenance
Crack Sealing	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Crack Sealing	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Crack Sealing	Objective	String	The objective that the crack sealing starts for	Literature	Maintenance
Crack Sealing	Method	String	The description of the method used for the crack filling	Literature	Maintenance

Crack Sealing	Standard	String	The standard used for the crack sealing	Literature	Maintenance
Crack Sealing	Contractor	String	The name of the contractor that performing the crack sealing	Literature	Maintenance
Crack Sealing	Operator Sex	String	The sex of operator	Literature	Maintenance
Crack Sealing	Operator Age	Integer	The age of operator	Literature	Maintenance
Crack Sealing	Operator Experience	Integer	The experience of operator in years	Literature	Maintenance
Crack Sealing	Hottest Average Temperature (°C)	Double	The average hottest temperature in the location of crack sealing annually	Literature	Maintenance
Crack Sealing	Coldest Average Temperature (°C)	Double	The average coldest temperature in the location of crack sealing annually	Literature	Maintenance
Crack Sealing	Average Temperature (°C)	Double	The average temperature in a day that crack sealing is taken place	Literature	Maintenance
Crack Sealing	Humidity (%)	Double	The humidity in a day that crack sealing takes place	Literature	Maintenance
Crack Sealing	Average Wind Speed (km/h)	Double	The average wind speed in a day that crack sealing is taken place	Literature	Maintenance
Crack Sealing	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that crack sealing is taken place	Literature	Maintenance
Crack Sealing	Material Type	String	The type of material used for crack sealing	Literature	Maintenance
Crack Sealing	Preperation Time (min)	Integer	The preparation time for the material used for crack sealing	Literature	Maintenance
Crack Sealing	Curing Time (day)	Integer	The curing time for the material used for crack sealing	Literature	Maintenance

Crack Sealing	Cone Penetration @25°C (dmm)	Double	The amount of penetration in cone penetration test at temperature of 25 °C	Literature	Maintenance
Crack Sealing	Cone Penetration @4°C (dmm)	Double	The amount of penetration in cone penetration test at temperature of 4 °C	Literature	Maintenance
Crack Sealing	Cone Penetration -18°C (dmm)	Double	The amount of penetration in cone penetration test at temperature of -18 °C	Literature	Maintenance
Crack Sealing	Resilience @25°C (%)	Double	The percent of recovery in resilient test at 25 °C	Literature	Maintenance
Crack Sealing	Softening Point (°C)	Double	The softening point of the material	Literature	Maintenance
Crack Sealing	Extrusion Rate (mL/min)	Double	The amount of extrusion rate in ml per min	Literature	Maintenance
Crack Sealing	Tensile stress@150 % strain@23° C (kPa)	Double	The tensile stress when strain is 150 % and at 23 °C	Literature	Maintenance
Crack Sealing	Tack-Free Time (h)	Double	The tack-free time for the material used in hour	Literature	Maintenance
Crack Sealing	Stiffness@0 .1 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Crack Sealing	Stiffness@0 .2 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Crack Sealing	Stiffness@0 .5 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Crack Sealing	Stiffness@1 .0 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness@2 .0 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance

Crack Sealing	Stiffness@5.0Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness@8.0Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness@10.0 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness@20.0 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness@30.0 Hz	Double	The stiffness of a crack sealing material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a crack sealing material measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Crack Sealing	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a crack sealing material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a crack sealing material measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Crack Sealing	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a crack sealing material measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Crack Sealing	Bonding	String	The pass or fail value in the bonding test based on the EN standard	Literature	Maintenance
Crack Sealing	Hardness	Integer	The amount of hardness in the hardness test based on the EN standard	Literature	Maintenance
Crack Sealing	Flow@60°C (mm)	Double	The flow amount (mm) for the materials at 60°C	Literature	Maintenance
Crack Sealing	Year of Service (year)	Integer	The years that the material can be in service	Literature	Maintenance

Crack Sealing	Crack Cutting Equipment Type	String	The type of equipment used for crack cutting	Literature	Maintenance
Crack Sealing	Crack Cleaning/Drying Equipment Type	String	The type of equipment used for crack cleaning/drying	Literature	Maintenance
Crack Sealing	Material Installation Equipment Type	String	The type of equipment used for material installation	Literature	Maintenance
Crack Sealing	Material Finishing Equipment Type	String	The type of equipment used for material finishing	Literature	Maintenance
Crack Sealing	Comments	String	Remarks associated with the crack sealing	Literature	Maintenance
Induction Heating	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Induction Heating	Start Time	String	The time that the task is started	Literature	Maintenance
Induction Heating	End Time	String	The time that the task is started	Literature	Maintenance
Induction Heating	Date	String	The date that the task is taken place	Literature	Maintenance
Induction Heating	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Induction Heating	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Induction Heating	Objective	String	The objective is that the induction heating starts for	Literature	Maintenance
Induction Heating	Method	String	The description of the method used for the induction heating	Literature	Maintenance

Induction Heating	Standard	String	The standard used for the induction heating	Literature	Maintenance
Induction Heating	Contractor	String	The name of the contractor that performing the induction heating	Literature	Maintenance
Induction Heating	Average Temperature (°C)	Double	The average temperature in a day that induction heating is taken place	Literature	Maintenance
Induction Heating	Humidity (%)	Double	The humidity on a day that induction heating takes place	Literature	Maintenance
Induction Heating	Average Wind Speed (km/h)	Double	The average wind speed in a day that induction heating is taken place	Literature	Maintenance
Induction Heating	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that induction heating is taken place	Literature	Maintenance
Induction Heating	Heater Type	String	The type of heating used for the method	Literature	Maintenance
Induction Heating	Heater Width (m)	Double	The heater width	Literature	Maintenance
Induction Heating	Heater Length (m)	Double	The heater Length	Literature	Maintenance
Induction Heating	Heater Operating Temperature (°C)	Double	The temperature that heater heats the asphalt pavement	Literature	Maintenance
Induction Heating	Number of Passes	Integer	The number of passes that heater passes the asphalt pavement	Literature	Maintenance
Induction Heating	Comments	String	Remarks associated with the induction heating	Literature	Maintenance
Microsurfacing	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Microsurfacing	Start Time	String	The time that the task is started	Literature	Maintenance
Microsurfacing	End Time	String	The time that the task is started	Literature	Maintenance

Microsurfacing	Date	String	The date that the task is taken place	Literature	Maintenance
Microsurfacing	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Microsurfacing	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Microsurfacing	Objective	String	The objective that the microsurfacing starts for	Literature	Maintenance
Microsurfacing	Method	String	The description of the method used for the microsurfacing	Literature	Maintenance
Microsurfacing	Standard	String	The standard used for the microsurfacing	Literature	Maintenance
Microsurfacing	Contractor	String	The name of the contractor that performing the microsurfacing	Literature	Maintenance
Microsurfacing	Average Temperature (°C)	Double	The average temperature in a day that microsurfacing is taken place	Literature	Maintenance
Microsurfacing	Humidity (%)	Double	The humidity on a day that microsurfacing takes place	Literature	Maintenance
Microsurfacing	Average Wind Speed (km/h)	Double	The average wind speed in a day that microsurfacing is taken place	Literature	Maintenance
Microsurfacing	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that microsurfacing is taken place	Literature	Maintenance
Microsurfacing	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	Maintenance
Microsurfacing	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	Maintenance
Microsurfacing	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	Maintenance
Microsurfacing	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	Maintenance
Microsurfacing	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	Maintenance

Microsurfacing	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	Maintenance
Microsurfacing	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	Maintenance
Microsurfacing	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	Maintenance
Microsurfacing	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	Maintenance
Microsurfacing	Virgin Bitumen Grade	String	The PG grading of the bitumen	Literature	Maintenance
Microsurfacing	Bitumen Content (%)	Double	The optimum bitumen content	Literature	Maintenance
Microsurfacing	Soluble Bitumen Content (%)	Double	The soluble bitumen content	Literature	Maintenance
Microsurfacing	Penetration @25 °C (0.1mm)	Integer	The test measures the hardness or softness of used virgin bitumen for road construction project	Literature	Maintenance
Microsurfacing	Softening point (°C)	Double	Softening point is a temperature that virgin bitumen softens (bitumen)	Literature	Maintenance
Microsurfacing	Penetration index	Double	PI measures the behavior of virgin bitumen against the variation in temperature	Literature	Maintenance
Microsurfacing	Ductility (cm)	Integer	Ductility is a feature that evaluates the elongation of the bitumen under traffic condition	Literature	Maintenance
Microsurfacing	Flashpoint (°C)	Integer	A temperature at which virgin bitumen ignites	Literature	Maintenance
Microsurfacing	Specific gravity@25 °C (g/cm3)	Double	Specific gravity of virgin bitumen at 25 °C	Literature	Maintenance
Microsurfacing	Stiffness@0.1 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Microsurfacing	Stiffness@0.2 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Microsurfacing	Stiffness@0.5 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance

Microsurfacing	Stiffness@1.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness@2.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness@5.0Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness@8.0Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness@10.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness@20.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness@30.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Microsurfacing	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Microsurfacing	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Microsurfacing	Emulsifier Type	String	The type of emulsifier	Literature	Maintenance
Microsurfacing	Percentage of Emulsifier (%)	Integer	The perncetage of emulsifier	Literature	Maintenance

Microsurfacing	Emulsifier Active Content (%)	Double	The content of the emulsifier active	Literature	Maintenance
Microsurfacing	Emulsifier pH	Integer	The pH of the emulsifier	Literature	Maintenance
Microsurfacing	Emulsifier Solubility (%)	Double	The solubility of the emulsifier	Literature	Maintenance
Microsurfacing	Bitumen Type	String	The type of bitumen used i.e. is not the virgin bitumen, the type of combined bitumen (virgin bitumen and emulsifier) used for the project	Literature	Maintenance
Microsurfacing	Storage Stability (%)	Integer	The storage stability of asphalt emulsion	Literature	Maintenance
Microsurfacing	Mixing Time (s)	Double	The mixing time for the microsurfacing mix	Literature	Maintenance
Microsurfacing	Demulsification Time (min)	Double	The demulsification time for the microsurfacing mix	Literature	Maintenance
Microsurfacing	Abrasion Value (g/m2)	Double	The abrasion value for the microsurfacing mix	Literature	Maintenance
Microsurfacing	Comments	String	Remarks associated with the microsurfacing	Literature	Maintenance
Slurry Sealing	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Slurry Sealing	Start Time	String	The time that the task is started	Literature	Maintenance
Slurry Sealing	End Time	String	The time that the task is started	Literature	Maintenance
Slurry Sealing	Date	String	The date that the task is taken place	Literature	Maintenance
Slurry Sealing	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Slurry Sealing	End Point Location	String	The GPS location of ending point	Literature	Maintenance

Slurry Sealing	Objective	String	The objective that the slurry sealing starts for	Literature	Maintenance
Slurry Sealing	Method	String	The description of the method used for the slurry sealing	Literature	Maintenance
Slurry Sealing	Standard	String	The standard used for the slurry sealing	Literature	Maintenance
Slurry Sealing	Contractor	String	The name of the contractor that performing the slurry sealing	Literature	Maintenance
Slurry Sealing	Average Temperature (°C)	Double	The average temperature in a day that slurry sealing is taken place	Literature	Maintenance
Slurry Sealing	Humidity (%)	Double	The humidity on a day that slurry sealing takes place	Literature	Maintenance
Slurry Sealing	Average Wind Speed (km/h)	Double	The average wind speed in a day that slurry sealing is taken place	Literature	Maintenance
Slurry Sealing	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that slurry sealing is taken place	Literature	Maintenance
Slurry Sealing	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	Maintenance
Slurry Sealing	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	Maintenance
Slurry Sealing	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	Maintenance
Slurry Sealing	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	Maintenance
Slurry Sealing	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	Maintenance
Slurry Sealing	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	Maintenance
Slurry Sealing	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	Maintenance
Slurry Sealing	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	Maintenance

Slurry Sealing	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	Maintenance
Slurry Sealing	Virgin Bitumen Grade	String	The PG grading of the bitumen	Literature	Maintenance
Slurry Sealing	Bitumen Content (%)	Double	The optimum bitumen content	Literature	Maintenance
Slurry Sealing	Soluble Bitumen Content (%)	Double	The soluble bitumen content	Literature	Maintenance
Slurry Sealing	Penetration @25 °C (0.1mm)	Integer	The test measures the hardness or softness of used virgin bitumen for road construction project	Literature	Maintenance
Slurry Sealing	Softening point (°C)	Double	Softening point is a temperature at that virgin bitumen softens (bitumen)	Literature	Maintenance
Slurry Sealing	Penetration index	Double	PI measures the behavior of virgin bitumen against the variation in temperature	Literature	Maintenance
Slurry Sealing	Ductility (cm)	Integer	Ductility is a feature that evaluates the elongation of the bitumen under traffic condition	Literature	Maintenance
Slurry Sealing	Flashpoint (°C)	Integer	A temperature at which virgin bitumen ignites	Literature	Maintenance
Slurry Sealing	Specific gravity@25 °C (g/cm3)	Double	Specific gravity of virgin bitumen at 25 °C	Literature	Maintenance
Slurry Sealing	Stiffness@0.1 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@0.2 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@0.5 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@1.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@2.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@5.0Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance

Slurry Sealing	Stiffness@8.0Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@10.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@20.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@30.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Slurry Sealing	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Slurry Sealing	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Slurry Sealing	Emulsifier Type	String	The type of emulsifier	Literature	Maintenance
Slurry Sealing	Percentage of Emulsifier (%)	Integer	The perncetage of emulsifier	Literature	Maintenance
Slurry Sealing	Emulsifier Active Content (%)	Double	The content of the emulsifier active	Literature	Maintenance
Slurry Sealing	Emulsifier pH	Integer	The pH of the emulsifier	Literature	Maintenance

