Exposure Database V7

Data Documentation
Technical Report and
Exposure Model

ARUP,

Helen Crowley, Jeroen Uilenreef and Roy Scheefhals

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General Introduction

To be able to assess the risk for the buildings and community in Groningen resulting from induced earthquakes knowledge of full occupied build stock in the region of the Groningen field is required. For this purpose, an exposure database was built. An earlier version of this database (V2) (Ref. 1) was used for the Hazard and Risk Assessment of November 2015 and Hazard and Risk Assessment for Winningsplan 2016. Since then the exposure database has been updated regular. Early 2017, the update of the V3 update of the databased was issued (Ref. 2) followed early 2018 by the V5 update of the databased (Ref. 3). In 2018, data from the municipality archives was used to further improve the exposure database (Ref. 4 and 5). These were incorporated in the V6 update of the database, which became available in July 2019 (Ref. 6).

The documentation of the V7 update of the exposure database consists of three sections:

Data Documentation: For each dataset, a description is provided, along with the contents, processing requirements and the limitations. The datasets used for the EDB are categorised as follows:

- Source data Datasets which have been received and maintained by external sources such as government departments.
- Project data Datasets which have been produced within the project such as inspection datasets and desktop studies. This includes project information produced by Arup and external consultants.
- Processed data Datasets which Arup has created utilising source datasets, assumptions and analysis to provide information that is not available from external sources.

Technical Report: This report describes the process of populating the Exposure Database with attributes for all buildings in the Groningen region. Special attention is given to Structural System Classification in particular for farm buildings (both dwelling and barns).

Technical Note: A separate report contains the description of post-processing of the Exposure Database to produce the Exposure Model.

Assurance of the Exposure Model was performed by the assurance panel during a workshop February 2018 (Ref. 7). The assurance panel made a check on the follow-up of their recommendations late 2019 (Ref. 8).

References

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NAM

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Organisation	ARUP	Organisation	NAM
Place in the Study and Data Acquisition Plan	Study Theme: Exposure Database Comment: To be able to assess the risk for the buildings and community in Groningen resulting from induced earthquakes knowledge of full occupied build stock in the region of the Groningen field is required. For this purpose, an exposure database was built. An earlier version of this database (V2) was used for the Hazard and Risk Assessment of November 2015 and Hazard and Risk Assessment for Winningsplan 2016. Since then the exposure database has been updated regular. Early 2017, the update of the V3 update of the databased was issued followed early 2018 by the V5 update of the databased (Ref. 3). In 2018, data from the municipality archives was used to further improve the exposure database. These were incorporated in the V6 update of the database, which became available in July 2019. The documentation of the V7 update of the exposure database consists of three sections: Data Documentation: For each dataset, a description is provided, along with the contents, processing requirements and the limitations. The datasets used for the EDB are categorised as follows: ▪ Source data Datasets which have been received and maintained by external sources such as government departments. ▪ Project data Datasets which have been produced within the project such as inspection datasets and desktop studies. This includes project information produced by Arup and external consultants. ▪ Processed data Datasets which Arup has created utilising source datasets, assumptions and analysis to provide information that is not available from external sources. Technical Report: This report describes the process of populating the Exposure Database with attributes for all buildings in the Groningen region. Special attention is given to Structural System Classification in particular for farm buildings (both dwelling and barns). Technical Note: A separate report contains the description of post-processing of the Exposure Database to produce the Exposure Model.		

	Assurance of the Exposure Model was performed by the assurance panel during a workshop February 2018. The assurance panel made a check on the follow-up of their recommendations late 2019.
Directliy linked research	(1) Risk Assessment (2) Modelling of the response of Building to earthquakes (3) Experiments of building fragility
Used data	Large number of public databases, building information with municipality and direct observation from street level.
Associated organisation	ARUP
Assurance	By dedicated assurance pnael fro fragility consequence and exposure model.

Client: Nederlandse Aardolie Maatschappij

Arup Project Title: Groningen Earthquake - Structural Upgrading

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Arup bv
Naritaweg 118
1043 CA Amsterdam
PO box 57145
1040 BA Amsterdam
The Netherlands

ARUP

Contents

Acronyms

A list of acronyms (abbreviations) used in the document can be found in Table 1.

Table 1: List of acronyms used in the report.

Acroymn	**Description**
AHN	*Actueel Hoogtebestand Nederland*
ASCE	American Society of Civil Engineers
BAG	*Basisregistratie Adressen en Gebouwen* Key registry of Addresses and buildings
BRIN	*Basisregister Instellingen* Key registry of Educational Institutions
CBS	*Centraal Bureau voor de Statistiek* Center of Statistics Netherlands
CVW	*Centrum Veilig Wonen*
DUO	*Dienst Uitvoering Onderwijs* Department of Education
EDB	Exposure Database
EVS	Extended Visual Screening
GEM	Global Earthquake Model
GIS	Geographic Information System
HRBE	High Risk Building Elements
JBG	*Jorritsma Bouw Groningen*
MER	Maximum Enclosed Rectangle
NAM	*Nederlands Aardolie Maatschappij*
PDBC	Project Data Building Characterisation
RVS	Rapid Visual Screening
TA	Ticinum Aerospace

Definition

Building: The building is the unit at which the Exposure Database V7 is analysed. A building in EDB V7 is the equivalent of the object type *pand* in the *Basisregistratie Adressen en Gebouwen* (BAG) [19]. According to BAG, a *pand* is the smallest functional and structural independent unit that is directly and permanently connected to the earth which can be accessed and locked [27]. Note that a *pand* in BAG corresponds to one unit in a terraced row of houses and to a full apartment block within modern construction. Examples of *panden*, each with a unique id as assigned by BAG, can be found in Figure 1.

Further information on BAG including *pand* and other object types can be found in Section 2.1.1.

Figure 1: Examples of *panden* as identified by BAG which represent a building in EDB V7.

1 Introduction

The Exposure Database (EDB) V7 delivered in December 2019 [7] is accompanied by a reporting suite which includes:

- Exposure Database V7 Technical Report [8]

  Describes the contents of the EDB V7 and the building classification methodology.

- Exposure Database V7 Data Documentation (this document).

This document provides information on the datasets used to create the EDB V7. For each dataset, a description is provided, along with the contents, processing requirements and the limitations.

The datasets used for the EDB are categorized as below:

- **Source data**

  External datasets maintained by external parties such as government departments.

- **Project data**

  Datasets that have been produced within the project such as inspection datasets and desktop studies produced by Arup and other consultants.

- **Processed data**

  Datasets which Arup has generated utilizing source datasets, project specific assumptions and analysis to provide information that is not directly available from external sources.

All the datasets described in this document are subject to the EDB V7 study area [8].

2 Data overview

In this section the datasets are briefly described to give a general overview on their content and how they have been used in the EDB V7 [8].

2.1 Source Datasets

2.1.1 BAG

The *Basisregistratie Adressen en Gebouwen* (BAG) or Base Registration Addresses and buildings datasets, produced by Kadaster [19], provides data on registered addresses and buildings including building year and status. The BAG register provides the unique identifiers for buildings and addresses used in the EDB and by other data providers.

The BAG datasets used for the EDB V7 were updated by Arup using Kadaster's available data on August 2019 and filtered to contain only existing buildings within the study area.

Further detail can be found in Section 3.1.

2.1.2 DataLand

DataLand provides real estate information based on addresses [13]. The DataLand dataset is used to provide insight into building use, population and to flag specific architectural building types (i.e. barn with house and drive-in terraced houses). The DataLand dataset used for EDB V7 was provided by NAM in September 2018.

Further detail can be found in Section 3.2.

2.1.3 AHN

The Actueel Hoogtebestand Nederland [1] contains detailed height information at 0.5m resolution for the Netherlands, obtained by using laser altimetry.

The latest data for the study area (AHN2) was released in 2009. Accordingly, there is no AHN data available for buildings built post-2009. The dataset remains the same from previous versions of the EDB and it is used, along with other datasets, to calculate Average Gutter Height (Section 5.5) of the buildings.

Further detail can be found in Section 3.3.

2.1.4 DUO Basisregister Instellingen

The *Dienst Uitvoering Onderwijs* (DUO) or the Office of Education manages the Basisregister Instellingen [14], which is the register of educational institutions in the Netherlands. This dataset is used to identify primary schools, high schools, special educational schools, vocational schools, colleges and university buildings. The School Registry used for EDB V7 was downloaded by Arup on January 2019.

The dataset was used as input into the population analysis as described in Section 5.8.

Further detail can be found in Section 3.4.

2.1.5 Ticinum Aerospace (TA)

Ticinum Aerospace (TA) [30] provided a dataset containing opening percentage and storey count of buildings through the automated processing of street view imagery. The data was used as input into the building classification process and was received on September 2019 through NAM's subconsultants [31].

Further detail can be found in Section 3.5.

2.1.6 Strengthened List

The *Strengthened List* is a list of buildings which have been strengthen by *Centrum Veilig Wonen* (CVW). The list which was used for EDB V7 was provided by CVW via NAM on January 2019 [21] .

Further detail can be found in Section 3.6.

2.1.7 Nieuwbouwregeling List

The *Nieuwbouwregeling List* [23] is a list of newly built buildings which have received funding through NAM for additional construction cost deriving from dedicated seismic design. The list used for EDB V7 was provided by NAM on October 2019 [23].

Further detail can be found in Section 3.7.

2.1.8 CBS Wijken en Buurten

The *Centraal Bureau voor de Statistiek* (CBS) *Wijken en Buurten* dataset provides statistical information on municipality, district and neighbourhood [11]. For EDB V7, the boundaries of the municipalities, district and neighbourhood were acquired and used on January 2019. The dataset was used as input into the population and community analysis as described in Section 5.8 and Section 5.9.

Further detail can be found in Section 3.8.

2.1.9 Landelijk Register Kinderopvang

The *Landelijk Register Kinderopvang* or the National Childcare Register provides information on childcare facilities by the Rijksoverheid [29]. It includes information on the childcare facilities including number of child places. The *Landelijk Register Kinderopvang* dataset used for EDB V7 was last updated on January 2019. The dataset was used as input into the population analysis as described in Section 5.8.

Further detail can be found in Section 3.9.

2.2 Project Datasets

2.2.1 RVS

The *Rapid Visual Screening* (RVS) was a preliminary building assessment process adapted from existing international guidelines (FEMA) [4][15]. It collected building information from the public realm (without entering the property boundaries). The RVS focused on providing a safety assessment for inhabitants, identify external High Risk Building Elements (HRBE) and provided input for future assessment activities as an initial step of a tiered seismic assessment approach. The RVS dataset was used as input into the Project Data Building Characterisation (PDBC) analysis.

RVS inspections carried out by Arup (up to November 2015) were included in EDB V7. Further detail can be found in Section 4.1.

2.2.2 EVS

The *Extended Visual Screening* (EVS) is a structural assessment based on a visual inspection of the building's interior and exterior [5]. The EVS focuses on identifying potential falling hazards, existing structural damage, existing deformations and overall building configuration related metrics. The EVS inspections included the collection and recording of structural information and construction details where visible. The EVS dataset was used as input into the PDBC analysis.

For EDB V7, EVS inspections carried out by Arup (up to November 2015) were included. Further detail can be found in Section 4.2.

2.2.3 Drawing Data

The archive *Drawing Data* provides information about the construction and internal features of selected buildings obtained by reviewing existing architectural and construction drawings, where available [3]. The drawings of selected buildings were obtained from the relevant municipalities and construction information was then collected from them in a structured format by Arup. The Drawing Data dataset was used as input into the PDBC analysis.

Further detail can be found in Section 4.3.

2.2.4 Data Collection

The *Data Collection* set provides information about construction and internal features of selected buildings from the H&R model as provided by NAM [25], focusing on parameters relevant to assessing seismic risk at regional scale. Like the *Drawing Data* (Section 2.2.3), drawings of selected buildings were obtained from municipalities and construction information was then collected from them in a structured format by Arup. The Data Collection dataset was used as input into the PDBC analysis.

Further detail can be found in Section 4.4.

2.2.5 Desktop Visual Inspections

The *Desktop Visual Inspections* undertaken by *Jorritsma Bouw Groningen* (JBG) [10], is a desk study, designed to collect building information using Google Streetview [17] and additional building pictures produced by the company Horus. These visual inspections were delivered on July 2017 and covered most of the habitable buildings within the core of the study area [26]. Buildings covered by the *Drawing Data* (Section 2.2.3) were not included in this desk study.

Further detail can be found in Section 4.5.

2.3 Processed Datasets

2.3.1 Project Data Building Characterisation

The *Project Data Building Characterisation* (PDBC) provides the material and lateral support system in the convention used for EDB V7, assigned through project datasets listed in Section 4. The dataset is used as an input into the building classification process.

Further detail can be found in Section 5.1.

2.3.2 Building use

The *Building Use* dataset provides the main and secondary use (where relevant) of a building and a flag to identify residential building usage. A building's main use is included as a direct data field in the EDB extract and as an input parameter for the building classification process [8].

Further detail can be found in Section 5.2.

2.3.3 Adjacency

The *Adjacency* dataset provides insight into the spatial relation between buildings; i.e. whether a building is touching another building. The dataset provides a set of parameters which are input for the building classification − mainly to help determine freestanding and terraced units.

Further detail can be found in Section 5.3.

2.3.4 Exposed Footprint Length

The *Exposed Footprint Length* captures the length of the building's footprint which are exterior facing (i.e. not including walls between buildings). The exposed footprint length is used as an input into the building classification.

Further detail can be found in Section 5.4.

2.3.5 Average Gutter Height

The *Average Gutter Height* is the average height of the building's walls excluding sloped roof planes (i.e. where the gutter would be located). As buildings may have several different gutter heights, the average weighted by the length of the perimeter wall is used. The *Average Gutter Height* is an input into the building classification process.

Further detail can be found in Section 5.5.

2.3.6 Gutter Height Proxy

The *Gutter Height Proxy* provides an estimation of the gutter height. It is based on the total amount of useable area divided by the building footprint and an estimated floor to ceiling height. The *Gutter Height Proxy* is used as an input into the building classification where alternative height information is unavailable.

Further detail can be found in Section 5.6.

2.3.7 Maximum Enclosed Rectangle

The *Maximum Enclosed Rectangle* (MER) captures the dimensions of the largest rectangle which can fit within a building footprint. The rectangle and its dimensions provide information about the building footprint and is used as an input into the building classification process.

Further detail can be found in Section 5.7.

2.3.8 Population

The *Population* dataset contains information on estimated population per building. The dataset provides a breakdown of the number of people inside, directly outside and runners passing by buildings during the day and night. The methodology and several updated datasets were provided by NAM [24]. Arup used the provided methodology and updated the data inputs to calculate the population dataset for EDB V7.

The *Population* dataset is a direct input into the EDB V7 extract.

Further detail can be found in Section 5.8.

2.3.9 Community

The Community dataset assigns buildings to seven communities as defined by the client where relevant. The Community dataset is a direct input into the EDB V7 extract.

Further detail can be found in Section 5.9.

3 Source Data

3.1 BAG

The '*Basisregistratie Adressen en Gebouwen'* (BAG) or Base Registration Addresses and buildings datasets, produced by Kadaster [19], provides information on registered addresses and buildings. The BAG datasets are the key source datasets used to relate other datasets to a building level alongside providing a basis for various analyses and the EDB V7 extract.

The BAG data is delivered in the form of several relational data tables which correspond to how BAG records and structures the buildings and addresses register [19]. These datasets and their descriptions can be found below:

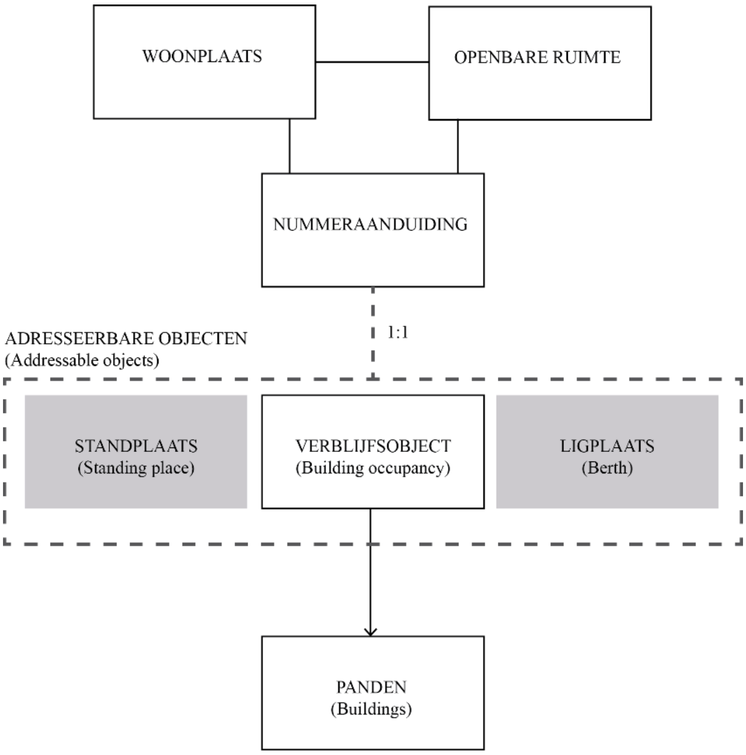
***Openbare ruimte, nummeraanduiding and woonplaats* (Address)**
The combination of *openbare ruimte*, *woonplaats* and *nummeraanduiding* forms the address and describes the geographic location through the street name, house number, letter, postal code and town. Addresses can only be assigned to an *addresseerbaar object* (i.e. addressable object) of either a *standplaats, verblijfsobject* or *ligplaats* (described below). Each address has a unique ID from the *nummeraanduiding* (nummer_id) and is geometrically described as a point feature.

***Verblijfsobjecten* (Use)**
The *verblijfsobject* or VBO is the smallest unit of function (use) within one or more building objects. The VBO can be accessed, has a lockable entrance from a public road, yard or shared space, is subject to property law and is functionally independent from other VBOs. Each VBO has a unique ID (vbo_id). It is an addressable object and each VBO has a one-to-one relationship with an address ID. Note that no VBO can exist without a relationship to a building. VBO is geometrically described as a point.

***Standplaats and ligplaats* (Standing and Berth)**
Standplaats and *ligplaats* are the smallest unit of function (use) related to a 'standing place' (i.e. registered caravan point) or 'berth' (i.e. registered boat house berth). In both cases, the objects at a standing place and berth are not permanently connected to the ground (i.e. movable) and are considered not relevant to the scope of the project.

***Panden* (Buildings)**
The *pand* is the smallest unit that is directly and permanently connected to the ground, able to be entered, lockable and structurally independent. Each building has a unique id (pand_id). The *pand* is equivalent to a 'building' for the purposes of the EDB and for ease, *panden* or *pand* will be referred to as buildings or building respectively. As noted above, buildings are related to VBOs and accordingly, addresses. Note that while a VBO cannot exist without a relationship to a building, a building may have no relationship to a VBO and address. buildings are geometrically described as a polygon on plan view.

Figure 2 shows the relationship between the datasets.



VBO and Address have a 1:1 relationship
VBO / Address cannot exist without a building but a building can exist without a VBO / Address.
A building may also have multiple VBO / Address

Figure 2 Schematic overview of relationships within the BAG.

The relationships can also be explained through an example. One building may contain several VBOs and thus several addresses, as in a case of an apartment block. A building may also contain no VBO and thus no address, as in the case of a shed behind a house or farm.

For the EDB V7 the BAG datasets from August 2019 were used.

3.1.1 Data Schema

The BAG information was processed to contain clear and traceable relationships between the three pieces of relevant BAG information: address (*nummer*), VBO and buildings.

The output schema of the three datasets are given in Table 2 to Table 4.

Table 2 BAG address (*nummer*) schema.

Address / Nummer		
Field Name	**Type**	**Description**
nummer_id	Text	Unique identification code assigned per address by BAG
straatnaam	Text	Street name
huisnummer	Integer	House number
huisletter	Text	House letter
toevoeging	Text	Extra house numbers or letters
woonplaats	Text	City
postcode	Text	Postcode
type	Text	Type of *addresseerbaar object* (i.e. addressable object)
vbo_id	Text	Unique VBO identification code related to the address
pand_id	Text	Unique *pand* identification code related to the address

Table 3 BAG VBO schema

VBO		
Field Name	**Type**	**Description**
vbo_id	Text	Unique identification code assigned per VBO by BAG
pand_id	Text	Unique *pand* identification code related to the VBO
gebruiksdoel	Text	Function/s (use)
oppervlak	Double	Usable floor area

Table 4 BAG pand (building) schema

Pand (building)		
Field Name	**Type**	**Description**
pand_id	Text (50)	Unique identification code assigned per building by BAG
bouwjaar	Text (30)	building construction year

3.1.2 Processing

The BAG information requires some processing to only contain the relevant buildings required for the study. This includes filtering historic or inactive records, non-building objects (i.e. standing place and berth) and clipping to the required study area.

To process the BAG dataset prior to use for EDB, the following main steps were taken:

1. Filter out the inactive / historic records from all datasets
2. Filter out the objects outside of the project scope (i.e. standing place and berth)

3. Clip the three datasets to the study area scope.
4. Confirm the relationships of the three datasets (addresses, VBO and buildings).

3.1.3 Data Coverage

The study area of the exposure database includes 251,479 active addresses and 263,399 buildings as per the BAG. Of these buildings, 166,100 buildings have addresses (with 16,372 buildings such as apartments blocks, containing multiple addresses) leaving a total of 97,299 buildings with no address. These buildings are usually sheds, barns or other secondary buildings related to a building with an address.

3.1.4 Data Limitations

The BAG dataset is a continuously evolving dataset that is updated as buildings are demolished and built. While it is used as the reference for the existence of buildings and their building outline (as it is the best data available that is governed by the Dutch land registry, Kadaster), it may not have full coverage. This is evident when looking at the results of the updates between the two BAG versions and the addition of several buildings which are not new builds but were missing previously.

Some additional limitations have been observed:

- Small drawing errors have been identified in the BAG data: e.g. minor gaps between BAG buildings, when the buildings are adjacent structures, or odd geometry has been defined (see Figure 3) Similarly, small overlaps of BAG buildings do exist in the data, where there should not be any overlap.
- There are some polygons observed that represent underground parking garages.
- It is observed, when a building might be renovated or extended, that the building year gets updated inconsistently throughout the catalogue.
- Within the V7 scope there are 6,107 buildings, that have overlapping geometries, 137 of which do not have active status (i.e. “Pand in gebruik”)

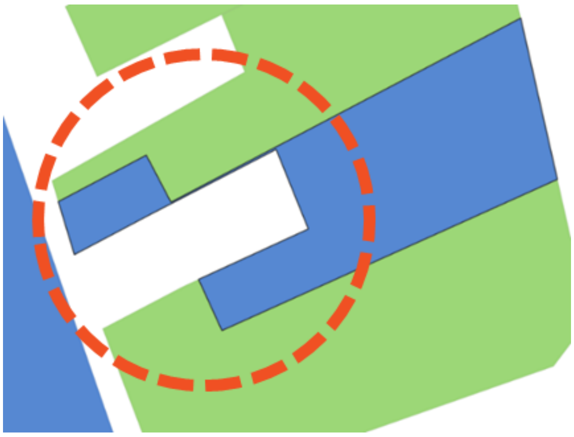


Figure 3 An example of an invalid geometry in BAG

3.2 DataLand

DataLand provides real estate information based on addresses [13]. DataLand is the precursor of the various governmental *basisregistraties (key registries)* set up in 2009, including BAG. Therefore, DataLand includes similar data and classifications as is in the BAG dataset but with additional building information such as architectural type, which is not found in BAG. The relation between DataLand and the governmental *basisregistraties* can be seen in Figure 4.

The DataLand dataset is used to provide insight into building use, population and to flag specific architectural building types (i.e. barn with house and drive-in terraced houses). The DataLand dataset used for EDB V7 was provided by NAM in September 2018.

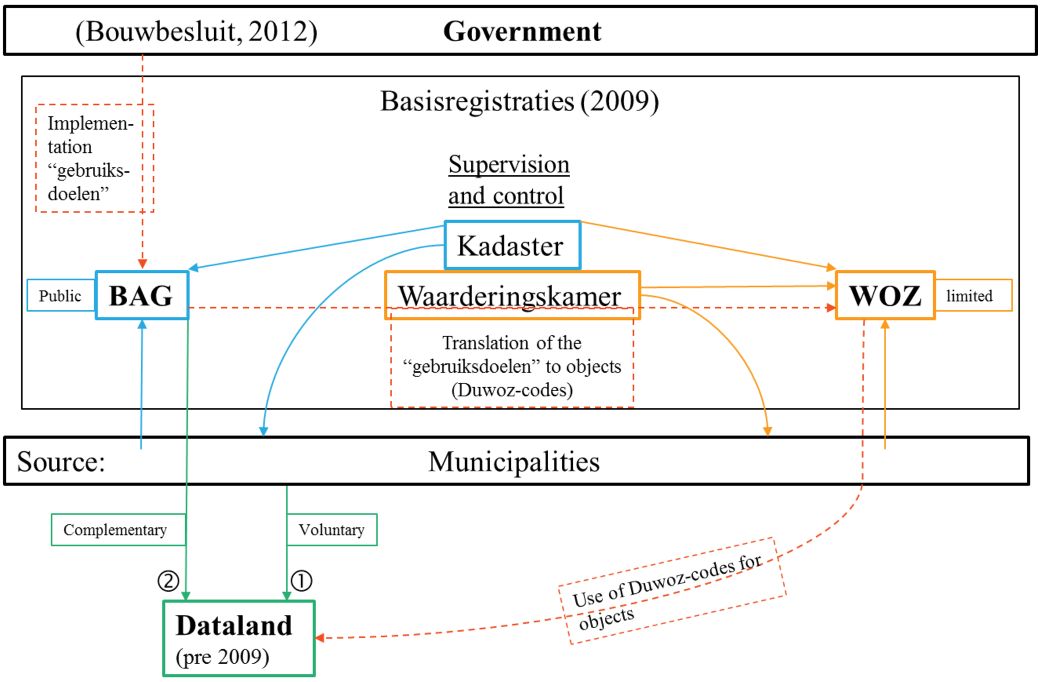


Figure 4 Relation between BAG and DataLand (Source: Arup)

3.2.1 Data Schema

The schema of the DataLand dataset used in the EDB V7 data after processing is shown in Table 5.

Table 5 DataLand schema

Field Name	Type	Description
nummer id	Text	Unique identification code assigned per address by BAG
bouwkundige bestemming actueel	Numeric	Architectural type code
bouwkundige bestemming omschrijving	Text	Architectural type description
gebruiksklasse	Numeric	Use class code
gebruiksklasse omschrijving	Text	Use class description

3.2.2 Processing

The DataLand data requires processing to contain only the data that is relevant to the project, remove duplicate records and fields described by the provider as limited and/or unreliable. The key steps taken are described below:

1. Filter out fields that are not required for the project.
2. Establish relationship with BAG's addresses used in the project via DataLand's provided *identificatie nummeraanduiding* (nummer_id). This removed any address ids in DataLand which were not relevant to the project.
3. To remove duplicate addresses (nummer_id) in the dataset, only the record with the most data was retained.

3.2.3 Data Coverage

Table 6 displays the coverage of DataLand against the buildings (panden) and addresses within the scope area through BAG.

Table 6 Coverage of DataLand against the building and addresses within the project scope area.

	Scope Area	DataLand Coverage		Missing DataLand	
	Count	Count	%	Count	%
buildings	263,399	165,320	62.6%	98,079	37.4%
buildings with addresses	166,100	165,320	99.5%	780	0.5%
addresses	251,479	248,898	99.0%	2581	1.0%

3.2.4 Data Limitations

DataLand only provides information on buildings with an address so that buildings without an address do not have corresponding DataLand information. The coverage of the dataset is described above.

Where a building has DataLand information, it was found that not all fields of the dataset were complete. This includes missing values for the 'architectural type', which is used to identify flags for specific building types and population.

3.3 AHN

The *Actueel Hoogtebestand Nederland* (AHN) [1] provides detailed height models for the Netherlands obtained through laser altimetry. Arup uses two height models in raster format:

- The terrain model which describes the height of the terrain excluding any object on the terrain; and
- The complete height model which includes all objects such as buildings, vegetation, cars, etc.

The latest data for the study area (AHN2) was released in 2009 and is provided at 0.5m x 0.5m resolution. Accordingly, there is no AHN data available for buildings built post-2009. The dataset remains the same from previous versions of the EDB and it is used to calculate building heights.

3.3.1 Processing

The two height models were processed to provide point data with a height value for buildings. The key steps are as follows:

1. Interpolation of the terrain model to fill gaps (i.e. where aboveground objects were removed)
2. Clipping of the interpolated terrain model to building outlines to calculate an estimated base height of the building based on the mean of the terrain height value.
3. Applying a vegetation filter on the complete height model to remove building height discrepancies from overhanging trees. See Figure 5 and Figure 6 for example of overhanging trees and results from the vegetation filter.
4. Clipping of the filtered height model to building outlines.
5. Calculation of the relative height of the building between the interpolated terrain model and filtered height model.
6. Conversion of the resulting raster to points and spatial join to the building outline to assign points to a building id (pand_id).

Figure 5 Example of overhanging trees potentially creating noise in the height data.

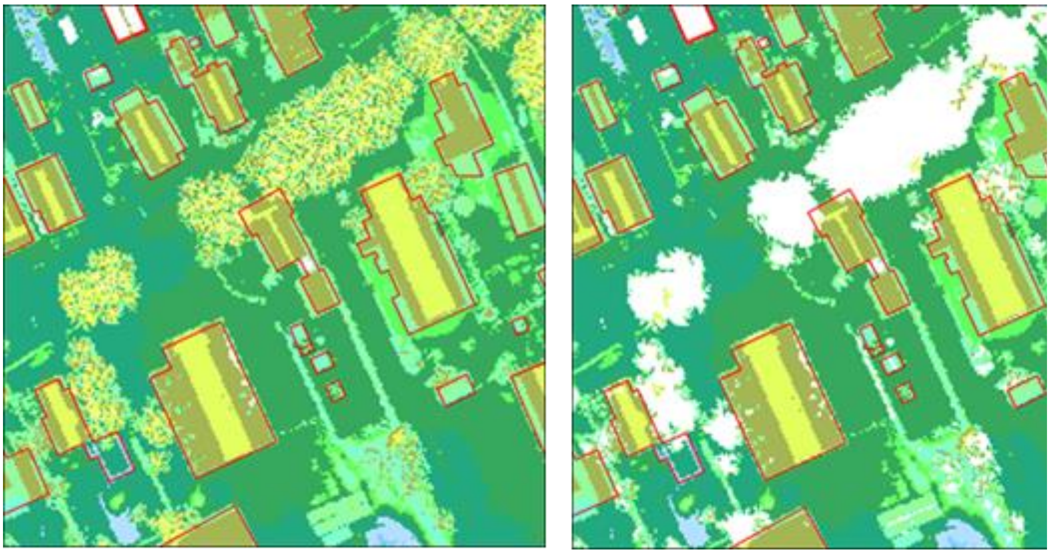


Figure 6 building outlines overlaying height data before (left) and after (right) vegetation filtering. Note: in this example the raster data is not clipped to the building outline.

3.3.2 Data Coverage

There are 27,976 buildings within the scope area which do not have AHN data available. This includes 24,926 buildings, which are built in and post 2009.

There are 28,060 buildings missing height data, built post January 2009 or obstructed by vegetation.

3.3.3 Data Limitations

As mentioned above, the AHN used does not have data for buildings built after 2009 and the vegetation filtering has removed height data for a selection of buildings which have large overhanging trees. AHN has been updated as of Q1 2020, therefore it was not incorporated in EDB V7.

3.4 DUO Basisregister Instellingen

The *Dienst Uitvoering Onderwijs* (DUO) or the Office of Education manages the *Basisregister Instellingen* [14], which is the register of educational institutions in the Netherlands. The register provides educational institutions with identification number (BRIN) and contains information on type of education and student and staff numbers.

This dataset is used to identify primary schools, high schools, special educational schools, vocational schools, colleges and university buildings and their related data as an input into the population analysis.