Slurry Sealing	Emulsifier Solubility (%)	Double	The solubility of the emulsifier	Literature	Maintenance
Slurry Sealing	Bitumen Type	String	The type of bitumen used i.e. is not the virgin bitumen, the type of combined bitumen (virgin bitumen and emulsifier) used for the project	Literature	Maintenance
Slurry Sealing	Storage Stability (%)	Integer	The storage stability of asphalt emulsion	Literature	Maintenance
Slurry Sealing	Mixing Time (s)	Double	The mixing time for the slurry sealing mix	Literature	Maintenance
Slurry Sealing	Demulsification Time (min)	Double	The demulsification time for the slurry sealing mix	Literature	Maintenance
Slurry Sealing	Abrasion Value (g/m2)	Double	The abrasion value for the slurry sealing mix	Literature	Maintenance
Slurry Sealing	Comments	String	Remarks associated with the slurry sealing	Literature	Maintenance
Chip Sealing	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Chip Sealing	Start Time	String	The time that the task is started	Literature	Maintenance
Chip Sealing	End Time	String	The time that the task is started	Literature	Maintenance
Chip Sealing	Date	String	The date that the task is taken place	Literature	Maintenance
Chip Sealing	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Chip Sealing	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Chip Sealing	Objective	String	The objective that the chip sealing starts for	Literature	Maintenance
Chip Sealing	Method	String	The description of the method used for the chip sealing	Literature	Maintenance
Chip Sealing	Standard	String	The standard used for the chip sealing	Literature	Maintenance

Chip Sealing	Contractor	String	The name of the contractor that performing the chip sealing	Literature	Maintenance
Chip Sealing	Average Temperature (°C)	Double	The average temperature in a day that chip sealing is taken place	Literature	Maintenance
Chip Sealing	Humidity (%)	Double	The humidity on a day that chip sealing takes place	Literature	Maintenance
Chip Sealing	Average Wind Speed (km/h)	Double	The average wind speed in a day that chip sealing is taken place	Literature	Maintenance
Chip Sealing	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that chip sealing is taken place	Literature	Maintenance
Chip Sealing	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	Maintenance
Chip Sealing	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	Maintenance
Chip Sealing	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	Maintenance
Chip Sealing	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	Maintenance
Chip Sealing	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	Maintenance
Chip Sealing	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	Maintenance
Chip Sealing	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	Maintenance
Chip Sealing	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	Maintenance
Chip Sealing	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	Maintenance
Chip Sealing	Virgin Bitumen Grade	String	The PG grading of the bitumen	Literature	Maintenance
Chip Sealing	Bitumen Content (%)	Double	The optimum bitumen content	Literature	Maintenance

Chip Sealing	Soluble Bitumen Content (%)	Double	The soluble bitumen content	Literature	Maintenance
Chip Sealing	Penetration @25 °C (0.1mm)	Integer	The test measures the hardness or softness of used virgin bitumen for road construction project	Literature	Maintenance
Chip Sealing	Softening point (°C)	Double	Softening point is a temperature at that virgin bitumen softens (bitumen)	Literature	Maintenance
Chip Sealing	Penetration index	Double	PI measures the behavior of virgin bitumen against the variation in temperature	Literature	Maintenance
Chip Sealing	Ductility (cm)	Integer	Ductility is a feature that evaluates the elongation of the bitumen under traffic condition	Literature	Maintenance
Chip Sealing	Flashpoint (°C)	Integer	A temperature at which virgin bitumen ignites	Literature	Maintenance
Chip Sealing	Specific gravity@25 °C (g/cm3)	Double	Specific gravity of virgin bitumen at 25 °C	Literature	Maintenance
Chip Sealing	Stiffness@0.1 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Chip Sealing	Stiffness@0.2 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Chip Sealing	Stiffness@0.5 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Chip Sealing	Stiffness@1.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness@2.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness@5.0Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness@8.0Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness@10.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness@20.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance

Chip Sealing	Stiffness@30.0 Hz	Double	The stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Chip Sealing	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Chip Sealing	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a virgin bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Chip Sealing	Emulsifier Type	String	The type of emulsifier	Literature	Maintenance
Chip Sealing	Percentage of Emulsifier (%)	Integer	The perncetage of emulsifier	Literature	Maintenance
Chip Sealing	Emulsifier Active Content (%)	Double	The content of the emulsifier active	Literature	Maintenance
Chip Sealing	Emulsifier pH	Integer	The pH of the emulsifier	Literature	Maintenance
Chip Sealing	Emulsifier Solubility (%)	Double	The solubility of the emulsifier	Literature	Maintenance
Chip Sealing	Polymer Type	String	The type of polymer used	Literature	Maintenance

Chip Sealing	Percentage of Polymer (%)	Integer	The percentage of polymer used	Literature	Maintenance
Chip Sealing	Crumbed Rubber Type	String	The type of crumbed rubber	Literature	Maintenance
Chip Sealing	Percentage of Crumbed Rubber (%)	Integer	The percentage used for crumbed rubber	Literature	Maintenance
Chip Sealing	Bitumen Type	String	The type of bitumen used i.e. is not the virgin bitumen, the type of combined bitumen (virgin bitumen and emulsifier) used for the project	Literature	Maintenance
Chip Sealing	Storage Stability (%)	Integer	The storage stability of asphalt emulsion	Literature	Maintenance
Chip Sealing	Mixing Time (s)	Double	The mixing time for the chip sealing mix	Literature	Maintenance
Chip Sealing	Demulsification Time (min)	Double	The demulsification time for the chip sealing mix	Literature	Maintenance
Chip Sealing	Abrasion Value (g/m2)	Double	The abrasion value for the chip sealing mix	Literature	Maintenance
Chip Sealing	Comments	String	Remarks associated with the chip sealing	Literature	Maintenance
Hot Patching	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Hot Patching	Start Time	String	The time that the task is started	Literature	Maintenance
Hot Patching	End Time	String	The time that the task is started	Literature	Maintenance
Hot Patching	Date	String	The date that the task is taken place	Literature	Maintenance
Hot Patching	Location	String	The GPS location of pothole	Literature	Maintenance
Hot Patching	Objective	String	The objective that the patching starts for	Literature	Maintenance

Hot Patching	Method	String	The description of the method used for the patching	Literature	Maintenance
Hot Patching	Standard	String	The standard used for the patching	Literature	Maintenance
Hot Patching	Contractor	String	The name of the contractor that performing the patching	Literature	Maintenance
Hot Patching	Operator Sex	String	The sex of operator	Literature	Maintenance
Hot Patching	Operator Age	Integer	The age of operator	Literature	Maintenance
Hot Patching	Operator Experience	Integer	The experience of operator in years	Literature	Maintenance
Hot Patching	Hottest Average Temperature (°C)	Double	The average hottest temperature in the location of patching annually	Literature	Maintenance
Hot Patching	Coldest Average Temperature (°C)	Double	The average coldest temperature in the location of patching annually	Literature	Maintenance
Hot Patching	Average Temperature (°C)	Double	The average temperature in a day that patching is taken place	Literature	Maintenance
Hot Patching	Humidity (%)	Double	The humidity on a day that patching takes place	Literature	Maintenance
Hot Patching	Average Wind Speed (km/h)	Double	The average wind speed in a day that patching is taken place	Literature	Maintenance
Hot Patching	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that patching is taken place	Literature	Maintenance
Hot Patching	Bitumen Type	String	The type of bitumen used i.e. is not the virgin bitumen, the type of combined bitumen (virgin bitumen and additive) used for the project	Literature	Maintenance
Hot Patching	Bitumen Content (%)	Double	The optimum bitumen content	Literature	Maintenance

Hot Patching	Stiffness@0.1 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Hot Patching	Stiffness@0.2 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Hot Patching	Stiffness@0.5 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Hot Patching	Stiffness@1.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Hot Patching	Stiffness@2.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Hot Patching	Stiffness@5.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Hot Patching	Stiffness@8.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Hot Patching	Stiffness@10.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Hot Patching	Stiffness@20.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Hot Patching	Stiffness@30.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Hot Patching	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Hot Patching	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Hot Patching	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Hot Patching	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance

Hot Patching	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	Maintenance
Hot Patching	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	Maintenance
Hot Patching	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	Maintenance
Hot Patching	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	Maintenance
Hot Patching	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	Maintenance
Hot Patching	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	Maintenance
Hot Patching	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	Maintenance
Hot Patching	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	Maintenance
Hot Patching	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	Maintenance
Hot Patching	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	Maintenance
Hot Patching	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	Maintenance
Hot Patching	Mixture type	String	Hot asphalt mix type	Literature	Maintenance
Hot Patching	Mixture description	String	Description of the hot asphalt mixture	Literature	Maintenance
Hot Patching	Pothole Cutting Equipment Type	String	The type of equipment used for pothole cutting	Literature	Maintenance
Hot Patching	Cutting Depth (mm)	Double	The Depth of cutting	Literature	Maintenance
Hot Patching	Cutting Width (cm)	Double	The Width of cutting	Literature	Maintenance

Hot Patching	Cutting Length (cm)	Double	The Length of cutting	Literature	Maintenance
Hot Patching	Pothole Cleaning/Drying Equipment Type	String	The type of equipment used for pothole cleaning/drying	Literature	Maintenance
Hot Patching	Pothole Bonding Material Type	String	The type of material used for creating bonds at the edge of the pothole	Literature	Maintenance
Hot Patching	Material Installation Equipment Type	String	The type of equipment used for material installation	Literature	Maintenance
Hot Patching	Material Compaction Equipment Type	String	The type of equipment used for compacting the hot mix asphalt	Literature	Maintenance
Hot Patching	Description of Material Compaction	String	The description regarding how compaction is done by the equipment	Literature	Maintenance
Hot Patching	Material Finishing Equipment Type	String	The type of equipment used for material finishing	Literature	Maintenance
Hot Patching	Polymer Type	String	The type of polymer used	Literature	Maintenance
Hot Patching	Percentage of Polymer (%)	Integer	The percentage of polymer used	Literature	Maintenance
Hot Patching	Storage Stability (%)	Integer	The storage stability of bitumen	Literature	Maintenance

Hot Patching	Water sensitivity (TSR) (%)	Double	The sensitivity of an asphalt mixture to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	Maintenance
Hot Patching	Creep rate (µstrain/load cycle)	Double	The deformation resistance of an asphalt mixture measured in the triaxial test	Literature	Maintenance
Hot Patching	Resilient modulus (MPa)	Integer	The ratio of the applied peak stress to the recoverable strain in the resilient modulus test, 20° C and a frequency of 8 Hz	Literature	Maintenance
Hot Patching	Comments	String	Remarks associated with the patching	Literature	Maintenance
Structural Overlays	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Structural Overlays	Start Time	String	The time that the task is started	Literature	Maintenance
Structural Overlays	End Time	String	The time that the task is started	Literature	Maintenance
Structural Overlays	Date	String	The date that the task is taken place	Literature	Maintenance
Structural Overlays	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Structural Overlays	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Structural Overlays	Objective	String	The objective that the overlays start for	Literature	Maintenance
Structural Overlays	Method	String	The description of the method used for the overlays	Literature	Maintenance
Structural Overlays	Standard	String	The standard used for the overlays	Literature	Maintenance
Structural Overlays	Contractor	String	The name of the contractor that performing the overlays	Literature	Maintenance
Structural Overlays	Average Temperature (°C)	Double	The average temperature in a day that overlays is taken place	Literature	Maintenance

Structural Overlays	Humidity (%)	Double	The humidity on a day that overlays takes place	Literature	Maintenance
Structural Overlays	Average Wind Speed (km/h)	Double	The average wind speed in a day that overlays is taken place	Literature	Maintenance
Structural Overlays	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that overlays is taken place	Literature	Maintenance
Structural Overlays	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	Maintenance
Structural Overlays	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	Maintenance
Structural Overlays	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	Maintenance
Structural Overlays	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	Maintenance
Structural Overlays	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	Maintenance
Structural Overlays	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	Maintenance
Structural Overlays	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	Maintenance
Structural Overlays	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	Maintenance
Structural Overlays	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	Maintenance
Structural Overlays	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	Maintenance
Structural Overlays	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	Maintenance
Structural Overlays	Virgin Bitumen Grade	String	The PG grading of the bitumen	Literature	Maintenance
Structural Overlays	Bitumen Content (%)	Double	The optimum bitumen content	Literature	Maintenance

Structural Overlays	Soluble Bitumen Content (%)	Double	The soluble bitumen content	Literature	Maintenance
Structural Overlays	Penetration @25 °C (0.1mm)	Integer	The test measures the hardness or softness of used virgin bitumen for road construction project	Literature	Maintenance
Structural Overlays	Softening point (°C)	Double	Softening point is a temperature at that virgin bitumen softens (bitumen)	Literature	Maintenance
Structural Overlays	Penetration index	Double	PI measures the behavior of virgin bitumen against the variation in temperature	Literature	Maintenance
Structural Overlays	Ductility (cm)	Integer	Ductility is a feature that evaluates the elongation of the bitumen under traffic condition	Literature	Maintenance
Structural Overlays	Flashpoint (°C)	Integer	A temperature at which virgin bitumen ignites	Literature	Maintenance
Structural Overlays	Specific gravity@25 °C (g/cm3)	Double	Specific gravity of virgin bitumen at 25 °C	Literature	Maintenance
Structural Overlays	Stiffness@0.1 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Structural Overlays	Stiffness@0.2 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Structural Overlays	Stiffness@0.5 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Structural Overlays	Stiffness@1.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness@2.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness@5.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness@8.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness@10.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness@20.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance

Structural Overlays	Stiffness@30.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Structural Overlays	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Structural Overlays	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Structural Overlays	Emulsifier Type	String	The type of emulsifier	Literature	Maintenance
Structural Overlays	Percentage of Emulsifier (%)	Integer	The perncetage of emulsifier	Literature	Maintenance
Structural Overlays	Emulsifier Active Content (%)	Double	The content of the emulsifier active	Literature	Maintenance
Structural Overlays	Emulsifier pH	Integer	The pH of the emulsifier	Literature	Maintenance
Structural Overlays	Emulsifier Solubility (%)	Double	The solubility of the emulsifier	Literature	Maintenance
Structural Overlays	Polymer Type	String	The type of polymer used	Literature	Maintenance