The *Basisregister Instellingen* used for EDB V7 was last updated in January 2019. The dataset was used as input into the population analysis described in Section 5.8.

3.4.1 Data Schema

Basisregister Instellingen (BRIN) provides data per type of educational institution nationally. The data was processed to consolidate BRIN numbers with relevant addresses and buildings within the scope area. The resulting schema is shown in Table 7 to Table 9.

Table 7 Primary education (*basisonderwijs*) and special primary education (*speciaal basisonderwijs*) schema

Primary and Special Primary Education		
Field Name	**Type**	**Description**
nummer_id	Text	Unique identification code assigned per address by BAG
school_type	Text	Type of the educational institution
school_name	Text	The name of the institution
school_reference	Text	School reference id
school_population_students	Numeric	Student population in the institution
school_brin	Text	Institution’s id in the DUO register

Table 8 Secondary education (*voortgezet onderwijs*) schema

Secondary Education		
Field Name	**Type**	**Description**
nummer_id	Text	Unique identification code assigned per address by BAG
school_type	Text	Type of the educational institution
school_name	Text	The name of the institution
school_reference	Text	School reference id
school_population_students	Numeric	Student population in the institution
school_brin	Text	Institution's id in the DUO register

Table 9 Vocational education (*middelbaar beroepsonderwijs*), higher vocational education (*hoger beroepsonderwijs*) and academic education (*wetenschappelijk onderwijs*) schema

Vocational, Higher and Academic Education		
Field Name	**Type**	**Description**
nummer_id	Text	Unique identification code assigned per address by BAG
school_type	Text	Type of the educational institution
school_name	Text	The name of the institution
school_brin	Text	Institution's id in the DUO register

3.4.2 Processing

The *Basisregister Instellingen* datasets were processed using the following key steps:

1. Filter out the educational institutions outside of the scope area.
2. Identify additional buildings / addresses for higher vocational and academic education institutions as only single addresses are provided per BRIN and higher educational institutions (i.e. Groningen University) have multiple buildings.
3. Assign student population to addresses per BRIN. Where a BRIN is assigned to multiple address, the student population of the institution is distributed based on the *oppervlak* (usable area) of the *vbo* (occupancy) related to the address. Refer to Section 3.1 for information on the relationship between VBO and address.

3.4.3 Data Coverage

The result has 204 unique BRIN (education institutions) within the project scope area. The resulting counts of addresses and buildings (panden) can be found in Table 10. As there are educational institutions which occupy the same address and building, the total counts and unique counts (i.e. removing duplicate occupancies) are also listed.

Table 10 Counts per educational institution type

School type	Address count	Building count
Primary Education	164	165 (160 unique)
Special Primary Education	23	23
Secondary Education	55	53
Vocational Education	22	22
Higher Education	23	23
Academic Education	49	60
Total	336	346 (341 unique)

3.4.4 Limitations

Student population was only complete for primary education institutions as other education institution types were missing the relevant information. The *Basisregister Instellingen* only provided a single address per institution via the BRIN. While efforts were made to identify institutions with multiple buildings and identify the relevant addresses there will be several institutions and addresses missed which may cause addresses to be assigned higher student population than reality.

3.5 Ticinum Aerospace (TA)

Ticinum Aerospace (TA) [30] [31] produced a dataset containing the storey count of buildings through the automated processing of street view imagery. The dataset was commissioned by NAM and provided to Arup. The storey count data was used as input into the building classification process and was received in September 2019 [31].

3.5.1 Data Schema

The schema of the TA dataset used in the EDB V7 data after processing is shown in Table 11.

Table 11 TA data schema

Field Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
ta_storey_count	Numeric	Storey count

3.5.2 Processing

Processing was undertaken to ensure consistency of the pand_id and removal of duplicate records. The following key steps were undertaken:

1. Reformat the provided building id to match the standard format provided by BAG.
2. Filter out the buildings which are outside of the project scope or are duplicates, remove fields which are not required and remove records which do not have a valid value (i.e. 0 or –1).

3.5.3 Data Coverage

The resulting processed data covers 133,318 buildings with valid values. This is equivalent to 51% of buildings or 80% of buildings with addresses within the scope area.

3.5.4 Limitations

The TA storey count data is derived from streetview imagery which may not contain a clear image of the building façade and thus impact on the assignment of storey count. This could be due to vegetation obstructions or where the street is too narrow for the entire façade to be captured (i.e. top of the building is out of the image frame). The NAM's Hazard & Risk sub-consultants had reviewed a version of the dataset's storey count [12] and it was determined that the storey count was appropriate to be used.

3.6 Strengthened List

The *Strengthened List* is a list of buildings which have been strengthened by *Centrum Veilig Wonen* (CVW). The list that was used for EDB V7 was provided by CVW via NAM on January 2019 [21].

3.6.1 Data Schema

The schema of the Strengthened List used in the EDB V7 data is shown in Table 12.

Table 12 Strengthened list schema

Field Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
strengthened flag	Boolean	Flag of where a building has been identified as strengthened using TRUE or FALSE.

3.6.2 Processing

The data delivered required processing to validate and consolidate the list to building level and flag the buildings with the appropriate status. The following steps were taken:

1. Filter the addresses within the scope area and consolidate to building level.
2. Flag the buildings which have the status *Gereed*, *BKV Gereed* or *Gereed Sloop*.

3.6.3 Data Coverage

There were 354 buildings with a strengthened flag in the project scope area.

3.6.4 Limitations

The strengthened list was processed with the assumption that while the dataset contains information on an address level, the strengthening would be on a building level.

The original dataset provided is assumed to be an excerpt of an ongoing maintained list while the strengthening programme progresses. This means that the dataset is likely to have a low temporal resolution (i.e. easily out of date) as excerpts of the data are provided infrequently.

The dataset was taken as is with no additional checks on whether the strengthening was undertaken.

3.7 Nieuwbouwregeling List

The *Nieuwbouwregeling List* is a list of newly built buildings which have received funding through NAM for additional construction cost deriving from dedicated seismic design. The list which was used for EDB V7 was provided by NAM on October 2019 [23].

3.7.1 Data Schema

The schema of the Nieuwbouwregeling List used in the EDB V7 data after processing is shown in Table 13.

Table 13 Nieuwbouwregeling list schema

Field Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
nieuwbouwregeling_flag	Boolean	Flag of where a building has been identified on the Nieuwbouwregeling List using TRUE or FALSE.

3.7.2 Processing

The dataset was provided as a list of addresses and processing was required to provide consistency, ensure there was an address per record and to identify the relevant nummer_id and subsequent pand_id. The following steps were undertaken:

1. Manually disaggregate the addresses so that there was a single address per record. This included splitting addresses which were described as a start and end house number and street name and checks using the BAG viewer [18].
2. Match the addresses with the BAG addresses based on city name, street name, house number and house letter (where applicable) to assign a nummer_id per record. Postcode was not used as not all addresses in the list included it.
3. Aggregate the nummer_ids to pand_ids and filter out the buildings outside of the scope area.
4. Flag the buildings with the nieuwbouwregeling flag.

3.7.3 Data Coverage

There were 854 buildings (panden) with a nieuwbouwregeling flag in the EDB V7 scope area.

3.7.4 Data Limitations

The provided data included inconsistent formatting of address and required some interpretations, particularly where addresses were identifying a series of addresses. Additionally, as the complete address was not always provided (i.e.

missing postcode), the resulting assigned number_id and pand_id may not always be correct.

The list was provided as addresses which have received funding for new construction and it is possible that the buildings at the addresses are not yet constructed resulting in existing older buildings being flagged or that the address may not yet exist.

Where a building has been newly built and flagged, it has not been evaluated whether the building is NEN-NPR 9998 compliant.

3.8 CBS Wijken en Buurten

The *Centraal Bureau voor de Statistiek* (CBS) *Wijken en Buurten* dataset provides statistical information and boundaries of municipality (*gemeente*), district (*wijken*) and neighbourhood (*buurten*)[11].

For EDB V7, the boundaries of the municipalities, district and neighbourhood were used for the population analysis and acquired on January 2019.

3.8.1 Data Schema

The schema of the CBS boundaries used in the EDB V7 data is shown in Table 14.

Table 14 CBS Wijken en Buurten schema

Field Name	Type	Description
area_source	Text	Source of the area including type (i.e. municipality, district, neighbourhood)
area_name	Text	The name of the area
area_code	Text	The code of the area
geom	Geometry	The geometry of the feature

3.8.2 Processing

The datasets provided are received per administration boundary covering the country and processed into a single dataset. Processing was undertaken, which can be summarized in the following steps:

1. Consolidate the three administration boundary types into a single dataset.

2. Clip the boundaries to the project scope area so only boundaries within the scope area remain.

3.8.3 Data Coverage

The number of municipalities, districts and neighbourhoods within the project scope area can be found in Table 15.

Table 15 The summary of the output

Type	Type Count
Buurt (neighbourhood)	430
Wijk (district)	94
Gemeente (municipality)	23

3.8.4 Data Limitations

Administration boundaries may change in the future as they did on January 1st, 2019 [28]. Consideration should be taken on whether an update of the datasets will be required in the future.

3.9 Landelijk Register Kinderopvang

The *Landelijk Register Kinderopvang* or the National Childcare Register provides information on childcare facilities by the *Rijksoverheid* [29]. It includes information on the childcare facilities including number of child places [20]. The dataset used for EDB V7 was last updated on January 2019. The dataset was used as input into the population analysis described in Section 5.8.

3.9.1 Data Schema

The schema of the Landelijk Register Kinderopvang used in the EDB V7 data is shown in Table 16.

Table 16 Landelijk Register Kinderopvang schema

Field Name	Type	Description
nummer_id	Text	Unique identification code assigned per address by BAG
daycare_name	Text	Name of the day-care institution
daycare_population__children	Numeric	Number of children in the object
daycare_reference	Text	Reference to the id from the input data
daycare_type	Text	Type of the day-care institution

3.9.2 Processing

Processing was required as the dataset already contained a vbo_id as per BAG dataset presented in Section 3.1. The following steps were undertaken:

1. Assign a nummer_id using the dataset vbo_id
2. Filter out facilities outside of the project scope area

3.9.3 Data Coverage

The output of the process is summarized in Table 17.

Table 17 The summary of the output

Type	Count of childcare facilities in the study area
Addresses	1,012
Buildings (panden)	1,008

3.9.4 Data Limitations

The dataset covers registered child care facilities which includes out-of-school care. Out-of-school care may also be at a school which may overlap with the DUO dataset described in Section 3.4. As both these datasets are input into the population datasets, there may be a student and child care population assigned to the same building which may cause an over estimation in population.

4 Project Data

4.1 RVS

The Rapid Visual Screening (RVS) is a preliminary building assessment process designed to collect building information from the public realm (without entering the property boundaries), with a focus on capturing high risk building elements. The collected information is used to perform a rapid and preliminary assessment of the seismic risk of buildings, building elements, and to prioritise them for more detailed assessments and/or mitigation measures.

The specific objectives of the screening are:

- Perform a safety assessment, to evaluate the safety of inhabitants and to ensure safe conditions for the inspectors to carry out the RVS screening;
- Identify external High Risk building Elements (HRBEs), such as chimneys and parapets, which could pose a life safety risk during a seismic event;
- Gathering of additional information on site that will allow evaluation of the building performance during a seismic event.

The outcome of the RVS assessment is used to prioritise the follow up actions of either identify measures on individual HRBEs or perform an Extended Visual Screening (EVS).

RVS inspections were used in the Project Data Building Characterisation analysis (Section 5.1) with its results being used in the building classification process. RVS inspections carried out by Arup (up to November 2015) were included in EDB V7.

4.1.1 Data

The RVS data is separated into different datasets. Table 18 gives a description of these datasets.

Table 18 RVS datasets.

Data set	Data set Description
RVS I-II-A	The RVS I-II-A batch contains the RVS inspections done for client NAM. The scope contained importance class I and II buildings throughout the whole region.
RVS I-II-A-M1	The RVS I-II-M1 batch contains a repair action for the RVS inspections executed in Loppersum. The repair action consisted of migrating the manual inspection data into the database.
RVS CC-1B-A	The RVS CC-1B-A batch contains the RVS inspections done for client CVW. The scope contained consequence class CC1b buildings throughout the whole region.

The method of acquiring RVS inspection data and the whole list of building characteristics collected are described in more detail in the dedicated literature [4][5]. This appendix describes the schema of the RVS dataset, described in

Section 4.1, and the changes, and the confidence of the collected RVS inspection data.

Table 37 in Appendix A1 gives a description of the data provided to the inspectors and collected during the RVS process.

4.1.2 Data Coverage

RVS inspections were carried out on 17,860 addresses corresponding to 15,508 buildings (panden) within the project scope area.

4.1.3 Data limitations

As per its definition, the RVS is designed to collect building information from the public realm. This restriction reflects on the type of data that can be collected as well as on the confidence level. In addition, the aims of RVS activities give priority to safety rather than to an accurate evaluation of each attribute into a building that often is simply assumed, introducing a not reproducible nor standard variation due to the expertise of the inspectors and the status of the premises.

The inspection itself has been assisted by inspection tools. These tools have undergone a series of changes since their first release. These changes and the confidence of the collected inspection data have been summarized in Table 38, Appendix A1. Together they give an indication about the quality of the collected information.

4.2 Extended Visual Survey (EVS)

The EVS is a structural assessment based on the visual inspection of the building, internal and external, recording information required to determine structural upgrading measures for buildings. The EVS focuses on identifying potential falling hazards and significant structural damage and deformations. The inspection also includes the collection and recording of structural information and construction details, where visible. The inspection does not include invasive investigation or any testing, however the need for this type of investigations may be identified as a follow-up action.

The specific objectives of the EVS are to:

- Collect (initial) building information in preparation for potential future structural upgrading design works;
- Confirm the condition of HRBEs (High Risk Building Elements) identified during the RVS (Rapid Visual Screening) and identify and describe any additional HRBEs which could not be identified during the RVS;
- Validate data collected during the RVS and collect further data;
- Identifying the existing structure, to carry out a preliminary seismic evaluation according to Tier 1 of ASCE 41-13.

Only the primary residential building on a given address is fully assessed during the EVS. A detailed description of the scope of work can be found in [5].

EVS inspections were used in the Project Data Building Characterisation analysis (Section 5.1) with its results being used in the building classification process.

4.2.1 Data

Prior to conducting the on-site screening, a desk study is carried out by the inspection and engineering team. The objective of the desk study is to gather all available technical information from different sources (municipality archives, building owners, etc.), including the RVS report if available for the address. In particular, the parameters that define the risk associated with HRBEs are reviewed, so the relevant details can be screened during the visit. Details about the desk study process and the minimum required data to be collected can be found in [5].

The information obtained during the desk study is validated and supplemented by a screening on-site, limited to nonintrusive investigations. The final deliverable of this process in an EVS report. The EVS report summarizes the information obtained from the visual screening and provides a description of the building and its structure including photographs and drawings. The report contains the following base information:

- General information (for instance: address data building age, etc.)
- Building description
- Structural description

- Screening validation of HRBE
- Final HRBE recommendations
- Drawings of the building
- Safety Assessment Form
- RVS HRBE recommendations
- ASCE 41-13 Tier 1 checklist

Although the EVS report provides sufficient information for further structural analyses, the unstructured data contained in the report cannot be directly imported into database. A repair action in December 2015 was undertaken to extract the most relevant data from the available EVS reports to date with focus on the information required for the assignment of building typologies [22]. The data was captured in a structured format, so it could be imported into the database. The description of the extracted data is provided in Appendix A2.

4.2.2 Data Coverage

735 buildings (panden) with EVS inspections carried out by Arup and CVW were included in EDB V7. This only includes the EVS inspections carried out by Arup and CVW up to November 2015.

4.2.3 Data limitations

During the repair action from December 2015, the above fields were supplemented with a confidence value per field. This confidence value relates to the certainty with which the data could be retrieved from the report and ranges from ‘assumed’ to ‘verified’. The data collection had not been conceived to be used separately from the report and/or for other users than the inspectors.

EVS inspections are recorded manually (i.e. with no data structure) and stored as a report. To allow for the EVS information to be used in data processing, the reports were interpreted by engineers and recorded in a structured data format. While check processes were implemented during the translation of the reports to structured data, several misinterpretations and human errors (including inconsistent field values) in the data were included.

4.3 Drawing Data

The Drawing Data provides information about the construction and internal features of selected buildings obtained by reviewing architectural and construction drawings where available [3]. The dataset includes information collected for several studies which includes apartments, terraced and semi-detached buildings.

The collection method included retrieving drawings (architectural and structural where possible) and extracting relevant building attributes into a structured format to be hosted in a database. The primary purpose of the drawing data collection is to provide detailed information which may assist with the inspection process and structural assessment.

Drawing Data was used in the Project Data Building Characterisation analysis (Section 5.1) with its results being used in the building classification process.

4.3.1 Data

Table 40 in Appendix A3 shows the fields of the Drawing Data. Where values have been identified from a predefined list, the field has been marked with a comment of ‘list’.

4.3.2 Data Coverage

The Drawing Data contains information for 11,736 buildings (panden).

4.3.3 Data limitations

The Drawing Data requires architectural and structural drawings to be interpreted by engineers and recorded in a structured data format. Misinterpretations and human errors (i.e. during data entry) from the translation of drawings to structured data were identified while using the data. It should be noted that the Drawing Data attributes were not designed to match a format suitable for the EDB classification, therefore assumptions while converting the original data collected were sometimes required (see Section 5.1).

4.4 Data Collection

The Data Collection provides information about construction and internal features of selected buildings [25], focusing on parameters relevant to assessing seismic risk at regional scale to input into the EDB. Like the Drawing Data (Section 2.2.3), drawings of selected buildings were obtained from municipalities and construction information was then collected from them in a structured format by Arup.

Data Collection was undertaken from May 2018 and included information collected up to December 2019 for the EDB V7. Data Collection was used in the Project Data Building Characterisation analysis (Section 5.1) with its results being used in the building classification process.

4.4.1 Data

Table 41 in the Appendix A4 gives a description of the data provided as part of the Data Collection [3]. Where values have been identified from a predefined list, the field has been marked with a comment of ‘list’.

4.4.2 Data Coverage

The Data Collection contains information for 2,999 buildings (panden).

4.4.3 Data limitations

The Data Collection requires architectural and structural drawings to be interpreted by engineers and recorded in a structured data format. Misinterpretations and human errors (i.e. during data entry) from the translation of drawings to structured data were identified while using the data.

4.5 Desktop Visual Inspections

Desktop visual inspections were undertaken on buildings within a set scope area using Google Streetview or Horus photos (collected street imagery for the project by Horus) [10]. Buildings which were identified to be terraced or semi-detached buildings as per the Exposure Database V3 [6] were not included as these were expected to be covered by the Drawing Data (see Section 4.3). The Desktop visual inspections were commissioned by NAM and undertaken by sub-contractors *Jorritsma Bouw Groningen* (JBG).

The primary purpose of these visual inspections was twofold:

- Validate the types of buildings which had been assigned to Exposure Database V3 Intermediate classes, and
- Collect and assess additional exterior building characteristics which may have an influence on the building structural system to help refine the classification process.

To assist with the data collection process, certain fields were prefilled which could be verified or corrected by the visual inspectors. Other parameters were provided with pre-set choice lists. The data was collected using a SharePoint tool developed by JBG and the buildings were processed in batches. The data was checked by JBG reviewers. Specific buildings which either contained incorrect information or where advice was required were further verified by Arup and sent back to JBG to be processed.

A high-level description of the Visual Inspections process, definitions used by inspectors, tools and data can be found in the manual [9].

The Visual Inspections were delivered on July 2017 from JBG to Arup.

The desktop visual inspections were used in the Project Data Building Characterisation analysis (Section 5.1) with its results being used in the building classification process.

4.5.1 Data

Appendix A5 provides an overview of the fields collected including whether prefilled information was provided. For each of the relevant fields, a corresponding confidence field was added to understand if the characteristic was observed or assumed.

4.5.2 Data Coverage

The Visual Inspection dataset covered 12,072 buildings (panden) within the project scope area.

4.5.3 Data limitations

The Desktop Visual Inspections used images available on Google Streetview or Horus images and required interpretation by the engineers. Misinterpretations of the parameter definitions and human errors (i.e. during data entry) produced from the images to structured data were identified while using the data.

Google Streetview and Horus imagery did not always provide a clear image of the building. This is due to the images being predominately captured from the road and buildings being set far back from the road, particularly in agricultural areas. Google Streetview's timestamp (i.e. date of data capture) changes across the region and is occasionally a few years old so the data captured may be based on an older version of the building.

5 Processed Data

5.1 Project Data Building Characterisation

The Project Data Building Characterisation (PDBC) provides the structural resisting system and materials in the convention used for EDB V7, assigned through project datasets.

The EDB V7 describes the structural resisting system of buildings using the conventions from thr building taxonomy developed by the GEM foundation [16] as a basis. The assignment in the PDBC provides six building attributes of the material and lateral support system (MLSS) which are presented as taxonomy tags. The six tags are concatenated with a '/' spacer to create a final building characterisation string. Table 19 provides a description of the six building attributes and example GEM tags.

Table 19 The MLSS composition using the GEM taxonomy

			Example	
Position	**Building Characteristics**		**Description**	**GEM code**
1	Direction X (Dx)	Material of the lateral load-resisting system	Masonry, unreinforced	MUR
2		Type of lateral load-resisting system	Walls	LWAL
3	Direction Y (Dy)	Material of the lateral load-resisting system	Masonry, unreinforced	MUR
4		Type of lateral load-resisting system	Walls	LWAL
5	Exterior Wall	Presence of exterior walls	Presence of exterior walls	EW
6	Floor	Material of floor system	Timber	FW

Further information on how the EDB V7 uses the GEM syntax to describe structural system of buildings can be found in the EDB V7 Report [8].

5.1.1 Data Schema

Table 20 describes the contents and the schema of the PDBC.

Table 20 PDBC format

Field Name	Type	Description
pand_id	Text	Unique BAG building ID
gem	String	The assigned GEM string – composed of the six GEM tags concatenated with '/' spacer.
source	Double	The source of the assigned GEM string.
gem_flag	Text	Indication of whether the assigned GEM string is partial or full (i.e. contains all six building attributes).

5.1.2 Methodology

5.1.2.1 Input data

The following project datasets were included in the PDBC:

- RVS (Arup), Nov 2015
- EVS (Arup), Dec 2015
- Drawing Data (Arup), Dec 2019
- Data Collection (Arup), Dec 2019
- Visual Inspection (JBG), July 2017

Further information on these datasets can be found in Section 4.

5.1.2.2 Operations

To create the PDBC, the following key steps were undertaken:

1. **Translation of the project data attributes to the GEM syntax**

   Each of the project dataset's attributes was reviewed and assessed prior to selecting the relevant project attributes which could inform the six building attributes where available. The values of the project attributes were then reviewed and translated to a relevant GEM tag. The mapping tables which provide the translation from value to GEM tag for each of the project datasets can be found in the Appendix A6.

   The GEM tags were then used to create a GEM string composed of the six building attributes and a flag was created to indicate whether the GEM string was partially or fully complete (i.e. had values for all six attributes). This was done for each of the project datasets.

2. **Consolidating the mapped project datasets**

   To create a consolidated dataset where a building is assigned a single GEM string, the project datasets needed to be collated and prioritized. This is due to overlapping coverage where a building may have assigned GEM strings from several different sources.

The prioritisation was based on the method of data collection to indicate an assumed quality of the project datasets. The prioritisation of the project datasets can be seen on Table 21. Further information on the project datasets and their purposes and collection methods can be found in Section 4.

Table 21 Prioritisation of the project data

Priority	Project Dataset
1	Index Buildings
2	EVS
3	Data Collection
4	Drawing Data
5	RVS
6	Visual Inspections

5.1.3 Data Coverage

The resulting PDBC dataset covered 25,608 buildings in the project scope area. This corresponds to approximately 10% of the buildings within the project scope area. Table 22 provides a short breakdown of the assigned GEM strings including source and GEM Flag.

Table 22 The summary of the output

Source (Project Dataset)	GEM Flag	Building Counts
Index Buildings	Full	11
EVS	Full	654
Data Collection	Full	2,286
	Partial	705
Drawing Data	Full	9,979
	Partial	659
RVS	Partial	3,803
Visual Inspections	Partial	7,511
Total		**25,608**

5.1.4 Evaluation

An evaluation exercise was set up to assess the GEM mapping translation and the quality of the project data. The following steps were undertaken:

1. A sample of the project datasets was used to collect and manually review the information from the building's drawings against the assigned GEM string. The sample sets varied depending on the size of the project dataset and drawing availability at the municipalities. The assigned GEM string from the PDBC dataset that was used to evaluate was prior to consolidation process (i.e. Step 2 of the Operations described in Section 5.1.2.2).
2. The sample's GEM string was then cross checked with the mapped GEM string to evaluate accuracy. Where discrepancy was found, the attributes of

the project dataset were evaluated to identify if an improved mapping could be identified.

This was conducted for EVS, RVS and Visual Inspection project datasets. Data Collection and Drawing Data were not evaluated as their attributes were already assigned with collected drawing data.

The evaluation results only give an indication of the quality of the project datasets and the GEM mapping translation with the aim of improving the mapping translation and the resulting PDBC set.

5.1.4.1 EVS

The EVS dataset was used to map all six of the building characteristics. Information for 136 buildings was reviewed as part of the EVS sample set. The sample was 20% of the EVS used in the PDBC. This high sampling percentage is due to the low coverage of the EVS data and the availability of the drawings. Figure 7 below highlights the percentage of match from the sample set and the resulting PDBC data.

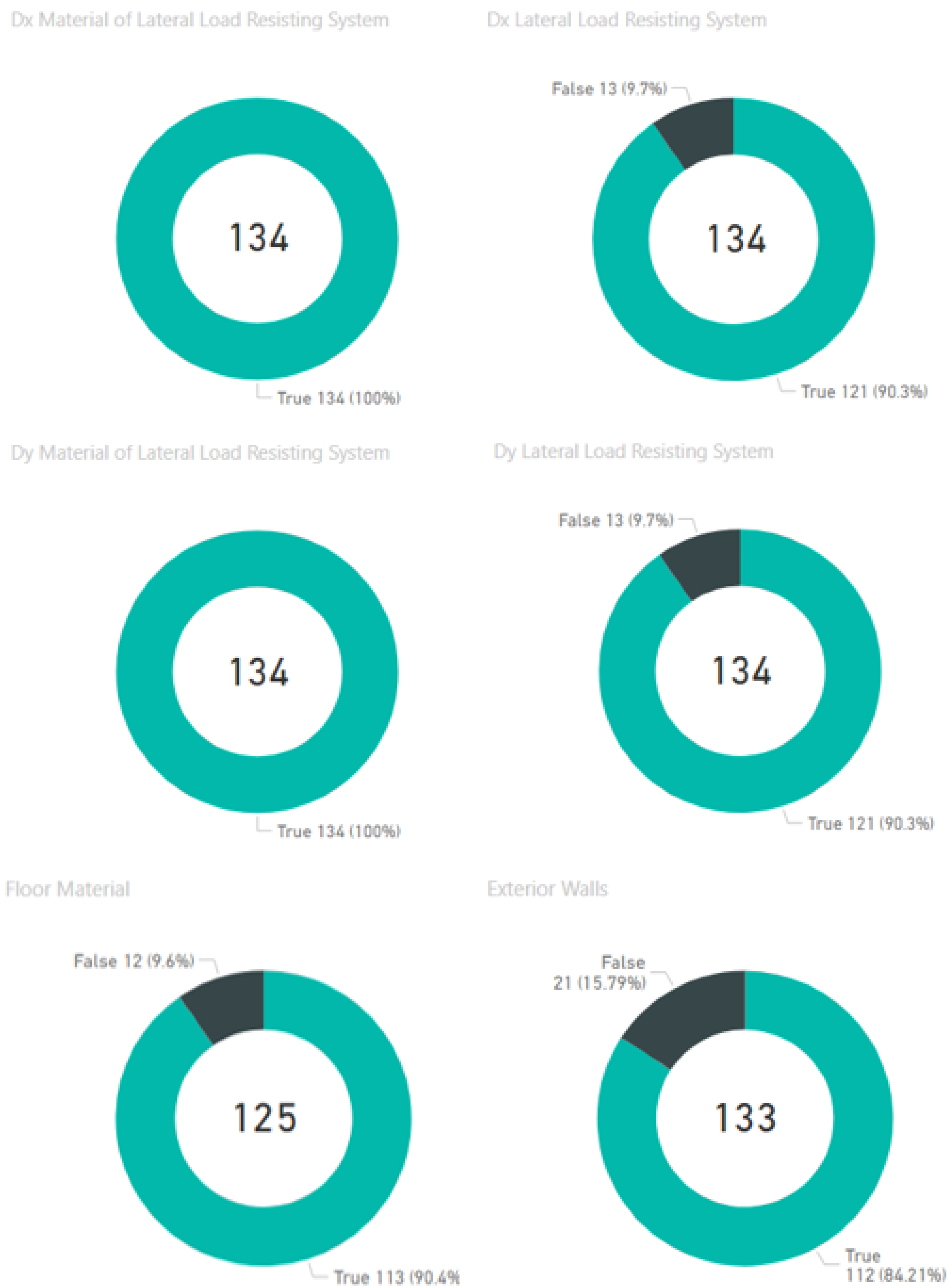


Figure 7 Percentage of match and number of records from the EVS sample set and the PDBC data per building characteristic.

The material of the lateral load resisting system had a sample set match of 100% to the PDBC's mapping of EVS for both Dx and Dy. Both the Dx and Dy directions of the lateral load resisting system had a sample set match of 90%. Most non-matching records were found to be due to an assignment of 'LWAL' ('Wall System') when the sample set had identified 'LH' ('Hybrid System'). The EVS data appears to have an inconsistent approach in describing hybrid systems which has impacted the PDBC assignment.

The exterior walls had a match rate to the sample set of 84%. The non-matching records were found to be from the assignment both ‘EW’ (‘Presence of Outer Leaf’) and ‘EWN’ (‘No Outer Leaf Cavity Walls’). An examination of the EVS data identified issues with incorrectly assigning ‘cavity’ and ‘solid’ walls clarifying the incorrect results.

The floor material had a 90% match to the sample set. The non-matching records were found to be due to either incorrectly collected values from the EVS reports or the assignment of ‘Other’ (resulting in ‘FO’ or ‘Floor Other’) when it could be assigned to ‘Timber’ or ‘Concrete’.

5.1.4.2 RVS

The RVS dataset was used to map four of the six building characteristics, excluding the lateral supporting system for Dx and Dy. Information for 502 buildings was collected as part of the RVS sample set. The sample was 13.2% of the RVS data used in the PDBC. Figure 8 highlights the percentage of match from the sample set and the resulting PDBC data.

Figure 8 Percentage of match and number of records from the RVS sample set and the PDBC data per building characteristics.

The material of the lateral load resisting system had a sample set match of 94% and 95% to PDBC’s mapping of RVS for Dx and Dy respectively. An examination of the non-matching records found that the RVS values were incorrectly collected for ‘MUR’ (Unreinforced Masonry). While the majority of the Dx and Dy were assigned the same values, including in the non-matching records, six records were identified to have different materials of the lateral load resisting system. This resulted in a small difference in the match percentage between Dx and Dy.

The exterior walls had a match rate to the sample set of 88%. The non-matching records were found to be from the assignment both ‘EW’ (‘Presence of Outer Leaf’) and ‘EWN’ (‘No Outer Leaf Cavity Walls’). An examination of the RVS data identified issues with incorrectly assigning values clarifying the incorrect results.

The floor material had 83% match to the sample set. The non-matching records were found to be due to incorrect collected values from the RVS dataset. This can be expected due to the difficulties of identifying floor materials from the exterior.

5.1.4.3 Visual Inspections

The Visual Inspection dataset was used to map five of the six building characteristics, excluding the floor system material. Not all five of the attributes were collected for all records in the Visual Inspections dataset Dx / Dy Lateral Load Resisting System having a low coverage. Accordingly, the evaluation only assessed the five attributes and where values from the Visual Inspections were available to be assessed.