Structural Overlays	Percentage of Polymer (%)	Integer	The percentage of polymer used	Literature	Maintenance
Structural Overlays	Crumbed Rubber Type	String	The type of crumbed rubber	Literature	Maintenance
Structural Overlays	Percentage of Crumbed Rubber (%)	Integer	The percentage used for crumbed rubber	Literature	Maintenance
Structural Overlays	Bitumen Type	String	The type of bitumen used i.e. is not the virgin bitumen, the type of combined bitumen (virgin bitumen and emulsifier) used for the project	Literature	Maintenance
Structural Overlays	Storage Stability (%)	Integer	The storage stability of asphalt emulsion	Literature	Maintenance
Structural Overlays	Comments	String	Remarks associated with the overlays	Literature	Maintenance
Cold Patching	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Cold Patching	Start Time	String	The time that the task is started	Literature	Maintenance
Cold Patching	End Time	String	The time that the task is started	Literature	Maintenance
Cold Patching	Date	String	The date that the task is taken place	Literature	Maintenance
Cold Patching	Location	String	The GPS location of pothole	Literature	Maintenance
Cold Patching	Objective	String	The objective that the patching starts for	Literature	Maintenance
Cold Patching	Method	String	The description of the method used for the patching	Literature	Maintenance
Cold Patching	Standard	String	The standard used for the patching	Literature	Maintenance
Cold Patching	Contractor	String	The name of the contractor that performing the patching	Literature	Maintenance
Cold Patching	Operator Sex	String	The sex of operator	Literature	Maintenance

Cold Patching	Operator Age	Integer	The age of operator	Literature	Maintenance
Cold Patching	Operator Experience	Integer	The experience of operator in years	Literature	Maintenance
Cold Patching	Hottest Average Temperature (°C)	Double	The average hottest temperature in the location of patching annually	Literature	Maintenance
Cold Patching	Coldest Average Temperature (°C)	Double	The average coldest temperature in the location of patching annually	Literature	Maintenance
Cold Patching	Average Temperature (°C)	Double	The average temperature in a day that patching is taken place	Literature	Maintenance
Cold Patching	Humidity (%)	Double	The humidity on a day that patching takes place	Literature	Maintenance
Cold Patching	Average Wind Speed (km/h)	Double	The average wind speed in a day that patching is taken place	Literature	Maintenance
Cold Patching	Precipitation (cm)	Double	The precipitation amount in centimeters in a day that patching is taken place	Literature	Maintenance
Cold Patching	Bitumen Type	String	The type of bitumen used i.e. is not the virgin bitumen, the type of combined bitumen (virgin bitumen and additive) used for the project	Literature	Maintenance
Cold Patching	Bitumen Content (%)	Double	The optimum bitumen content	Literature	Maintenance
Cold Patching	Stiffness@0.1 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Cold Patching	Stiffness@0.2 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Cold Patching	Stiffness@0.5 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Cold Patching	Stiffness@1.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance

Cold Patching	Stiffness@2.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Cold Patching	Stiffness@5.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Cold Patching	Stiffness@8.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Cold Patching	Stiffness@10.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Cold Patching	Stiffness@20.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Cold Patching	Stiffness@30.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Cold Patching	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Cold Patching	Stiffness@30.0 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Cold Patching	Stiffness standard deviation@20°, 8 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Cold Patching	Stiffness standard deviation@20°, 30 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Cold Patching	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	Maintenance
Cold Patching	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	Maintenance
Cold Patching	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	Maintenance
Cold Patching	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	Maintenance

Cold Patching	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	Maintenance
Cold Patching	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	Maintenance
Cold Patching	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	Maintenance
Cold Patching	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	Maintenance
Cold Patching	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	Maintenance
Cold Patching	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	Maintenance
Cold Patching	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	Maintenance
Cold Patching	Mixture type	String	Cold asphalt mix type	Literature	Maintenance
Cold Patching	Mixture description	String	Description of the hot asphalt mixture	Literature	Maintenance
Cold Patching	Pothole Cutting Equipment Type	String	The type of equipment used for pothole cutting	Literature	Maintenance
Cold Patching	Cutting Depth (mm)	Double	The Depth of cutting	Literature	Maintenance
Cold Patching	Cutting Width (cm)	Double	The Width of cutting	Literature	Maintenance
Cold Patching	Cutting Length (cm)	Double	The Length of cutting	Literature	Maintenance
Cold Patching	Pothole Cleaning/Drying Equipment Type	String	The type of equipment used for pothole cleaning/drying	Literature	Maintenance
Cold Patching	Pothole Bonding	String	The type of material used for creating bonds at the edge of the pothole	Literature	Maintenance

	Material Type				
Cold Patching	Material Installation Equipment Type	String	The type of equipment used for material installation	Literature	Maintenance
Cold Patching	Material Compaction Equipment Type	String	The type of equipment used for compacting the hot mix asphalt	Literature	Maintenance
Cold Patching	Description of Material Compaction	String	The description regarding how compaction is done by the equipment	Literature	Maintenance
Cold Patching	Material Finishing Equipment Type	String	The type of equipment used for material finishing	Literature	Maintenance
Cold Patching	Polymer Type	String	The type of polymer used	Literature	Maintenance
Cold Patching	Percentage of Polymer (%)	Integer	The percentage of polymer used	Literature	Maintenance
Cold Patching	Storage Stability (%)	Integer	The storage stability of bitumen	Literature	Maintenance
Cold Patching	Water sensitivity (TSR) (%)	Double	The sensitivity of an asphalt mixture to the action of moisture (ratio of conditioned ITS to dry ITS)	Literature	Maintenance
Cold Patching	Creep rate (µstrain/load cycle)	Double	The deformation resistance of an asphalt mixture measured in the triaxial test	Literature	Maintenance
Cold Patching	Resilient modulus (MPa)	Integer	The ratio of the applied peak stress to the recoverable strain in the resilient modulus test, 20° C and a frequency of 8 Hz	Literature	Maintenance

Cold Patching	Comments	String	Remarks associated with the patching	Literature	Maintenance
Reconstructing Layer	ID	String	Unique identifier (code) for the task	Literature	Maintenance
Reconstructing Layer	Layer	String	The name of the layer where reconstructing is taken place	Literature	Maintenance
Reconstructing Layer	Start Time	String	The time that the task is started	Literature	Maintenance
Reconstructing Layer	End Time	String	The time that the task is started	Literature	Maintenance
Reconstructing Layer	Date	String	The date that the task is taken place	Literature	Maintenance
Reconstructing Layer	Start Point Location	String	The GPS location of starting point	Literature	Maintenance
Reconstructing Layer	End Point Location	String	The GPS location of ending point	Literature	Maintenance
Reconstructing Layer	Objective	String	The objective that the reconstructing layer starts for	Literature	Maintenance
Reconstructing Layer	Method	String	The description of the method used for the reconstructing layer	Literature	Maintenance
Reconstructing Layer	Standard	String	The standard used for the reconstructing layer	Literature	Maintenance
Reconstructing Layer	Contractor	String	The name of the contractor that performing the reconstructing layer	Literature	Maintenance
Reconstructing Layer	Average Temperature (°C)	Double	The average temperature in a day that reconstructing layer is taken place	Literature	Maintenance
Reconstructing Layer	Humidity (%)	Double	The humidity on a day that reconstructing layer takes place	Literature	Maintenance
Reconstructing Layer	Average Wind Speed (km/h)	Double	The average wind speed in a day that reconstructing layer is taken place	Literature	Maintenance
Reconstructing Layer	Precipitation (cm)	Double	The precipitation amount in centimetres in a day that reconstructing layer takes place	Literature	Maintenance

Reconstructing Layer	22,4 mm (%)	Double	The mass fraction of the aggregate through sieve size 22.4 mm	Literature	Maintenance
Reconstructing Layer	16 mm (%)	Double	The mass fraction of the aggregate through sieve size 16 mm	Literature	Maintenance
Reconstructing Layer	11,2 mm (%)	Double	The mass fraction of the aggregate through sieve size 11.2 mm	Literature	Maintenance
Reconstructing Layer	8 mm (%)	Double	The mass fraction of the aggregate through sieve size 8 mm	Literature	Maintenance
Reconstructing Layer	5,6 mm (%)	Double	The mass fraction of the aggregate through sieve size 5.6 mm	Literature	Maintenance
Reconstructing Layer	4 mm (%)	Double	The mass fraction of the aggregate through sieve size 4 mm	Literature	Maintenance
Reconstructing Layer	2 mm (%)	Double	The mass fraction of the aggregate through sieve size 2 mm	Literature	Maintenance
Reconstructing Layer	0,5 mm (%)	Double	The mass fraction of the aggregate through sieve size 500 µm	Literature	Maintenance
Reconstructing Layer	0,18 mm (%)	Double	The mass fraction of the aggregate through sieve size 180 µm	Literature	Maintenance
Reconstructing Layer	0,125 mm (%)	Double	The mass fraction of the aggregate through sieve size 125 µm	Literature	Maintenance
Reconstructing Layer	0,063 mm (%)	Double	The mass fraction of the aggregate through sieve size 63 µm	Literature	Maintenance
Reconstructing Layer	Virgin Bitumen Grade	String	The PG grading of the bitumen	Literature	Maintenance
Reconstructing Layer	Bitumen Content (%)	Double	The optimum bitumen content	Literature	Maintenance
Reconstructing Layer	Soluble Bitumen Content (%)	Double	The soluble bitumen content	Literature	Maintenance
Reconstructing Layer	Penetration @25 °C (0.1mm)	Integer	The test measures the hardness or softness of used virgin bitumen for reconstructing layer	Literature	Maintenance
Reconstructing Layer	Softening point (°C)	Double	Softening point is a temperature at that virgin bitumen softens (bitumen)	Literature	Maintenance

Reconstructing Layer	Penetration index	Double	PI measures the behavior of virgin bitumen against the variation in temperature	Literature	Maintenance
Reconstructing Layer	Ductility (cm)	Integer	Ductility is a feature that evaluates the elongation of the bitumen under traffic condition	Literature	Maintenance
Reconstructing Layer	Flashpoint (°C)	Integer	A temperature at which virgin bitumen ignites	Literature	Maintenance
Reconstructing Layer	Specific gravity@25 °C (g/cm3)	Double	Specific gravity of virgin bitumen at 25 °C	Literature	Maintenance
Reconstructing Layer	Stiffness@0.1 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@0.2 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.2 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@0.5 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 0.5 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@1.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 1.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@2.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 2.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@5.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 5.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@8.0Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@10.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 10.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@20.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 20.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@30.0 Hz	Double	The stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@0.1 Hz (final measurement)	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 0.1 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness@30.0 Hz (final	Double	The final measurement of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance

	measurement)				
Reconstructing Layer	Stiffness standard deviation@ 20°, 8 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 8.0 Hz	Literature	Maintenance
Reconstructing Layer	Stiffness standard deviation@ 20°, 30 Hz	Double	The standard deviation of the stiffness of a bitumen measured in a frequency sweep at 20°C and 30.0 Hz	Literature	Maintenance
Reconstructing Layer	Emulsifier Type	String	The type of emulsifier	Literature	Maintenance
Reconstructing Layer	Percentage of Emulsifier (%)	Integer	The percentage of emulsifier	Literature	Maintenance
Reconstructing Layer	Emulsifier Active Content (%)	Double	The content of the emulsifier active	Literature	Maintenance
Reconstructing Layer	Emulsifier pH	Integer	The pH of the emulsifier	Literature	Maintenance
Reconstructing Layer	Emulsifier Solubility (%)	Double	The solubility of the emulsifier	Literature	Maintenance
Reconstructing Layer	Polymer Type	String	The type of polymer used	Literature	Maintenance
Reconstructing Layer	Percentage of Polymer (%)	Integer	The percentage of polymer used	Literature	Maintenance
Reconstructing Layer	Crumbed Rubber Type	String	The type of crumbed rubber	Literature	Maintenance
Reconstructing Layer	Percentage of Crumbed Rubber (%)	Integer	The percentage used for crumbed rubber	Literature	Maintenance

Reconstructing Layer	Bitumen Type	String	The type of bitumen used i.e. is not the virgin bitumen, the type of combined bitumen (virgin bitumen and emulsifier) used for the project	Literature	Maintenance
Reconstructing Layer	Storage Stability (%)	Integer	The storage stability of asphalt emulsion	Literature	Maintenance
Reconstructing Layer	Comments	String	Remarks associated with the reconstructing layer	Literature	Maintenance

Table. Items name, type, description, source and lifecycle phase of deterioration and evaluation sub-ontologies.