Information for 314 buildings was collected as part of the Visual Inspection’s sample set. The sample was 4.2% of the Visual Inspection used in the PDBC. The figure below highlights the percentage of match for the sample set and PDBC dataset per building attribute using ‘True’ or ‘False’.

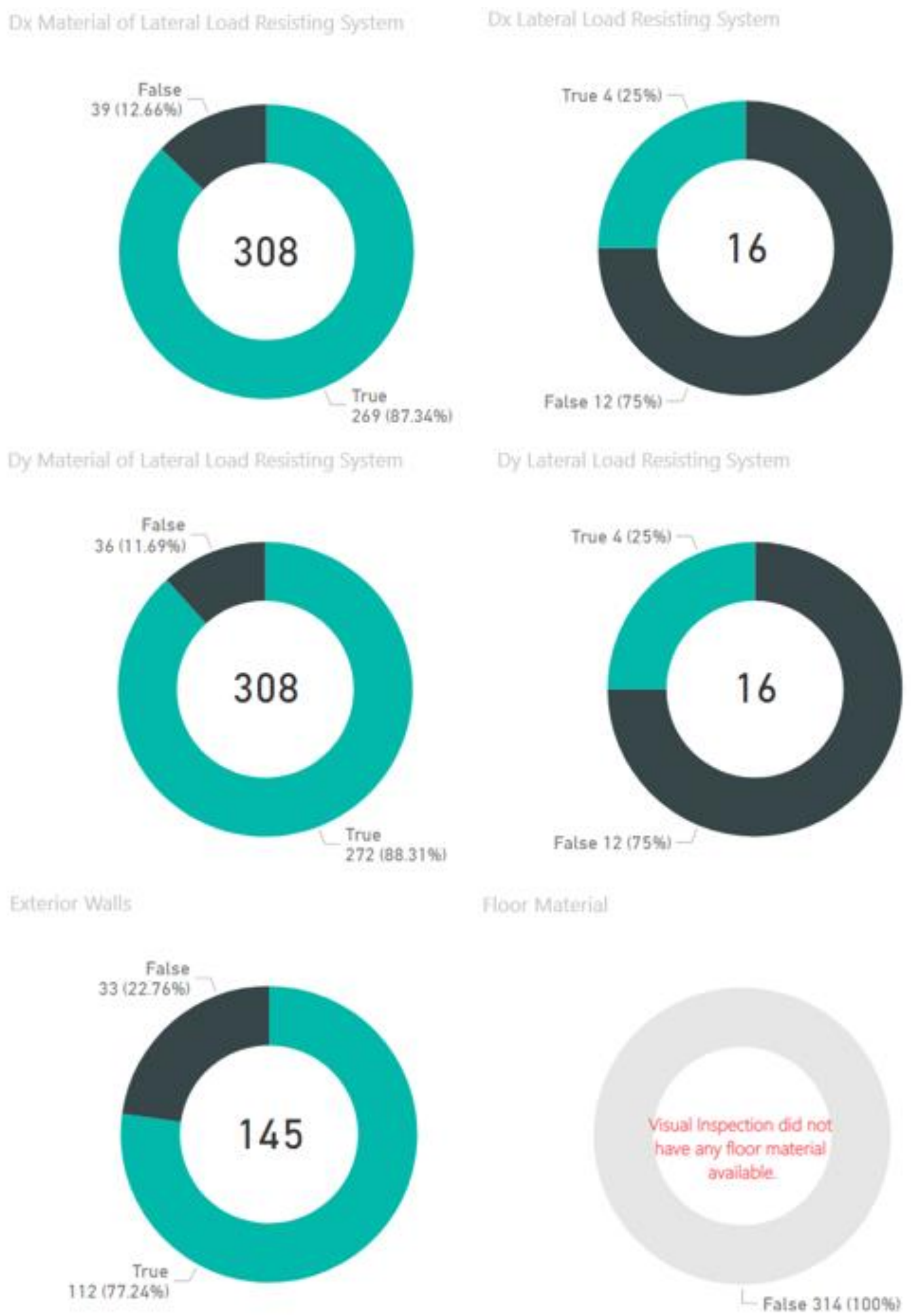


Figure 9 Percentage of match and number of records from the Visual Inspection sample set and the PDBC data per building characteristic.

The material of the lateral load resisting system was captured for all 314 buildings with the sample set matching 87% and 88% to PDBC’s mapping of Visual Inspections for Dx and Dy respectively. An examination of the non-matching records found that the Visual Inspection’s values were incorrectly collected for ‘MUR’ (Unreinforced Masonry) and ‘MATO’ (Material Other) types. The difference between the Dx and Dy match percentage was due to the identification of two different materials identified for Dx and Dy in the sample set. PDBC assigns the material fields for both directions from the same value as only one value was collected by the Visual Inspections

The lateral load resisting system had a low match to the sample set of 16 records at only 25% for both Dx and Dy. The low sampling reflected that only 8.7% of the Visual Inspection records was assigned a lateral load resisting system. The non-matching records were found to be due to an assignment of 'LH' ('Hybrid System') when the sample set had identified 'LWAL' ('Wall System'). An examination of the Visual Inspection data identified issues with the collected data which resulting in the incorrect result. The interpretation of the low match should be considered in the context of the limited records assessed. A review of the results also identified opportunities to extend the mapping process for Visual Inspections to provide further insights into the lateral load resisting system.

The exterior walls were captured for 145 buildings with a match rate to the sample set of 77%. The non-matching records were found to be from the assignment of 'EW' ('Presence of Outer Leaf') whereas the sample set identified 'EWN' ('No Outer Leaf Cavity Walls'). An examination of the Visual Inspection data identified issues with the collected data clarifying the incorrect results.

5.1.5 Data Limitations

The following limitations should be considered:

- The PDBC dataset inherits the limitations of the project datasets described in Section 4. This has been found in the evaluation process as described in Section 5.1.4 with issues in the project data's values. The issues are primarily around building characteristics not easily identifiable from the exterior or issues as a consequence of general human error.
- The original project datasets were not collected with the assignment of the MLSS in mind except for the Data Collection which was set up explicitly for EDB V7 classification.
- The project datasets were collected at different times using different protocols. While the definition of the parameters was considered in the creation of the mapping, there may be misalignment in definitions which can impact the resulting GEM string. The different collection periods may also result in the collected data being out of date.
- Where there is uncertainty on the definitions of the parameters from the project datasets or in the mapping, the more fragile resisting system / material of the available options has been assigned.
- The complexity of a building cannot always be captured in the GEM string. Therefore, the structural layout should be considered, and additional attention should be paid when using this result to cover building specific assessment.
- Some of the mapping assumptions have been agreed with the client to match the seismic vulnerability models and might not be valid outside of this framework.

5.2 Building Use

Building Use information provides the main and secondary use of a building and a flag to identify whether a building contains a Residential Use. These are used in the building classification process and as direct data fields in the EDB V7 extract.

For EDB V7, the Building Use analysis has been updated with updated source data and revised methodology.

5.2.1 Data Schema

Table 23 describes the contents and the schema of the Building Use dataset.

Table 23 Building Use data schema.

Field Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
main_use	Text	The main function of a building
secondary_use	Text	The secondary function of a building
has_residential_use	Boolean	Flag of whether the building has a residential use using TRUE or FALSE.

5.2.2 Methodology

5.2.2.1 Input data

For this analysis, the following dataset has been used:

- BAG (Kadaster), August 2019

5.2.2.2 Operations

BAG contains information on the *gebruiksdoel* or function / use which is assigned per VBO (occupancy). A list of distinct function values provided by BAG can be found in Table 24. Per VBO, the *gebruiksdoel* field is provided as a series, with as many functions as relevant listed (i.e. a VBO may be assigned both *woonfunctie* and *winkelfunctie* under the *gebruiksdoel* field).

Table 24 List of function values used in BAG.

Dutch	English
woonfunctie	Residential
winkelfunctie	Shop
kantoorfunctie	Office
bijeenkomstfunctie	Gathering
gezondheidszorgfunctie	Healthcare
onderwijsfunctie	Educational
logiesfunctie	Accommodation
sportfunctie	Sport
celfunctie	Prison
industriefunctie	Industrial
overige gebruiksfunctie	Other use

Additional information on BAG can be found in Section 3.1.

To assign a main and secondary use on a building level, the following steps were undertaken:

1. Summarise the *oppervlak* (useable area) per *gebruiksdoel* (function) per building (pand).
2. Rank the *gebruiksdoel* by the *oppervlak* within a building from largest to smallest to assign a main and secondary function with the relevant *gebruiksdoel*
3. Where the main *gebruiksdoel* contains a value, which describes a series of functions (i.e. *woonfunctie* and *winkelfunctie*), assign the first function of the series as the main function and the second of the series as the second function.
4. Flag the 'has residential' field if any of the *gebruiksdoel* of the pand_id includes *woonfunctie* regardless of ranking.

5.2.3 Data Coverage

The building use analysis has been performed for all the buildings with addresses within the EDB V7 scope, which is summarised in Table 25.

Table 25 Summary of the Building Use analysis results can be found below.

Main use	**Building count**
bijeenkomstfunctie	1,653
celfunctie	4
gezondheidszorgfunctie	365
industriefunctie	4,253
kantoorfunctie	1,606
logiesfunctie	1,131
onderwijsfunctie	389
overige gebruiksfunctie	12,794
sportfunctie	242
winkelfunctie	2,231
woonfunctie	141,233
Total	**165,901**

5.2.4 Evaluation

The results have been spot checked mainly through desktop studies using the BAG viewer and Google Streetview [17] and by comparing against previous EDB version's Building Use results.

5.2.5 Data limitations

Building Use is only available for buildings with addresses as BAG only provides function where an occupancy is assigned to a building.

The results of analysis on the Building Use dataset inherits any limitations from the BAG dataset as listed in Section 3.1.4

5.3 Adjacency

In the adjacency analysis the spatial relation between separate buildings is determined; i.e. how a building relates to neighbouring buildings. To capture this relationship, two units were defined – block and blockpart. Block is a unit used to describe the group of buildings touching each other. Blockpart is a unit to describe a group of buildings touching each other and that are similar to each other. Supporting parameters were created around these two units. To understand whether a building is touching a similar building, the buildings are tested on building year, footprint area and compactness of the geometry (footprint area/footprint area of minimum bounding circle).

The result of this analysis is a set of parameters which are input for the building typology classification (such as number of buildings in a block, number of neighbouring buildings etc.).

5.3.1 Data Schema

Table 26 describes the contents and the schema of the resulting dataset.

Table 26 Adjacency schema

Field Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
block_id	Text	Unique identification assigned to a block
blockpart_id	Text	Unique identification assigned to a blockpart
neighbours	Text[]	List of all buildings touching the reference building
block_flag	Short	Flag when part of a block (with more than 1 building)
blockpart_flag	Short	Flag when part of a blockpart (with more than 1 building in blockpart)
nbr_block	Short	Number of buildings in a block
nbr_with_vbo	Short	Number of buildings in block with vbo
nbr_without_vbo	Short	Number of buildings in block without vbo
bldg_within_05m	Short	Number of buildings within 0.5 metres of building (excluding neighbours)
bldg_within_05m_without_vbo	Short	Number of buildings without VBO within 0.5 metres of building (excluding neighbours)

5.3.2 Methodology

5.3.2.1 Input data

For this analysis, the following input data is used:

- BAG (Kadaster), August 2019

5.3.2.2 Operations

The required characteristics are determined for each individual building through a spatial analysis of all the buildings within the scope area. The analysis is divided into three main parts:

1. **Geometric pre-processing**
    a. For each building, draw geometries buffered by 0.25m and dissolve touching buildings to form *blocks*.
    b. Calculate related *block* parameters including number of buildings in *block* and compactness.
2. **Topological analysis**
    a. For all buildings, identify all touching buildings to identify neighbours.
    b. Calculate parameters, that exclude the neighbours (e.g. bldg_within_05m)

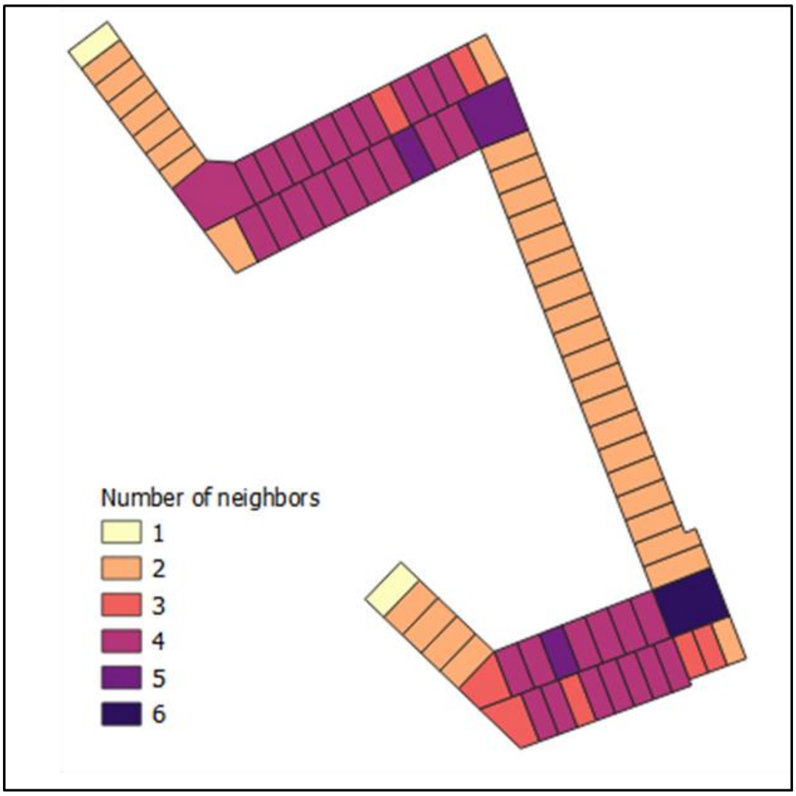


Figure 10 Preview of neighbour analysis results

3. **Blockpart analysis**

   To identify the *blockparts* (i.e. buildings which are touching that are similar), buildings are checked against their neighbours for similarities. The building and its neighbours are considered similar if:

   - The building years have a difference of two or less years and buildings' areas differ less than 20%, OR
   - The buildings' area and circularity values (i.e. how square the footprint is) differ by less than 10%.

5.3.3 Data Coverage

The adjacency analysis has been performed for all buildings (panden) covering the EDB V7 assessment area.

Table 27 provides a summary of the key adjacency results.

Table 27 The summary of the output

Adjacency type	Building count	Blockparts count
Freestanding	105,888 (including 58,302 which do not have an address)	n/a
Freestanding but touching another building without an address (i.e. shed or garage)	6,924	n/a
Not-freestanding	150,587 (98,545 are in blockparts)	24,656
Total	263,399	24,656

5.3.4 Evaluation

To evaluate the *blockpart* results, a *blockpart* uniformity checks has been performed. This assesses four attributes of all the buildings within a blockpart to check if the attributes are also uniform.

Additional datasets used in the evaluation include:

- TA, 2019
- Average Gutter Height (see Section 2.3.5)

The four attributes and the definition of uniformity for each attribute can be seen below:

- min and max *building years*, that do not differ by more than 2 years
- *average gutter height* OR *TA storey count*, that do not differ more than by 1m
- min and max values for *area*, that do not differ by more than 10%
- min and max values for *compactness*, that do not differ by more than 10%

The results of the uniformity analysis are summarized in

Table 28.

Table 28 The output summary of the uniformity analysis

Attribute	Buildings in uniform blockparts	Buildings in heterogenous blockparts
building_year	94,760	3,785
area_10	59,126	39,419
area_20	79,135	19,410
compactness	62,045	36,500
ta_storey_count	70,140	28,405
avg_gutter_height	77,217	21,328
Blockpart membership function ((building_year AND area_20) OR (area_10 AND compactness))	78,259 (21,166 blockparts)	20,286 (3,490 blockparts)

The analysis results are more conservative (i.e. stricter rules were used to form blockparts) and more consistent compared to the V6 approach (see Figure 11). The 3,490 heterogenous blockparts (

Table 28) come due to the parameter gradient in the block. For instance, in Figure 12 adjacent neighbors are similar, yet buildings in blockpart as a collection do not conform to the membership function (*building_year is not within 2 year threshold OR (area AND compactness are within 10% threshold)*). After visual validation, these blockparts were accepted as suitable for further analysis.

Additionally, visual checks were undertaken on both intermediate and final outputs with focus on pre-defined problematic blocks. An example of such block is seen in Figure 13.

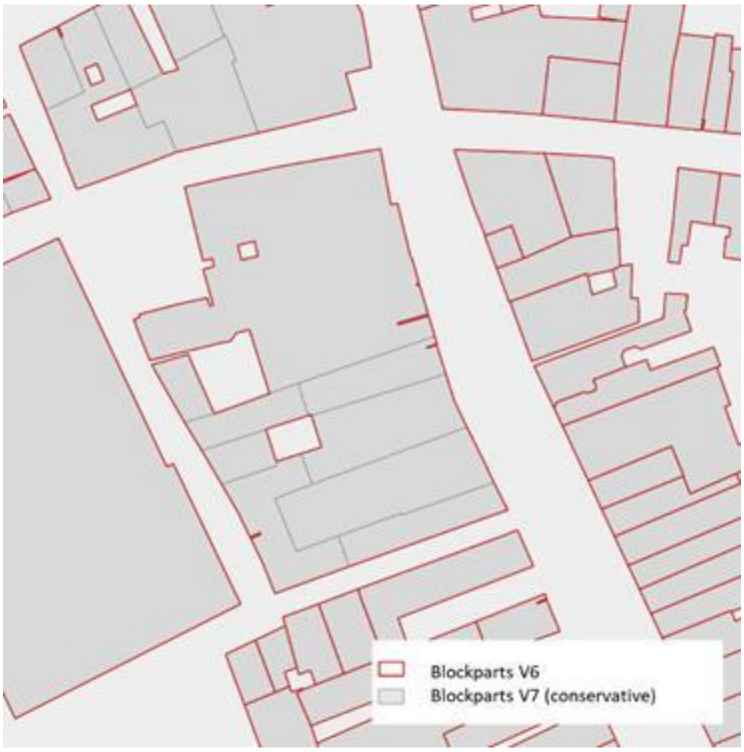


Figure 11 Comparison between V6 and V7 blockparts

Figure 12 Example of a heterogenous blockpart (A- area, C- compactness, Y- building year)

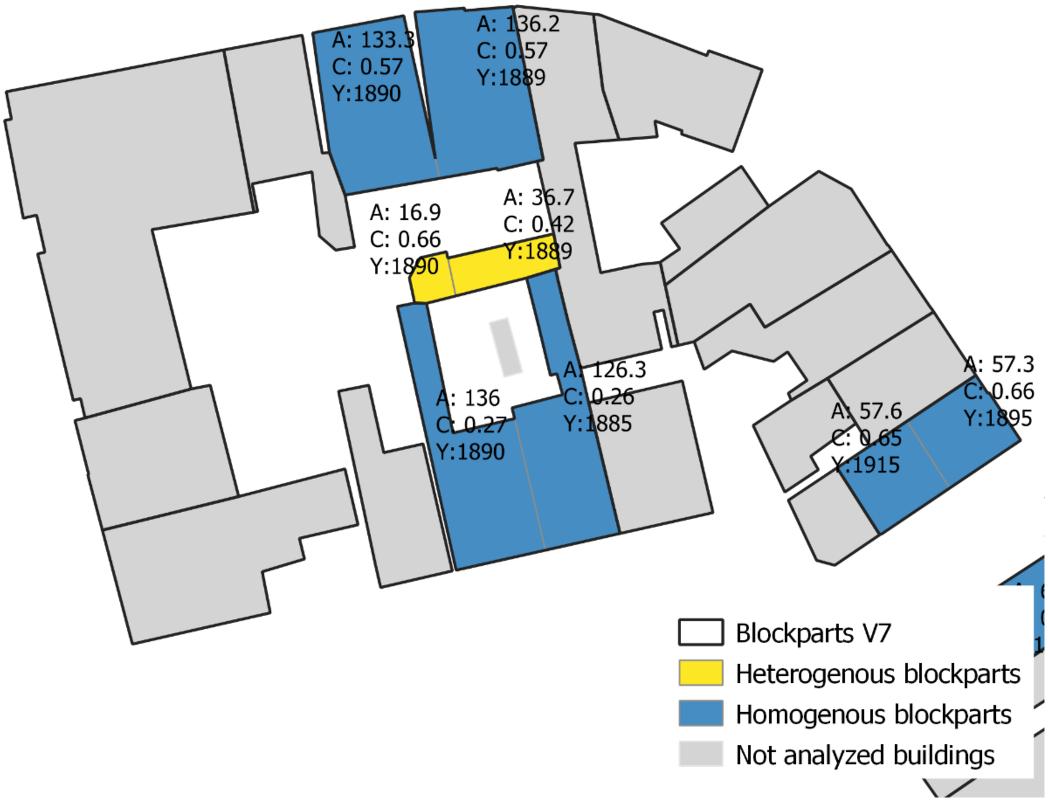


Figure 13 Example complex block (A- area, C- compactness, Y- building year)

5.3.5 Data limitations

The results of this analysis are expected to inherit the limitations of BAG (Section 3.1.4).

5.4 Exposed Footprint

The exposed footprint length captures the length of the building's footprint (i.e. building outline) which are exterior facing (i.e. not including walls between buildings). The exposed footprint length is an input for the building typology classification

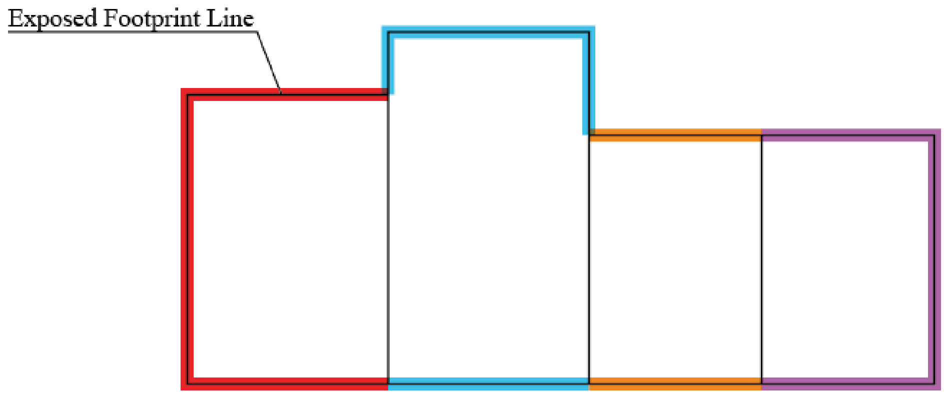


Figure 14 Example of the exposed footprint length/s of different buildings.

5.4.1 Data Schema

Table 29 describes the contents and the schema of the Exposed Footprint dataset.

Table 29 Exposed footprint table format.

Field Name	Type	Description
pand_id	Text	Unique BAG building ID
footprint_length	Double	The perimeter of the footprint
exposed_footprint_length	Double	The length of the exposed, outer wall per building in metres.

5.4.2 Methodology

5.4.2.1 Input data

For this analysis, the BAG building outlines was used.

- BAG (Kadaster), August 2019

5.4.2.2 Operations

The BAG building outlines was used as input into the spatial analysis. The following steps were taken:

1. Calculate the length of the building polygon to identify the footprint length.
2. Dissolve/merge all touching polygons to create a perimeter outline.

3. Split the perimeter outline by the edges within the dissolved polygon.
4. Sum the lengths of all lines belonging to the same building to calculate the total exposed footprint length.

5.4.3 Data Coverage

This analysis has been performed for all buildings (panden) within the scope area. In the figure below an example of the expected output can be seen. Every colour represents another exposed wall.

ID	LENGTH	UNIT
1	24.2	m
2	12.3	m
3	12.3	m
4	12.4	m
5	12.3	m
6	12.3	m
7	24.1	m
8	12.3	m

Figure 15 Expected output of the exposed wall analysis

5.4.4 Evaluation

A visual check on several buildings has been performed and a sample of buildings has been measured through GIS against the results. It was identified that approximately 1% of the calculations were incorrect due to invalid geometries from BAG (e.g. Figure 3 in Section 3.1). This includes polygons with crossed lines and sliver polygons.

5.4.5 Data limitation

The results of this analysis are expected to inherit the limitations of BAG, see Section 3.1.4.

5.5 Average Gutter Height

Gutter height is defined as the height of the exterior wall between the ground and point where the wall intersects with the roof structure (i.e. where the gutter would be installed). The gutter height of a building is not always represented by a unique value as each one of its walls might have a different gutter height, which can also vary throughout the length of the wall itself.

The gutter height algorithm returns an average height (AvHeight) per wall along with its length (L). This information is then processed to return an average weighted gutter height for each building.

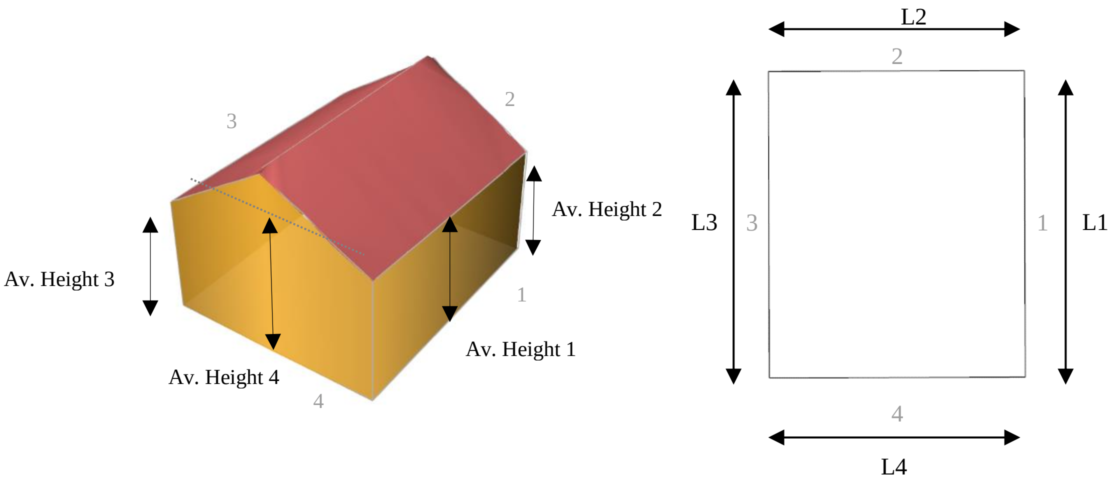


Figure 16 Definition of the average gutter height and corresponding wall length

The gutter height is one of the main geometric features used in the building classification process and a field in the extract [7].

5.5.1 Data Schema

Table 30 describes the contents and the schema of the resulting dataset.

Table 30 Gutter height table format

Field Name	Type	Description
pand_id	Text	Unique BAG building ID
gutter_height	String	The length and average height per outer wall per building in metres. Format is described below.
average_gutter_height	Double	The overall average gutter height weighted by the length of the building.

The gutter height is returned in the following format:

$(L_1|AvHeight_1;\ L_2|AvHeight_2;\ L_3|AvHeight_3; \ldots;\ L_n|AvHeight_n)$

Where “L” and “AvHeight” are length and average height respectively.

5.5.2 Methodology

5.5.2.1 Input data

For this analysis, the following input data is used:

- BAG (Kadaster), August 2019
- AHN height data, 2009.

5.5.2.2 Operations

The gutter height calculation (shown in Figure 17) is based on three key steps:

1. Selecting the height data (point cloud) close to each segment of the footprint outline through a buffer.
2. Identifying the average heights of the points per segment of the footprint outline.
3. The geometric parameters are then recorded with the length of each segment and corresponding average height.

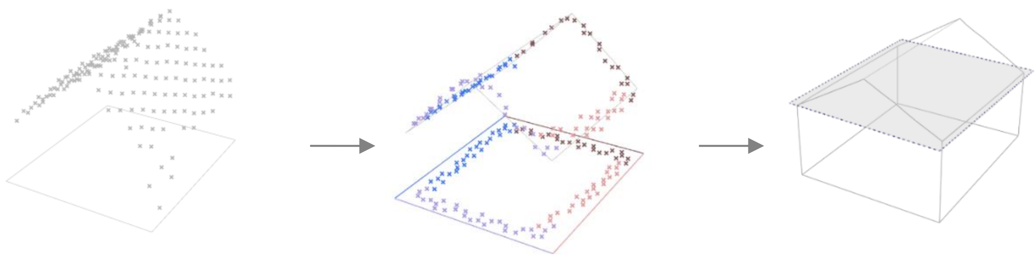


Figure 17 Operations undertaken to calculate the gutter height.

To calculate the average gutter height per building, an average of the segment's average height ("$AvHeight_n$"), weighted by the corresponding length ("L_n") was calculated using the formula below. This ensured that the overall average gutter height was proportionally adjusted where a small part of the building was either very tall or short.

$$average\_gutter\_height = \frac{(L_1 * AvHeight_1) + (L_2 * AvHeight_2) + \cdots + (L_n * AvHeight_n)}{L_1 + L_2 + \cdots + L_n}$$

5.5.3 Data Coverage

The analysis has been performed on 229,184 buildings. Buildings without a resulting gutter height (34,215 buildings) either had:

- Insufficient amount of point cloud data due to filtering of vegetation; or

- There was no point cloud data available due to the building being built in a later date than when the point cloud scan was generated (2009).

5.5.4 Evaluation

To evaluate the accuracy of the results of this parameter, a comparison between the calculated and inspection data was performed, as documented in a dedicated note [2]. The study showed a sufficient agreement between inspection and algorithmic data.

5.5.5 Data limitations and recommendations

This algorithm uses as input the BAG and AHN datasets, therefore related limitations are inherited from these datasets as described in Sections 3.1 and 3.3. The main limitations relate to the absence of point cloud data for buildings built after 2009 and to occasional observed inaccuracies on the footprint outline data of BAG.

The point cloud data is based on a 0.5m grid. The resolution of this grid can result in inaccuracies in the produced geometries.

Additionally, the AHN data does not account for roof overhangs leading to slight misalignment of the roof profile with the actual wall.

It should be noted that, after filtering points related to overhanging trees, the geometry of that area is an approximation based on extending the plane of the roof geometry. Therefore, if below the trees the roof is discontinuous (e.g. at the location of a dormer) this would not be captured by the algorithm.

5.6 Gutter Height Proxy

The Gutter Height Proxy provides an estimation of the gutter height. It is based on the total amount of useable area divided by the building footprint and an estimated floor to ceiling height. The Gutter Height Proxy is used as an input into the building classification where alternative height information is unavailable.

5.6.1 Data Schema

Table 31 describes the contents and the schema of the resulting dataset.

Table 31 Output table schema

Field Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
avg_gutter_height_proxy	Numerical	Estimated gutter height based on the buildings useable area, footprint area and assumed storey height.

5.6.2 Methodology

5.6.2.1 Input

For this analysis, the following datasets were used:

- BAG (Kadaster), August 2019

5.6.2.2 Operations

BAG's information on the *oppervlak* or useable area and the building outlines was input into the calculation. The following steps were undertaken:

1. Aggregate the useable area to building level. The useable area is provided by BAG per vbo_id and multiple vbo_id's can be assigned to a building.

2. Calculate the building's footprint area using the geometry outlines

3. Calculate the average gutter height proxy using the equation below.

$$\frac{\text{useable area}}{\text{footprint area}} \times \text{storey height}$$

   An estimated storey count can be identified by dividing the useable area by the footprint area. Using an assumed storey height, an average gutter height proxy can be calculated.

4. Filter out the results where the estimated storey count is above 15. This assumes that there is no building in the project scope area which has more than 15 storeys.

5.6.3 Data Coverage

The building use analysis has been performed for all the buildings with addresses within the EDB V7 scope, as summarised in Table 32. Only buildings with address can be included in this analysis as it is based on a usable area which is only provided for buildings with occupancy.

The coverage is 99.94% of buildings with addresses within the scope area. There are 99 buildings with addresses missing an average gutter height proxy. This is due to their estimated storey count being larger than 15 storeys. This has been spot checked and identified as an error in BAG's useable area.

Table 32 Output data coverage for the EDB V7 scope.