Item name	Type of item	Description of item	Source of item (applications or literature)	Life cycle phase
Road Infrastructure	Class	Every physical objects of the road such as road itself and other objects on the road	PIM	
Quality Assessment	Class	Road pavement has a quality	Literature	
Failure Modes Object	Class	Road pavement has failure modes	Literature	
Design Quality	Class	The quality can be defined based on the design, construction and operation qualities	Literature	Design
Construction Quality	Class	The quality can be defined based on the design, construction and operation qualities	Literature	Construction
Operation Quality	Class	The quality can be defined based on the design, construction and operation qualities	Literature	Operation
Distortion	Class	Any type of shifting and transferring the asphalt pavement under stress	Literature	Operation
Skidding Hazards	Class	Lack of adequate traction between the vehicle (tire) and the surface of asphalt pavement	Literature	Operation
Cracking	Class	All types of asphalt pavement cracking	Literature	Operation
Disintegration	Class	All types of separation between the parts of asphalt pavement (aggregate and bitumen or small part of asphalt pavement)	Literature	Operation
Treatment Distress	Class	Distress that relates to the treatments performed on the road	Literature	Operation
Reliability	Class	Reliability indicators can show whether or not the design is performed by considering some specific functions such as suitability of new technique and material used in the design, acceptable polishing number for coarse aggregates, etc.	Literature	Design

Safety	Class	Safety indicators can show whether or not the design is performed by considering some safety functions such as skid resistance.	Literature	Design
Environmental Nuisance	Class	Environmental nuisance indicators can show whether or not the design is performed by considering some environmental functions such as reducing noise.	Literature	Design
Durability	Class	Durability indicators can show whether or not the design is performed by considering some durable functions such as ECI.	Literature	Design
Future-proofing	Class	Future-proofing indicators can show whether or not the design is performed by considering some functions for future-proofing such as reusability of material.	Literature	Design
Temperature Homogeneity	Class	This indicator can show os whether or not the temperature of the paving process is homogeneous for the entire road profile	PQi	Construction
Compaction Consistency	Class	This indicator can show os whether or not the compaction of the road construction process is consistent for the entire road profile	PQi	Construction
Compaction Efficiency	Class	This indicator can show os whether or not the compaction of the road construction process is performed in the acceptable temperature window for the entire road profile	PQi	Construction
Density Homogeneity	Class	This indicator can show os whether or not the road density is efficient for the entire road profile	Literature	Construction
Thickness Homogeneity	Class	This indicator can show os whether or not the road thickness is homogeneous for the entire road profile	Literature	Construction
Roughness Homogeneity	Class	This indicator can show os whether or not the road roughness is homogeneous for the entire road profile	Literature	Construction
IRI	Class	International Roughness Index (IRI) is an indicator to measure the comfortability of road	Literature	Operation
Maintenance Year	Class	Year of Maintenance can show the general condition of the road section based on all types of failure modes by representing how many years the road has before maintenance is started	PMS	Operation
FWD	Class	The bearing capacity of pavement (deflection, E modulus, stiffness, etc) can be obtained by Falling Weight Deflectometer (FWD) and it is an indicator of operation quality	Literature	Operation
Permeability	Class	The permeability of open-graded asphalt (porous asphalt) that is an indicator, especially for the porous asphalt	Literature	Operation
Rutting	Class	Rutting is a type of surface depression (linear depression) that occurs in the wheel path	Literature	Operation
Shoving	Class	Shoving happens because of the heavy load (horizontal stress) and forms ripple on the surface (happens mostly at intersections and bus stations)	Literature	Operation
Upheaval	Class	Upheavel or localized upward movement happens because of swelling the sub-grade	Literature	Operation
Pumping	Class	Pumping occurs due to the ejection or movement of materials underneath the slap (concrete slap) and can produce distortion for the asphalt mixture in the above layers	Literature	Operation

Depressions		Class	Depression or bird-baths happens because of settlement or failure in the pavement layer underneath and is taken place in low spots in the pavement surface	Literature	Operation
Patch Failure		Class	Patch failure occurs because of patching treatment	Literature	Operation
Polishing		Class	The aggregate surface becomes smooth and the texture can not provide appropriate skid resistance with traffic vehicles (texture measurement)	Literature	Operation
Bleeding		Class	Covering the pavement surface with bitumen and decreasing the skid resistance are two major consequences of bleeding	Literature	Operation
Lack of Skid Resistance		Class	Lack of skid resistance can affect drivers' safety	Literature	Operation
Fatigue		Class	This is an interconnected crack like alligator skin and starts to happen from the bottom layer of asphalt layer	Literature	Operation
Block		Class	Series of rectangular and large cracks on the pavement surface called block pavement	Literature	Operation
Edge		Class	longitudinal crack develops close to the edge of pavement	Literature	Operation
Longitudinal		Class	This crack happens in the longitudinal direction at the centerline of the pavement, not the edges	Literature	Operation
Transverse		Class	The crack perpendicular to the centerline of the pavement is called transfer cracks	Literature	Operation
Slippage		Class	Half-moon or crescent shape cracks are called slippage cracks	Literature	Operation
Reflection		Class	The crack occurs due to the movement of old pavement and forms over joints (concrete pavement or overlay)	Literature	Operation
Pothole		Class	The bow-shaped holes and happens due to the disintegration of the pavement surface	Literature	Operation
Raveling		Class	Disintegration of the asphalt surface causes raveling	Literature	Operation
Aggregate Cover Loss		Class	This distress is a type of surface treatment ones and occurs because of opening the traffic sone than aggregate bonded or using dirty aggregate, etc	Literature	Operation
Streaking		Class	Presence of alternative strips of asphalt or aggregate on the surface	Literature	Operation
Class name	**Attribute of the class**	**Type of attribute**	**Description of attribute**	**Source of attribute (applications or literature)**	**Life cycle phase**

Design Quality	ID	String	Unique identifier (code) of the design quality	Literature	Design
Design Quality	Project ID	String	Unique identifier (code) of the project	Literature	Design
Design Quality	Contract ID	String	Unique identifier (code) of the contract	Literature	Design
Design Quality	Design ID	String	Unique identifier (code) of design	Literature	Design
Design Quality	Comments	String	Remarks associated with the design quality	Literature	Design
Reliability	ID	String	Unique identifier (code) of the reliability	Literature	Design
Reliability	New Material	Boolean	Whether or not the new material intended to be used in the project has been passed the verification in a laboratory	Literature	Design
Reliability	Polishing Number of Coarse Aggregate	Boolean	Whether or not the coarse aggregate has a polishing number of at least 58 based on the NEN-EN 1097-8	Literature	Design
Reliability	Broken Surface	Boolean	Whether or not the coarse aggregate has an acceptable broken surface based on the NEN-EN13043	Literature	Design
Reliability	Comments	String	Remarks associated with the reliability	Literature	Design
Safety	ID	String	Unique identifier (code) of the safety	Literature	Design
Safety	Wet Skid Resistance	Boolean	Whether or not the new road pavement has a skid wet resistance of 0.00	Literature	Design
Safety	Comments	String	Remarks associated with the safety	Literature	Design
Environmental Nuisance	ID	String	Unique identifier (code) of the environmental nuisance	Literature	Design
Environmental Nuisance	Noise reduction	Boolean	Whether or not the new road pavement has a noise reduction according to the CROW 316	Literature	Design

Environmental Nuisance	Comments	String	Remarks associated with the environmental nuisance	Literature	Design
Durability	ID	String	Unique identifier (code) of the durability	Literature	Design
Durability	ECI Value	Boolean	Whether or not the new road pavement has a min ECI value according to the VB par.14.1	Literature	Design
Durability	Comments	String	Remarks associated with the durability	Literature	Design
Future-proofing	ID	String	Unique identifier (code) of the future-proofing	Literature	Design
Future-proofing	Reusibility	Boolean	Whether or not the pavement material is reusable in the equivalent application for the future	Literature	Design
Future-proofing	Comments	String	Remarks associated with the future-proofing	Literature	Design
Construction Quality	ID	String	Unique identifier (code) of the construction quality	Literature	Construction
Construction Quality	Project ID	String	Unique identifier (code) of the project	Literature	Construction
Construction Quality	Contract ID	String	Unique identifier (code) of the contract	Literature	Construction
Construction Quality	Construction ID	String	Unique identifier (code) of construction	Literature	Construction
Construction Quality	Comments	String	Remarks associated with the construction quality	Literature	Construction
Temperature Homogeneity	ID	String	Unique identifier (code) of the indicator	PQi	Construction
Temperature	TCP	String	The link that is attached to the Temperature Contour Plot (TCP) of the construction project	PQi	Construction

Homogeneity					
Temperature Homogeneity	Comments	String	Remarks associated with the indicator	PQi	Construction
Compaction Consistency	ID	String	Unique identifier (code) of the indicator	PQi	Construction
Compaction Consistency	CCP	String	The link that is attached to the Compaction Contour Plot (CCP) of the construction project	PQi	Construction
Compaction Consistency	Comments	String	Remarks associated with the indicator	PQi	Construction
Compaction Efficiency	ID	String	Unique identifier (code) of the indicator	PQi	Construction
Compaction Efficiency	CQP	String	The link that is attached to the Compaction Quality Plot (CQP) of the construction project	PQi	Construction
Compaction Efficiency	Comments	String	Remarks associated with the indicator	PQi	Construction
Density Homogeneity	ID	String	Unique identifier (code) of the indicator	Literature	Construction
Density Homogeneity	DCP	String	The link that is attached to the Density Contour Plot (DCP) of the construction project	Literature	Construction

Density Homogeneity	Comments	String	Remarks associated with the indicator	Literature	Construction
Thickness Homogeneity	ID	String	Unique identifier (code) of the indicator	Literature	Construction
Thickness Homogeneity	THCP	String	The link that is attached to the Thickness Contour Plot (THCP) of the construction project	Literature	Construction
Thickness Homogeneity	Comments	String	Remarks associated with the indicator	Literature	Construction
Roughness Homogeneity	ID	String	Unique identifier (code) of the indicator	Literature	Construction
Roughness Homogeneity	RCP	String	The link that is attached to the Roughness Contour Plot (RCP) of the construction project	Literature	Construction
Roughness Homogeneity	Comments	String	Remarks associated with the indicator	Literature	Construction
Operation Quality	ID	String	Unique identifier (code) of the operation quality	Literature	Operation
Operation Quality	Project ID	String	Unique identifier (code) of the project	Literature	Operation
Operation Quality	Contract ID	String	Unique identifier (code) of the contract	Literature	Operation
Operation Quality	Operation ID	String	Unique identifier (code) of operation	Literature	Operation
Operation Quality	Comments	String	Remarks associated with the operation quality	Literature	Operation

Rutting	ID	String	Unique identifier (code) of the rutting class	Literature	Operation
Rutting	Operator ID	String	Unique identifier (code) of the operator of rutting measurement	Literature	Operation
Rutting	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Rutting	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Rutting	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Rutting	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Rutting	Rut Depth (mm)	Double	The rut depth for the pointed location (cell)	Literature	Operation
Rutting	Rut Width (mm)	Double	The rut width for the pointed location (cell)	Literature	Operation
Rutting	Rut Area (mm2)	Double	The rut area for the pointed location (cell)	Literature	Operation
Rutting	Level RWS	String	The level of the rutting based on the Rijkswaterstaat classification	Literature	Operation
Rutting	Level CROW	String	The level of the rutting based on the CROW classification	Literature	Operation
Rutting	Time	String	The time that measurement is taken place	Literature	Operation
Rutting	Comments	String	Remarks associated with the rutting	Literature	Operation
Shoving	ID	String	Unique identifier (code) of the shoving class	Literature	Operation
Shoving	Operator ID	String	Unique identifier (code) of the operator of shoving measurement	Literature	Operation
Shoving	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Shoving	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation

Shoving	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Shoving	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Shoving	Shoving Height (mm)	Double	The shoving height for the pointed location (cell)	Literature	Operation
Shoving	Shoving Width (mm)	Double	The shoving width for the pointed location (cell)	Literature	Operation
Shoving	Shoving Depth (mm)	Double	The shoving depth for the pointed location (cell)	Literature	Operation
Shoving	Level RWS	String	The level of shoving based on the Rijkswaterstaat classification	Literature	Operation
Shoving	Level CROW	String	The level of the shoving based on the CROW classification	Literature	Operation
Shoving	Time	String	The time that measurement is taken place	Literature	Operation
Shoving	Comments	String	Remarks associated with the shoving	Literature	Operation
Upheaval	ID	String	Unique identifier (code) of the upheaval class	Literature	Operation
Upheaval	Operator ID	String	Unique identifier (code) of the operator of upheaval measurement	Literature	Operation
Upheaval	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Upheaval	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Upheaval	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Upheaval	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Upheaval	Upheaval Height (mm)	Double	The upheaval height for the pointed location (cell)	Literature	Operation
Upheaval	Upheaval Area (mm2)	Double	The upheaval area for the pointed location (cell)	Literature	Operation

Upheaval	Level RWS	String	The level of the upheaval based on the Rijkswaterstaat classification	Literature	Operation
Upheaval	Level CROW	String	The level of the upheaval based on the CROW classification	Literature	Operation
Upheaval	Time	String	The time that measurement is taken place	Literature	Operation
Upheaval	Comments	String	Remarks associated with the upheaval	Literature	Operation
Pumping	ID	String	Unique identifier (code) of the pumping class	Literature	Operation
Pumping	Operator ID	String	Unique identifier (code) of the operator of pumping measurement	Literature	Operation
Pumping	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Pumping	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Pumping	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Pumping	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Pumping	Pumping Check	Boolean	Checking the availability of pumping for the pointed location (cell)	Literature	Operation
Pumping	Time	String	The time that measurement is taken place	Literature	Operation
Pumping	Comments	String	Remarks associated with the pumping	Literature	Operation
Depressions	ID	String	Unique identifier (code) of the depressions class	Literature	Operation
Depressions	Operator ID	String	Unique identifier (code) of the operator of depressions measurement	Literature	Operation
Depressions	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation

Depressions	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Depressions	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Depressions	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Depressions	Depressions Depth (mm)	Double	The depressions depth for the pointed location (cell)	Literature	Operation
Depressions	Depressions Area (mm2)	Double	The depressions area for the pointed location (cell)	Literature	Operation
Depressions	Level RWS	String	The level of the depressions based on the Rijkswaterstaat classification	Literature	Operation
Depressions	Level CROW	String	The level of the depressions based on the CROW classification	Literature	Operation
Depressions	Time	String	The time that measurement is taken place	Literature	Operation
Depressions	Comments	String	Remarks associated with the depressions	Literature	Operation
Patch Failure	ID	String	Unique identifier (code) of the patch class	Literature	Operation
Patch Failure	Operator ID	String	Unique identifier (code) of the operator of patch measurement	Literature	Operation
Patch Failure	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Patch Failure	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Patch Failure	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Patch Failure	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Patch Failure	Patch Depth (mm)	Double	The patch depth for the pointed location (cell)	Literature	Operation
Patch Failure	Patch Area (mm2)	Double	The patch area for the pointed location (cell)	Literature	Operation