Field Name	Building Count	Percentage coverage of buildings within the scope area.	Percentage coverage for buildings with addresses within the scope area
avg_gutter_height_proxy	166,002	63%	99.94%

5.6.4 Data Limitations

The average gutter height proxy is only an estimation meant to provide some information where other sources are not available.

The current assumed storey height of 3.31m was calculated using available storey count and gutter height data collected as part of the Drawing Data (see Section 4.3). As the Drawing Data collected specific building types such as terraced buildings and only one assumed storey height was used in this analysis, the correct storey count maybe larger or smaller depending on the building.

The average gutter height proxy only covers buildings with addresses as the useable area is only available for such buildings. The attribute also inherits limitations and inaccuracies from BAG (see Section 3.1.4). It has been observed that the useable area can contains inaccuracies when looking at outliers on Google Streetview (i.e. small shed-like building with a large useable area)

5.7 Maximum Enclosed Rectangle

The “Maximum Enclosed Rectangle” (MER) values capture the dimensions of the largest possible rectangle to fit within a building footprint. The rectangle and its dimensions are expected to provide information about the likely structures used for the building’s construction.

Figure 18 shows a few samples of the identification of the MER (shown in red) within building footprints of different shapes (rectangular, L-shaped and T-shaped).

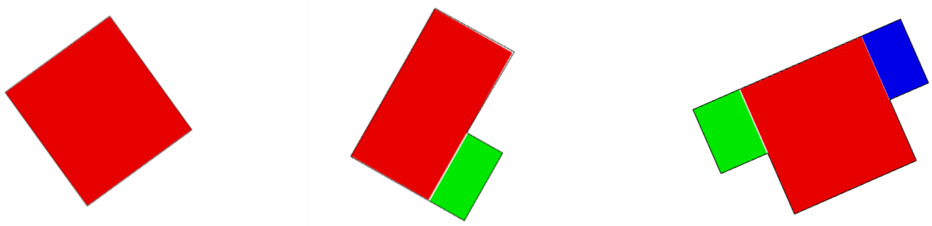


Figure 18 Examples of building footprints and their corresponding MER. The red rectangle shows the largest fitting rectangle.

5.7.1 Data Schema

Table 33 describes the contents and the schema of the dataset.

Table 33 MER table schema

Field Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
mer_1_x	Double	Length of the largest rectangle within the building footprint
mer_1_y	Double	Width of the largest rectangle within the building footprint

5.7.2 Methodology

5.7.2.1 Input data

For this analysis, the following input data is used:

- BAG (Kadaster), August 2019

5.7.2.2 Operations

The algorithm performs a sequence of operations on the building’s footprint outline (polygon) to calculate the dimensions of the MER. The following key steps were undertaken:

- The building footprint (pand) outline is divided into segments
- Rectangles are drawn connecting all division points
- The largest rectangle that is fully included within the polygon outline is identified as the maximum enclosed rectangle (see Figure 19)

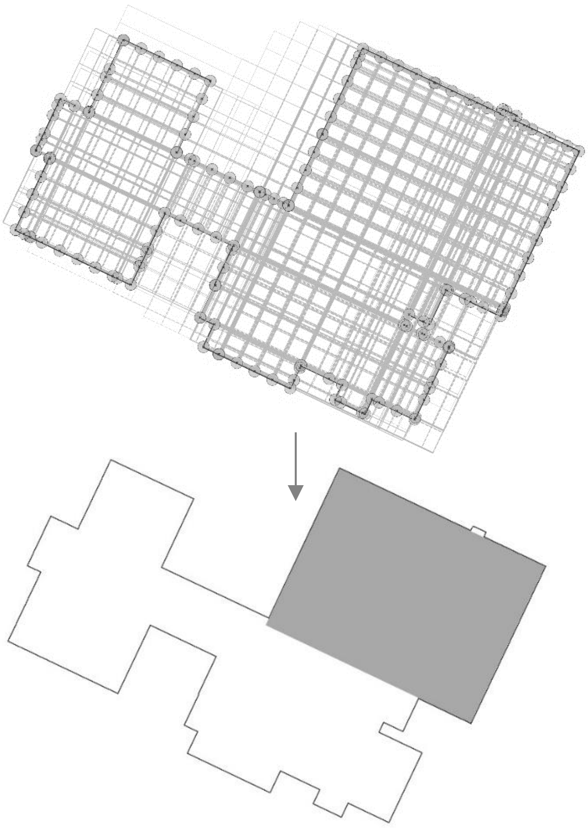


Figure 19 Operation steps undertaken to calculate the dimensions of the Maximum Enclosed Rectangle.

5.7.3 Data Coverage

The areas and dimensions of the MERs have been captured for all 263,399 buildings (panden) in the EDB V7 scope area.

For a small number of cases the algorithm needed to be revised to ignore invalid geometries of the building outlines or to modify the tolerances for large or very small footprints. An example of both cases is shown in Figure 20.

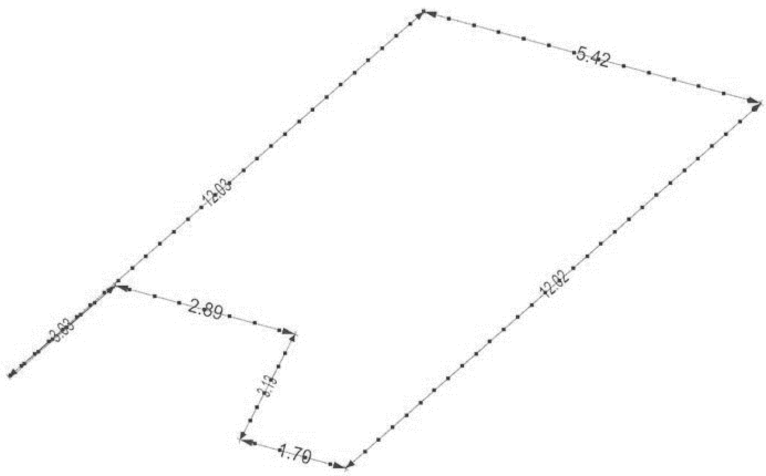


Figure 20 Examples of BAG footprint outlines that required recalibrated tolerances (the dimensions shown are in metres).

5.7.4 Evaluation

Spot checks on the building footprint outlines have been performed visually and were found to be adequately precise in calculating the dimensions of the maximum enclosed rectangle given an input polygon.

5.7.5 Data limitations

The creation of the MER dataset is based on the building outlines from BAG. Some inaccuracies on the outlines of buildings in this dataset have been observed. It should be noted that it has been observed that the building outlines provided by BAG also include building / roof overhangs so may not accurately represent the building footprint.

A full description of the BAG dataset and its limitations can be found in Section 3.1.

The MER dataset has been updated incrementally since EDB V5. This means that only new or changed building footprints are recalculated to avoid running the analysis on all the buildings when majority of buildings have not changed. For EDB V7, 11,540 buildings were either updated or added to the MER dataset with the resulting 251,859 buildings within the scope containing results from the MER analysis run from V6 or V5.

5.8 Population

The population dataset contains information on estimated population per building. The dataset provides a breakdown of the number of people inside, directly outside and runners passing by buildings during the day and during the night.

The methodology was provided by NAM who performed the population analysis for EDB V5 [24]. NAM also provided a number of updated datasets described in Section 5.8.2.1. Arup used the provided methodology and updated the data inputs to calculate the population dataset for EDB V7.

The population dataset is a direct input into the extract.

5.8.1 Data Schema

Table 34 describes the contents and the schema of the population dataset.

Table 34: Population data table format.

Column Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
sum_pop_in_day	Double	Number of people inside the building, during day time
sum_pop_run_day	Double	Number of people running outside at the event of an earthquake that are estimated to be in the at-risk zone from debris falling outside a building, during day time
sum_pop_pas_day	Double	Number of people passing-by or staying present in the at-risk zone from debris falling outside a building, during day time
sum_pop_in_night	Double	Number of people inside the building, during night time
sum_pop_in_day	Double	Number of people running outside at the event of an earthquake that are estimated to be in the at-risk zone from debris falling outside a building, during night time
sum_pop_run_day	Double	Number of people passing-by or staying present in the at-risk zone from debris falling outside a building, during night time

5.8.2 Method

NAM provided the population methodology via a short memo and scripts in the form of FME workbenches which they used to calculate the population in V5 [24]. For V7, NAM's methodology was processed by Arup based on updated data.

This was used to calculate the population dataset for all buildings within the municipalities covered by the scope area.

5.8.2.1 Input Data

For the analysis, several datasets were used. The following describes the input data along with the source and provider.

- NCG Population dataset, 2018, provided by NAM [24]
- Tony Taig Footfall data, October 2015, provided by NAM [24]
- BAG (Kadaster), August 2019
- DUO Basisregister Instellingen, January 2019
- Landelijk Register Kinderopvang, January 2019
- Dataland, September 2019
- CBS Wijken en Buurten, 2019

5.8.3 Data Coverage

Population data was provided for 166,101 buildings. This is all of the buildings with addresses and occupancy (as per BAG) within the EDB V7 scope area.

5.9 Community

The community dataset identifies buildings which are within pre-selected areas (i.e. communites) as defined by the client. These areas are the following:

- Neighbourhood (*buurten*): Bedum, Loppersum, Middelstum, Ten Boer
- District/Ward (*wijken*): Appingedem, Delfzijl
- Municipality (*gementee*): Groningen.

The community dataset is a direct input into the extract.

5.9.1 Data Schema

Table 34 describes the contents and the schema of the community dataset.

Table 35: Population data table format.

Column Name	Type	Description
pand_id	Text	Unique identification code assigned per building by BAG
community	Text	The name of the community a building belongs to

5.9.2 Method

5.9.2.1 Input Data

For the analysis, several datasets were used. The following describes the input data along with the source and provider.

- BAG (Kadaster), August 2019
- CBS Wijken en Buurten, 2019

5.9.2.2 Operations

The following key steps were undertaken:

- The communities as defined in Section 5.9 were selected from the CBS's dataset to extract their boundaries.
- The building's centroids which intersected with the boundaries were then assigned the community boundary it intersected (i.e. spatial join).

5.9.3 Data Coverage

A total of 102,852 buildings were assigned a community value.

Table 36 provides a summary of the results per community.

Table 36 Summary of community results.

Community	Building count V7
Groningen	72,132
Delfzijl	11,121
Appingedam	9,149
Bedum	4,604
Ten Boer	2,465
Loppersum	1,834
Middelstum	1,547
Total	102,852

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A1 RVS Data Schema

This appendix describes the schema of the RVS dataset, described in Section 4.1, and the changes, and the confidence of the collected RVS inspection data.

Table 37 RVS Schema.

Field ID	Field Name	Source	Field Type	Field Description	Comments
001	Address	GIS	Text	House number-Additional House Number Street/Public Space_City Name	
002	Unique Reference	GIS	Text	Address ID_Premise ID	
003	Status	RVS	List	Status of the record in the inspection process.	
004	Street/Public Space	GIS	Text	Street name.	Source: BAG (03/2015)
005	House Number	GIS	Integer	House number.	Source: BAG (03/2015)
006	Additional House Number	GIS	Text	Extra house numbers or letters.	Source: BAG (03/2015)
007	Postcode	GIS	Text	Postal code.	Source: BAG (03/2015)
008	House Number (manual)	RVS	Integer	Corrected house number, as assessed during inspection.	
009	City Name	GIS	Text	Name of village/town in municipalities.	Source: BAG (03/2015)
010	Additional House Number (manual)	RVS	Text	Corrected extra house numbers or letters, as assessed during inspection.	
011	Postcode (manual)	RVS	Text	Corrected postal code, as assessed during inspection.	
012	City Name (manual)	RVS	List	Corrected name of village/town in municipalities, assessed during inspection.	
013	Street/Public Space (manual)	RVS	Text	Corrected street name, as assessed during inspection.	
014	Recommendati on Engineer	RVS	List	Recommendation given by the engineer after review of the inspection report.	
015	Facade Height (YL)	RVS	Double	Height (m) of the left façade.	Pre 06/2014 the average height was recorded, later the maximum height.
016	Facade Length (YL)	RVS	Double	Maximum length (m) of the left façade.	

017	Total Area of Facade(s) (YL)	RVS	Double	Total area of the left façade, including openings.	
018	Certainty (YL)	RVS	Double	Indicates the certainty with which the inspector could provide the data regarding the left façade.	
019	Facade Height (YR)	RVS	Double	Height (m) of the left façade.	Pre 06/2014 the average height was recorded, later the maximum height.
020	Facade Length (YR)	RVS	Double	Maximum length (m) of the right façade.	
021	Total Area of Facade(s) (YR)	RVS	Double	Total area of the right façade, including openings.	
022	Certainty (YR)	RVS	Double	Indicates the certainty with which the inspector could provide the data regarding the right façade.	
023	Facade Height (XB)	RVS	Double	Height (m) of the street facing (front) façade.	Pre 06/2014 the average height was recorded, later the maximum height.
024	Facade Length (XB)	RVS	Double	Maximum length (m) of the rear façade.	
025	Total Area of Facade(s) (XB)	RVS	Double	Total area of the rear façade, including openings.	
026	Certainty (XB)	RVS	Double	Indicates the certainty with which the inspector could provide the data regarding the rear façade.	
027	Facade Height (XF)	RVS	Double	Height (m) of the rear façade.	Pre 06/2014 the average height was recorded, later the maximum height.
028	Facade Length (XF)	RVS	Double	Maximum length (m) of the street facing (front) façade.	
029	Total Area of Facade(s) (XF)	RVS	Double	Total area of the street facing (front) façade, including openings.	
030	Certainty (XF)	RVS	Double	Indicates the certainty with which the inspector could provide the data regarding the street facing (front) façade.	
031	X Front Inspection possible	RVS	List	Indicates the possibility of inspecting the street facing (front) façade.	
032	Openings (YL)	RVS	Integer	Opening percentage of the left façade, considered for the most unfavourable shear-plan at ground floor.	

033	Openings (YR)	RVS	Integer	Opening percentage of the right façade, considered for the most unfavourable shear-plan at ground floor.	
034	Openings (XB)	RVS	Integer	Opening percentage of the rear façade, considered for the most unfavourable shear-plan at ground floor.	
035	Openings (XF)	RVS	Integer	Opening percentage of the street facing (front) façade, considered for the most unfavourable shear-plan at ground floor.	
036	X Front Reason if not possible	RVS	List	Reason why the inspection of the street facing (front) façade was not possible.	
037	Y Right Inspection possible	RVS	List	Indicates the possibility of inspecting the right façade.	
038	Y Right Reason if not possible	RVS	List	Reason why the inspection of the right façade was not possible.	
039	X Back Inspection possible	RVS	List	Indicates the possibility of inspecting the rear façade.	
040	X Back Reason if not possible	RVS	List	Reason why the inspection of the rear façade was not possible.	
041	Y Left Inspection possible	RVS	List	Indicates the possibility of inspecting the left façade.	
042	Y Left Reason if not possible	RVS	List	Reason why the inspection of the left façade was not possible.	
043	Walls out of plane	RVS	List	Indicates the presence of a HRBE 1, assessed during inspection.	
044	Recommendation Wall Out of Plane	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
045	Column crack(s) or slenderness issues	RVS	List	Indicates the presence of a HRBE 2, assessed during inspection.	
046	Recommendation column crack(s) or slenderness issues	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
047	Wall cracks	RVS	List	Indicates the presence of a HRBE 3, assessed during inspection.	

048	Recommendation on wall cracks	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
049	Deflected lintels	RVS	List	Indicates the presence of a HRBE 4, assessed during inspection.	
050	Recommendation on Deflected Lintels	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
051	Wall ties damage	RVS	List	Indicates the presence of a HRBE 12, assessed during inspection.	
052	Recommendation on wall ties	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
053	Balcony(s) present	RVS	List	Indicates the presence of a HRBE 6, assessed during inspection.	
054	Parapet(s) present	RVS	List	Indicates the presence of a HRBE 6, assessed during inspection.	
055	Cantilevered elements present	RVS	List	Indicates the presence of a HRBE 6, assessed during inspection.	
056	Canopy(s) present	RVS	List	Indicates the presence of a HRBE 6, assessed during inspection.	
057	Recommendation on Balcony-Parapets-Canopies	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
058	Slender chimney(s) present	RVS	List	Indicates the presence of a HRBE 7, assessed during inspection.	
059	Recommendation on Slender Chimneys	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
060	Damaged chimney(s) present	RVS	List	Indicates the presence of a HRBE 8, assessed during inspection.	
061	Recommendation on Damaged Chimney(s)	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
062	Unsafe roof cladding	RVS	List	Indicates the presence of a HRBE 9, assessed during inspection.	