Patch Failure	Level RWS	String	The level of the patch failure based on the Rijkswaterstaat classification	Literature	Operation
Patch Failure	Level CROW	String	The level of the patch failure based on the CROW classification	Literature	Operation
Patch Failure	Time	String	The time that measurement is taken place	Literature	Operation
Patch Failure	Comments	String	Remarks associated with the patch	Literature	Operation
Polishing	ID	String	Unique identifier (code) of the polishing class	Literature	Operation
Polishing	Operator ID	String	Unique identifier (code) of the operator of polishing measurement	Literature	Operation
Polishing	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Polishing	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Polishing	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Polishing	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Polishing	MPD (mm)	Double	Mean Profile Depth (MPD)	Literature	Operation
Polishing	Level RWS	String	The level of the MPD based on the Rijkswaterstaat classification	Literature	Operation
Polishing	Level CROW	String	The level of the MPD based on the CROW classification	Literature	Operation
Polishing	Time	String	The time that measurement is taken place	Literature	Operation
Polishing	Comments	String	Remarks associated with the polishing	Literature	Operation
Bleeding	ID	String	Unique identifier (code) of the bleeding class	Literature	Operation

Bleeding	Operator ID	String	Unique identifier (code) of the operator of bleeding measurement	Literature	Operation
Bleeding	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Bleeding	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Bleeding	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Bleeding	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Bleeding	Level RWS	String	The level of bleeding based on the Rijkswaterstaat classification	Literature	Operation
Bleeding	Level CROW	String	The level of the bleeding based on the CROW classification	Literature	Operation
Bleeding	Time	String	The time that measurement is taken place	Literature	Operation
Bleeding	Comments	String	Remarks associated with the bleeding	Literature	Operation
Lack of Skid Resistance	ID	String	Unique identifier (code) of the skid resistance class	Literature	Operation
Lack of Skid Resistance	Operator ID	String	Unique identifier (code) of the operator of skid resistance measurement	Literature	Operation
Lack of Skid Resistance	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Lack of Skid Resistance	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Lack of Skid Resistance	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation

Lack of Skid Resistance	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Lack of Skid Resistance	Dry Coefficient	Double	The coefficient of measured cell in dry condition	Literature	Operation
Lack of Skid Resistance	Wet Coefficient	Double	The coefficient of measured cell in wet condition	Literature	Operation
Lack of Skid Resistance	Side Force Coefficient	Double	The coefficient of measured cell in side force condition	Literature	Operation
Lack of Skid Resistance	Level RWS Dry	String	The level of the dry coefficient based on the Rijkswaterstaat classification	Literature	Operation
Lack of Skid Resistance	Level CROW Dry	String	The level of the dry coefficient based on the CROW classification	Literature	Operation
Lack of Skid Resistance	Level RWS Wet	String	The level of the wet coefficient based on the Rijkswaterstaat classification	Literature	Operation
Lack of Skid Resistance	Level CROW Wet	String	The level of the wet coefficient based on the CROW classification	Literature	Operation
Lack of Skid Resistance	Level RWS Side Force	String	The level of the side force coefficient based on the Rijkswaterstaat classification	Literature	Operation
Lack of Skid Resistance	Level CROW Side Force	String	The level of the side force coefficient based on the CROW classification	Literature	Operation
Lack of Skid Resistance	Time	String	The time that measurement is taken place	Literature	Operation
Lack of Skid Resistance	Comments	String	Remarks associated with the bleeding	Literature	Operation

Fatigue	ID	String	Unique identifier (code) of the fatigue class	Literature	Operation
Fatigue	Operator ID	String	Unique identifier (code) of the operator of fatigue measurement	Literature	Operation
Fatigue	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Fatigue	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Fatigue	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Fatigue	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Fatigue	Crack Area (mm2)	Double	The area of the cell covered by the fatigue cracking	Literature	Operation
Fatigue	Crack Percentage (%)	Double	The percentage of the cell covered by the fatigue area	Literature	Operation
Fatigue	Level RWS	String	The level of fatigue based on the Rijkswaterstaat classification	Literature	Operation
Fatigue	Level CROW	String	The level of fatigue based on the CROW classification	Literature	Operation
Fatigue	Time	String	The time that measurement is taken place	Literature	Operation
Fatigue	Comments	String	Remarks associated with the fatigue	Literature	Operation
Block	ID	String	Unique identifier (code) of the block class	Literature	Operation
Block	Operator ID	String	Unique identifier (code) of the operator of block measurement	Literature	Operation
Block	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Block	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation

Block	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Block	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Block	Crack Area (mm2)	Double	The area of the cell covered by the block cracking	Literature	Operation
Block	Crack Percentage (%)	Double	The percentage of the cell covered by the block area	Literature	Operation
Block	Level RWS	String	The level of the block based on the Rijkswaterstaat classification	Literature	Operation
Block	Level CROW	String	The level of the block based on the CROW classification	Literature	Operation
Block	Time	String	The time that measurement is taken place	Literature	Operation
Block	Comments	String	Remarks associated with the block	Literature	Operation
Edge	ID	String	Unique identifier (code) of the edge class	Literature	Operation
Edge	Operator ID	String	Unique identifier (code) of the operator of edge measurement	Literature	Operation
Edge	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Edge	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Edge	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Edge	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Edge	Crack Depth (mm)	Double	The crack depth for the pointed location (cell)	Literature	Operation
Edge	Crack Width (mm)	Double	The crack width for the pointed location (cell)	Literature	Operation
Edge	Crack Length (mm)	Double	The crack length for the pointed location (cell)	Literature	Operation

Edge	Level RWS	String	The level of the edge based on the Rijkswaterstaat classification	Literature	Operation
Edge	Level CROW	String	The level of the edge based on the CROW classification	Literature	Operation
Edge	Time	String	The time that measurement is taken place	Literature	Operation
Edge	Comments	String	Remarks associated with the edge	Literature	Operation
Longitudinal	ID	String	Unique identifier (code) of the longitudinal class	Literature	Operation
Longitudinal	Operator ID	String	Unique identifier (code) of the operator of longitudinal measurement	Literature	Operation
Longitudinal	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Longitudinal	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Longitudinal	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Longitudinal	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Longitudinal	Crack Depth (mm)	Double	The crack depth for the pointed location (cell)	Literature	Operation
Longitudinal	Crack Width (mm)	Double	The crack width for the pointed location (cell)	Literature	Operation
Longitudinal	Crack Length (mm)	Double	The crack length for the pointed location (cell)	Literature	Operation
Longitudinal	Level RWS	String	The level of the longitudinal based on the Rijkswaterstaat classification	Literature	Operation
Longitudinal	Level CROW	String	The level of the longitudinal based on the CROW classification	Literature	Operation
Longitudinal	Time	String	The time that measurement is taken place	Literature	Operation
Longitudinal	Comments	String	Remarks associated with the longitudinal	Literature	Operation

Transverse	ID	String	Unique identifier (code) of the transverse class	Literature	Operation
Transverse	Operator ID	String	Unique identifier (code) of the operator of transverse measurement	Literature	Operation
Transverse	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Transverse	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Transverse	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Transverse	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Transverse	Crack Depth (mm)	Double	The crack depth for the pointed location (cell)	Literature	Operation
Transverse	Crack Width (mm)	Double	The crack width for the pointed location (cell)	Literature	Operation
Transverse	Crack Length (mm)	Double	The crack length for the pointed location (cell)	Literature	Operation
Transverse	Level RWS	String	The level of the transverse based on the Rijkswaterstaat classification	Literature	Operation
Transverse	Level CROW	String	The level of the transverse based on the CROW classification	Literature	Operation
Transverse	Time	String	The time that measurement is taken place	Literature	Operation
Transverse	Comments	String	Remarks associated with the transverse	Literature	Operation
Slippage	ID	String	Unique identifier (code) of the slippage class	Literature	Operation
Slippage	Operator ID	String	Unique identifier (code) of the operator of slippage measurement	Literature	Operation
Slippage	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation

Slippage	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Slippage	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Slippage	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Slippage	Crack Depth (mm)	Double	The crack depth for the pointed location (cell)	Literature	Operation
Slippage	Crack Width (mm)	Double	The crack width for the pointed location (cell)	Literature	Operation
Slippage	Crack Length (mm)	Double	The crack length for the pointed location (cell)	Literature	Operation
Slippage	Level RWS	String	The level of the slippage based on the Rijkswaterstaat classification	Literature	Operation
Slippage	Level CROW	String	The level of the slippage based on the CROW classification	Literature	Operation
Slippage	Time	String	The time that measurement is taken place	Literature	Operation
Slippage	Comments	String	Remarks associated with the slippage	Literature	Operation
Reflection	ID	String	Unique identifier (code) of the reflection class	Literature	Operation
Reflection	Operator ID	String	Unique identifier (code) of the operator of reflection measurement	Literature	Operation
Reflection	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Reflection	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Reflection	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Reflection	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Reflection	Crack Depth (mm)	Double	The crack depth for the pointed location (cell)	Literature	Operation

Reflection	Crack Width (mm)	Double	The crack width for the pointed location (cell)	Literature	Operation
Reflection	Crack Length (mm)	Double	The crack length for the pointed location (cell)	Literature	Operation
Reflection	Level RWS	String	The level of the reflection based on the Rijkswaterstaat classification	Literature	Operation
Reflection	Level CROW	String	The level of the reflection based on the CROW classification	Literature	Operation
Reflection	Time	String	The time that measurement is taken place	Literature	Operation
Reflection	Comments	String	Remarks associated with the reflection	Literature	Operation
Pothole	ID	String	Unique identifier (code) of the pothole class	Literature	Operation
Pothole	Operator ID	String	Unique identifier (code) of the operator of pothole measurement	Literature	Operation
Pothole	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Pothole	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Pothole	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Pothole	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Pothole	Depth (mm)	Double	The depth of the pothole	Literature	Operation
Pothole	Area (mm2)	Double	The area of the pothole	Literature	Operation
Pothole	Level RWS	String	The level of the pothole based on the Rijkswaterstaat classification	Literature	Operation
Pothole	Level CROW	String	The level of the pothole based on the CROW classification	Literature	Operation
Pothole	Time	String	The time that measurement is taken place	Literature	Operation

Pothole	Comments	String	Remarks associated with the pothole	Literature	Operation
Raveling	ID	String	Unique identifier (code) of the raveling class	Literature	Operation
Raveling	Operator ID	String	Unique identifier (code) of the operator of raveling measurement	Literature	Operation
Raveling	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Raveling	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Raveling	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
Raveling	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Raveling	Level RWS	String	The level of the raveling based on the Rijkswaterstaat classification	Literature	Operation
Raveling	Level CROW	String	The level of the raveling based on the CROW classification	Literature	Operation
Raveling	Time	String	The time that measurement is taken place	Literature	Operation
Raveling	Comments	String	Remarks associated with the raveling	Literature	Operation
IRI	ID	String	Unique identifier (code) of the IRI class	Literature	Operation
IRI	Operator ID	String	Unique identifier (code) of the operator of IRI measurement	Literature	Operation
IRI	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
IRI	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
IRI	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation

IRI	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
IRI	IRI Value	Double	The value of International Roughness Index for each cell	Literature	Operation
IRI	Level RWS	String	The level of the IRI based on the Rijkswaterstaat classification	Literature	Operation
IRI	Level CROW	String	The level of the IRI based on the CROW classification	Literature	Operation
IRI	Time	String	The time that measurement is taken place	Literature	Operation
IRI	Plot	String	The link that is attached to the IRI Contour Plot of the project that shows the IRI for the entire road section	Literature	Operation
IRI	Comments	String	Remarks associated with the IRI	Literature	Operation
FWD	ID	String	Unique identifier (code) of the bearing capacity class	Literature	Operation
FWD	Operator ID	String	Unique identifier (code) of the operator of bearing capacity measurement	Literature	Operation
FWD	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
FWD	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
FWD	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation
FWD	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
FWD	Deflection (mm)	Double	The deflection of the measured point	Literature	Operation
FWD	Effective Pavement Modulus (kPa)	Double	Effective pavement modulus	Literature	Operation
FWD	Resilient Modulus (kPa)	Double	The crack length for the pointed location (cell)	Literature	Operation

FWD	Air Temperature (°C)	Double	The air temperature	Literature	Operation
FWD	Surface Temperature (°C)	Double	The surface temperature of the pavement	Literature	Operation
FWD	Core Temperature (°C)	Double	The core temperature of the pavement	Literature	Operation
FWD	Thickness (mm)	Double	The thickness of the measuring cell	Literature	Operation
FWD	Time	String	The time that measurement is taken place	Literature	Operation
FWD	Plot	String	The link that is attached to the E Moduli Contour Plot of the project that shows the entire road section	Literature	Operation
FWD	Comments	String	Remarks associated with the reflection	Literature	Operation
Maintenance Year	ID	String	Unique identifier (code) of the indicator	Literature	Operation
Maintenance Year	Year	Integer	Years that the road has before maintenance is started	Literature	Operation
Maintenance Year	Comments	String	Remarks associated with the indicator	Literature	Operation
Permeability	ID	String	Unique identifier (code) of the permeability	Literature	Operation
Permeability	Operator ID	String	Unique identifier (code) of the operator of permeability measurement	Literature	Operation
Permeability	Cell ID	String	Unique identifier (code) of the cell	Literature	Operation
Permeability	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	Literature	Operation
Permeability	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	Literature	Operation

Permeability	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	Literature	Operation
Permeability	Level RWS	String	The level of the raveling based on the Rijkswaterstaat classification	Literature	Operation
Permeability	Level CROW	String	The level of the raveling based on the CROW classification	Literature	Operation
Permeability	Coefficient permeability	Double	Coefficient permeability that measures based on Darcy's law	Literature	Operation
Permeability	Plot	String	The link that is attached to the Coefficient permeability Contour Plot of the project that shows the entire road section	Literature	Operation
Permeability	Comments	String	Remarks associated with the reflection	Literature	Operation

Table. Items name, type, description, source and lifecycle phase measurement and testing activity (activity sub-ontology).

Item name	**Type of item**	**Description of item**	**Source of item (applications or literature)**	**Life cycle phase**
Road Infrastructure	Class	Every physical objects of the road such as road itself and other objects on the road	PIM	
Measurements & Testing Activity	Class	All of the measurements and testing that are performed to evaluate the condition of the road pavement	Literature	
Data Collection	Class	Data collection is the process of collecting all types of data used in the pavement life cycle such as all the measurements and laboratory testing	Literature	
Data Analysis	Class	The data obtained by all types of measurements should be analyzed	Literature	
Laboratory Testing	Class	Pavement test which is conducted in asphalt Lab and is used for evaluating the road pavement materials in entire lifecycle	Literature	
Material Test	Class	Material test on the aggregate and bitumen	Literature	
Aggregate Test	Class	Different types of aggregate tests	Literature	
Bitumen Test	Class	Different types of bitumen tests	Literature	
Additive Test	Class	Different types of additive tests	Literature	
Mix Test	Class	Different types of mix tests	Literature	
Performance Test	Class	One type of mix test is performance test that defines the stability and responsiveness of asphalt mix under certain workload	Literature	

Mixture Characterization Test	Class	One type of mix test is the mix characterization test that defines the volumetric characteristics of asphalt mix	Literature	
Deformation Resistance Test	Class	Deformation resistance tests can be conducted in two different types of destructive and non-destructive tests such as rutting tests (static and dynamic creeps and Hamburg wheel truck) and modules tests (dynamic modulus)	Literature	
Fatigue Life Test	Class	Fatigue life test can define the resistance of asphalt mix against the cyclic loading and can be conducted in different forms	Literature	
Tensile Strength Test	Class	The max amount of load that asphalt mix can tolerate (when it is being stretched) before a fracture occurs, this test is useful to evaluate the resistance of asphalt mix against low-temperature cracking	Literature	
Stiffness Test	Class	The relation between stress and strain in an asphalt mix can define the stiffness	Literature	
Moisture Susceptibility Test	Class	The type of test that can define the behavior of asphalt mix against the moisture damage.	Literature	
Bulk Specific Gravity Test	Class	The specific gravity of compacted asphalt mix is called bulk specific gravity and can be defined by comparing the weight of asphalt mix to the weight of equal volume of water	Literature	
Theoretical Max Specific Gravity Test	Class	The test that can define the max specific gravity of asphalt mix when there is no air void in the sample	Literature	
Construction Measurement	Class	The construction measurements that perform to assess the construction process	Literature	Construction
Weather Condition Measurement	Class	Weather condition is one indicator that defined the quality of construction phase	Literature	Construction
Paving Temperature Measurement	Class	Paving Temperature is another indicator that shows the temperature of paving process	Literature	Construction
Location Measurement	Class	locations of paver and roller are important to define the speed and number of passes for paver and roller respectively	Literature	Construction
Paver Location	Class	Paver location is an important indicator to find the speed of the paver during the paving process	Literature	Construction
Roller Location	Class	Roller compaction is important to find the number of passes	Literature	Construction
Density Measurement	Class	Density of compacted asphalt is an important indicator that defined whether the asphalt mixture reaches the target density	Literature	Construction
Thickness Measurement	Class	The compacted thickness of asphalt layer is an indicator of appropriate paving and compaction processes	Literature	Construction
Core Temperature Measurement	Class	Core temperature is another indicator that determines the duration of compaction	Literature	Construction

Surface Temperature Measurement	Class	Surface temperature is another indicator that determines the duration of compaction	Literature	Construction
Operation Measurement	Class	All of the measurements that are performed to evaluate the condition of the road pavement in the operation phase	Literature	Operation
In-use Quality Measurement	Class	The quality measurement of the asphalt pavement in the operation phase (In-use quality)	Literature	Operation
Invasive Measurement	Class	One of the methods to evaluate the quality of the asphalt layer is an invasive measurement that damages the surface of asphalt pavement	Literature	Operation
Asphalt Coring	Class	Asphalt coring is the one type of invasive measurement	Literature	Operation
Core	Class	Core is drilled and has some features and attributes such as location, dimensions, time, etc. this information in this class is not the same as the core mixture however, these two have relation	Literature	Operation
Core Mixture	Class	An asphalt mix that is cored from the paved asphalt pavement (inspection which is the operation phase)	PIM	Operation
Noninvasive Measurement	Class	One of the methods to evaluate the quality of the asphalt layer is noninvasive measurement that does not damage the surface of asphalt pavement	Literature	Operation
Static Monitoring	Class	In this method, the data is collected automatically without any action (in this method, the sensor is installed once and then the data is saved automatically on the server without any physical actions)	Literature	Operation
Optical Fiber Monitoring	Class	By using the fiber optic in the asphalt layer, the strain and temperature of asphalt can be monitored	Literature	Operation
Strain Gage Monitoring	Class	Normal strain gage can be used in the asphalt layer to collect data regarding the strain of the layers	Literature	Operation
Wireless Monitoring	Class	By using wireless sensor in the predicted crack location, the propagation of the crack, pressure and temperature of asphalt can be monitored	Literature	Operation
Dynamic Monitoring	Class	In this method, the data is collected by acting on the road	Literature	Operation
Automated Road Survey	Class	In this method, a truck, van or any other vehicles with different types of sensor and lasers is used to monitor a road condition	Literature	Operation
Manual Road Survey	Class	Monitoring road by sending an inspector is one of the old methods to monitor a road condition	Literature	Operation
In-use Incident Measurement	Class	Any incident or occurrence happens during the in-use phase that can affect the service life of the asphalt pavement such as fire, pollution carcass (animal dead body) the heavy materials on the surface	Literature	Operation

Fire Measurement		Class	Measurements that are performed to collect data about fire	Literature	Operation
Flat Tire Measurement		Class	Measurements that are performed to collect data about flat tire	Literature	Operation
Carcass Measurement		Class	Measurements that are performed to collect data about carcass (animal dead body)	Literature	Operation
Extreme Weather Measurement		Class	Measurements that are performed to collect data about climate harsh conditions (extreme weather)	Literature	Operation
Pollution Measurement		Class	Measurements that are performed to collect data about pollution	Literature	Operation
In-use Traffic Measurement		Class	The traffic measurement that takes place in the operation phase	Literature	Operation
Traffic Volume Measurement		Class	The information regarding a traffic volume measurement	Literature	Operation
Sustainability Measurement		Class	The measurements that show the sustainability level of the pavement life cycle (this class can be linked to the Life Cycle Analysis Ontology)	Literature	
Instruments		Class	For all measurements, several types of instruments can be used to collect data	Literature	
Sensors		Class	Sensors are one type of instrument for data collection that can be linked to Sensor Ontology	Literature	
Data Preparation		Class	All of the process used to prepare data for modelling is called data preparation	Literature	
Data Modelling		Class	Modeling data to extract acceptable knowledge	Literature	
Data Filtering		Class	Selecting smaller parts of data instead of entire data to perform the analysis	Literature	
Data Scaling		Class	Changing the scale of data is required occasionally to be compared with the other data	Literature	
Data Synchronization		Class	The process of making consistency between the data from different sources or databases is called data synchronization	Literature	
Data Tagging		Class	Data tagging is a method that increases the efficiency of data by organizing it more accurately (using tag on data)	Literature	
Outlier Removal		Class	In this method, the data specialist removes the data that is an outlier by using a logical reason	Literature	
Machine Learning		Class	Machine learning is a method that which computers can identify patterns in data by preventing the intervention of human	Literature	
Class name	**Attribute of the class**	**Type of attribute**	**Description of attribute**	**Source of attribute (applications or literature)**	**Life cycle phase**

Aggregate Test	ID	String	Unique identifier (code) of the test	Literature	
Aggregate Test	Type	String	Type of the test	Literature	
Aggregate Test	Date	String	The date on which the test is conducted	Literature	
Aggregate Test	Standard	String	The standard which is used for the test	Literature	
Aggregate Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Aggregate Test	Lab Name	String	The name of the lab	Literature	
Aggregate Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Aggregate Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Aggregate Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Aggregate Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Aggregate Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Aggregate Test	Loading	String	Description of the loading condition of the test	Literature	
Aggregate Test	Frequency	String	Description of the frequency condition of the test	Literature	
Aggregate Test	Operator Sex	String	The sex of operator	Literature	
Aggregate Test	Operator Age	Integer	The age of operator	Literature	
Aggregate Test	Operator Experience	Integer	The experience of operator in years	Literature	
Aggregate Test	Comments	String	Remarks associated with the test	Literature	
Bitumen Test	ID	String	Unique identifier (code) of the test	Literature	
Bitumen Test	Type	String	Type of the test	Literature	
Bitumen Test	Date	String	The date on which the test is conducted	Literature	
Bitumen Test	Standard	String	The standard which is used for the test	Literature	
Bitumen Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Bitumen Test	Lab Name	String	The name of the lab	Literature	
Bitumen Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	

Bitumen Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Bitumen Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Bitumen Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Bitumen Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Bitumen Test	Loading	String	Description of the loading condition of the test	Literature	
Bitumen Test	Frequency	String	Description of the frequency condition of the test	Literature	
Bitumen Test	Operator Sex	String	The sex of operator	Literature	
Bitumen Test	Operator Age	Integer	The age of operator	Literature	
Bitumen Test	Operator Experience	Integer	The experience of operator in years	Literature	
Bitumen Test	Comments	String	Remarks associated with the test	Literature	
Additive Test	ID	String	Unique identifier (code) of the test	Literature	
Additive Test	Type	String	Type of the test	Literature	
Additive Test	Date	String	The date on which the test is conducted	Literature	
Additive Test	Standard	String	The standard which is used for the test	Literature	
Additive Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Additive Test	Lab Name	String	The name of the lab	Literature	
Additive Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Additive Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Additive Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Additive Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Additive Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Additive Test	Loading	String	Description of the loading condition of the test	Literature	
Additive Test	Frequency	String	Description of the frequency condition of the test	Literature	
Additive Test	Operator Sex	String	The sex of operator	Literature	
Additive Test	Operator Age	Integer	The age of operator	Literature	

Additive Test	Operator Experience	Integer	The experience of operator in years	Literature	
Additive Test	Comments	String	Remarks associated with the test	Literature	
Deformation Resistance Test	ID	String	Unique identifier (code) of the test	Literature	
Deformation Resistance Test	Type	String	Type of the test	Literature	
Deformation Resistance Test	Date	String	The date on which the test is conducted	Literature	
Deformation Resistance Test	Standard	String	The standard which is used for the test	Literature	
Deformation Resistance Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Deformation Resistance Test	Lab Name	String	The name of the lab	Literature	
Deformation Resistance Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Deformation Resistance Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Deformation Resistance Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Deformation Resistance Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Deformation Resistance Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Deformation Resistance Test	Loading	String	Description of the loading condition of the test	Literature	
Deformation Resistance Test	Frequency	String	Description of the frequency condition of the test	Literature	
Deformation Resistance Test	Operator Sex	String	The sex of operator	Literature	
Deformation Resistance Test	Operator Age	Integer	The age of operator	Literature	

Deformation Resistance Test	Operator Experience	Integer	The experience of operator in years	Literature	
Deformation Resistance Test	Comments	String	Remarks associated with the test	Literature	
Fatigue Life Test	ID	String	Unique identifier (code) of the test	Literature	
Fatigue Life Test	Type	String	Type of the test	Literature	
Fatigue Life Test	Date	String	The date on which the test is conducted	Literature	
Fatigue Life Test	Standard	String	The standard which is used for the test	Literature	
Fatigue Life Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Fatigue Life Test	Lab Name	String	The name of the lab	Literature	
Fatigue Life Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Fatigue Life Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Fatigue Life Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Fatigue Life Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Fatigue Life Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Fatigue Life Test	Loading	String	Description of the loading condition of the test	Literature	
Fatigue Life Test	Frequency	String	Description of the frequency condition of the test	Literature	
Fatigue Life Test	Operator Sex	String	The sex of operator	Literature	
Fatigue Life Test	Operator Age	Integer	The age of operator	Literature	

Fatigue Life Test	Operator Experience	Integer	The experience of operator in years	Literature	
Fatigue Life Test	Comments	String	Remarks associated with the test	Literature	
Tensile Strength Test	ID	String	Unique identifier (code) of the test	Literature	
Tensile Strength Test	Type	String	Type of the test	Literature	
Tensile Strength Test	Date	String	The date on which the test is conducted	Literature	
Tensile Strength Test	Standard	String	The standard which is used for the test	Literature	
Tensile Strength Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Tensile Strength Test	Lab Name	String	The name of the lab	Literature	
Tensile Strength Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Tensile Strength Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Tensile Strength Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Tensile Strength Test	Lab Equipment	String	The device (equipment) which test is conducted	Literature	
Tensile Strength Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Tensile Strength Test	Loading	String	Description of the loading condition of the test	Literature	
Tensile Strength Test	Frequency	String	Description of the frequency condition of the test	Literature	
Tensile Strength Test	Operator Sex	String	The sex of operator	Literature	
Tensile Strength Test	Operator Age	Integer	The age of operator	Literature	

Tensile Strength Test	Operator Experience	Integer	The experience of operator in years	Literature	
Tensile Strength Test	Comments	String	Remarks associated with the test	Literature	
Stiffness Test	ID	String	Unique identifier (code) of the test	Literature	
Stiffness Test	Type	String	Type of the test	Literature	
Stiffness Test	Date	String	The date on which the test is conducted	Literature	
Stiffness Test	Standard	String	The standard which is used for the test	Literature	
Stiffness Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Stiffness Test	Lab Name	String	The name of the lab	Literature	
Stiffness Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Stiffness Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Stiffness Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Stiffness Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Stiffness Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Stiffness Test	Loading	String	Description of the loading condition of the test	Literature	
Stiffness Test	Frequency	String	Description of the frequency condition of the test	Literature	
Stiffness Test	Operator Sex	String	The sex of operator	Literature	
Stiffness Test	Operator Age	Integer	The age of operator	Literature	
Stiffness Test	Operator Experience	Integer	The experience of operator in years	Literature	
Stiffness Test	Comments	String	Remarks associated with the test	Literature	
Moisture Susceptibility Test	ID	String	Unique identifier (code) of the test	Literature	

Moisture Susceptibility Test	Type	String	Type of the test	Literature	
Moisture Susceptibility Test	Date	String	The date on which the test is conducted	Literature	
Moisture Susceptibility Test	Standard	String	The standard which is used for the test	Literature	
Moisture Susceptibility Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Moisture Susceptibility Test	Lab Name	String	The name of the lab	Literature	
Moisture Susceptibility Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Moisture Susceptibility Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Moisture Susceptibility Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Moisture Susceptibility Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Moisture Susceptibility Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Moisture Susceptibility Test	Loading	String	Description of the loading condition of the test	Literature	
Moisture Susceptibility Test	Frequency	String	Description of the frequency condition of the test	Literature	

Moisture Susceptibility Test	Operator Sex	String	The sex of operator	Literature	
Moisture Susceptibility Test	Operator Age	Integer	The age of operator	Literature	
Moisture Susceptibility Test	Operator Experience	Integer	The experience of operator in years	Literature	
Moisture Susceptibility Test	Comments	String	Remarks associated with the test	Literature	
Bulk Specific Gravity Test	ID	String	Unique identifier (code) of the test	Literature	
Bulk Specific Gravity Test	Type	String	Type of the test	Literature	
Bulk Specific Gravity Test	Date	String	The date on which the test is conducted	Literature	
Bulk Specific Gravity Test	Standard	String	The standard which is used for the test	Literature	
Bulk Specific Gravity Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Bulk Specific Gravity Test	Lab Name	String	The name of the lab	Literature	
Bulk Specific Gravity Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Bulk Specific Gravity Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Bulk Specific Gravity Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	
Bulk Specific Gravity Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Bulk Specific Gravity Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	

Bulk Specific Gravity Test	Operator Sex	String	The sex of operator	Literature	
Bulk Specific Gravity Test	Operator Age	Integer	The age of operator	Literature	
Bulk Specific Gravity Test	Operator Experience	Integer	The experience of operator in years	Literature	
Bulk Specific Gravity Test	Comments	String	Remarks associated with the test	Literature	
Theoretical Max Specific Gravity Test	ID	String	Unique identifier (code) of the test	Literature	
Theoretical Max Specific Gravity Test	Type	String	Type of the test	Literature	
Theoretical Max Specific Gravity Test	Date	String	The date on which the test is conducted	Literature	
Theoretical Max Specific Gravity Test	Standard	String	The standard which is used for the test	Literature	
Theoretical Max Specific Gravity Test	Number of Replicas	Integer	The number of replicas (repetition) for the conducted tests for each sample	Literature	
Theoretical Max Specific Gravity Test	Lab Name	String	The name of the lab	Literature	
Theoretical Max Specific Gravity Test	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface	Literature	
Theoretical Max Specific Gravity Test	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface	Literature	
Theoretical Max Specific Gravity Test	Altitude	Double	Vertical direction between a reference datum and a point	Literature	

Theoretical Max Specific Gravity Test	Lab Equipment	String	The device (equipment) on which the test is conducted	Literature	
Theoretical Max Specific Gravity Test	Temperature (°C)	Integer	The temperature that the test is conducted at	Literature	
Theoretical Max Specific Gravity Test	Operator Sex	String	The sex of operator	Literature	
Theoretical Max Specific Gravity Test	Operator Age	Integer	The age of operator	Literature	
Theoretical Max Specific Gravity Test	Operator Experience	Integer	The experience of operator in years	Literature	
Theoretical Max Specific Gravity Test	Comments	String	Remarks associated with the test	Literature	
Construction Measurement	ID	String	Unique identifier (code) of the construction measurement	PQi	Construction
Construction Measurement	Comments	String	Remarks associated with the construction measurement	PQi	Construction
Weather Condition Measurement	ID	String	Unique identifier (code) of the weather	PQi	Construction
Weather Condition Measurement	Date	String	The date that the weather measurement is taken place	PQi	Construction
Weather Condition Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (weather station location)	PQi	Construction
Weather Condition Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (weather station location)	PQi	Construction

Weather Condition Measurement	Altitude	Double	Vertical direction between a reference datum and a point (weather station location)	PQi	Construction
Weather Condition Measurement	High Temperature (°C)	Double	High temperature measured at the specific time	PQi	Construction
Weather Condition Measurement	Low Temperature (°C)	Double	Low temperature measured at the specific time	PQi	Construction
Weather Condition Measurement	Humidity (%)	Double	The percentage of humidity	PQi	Construction
Weather Condition Measurement	Precipitation (cm)	Double	The amount of precipitation	PQi	Construction
Weather Condition Measurement	Wind Speed (km/h)	Double	The wind speed	PQi	Construction
Weather Condition Measurement	Wind Direction	String	The wind direction	PQi	Construction
Weather Condition Measurement	Pressure (hPa)	Double	The pressure of the weather	PQi	Construction
Weather Condition Measurement	Time	String	The time that measurement is taken place	PQi	Construction
Weather Condition Measurement	Comments	String	Remarks associated with the weather	PQi	Construction
Paving Temperature Measurement	ID	String	Unique identifier (code) of the temperature	PQi	Construction

Paving Temperature Measurement	Paver ID	String	Unique identifier (code) of the paver	PQi	Construction
Paving Temperature Measurement	Operator ID	String	Unique identifier (code) of the operator of paver	PQi	Construction
Paving Temperature Measurement	Cell ID	String	Unique identifier (code) of the cell	PQi	Construction
Paving Temperature Measurement	Date	String	The date that the temperature measurement is taken place	PQi	Construction
Paving Temperature Measurement	Initial Temperature (°C)	Double	The initial temperature of the cell after paving process	PQi	Construction
Paving Temperature Measurement	Time	String	The time that measurement is taken place	PQi	Construction
Paving Temperature Measurement	Comments	String	Remarks associated with the temperature	PQi	Construction
Location Measurement	ID	String	Unique identifier (code) of the location	PQi	Construction
Location Measurement	Date	String	The date of the construction project	PQi	Construction
Location Measurement	Comments	String	Remarks associated with the location	PQi	Construction
Paver Location	ID	String	Unique identifier (code) of the location	PQi	Construction
Paver Location	Paver ID	String	Unique identifier (code) of the paver	PQi	Construction
Paver Location	Operator ID	String	Unique identifier (code) of the operator of the paver	PQi	Construction

Paver Location	Cell ID	String	Unique identifier (code) of the cell	PQi	Construction
Paver Location	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (paver location)	PQi	Construction
Paver Location	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (paver location)	PQi	Construction
Paver Location	Altitude	Double	Vertical direction between a reference datum and a point (paver location)	PQi	Construction
Paver Location	Speed (m/min)	Double	The speed of the paver	PQi	Construction
Paver Location	GPS Time	String	The time is that received by GPS	PQi	Construction
Paver Location	Time	String	The time that measurement is taken place	PQi	Construction
Paver Location	Comments	String	Remarks associated with the paver location	PQi	Construction
Roller Location	ID	String	Unique identifier (code) of the location	PQi	Construction
Roller Location	Roller ID	String	Unique identifier (code) of the roller	PQi	Construction
Roller Location	Operator ID	String	Unique identifier (code) of the operator of roller	PQi	Construction
Roller Location	Cell ID	String	Unique identifier (code) of the cell	PQi	Construction
Roller Location	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (roller location)	PQi	Construction
Roller Location	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (roller location)	PQi	Construction
Roller Location	Altitude	Double	Vertical direction between a reference datum and a point (roller location)	PQi	Construction
Roller Location	Speed (m/min)	Double	The speed of the roller	PQi	Construction
Roller Location	GPS Time	String	The time is that received by GPS	PQi	Construction

Roller Location	Time	String	The time that measurement is taken place	PQi	Construction
Roller Location	Comments	String	Remarks associated with the roller location	PQi	Construction
Density Measurement	ID	String	Unique identifier (code) of the density class	PQi	Construction
Density Measurement	Operator ID	String	Unique identifier (code) of the operator of density measurement	PQi	Construction
Density Measurement	Cell ID	String	Unique identifier (code) of the cell	PQi	Construction
Density Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (point location)	PQi	Construction
Density Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (point location)	PQi	Construction
Density Measurement	Altitude	Double	Vertical direction between a reference datum and a point (point location)	PQi	Construction
Density Measurement	Distance from Start (m)	Double	The distance between the density location measurement and the start point of the construction project	PQi	Construction
Density Measurement	Density (kg/m3)	Double	The density of the measured cell	PQi	Construction
Density Measurement	Compaction Percent (%)	Double	The compaction percent regarding the measured point	PQi	Construction
Density Measurement	Air Void (%)	Double	The air void for the measured point	PQi	Construction
Density Measurement	Time	String	The time that measurement is taken place	PQi	Construction
Density Measurement	Comments	String	Remarks associated with the density	PQi	Construction
Thickness Measurement	ID	String	Unique identifier (code) of the thickness class	Literature	Construction
Thickness Measurement	Operator ID	String	Unique identifier (code) of the operator of thickness measurement	Literature	Construction

Thickness Measurement	Cell ID	String	Unique identifier (code) of the cell	Literature	Construction
Thickness Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (point location)	Literature	Construction
Thickness Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (point location)	Literature	Construction
Thickness Measurement	Altitude	Double	Vertical direction between a reference datum and a point (point location)	Literature	Construction
Thickness Measurement	Distance from Start (m)	Double	The distance between the thickness location measurement and the start point of the construction project	Literature	Construction
Thickness Measurement	Thickness (mm)	Double	The thickness of the measured cell	Literature	Construction
Thickness Measurement	Time	String	The time that measurement is taken place	Literature	Construction
Thickness Measurement	Comments	String	Remarks associated with the thickness	Literature	Construction
Core Temperature Measurement	ID	String	Unique identifier (code) of the core temperature class	PQi	Construction
Core Temperature Measurement	Operator ID	String	Unique identifier (code) of the operator of core temperature measurement	PQi	Construction
Core Temperature Measurement	Cell ID	String	Unique identifier (code) of the cell	PQi	Construction
Core Temperature Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (stand location)	PQi	Construction
Core Temperature Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (stand location)	PQi	Construction
Core Temperature Measurement	Altitude	Double	Vertical direction between a reference datum and a point (stand location)	PQi	Construction

Core Temperature Measurement	Distance from Start (m)	Double	The distance between the core temperature location measurement and the start point of the construction project	PQi	Construction
Core Temperature Measurement	Temperature C1 (°C)	Double	The temperature measured for the core temperature station (channel 1)	PQi	Construction
Core Temperature Measurement	Temperature C2 (°C)	Double	The temperature measured for the core temperature station (channel 2)	PQi	Construction
Core Temperature Measurement	Temperature C3 (°C)	Double	The temperature measured for the core temperature station (channel 3)	PQi	Construction
Core Temperature Measurement	Temperature C4 (°C)	Double	The temperature measured for the core temperature station (channel 4)	PQi	Construction
Core Temperature Measurement	Time	String	The time that measurement is taken place	PQi	Construction
Core Temperature Measurement	Comments	String	Remarks associated with the core temperature	PQi	Construction
Surface Temperature Measurement	ID	String	Unique identifier (code) of the surface temperature class	PQi	Construction
Surface Temperature Measurement	Operator ID	String	Unique identifier (code) of the operator of surface temperature measurement	PQi	Construction
Surface Temperature Measurement	Cell ID	String	Unique identifier (code) of the cell	PQi	Construction
Surface Temperature Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (pointed location)	PQi	Construction

Surface Temperature Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (pointed location)	PQi	Construction
Surface Temperature Measurement	Altitude	Double	Vertical direction between a reference datum and a point (pointed location)	PQi	Construction
Surface Temperature Measurement	Distance from Start (m)	Double	The distance between the surface temperature location measurement and the start point of the construction project	PQi	Construction
Surface Temperature Measurement	Surface Temperature (°C)	Double	The temperature measured for the surface temperature station	PQi	Construction
Surface Temperature Measurement	Time	String	The time that measurement is taken place	PQi	Construction
Surface Temperature Measurement	Comments	String	Remarks associated with the surface temperature	PQi	Construction
Asphalt Coring	ID	String	Unique identifier (code) for the asphalt core	Literature	Operation
Asphalt Coring	Device Name	String	The device name used for asphalt coring	Literature	Operation
Asphalt Coring	Method	String	The description of the method used for the coring process	Literature	Operation
Asphalt Coring	Standard	String	The standard used for the process	Literature	Operation
Asphalt Coring	Filling Material	String	The materials used to fill the core after drilling	Literature	Operation
Asphalt Coring	Distance (m)	Double	The distance between two consecutive cores	Literature	Operation
Asphalt Coring	Comments	String	Remarks associated with the asphalt coring method	Literature	Operation

Core	ID	String	Unique identifier (code) for the core	Literature	Operation
Core	Time	String	The time that drilling cored is taken place	Literature	Operation
Core	Date	String	The date that drilling cored is taken place	Literature	Operation
Core	Core Diameter (mm)	Double	The diameter of the core	Literature	Operation
Core	Core Height (mm)	Double	The height of the core	Literature	Operation
Core	Location	String	The GPS location of the core	Literature	Operation
Core	Layer	String	The layer the core is drilled	Literature	Operation
Core	Comments	String	Remarks associated with the core	Literature	Operation
Core Mixture	ID	String	Unique identifier (code) for the core mixture	Literature	Operation
Core Mixture	Bitumen content (%)	Double	The content of bitumen in core mixture	PIM	Operation
Core Mixture	Theoretical maximum specific gravity (kg/m3)	Double	The theoretically calculated density in a Lab from a core mixture	Literature	Operation
Core Mixture	Measured bulk specific gravity (kg/m3)	Double	The measured density of a core mixture	Literature	Operation
Core Mixture	Degree of compaction	Double	The measured bulk density to the target density of a core mixture	PIM	Operation
Core Mixture	Air void (%)	Double	The calculated amount of air void in a core mixture based on measured bulk density and theoretical maximum specific density	PIM	Operation
Core Mixture	22,4 mm (%)	Double	The mass fraction of the core aggregate through sieve size 22.4 mm	PIM	Operation
Core Mixture	16 mm (%)	Double	The mass fraction of the core aggregate through sieve size 16 mm	PIM	Operation

Core Mixture	11,2 mm (%)	Double	The mass fraction of the core aggregate through sieve size 11.2 mm	PIM	Operation
Core Mixture	8 mm (%)	Double	The mass fraction of the core aggregate through sieve size 8 mm	PIM	Operation
Core Mixture	5,6 mm (%)	Double	The mass fraction of the core aggregate through sieve size 5.6 mm	PIM	Operation
Core Mixture	4 mm (%)	Double	The mass fraction of the core aggregate through sieve size 4 mm	PIM	Operation
Core Mixture	2 mm (%)	Double	The mass fraction of the core aggregate through sieve size 2 mm	PIM	Operation
Core Mixture	0,5 mm (%)	Double	The mass fraction of the core aggregate through sieve size 500 µm	PIM	Operation
Core Mixture	0,18 mm (%)	Double	The mass fraction of the core aggregate through sieve size 180 µm	PIM	Operation
Core Mixture	0,125 mm (%)	Double	The mass fraction of the core aggregate through sieve size 125 µm	PIM	Operation
Core Mixture	0,063 mm (%)	Double	The mass fraction of the core aggregate through sieve size 63 µm	PIM	Operation
Core Mixture	Stiffness (MPa)	Double	The stiffness modulus of the core mix	PIM	Operation
Core Mixture	Water sensitivity (TSR) (%)	Double	The sensitivity of the core mix to the action of moisture (ratio of conditioned ITS to dry ITS)	PIM	Operation
Core Mixture	Indirect tensile strength (kPa)	Integer	Indirect tensile strength when the core mix is subjected to were subjected to loading from a diagonal direction at a constant load rate	Literature	Operation
Optical Fiber Monitoring	ID	String	Unique identifier (code) for the monitoring	Literature	Operation
Optical Fiber Monitoring	Type	String	The type of fiber optics used for measurement	Literature	Operation
Optical Fiber Monitoring	Start Time	String	The time that monitoring is started	Literature	Operation
Optical Fiber Monitoring	End Time	String	The time that monitoring is ended	Literature	Operation
Optical Fiber Monitoring	Date	String	The date that the monitoring is taken place	Literature	Operation

Optical Fiber Monitoring	In-use Duration (day)	Integer	The days that road is in-use (the duration between opening the road to traffic and the time survey is taking place)	Literature	Operation
Optical Fiber Monitoring	Start Point Location	String	The GPS location of starting point of the measurement	Literature	Operation
Optical Fiber Monitoring	End Point Location	String	The GPS location of ending point of the measurement	Literature	Operation
Optical Fiber Monitoring	Objective	String	The objective that the monitoring starts for	Literature	Operation
Optical Fiber Monitoring	Method	String	The description of the method used for the monitoring	Literature	Operation
Optical Fiber Monitoring	Standard	String	The standard used for the monitoring	Literature	Operation
Optical Fiber Monitoring	Comments	String	Remarks associated with the monitoring	Literature	Operation
Strain Gage Monitoring	ID	String	Unique identifier (code) for the monitoring	Literature	Operation
Strain Gage Monitoring	Type	String	The type of strain gage used for measurement	Literature	Operation
Strain Gage Monitoring	Start Time	String	The time that monitoring is started	Literature	Operation
Strain Gage Monitoring	End Time	String	The time that monitoring is ended	Literature	Operation
Strain Gage Monitoring	Date	String	The date that the monitoring is taken place	Literature	Operation
Strain Gage Monitoring	In-use Duration (day)	Integer	The days that road is in-use (the duration between opening the road to traffic and the time survey is taking place)	Literature	Operation
Strain Gage Monitoring	Start Point Location	String	The GPS location of starting point of the measurement	Literature	Operation
Strain Gage Monitoring	End Point Location	String	The GPS location of ending point of the measurement	Literature	Operation
Strain Gage Monitoring	Objective	String	The objective that the monitoring starts for	Literature	Operation
Strain Gage Monitoring	Method	String	The description of the method used for the monitoring	Literature	Operation

Strain Gage Monitoring	Standard	String	The standard used for the monitoring	Literature	Operation
Strain Gage Monitoring	Comments	String	Remarks associated with the monitoring	Literature	Operation
Wireless Monitoring	ID	String	Unique identifier (code) for the monitoring	Literature	Operation
Wireless Monitoring	Start Time	String	The time that monitoring is started	Literature	Operation
Wireless Monitoring	End Time	String	The time that monitoring is ended	Literature	Operation
Wireless Monitoring	Date	String	The date that the monitoring is taken place	Literature	Operation
Wireless Monitoring	In-use Duration (day)	Integer	The days that road is in-use (the duration between opening the road to traffic and the time survey is taking place)	Literature	Operation
Wireless Monitoring	Start Point Location	String	The GPS location of starting point of the measurement	Literature	Operation
Wireless Monitoring	End Point Location	String	The GPS location of ending point of the measurement	Literature	Operation
Wireless Monitoring	Objective	String	The objective that the monitoring starts for	Literature	Operation
Wireless Monitoring	Method	String	The description of the method used for the monitoring	Literature	Operation
Wireless Monitoring	Standard	String	The standard used for the monitoring	Literature	Operation
Wireless Monitoring	Comments	String	Remarks associated with the monitoring	Literature	Operation
Automated Road Survey	ID	String	Unique identifier (code) for the survey	Literature	Operation
Automated Road Survey	Type	String	The type of the vehicle used for the survey	Literature	Operation
Automated Road Survey	Ave Vehicle Speed (km/h)	Double	The average speed of vehicle used for the measurement	Literature	Operation

Automated Road Survey	Start Time	String	The time that survey is started	Literature	Operation
Automated Road Survey	End Time	String	The time that survey is ended	Literature	Operation
Automated Road Survey	Date	String	The date that the survey is taken place	Literature	Operation
Automated Road Survey	In-use Duration (day)	Integer	The days that road is in-use (the duration between opening the road to traffic and the time survey is taking place)	Literature	Operation
Automated Road Survey	Start Point Location	String	The GPS location of starting point	Literature	Operation
Automated Road Survey	End Point Location	String	The GPS location of ending point	Literature	Operation
Automated Road Survey	Objective	String	The objective that the survey starts for	Literature	Operation
Automated Road Survey	Method	String	The description of the method used for the survey	Literature	Operation
Automated Road Survey	Standard	String	The standard used for the survey	Literature	Operation
Automated Road Survey	Comments	String	Remarks associated with the surve	Literature	Operation
Manual Road Survey	ID	String	Unique identifier (code) for the survey	Literature	Operation
Manual Road Survey	Name	String	The name of the inspector	Literature	Operation
Manual Road Survey	Experience (year)	Integer	The experience of the inspector in years	Literature	Operation
Manual Road Survey	Start Time	String	The time that survey is started	Literature	Operation
Manual Road Survey	End Time	String	The time that survey is ended	Literature	Operation
Manual Road Survey	Date	String	The date that the survey is taken place	Literature	Operation
Manual Road Survey	In-use Duration (day)	Integer	The days that road is in-use (the duration between opening the road to traffic and the time survey is taking place)	Literature	Operation

Manual Road Survey	Start Point Location	String	The GPS location of starting point	Literature	Operation
Manual Road Survey	End Point Location	String	The GPS location of ending point	Literature	Operation
Manual Road Survey	Objective	String	The objective that the survey starts for	Literature	Operation
Manual Road Survey	Method	String	The description of the method used for the survey	Literature	Operation
Manual Road Survey	Standard	String	The standard used for the survey	Literature	Operation
Manual Road Survey	Comments	String	Remarks associated with the surve	Literature	Operation
Fire Measurement	ID	String	Unique identifier (code) for the incident	Literature	Operation
Fire Measurement	Time	String	The time that the incident happens	Literature	Operation
Fire Measurement	Duration (hr)	Double	The duration that the incident takes	Literature	Operation
Fire Measurement	Date	String	The date that the incident happens	Literature	Operation
Fire Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (centroid)	Literature	Operation
Fire Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (centroid)	Literature	Operation
Fire Measurement	Altitude	Double	Vertical direction between a reference datum and a point (centroid)	Literature	Operation
Fire Measurement	Description	String	The description of the incident collected by inspector	Literature	Operation
Fire Measurement	Comments	String	Remarks associated with the incident	Literature	Operation
Flat Tire Measurement	ID	String	Unique identifier (code) for the incident	Literature	Operation

Flat Tire Measurement	Time	String	The time that the incident happens	Literature	Operation
Flat Tire Measurement	Duration (hr)	Double	The duration that the incident takes	Literature	Operation
Flat Tire Measurement	Date	String	The date that the incident happens	Literature	Operation
Flat Tire Measurement	Start Point Location	String	The GPS location of starting point	Literature	Operation
Flat Tire Measurement	End Point Location	String	The GPS location of ending point	Literature	Operation
Flat Tire Measurement	Description	String	The description of the incident collected by inspector	Literature	Operation
Flat Tire Measurement	Comments	String	Remarks associated with the incident	Literature	Operation
Carcass Measurement	ID	String	Unique identifier (code) for the incident	Literature	Operation
Carcass Measurement	Time	String	The time that the incident happens	Literature	Operation
Carcass Measurement	Duration (hr)	Double	The duration that the incident takes (stays on the surface)	Literature	Operation
Carcass Measurement	Date	String	The date that the incident happens	Literature	Operation
Carcass Measurement	Type	String	The type of animal	Literature	Operation
Carcass Measurement	Area (cm2)	Double	The area of the surface that the animal's body covers	Literature	Operation
Carcass Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (centroid)	Literature	Operation
Carcass Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (centroid)	Literature	Operation
Carcass Measurement	Altitude	Double	Vertical direction between a reference datum and a point (centroid)	Literature	Operation
Carcass Measurement	Description	String	The description of the incident collected by inspector	Literature	Operation

Carcass Measurement	Comments	String	Remarks associated with the incident	Literature	Operation
Extreme Weather Measurement	ID	String	Unique identifier (code) for the incident	Literature	Operation
Extreme Weather Measurement	Time	String	The time that the incident happens	Literature	Operation
Extreme Weather Measurement	Duration (hr)	Double	The duration that the incident takes	Literature	Operation
Extreme Weather Measurement	Date	String	The date that the incident happens	Literature	Operation
Extreme Weather Measurement	Type	String	The type of extreme weather such as cold waves, storms, etc	Literature	Operation
Extreme Weather Measurement	Start Point Location	String	The GPS location of starting point	Literature	Operation
Extreme Weather Measurement	End Point Location	String	The GPS location of ending point	Literature	Operation
Extreme Weather Measurement	Description	String	The description of the incident collected by inspector	Literature	Operation
Extreme Weather Measurement	Comments	String	Remarks associated with the incident	Literature	Operation
Pollution Measurement	ID	String	Unique identifier (code) for the incident	Literature	Operation
Pollution Measurement	Time	String	The time that the incident happens	Literature	Operation

Pollution Measurement	Duration (hr)	Double	The duration that the incident takes (stays on the surface)	Literature	Operation
Pollution Measurement	Date	String	The date that the incident happens	Literature	Operation
Pollution Measurement	Type	String	The type of pollution	Literature	Operation
Pollution Measurement	Area (cm2)	Double	The area of the surface that the pollution covers	Literature	Operation
Pollution Measurement	Latitude	Double	Geographic coordinate that determines the north-south position of a point on the Earth's surface (centroid)	Literature	Operation
Pollution Measurement	Longitude	Double	Geographic coordinate that determines the east-west position of a point on the Earth's surface (centroid)	Literature	Operation
Pollution Measurement	Altitude	Double	Vertical direction between a reference datum and a point (centroid)	Literature	Operation
Pollution Measurement	Description	String	The description of the incident collected by inspector	Literature	Operation
Pollution Measurement	Comments	String	Remarks associated with the incident	Literature	Operation
Traffic Volume Measurement	ID	String	Unique identifier (code) for the measurement	Literature	Operation
Traffic Volume Measurement	Time	String	The time that the measurement happens	Literature	Operation
Traffic Volume Measurement	Duration (hr)	Double	The duration that the measurement takes	Literature	Operation
Traffic Volume Measurement	Date	String	The date that the measurement happens	Literature	Operation
Traffic Volume Measurement	Number of Vehicle	Integer	The total number of vehicles passes the measurement point	Literature	Operation
Traffic Volume Measurement	Number of Truck	Integer	The total number of trucks passes the measurement point	Literature	Operation
Traffic Volume Measurement	AADT	Integer	Average Annual Daily Traffic	Literature	Operation
Traffic Volume Measurement	Latitude	Double	Geographic coordinate for the measurement point that determines the north-south position of a point on the Earth's surface (centroid)	Literature	Operation

Traffic Volume Measurement	Longitude	Double	Geographic coordinate the measurement point that determines the east-west position of a point on the Earth's surface (centroid)	Literature	Operation
Traffic Volume Measurement	Altitude	Double	Vertical direction the measurement point between a reference datum and a point (centroid)	Literature	Operation
Traffic Volume Measurement	Description	String	The description of the incident collected by inspector	Literature	Operation
Traffic Volume Measurement	Comments	String	Remarks associated with the measurement	Literature	Operation