063	Recommendation on unsafe roof cladding	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
064	Mortar damage	RVS	List	Indicates the presence of a HRBE 10, assessed during inspection.	
065	Masonry dormer(s) present	RVS	List	Indicates the presence of a HRBE 11, assessed during inspection.	
066	Recommendation on Dormers	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
067	Lack of ties in cavity walls	RVS	List	Likelihood of the presence of adequate wall ties within cavity walls.	Assumption based on building year; a lack of ties is assumed prior 1991.
068	Recommendation on Mortar Damage	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
069	Recommendation on lack of ties in cavity walls	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
070	Other damages	RVS	List	Indicates the presence of a HRBE 13, assessed during inspection.	
071	Other Recommendations	RVS	List	Given the extent of the encountered HRBE a recommendation for further action is given.	
072	Inspection Possible	RVS	List	Indicates if it was possible to carry out the inspection.	
073	Abandonment	RVS	List	Indicates if an object is out of use.	
074	Reason inspection not performed	RVS	List	Reason why the inspection was not possible.	
075	Address ID	GIS	Text	Unique identification code assigned per address by BAG.	Source: BAG (03/2015)
076	Premises ID	GIS	Text	Unique identification code assigned per building by BAG.	Source: BAG (03/2015)
077	Latitude (Y)	GIS	Double	Y coordinate of address point.	Y coordinate in WGS84
078	Longitude (X)	GIS	Double	X coordinate of address point.	X coordinate in WGS84

079	PGA	GIS	Text	PGA value.	Source: Shell P&T PGA (09/2013)
080	Address Use 1	GIS	Text	Main use of the building.	Source: (batch 1-7) DataLand, (batch 8ff.) Source: BAG (03/2015)
081	Address Use 2	GIS	Text	Secondary use of the building.	Source: (batch 1-7) DataLand, (batch 8ff.) Source: BAG (03/2015)
082	BAG Address Use	GIS	Text	Main use of the building.	Source: BAG (03/2015)
083	Status of Premises	GIS	Text	Status of lifecycle of building (i.e. from planned to be demolished).	Source: BAG (03/2015)
084	Building Year	GIS	Integer	Building construction year.	Source: BAG (03/2015)
085	Importance Class	GIS	Text	Classification according to Eurocode 8, depending on the consequences of collapse for human life and the importance of the building for public safety.	
086	Occupancy Class	GIS	Text	Assumed population classification.	Source: Bridgis (March 2013)
087	Address Use 1 (manual)	RVS	List	Corrected main use, as assessed during inspection.	
088	Address Use 2 (manual)	RVS	Text	Corrected secondary use, as assessed during inspection. (obsolete)	
089	Address Use 2 (list)	RVS	List	Corrected secondary use, as assessed during inspection.	
090	BAG Address Use (manual)	RVS	List	Corrected main use, as assessed during inspection.	
091	Status of Premises (manual)	RVS	List	Corrected status of lifecycle of building, as assessed during inspection.	
092	Building Year (manual)	RVS	Integer	Corrected building construction year, as assessed during inspection.	Corrections were rounded at 5 years.
093	Importance Class (manual)	RVS	List	Corrected Eurocode 8 classification, as assessed during inspection.	
094	Occupancy Class (manual)	RVS	List	Corrected population classification, as assessed during inspection.	
095	Main Wall Material	GIS	Text	Main construction material of the outer walls.	Where building year < 1960 = wood and ≥1960 = concrete.

096	Main Wall Material (manual)	RVS	List	Corrected main construction material of the outer walls, as assessed during inspection.	
097	Ground Floor Material	GIS	Text	Construction material of the ground floor.	Where building year < 1960 = wood and ≥1960 = concrete.
098	Ground Floor Material (manual)	RVS	List	Corrected construction material of the ground floor, as assessed during inspection.	
099	Higher Floor Material	GIS	Text	Construction material of upper floors.	Where building year < 1960 = wood and ≥1960 = concrete.
100	Higher Floor Material (manual)	RVS	List	Corrected construction material of the upper floors, as assessed during inspection.	
101	Area Building Footprint	GIS	Double	Area (m2) of the building outline polygon.	Source: BAG (03/2015)
102	Building Height	GIS	Text	Height (m) of the building.	Source: Algemeen Hoogtebestand Nederland (2009)
103	Number of Storeys	GIS	Double	Number of building layers.	Calculated as total building height / 3.31.
104	Area Building Footprint (manual)	RVS	Double	Corrected area (m^2) of the 'main' building outline polygon, as assessed during inspection.	
105	Building Height (manual)	RVS	Text	Corrected height (m) of the building, as assessed during inspection.	Sometimes small height differences compared to the value provided by GIS are registered. There are two possible reasons for this: 1) terraced houses and semi-detached houses are made identical 2) subtraction of chimney heights >1m
106	Number of Storeys (manual)	RVS	Double	Corrected number of building layers, as assessed during inspection.	A building consisting of one storey means a building in which only the ground floor provides habitable space.
107	Horizontal Irregularity	RVS	List	Horizontal or plan irregular structures are those in which seismic response is not only	

				translational but also torsional and is a result of stiffness and/or mass eccentricity in the structure.	
108	Vertical Irregularity	RVS	List	Changes in structural system along the height, changes in story height, setbacks, changes in materials and unanticipated participation of non-structural components.	
109	Storey Height	RVS	Double	Average height (m) of a storey.	
110	Basement present	RVS	List	Indicates the presence of a basement, as assessed during inspection.	
111	Emergency confirmed?	RVS	List	Second opinion by the engineer regarding the emergency situation, after review of the inspection material.	
112	Safety Label	RVS	List	Indicates to what extent the encountered situation poses a possible safety risk for inhabitants and/or the inspector.	
113	Emergency Situation	RVS	List	Indicates if the encountered situation poses an immediate safety risk for the inhabitants and/or the inspector.	
114	Emergency intervention	RVS	List	Planned time frame for emergency interventions.	
115	S-Curve Value In Plane	RVS	Double	Based on information collected during the inspection, this automatically calculated value indicates the in plane seismic fragility of the building.	
116	S-Curve Value Out of Plane	RVS	Double	Based on information collected during the inspection, this automatically calculated value indicates the out of plane seismic fragility of the building.	
117	S-Curve version	RVS	Text	Version of the S-score calculation tool to be used.	Dependent on the available input parameters.
118	Presence Of Adequate Wall Ties	RVS	List	Indicates the presence of a HRBE 5, assessed during inspection.	
119	Joint Structure	RVS	List	Structure with at least one shared wall between building parts.	
120	Foundation Type	RVS	List	Type of foundation.	
121	Structure Certainty	RVS	List	Indicates the certainty with which the inspector could	

				provide the data regarding the structural characteristics.	
122	Roof Type	RVS	List	Roof construction type.	
123	Cavity Walls	RVS	List	Indicates if the façade consists of cavity walls.	
124	Presence of Wall Floor/Roof Ties	RVS	List	Visual observation from the outside of wall/roof ties.	As opposed to HRBE 5, this value is used for the calculation of the S-score.
125	Wall Thickness	RVS	Double	Total wall thickness.	
126	Thickness of Inner Leaf	RVS	Double	Thickness (mm) of the inner leaf of cavity walls.	
127	Thickness of Outer Leaf	RVS	Double	Thickness (mm) of the outer leaf of cavity walls.	
128	Maintenance Level	RVS	List	Impression of the general status of maintenance of the building structure.	
129	Deterioration of masonry	RVS	List	Indicates the extent to which the masonry is considered to be deteriorated.	
130	Deterioration of mortar over joints	RVS	List	Indicates the extent to which the mortar is considered to be deteriorated.	
131	Deterioration of concrete elements	RVS	List	Indicates the extent to which concrete elements are considered to be deteriorated.	
132	Deterioration of metal connections	RVS	List	Indicates the extent to which metal connections are considered to be deteriorated.	
133	Deterioration of wooden elements	RVS	List	Indicates the extent to which wooden elements are considered to be deteriorated.	
134	Solar Cells Present	RVS	List	Indicates the presence of solar cells.	
135	Roof suitable for Solar Cells	RVS	List	Indicates the possibility of installing solar cells on the roof.	
136	Consequence class	GIS	Text	The possible consequences of failure in terms of risk to life, injury, potential economic losses.	Replaces the previously used ‘Importance Class’.
137	Consequence class (manual)	RVS	List	Corrected consequence class as assessed during inspection.	
138	Slender chimney(s) - Height [m]	RVS	Double	Height (m) of the most unfavourable slender chimney.	
139	Slender chimney(s) - Short side [m]	RVS	Double	Short side in cross section (m) of the most unfavourable slender chimney.	

140	Slender chimney(s) - Long side [m]	RVS	Double	Long side in cross section (m) of the most unfavourable slender chimney.	
141	HRBE 7 - Slenderness ratio	RVS	Double	Calculated as chimney height/short side.	
142	Sloped chimney flue - Probability	RVS	List	Indicates the probability of a sloped chimney flue inside the building, based on observations regarding roof shape, location of chimneys and the facades.	
143	Sloped chimney flue - Additional recommendations	RVS	List	Given the probability of a sloped chimney flue inside the building, a recommendation for further action is given.	

Table 38 Changes and the confidence of the collected RVS inspection data.

Field ID	**Field Name**	**Source**	**Confidence**	**Dependencies**	**Date introduced**		**Changes made?**	**Type of change**	**Change description**
001	Address	GIS			released 12/2013		No		
002	Unique Reference	GIS			released 12/2013		No		
003	Status	RVS	n/a		released 12/2013		Yes	Extra / modified choice list items	
004	Street/Public Space	GIS			released 12/2013		No		
005	House Number	GIS			released 12/2013		No		
006	Additional House Number	GIS			released 12/2013		No		
007	Postcode	GIS			released 12/2013		No		
008	House Number (manual)	RVS	Observed		released 12/2013		No		
009	City Name	GIS			released 12/2013		No		
010	Additional House Number (manual)	RVS	Observed		released 12/2013		No		

011	Postcode (manual)	RVS	n/a		released 12/2013		No		
012	City Name (manual)	RVS	Observed		released 12/2013		No		
013	Street/Public Space (manual)	RVS	Observed		released 12/2013		No		
014	Recommendation Engineer	RVS	n/a		released 12/2013		No		
015	Facade Height (YL)	RVS	manual	018	released 19/03/2014		Yes	Inspection instructions	Changed to maximum wall height; in the period before the change (approx. starting June 2014) this field isn't used, since not considered in the S-score calculation v8.
016	Facade Length (YL)	RVS	manual	018	released 11/03/2014		No		
017	Total Area of Facade(s) (YL)	RVS	manual	018	released 12/2013		No		
018	Certainty (YL)	RVS	manual		released 12/2013		No		
019	Facade Height (YR)	RVS	manual	022	released 19/03/2014		Yes	Inspection instructions	Changed to maximum wall height; in the period before the change (approx. starting June 2014) this field isn't used, since not considered in the S-score calculation v8.
020	Facade Length (YR)	RVS	manual	022	released 11/03/2014		No		
021	Total Area of Facade(s) (YR)	RVS	manual	022	released 12/2013		No		
022	Certainty (YR)	RVS	manual		released 12/2013		No		

023	Facade Height (XB)	RVS	manual	026	released 19/03/2014		Yes	Inspection instructions	Changed to maximum wall height; in the period before the change (approx. starting June 2014) this field isn't used, since not considered in the S-score calculation v8.
024	Facade Length (XB)	RVS	manual	026	released 11/03/2014		No		
025	Total Area of Facade(s) (XB)	RVS	manual	026	released 12/2013		No		
026	Certainty (XB)	RVS	manual		released 12/2013		No		
027	Facade Height (XF)	RVS	manual	030	released 19/03/2014		Yes	Inspection instructions	Changed to maximum wall height; in the period before the change (approx. starting June 2014) this field isn't used, since not considered in the S-score calculation v8.
028	Facade Length (XF)	RVS	manual	030	released 11/03/2014		No		
029	Total Area of Facade(s) (XF)	RVS	manual	030	released 12/2013		No		
030	Certainty (XF)	RVS	manual		released 12/2013		No		
031	X Front Inspection possible	RVS	Observed		released 12/2013		No		
032	Openings (YL)	RVS	manual	018	released 12/2013		Yes	Field type	Choice list to number field.
033	Openings (YR)	RVS	manual	022	released 12/2013		Yes	Field type	Choice list to number field.
034	Openings (XB)	RVS	manual	026	released 12/2013		Yes	Field type	Choice list to number field.
035	Openings (XF)	RVS	manual	030	released 12/2013		Yes	Field type	Choice list to number field.

036	X Front Reason if not possible	RVS	Observed		released 12/2013		No		
037	Y Right Inspection possible	RVS	Observed		released 12/2013		No		
038	Y Right Reason if not possible	RVS	Observed		released 12/2013		No		
039	X Back Inspection possible	RVS	Observed		released 12/2013		No		
040	X Back Reason if not possible	RVS	Observed		released 12/2013		No		
041	Y Left Inspection possible	RVS	Observed		released 12/2013		No		
042	Y Left Reason if not possible	RVS	Observed		released 12/2013		No		
043	Walls out of plane	RVS	Observed		released 12/2013		No		
044	Recommendation Wall Out of Plane	RVS	Observed		released 12/2013		No		
045	Column crack(s) or slenderness issues	RVS	Observed		released 12/2013		No		
046	Recommendation column crack(s) or slenderness issues	RVS	Observed		released 12/2013		No		
047	Wall cracks	RVS	Observed		released 12/2013		No		
048	Recommendation wall cracks	RVS	Observed		released 12/2013		No		
049	Deflected lintels	RVS	Observed		released 12/2013		No		
050	Recommendation Deflected Lintels	RVS	Observed		released 12/2013		No		
051	Wall ties damage	RVS	Observed		released 11/03/2014		No		

052	Recommendation wall ties	RVS	Observed		released 12/2013		No		
053	Balcony(s) present	RVS	Observed		released 12/2013		No		
054	Parapet(s) present	RVS	Observed		released 12/2013		No		
055	Cantilevered elements present	RVS	Observed		released 21/05/2014		No		
056	Canopy(s) present	RVS	Observed		released 12/2013		No		
057	Recommendation Balcony-Parapets-Canopies	RVS	Observed		released 12/2013		No		
058	Slender chimney(s) present	RVS	Observed		released 12/2013		Yes	Inspection instructions	Procedure of reporting not slender, not damaged chimney's is changed; first all not slender chimneys were registered as HRBE 8 (reported as follows: Recommendation= 'No action', Presence of HRBE = 'No', but photographs and/or description provided). After the change, these chimneys were reported as HRBE 7
059	Recommendation Slender Chimneys	RVS	Observed		released 12/2013		No		
060	Damaged chimney(s) present	RVS	Observed		released 12/2013		Yes		Procedure of reporting not slender, not damaged chimney's is changed; first all not slender chimneys were registered as HRBE 8

									(reported as follows: Recommendation= 'No action', Presence of HRBE = 'No', but photographs and/or description provided). After the change, these chimneys were reported as HRBE 7
061	Recommendation Damaged Chimney(s)	RVS	Observed		released 12/2013		No		
062	Unsafe roof cladding	RVS	Observed		released 12/2013		No		
063	Recommendation unsafe roof cladding	RVS	Observed		released 12/2013		No		
064	Mortar damage	RVS	Observed		released 11/03/2014		No		
065	Masonry dormer(s) present	RVS	Observed		released 12/2013		No		
066	Recommendation Dormers	RVS	Observed		released 12/2013		No		
067	Lack of ties in cavity walls	RVS	Assumed		released 12/2013		No		
068	Recommendation Mortar Damage	RVS	Observed		released 12/2013		No		
069	Recommendation lack of ties in cavity walls	RVS	Observed		released 12/2013		No		
070	Other damages	RVS	Observed		released 12/2013		No		
071	Other Recommendations	RVS	Observed		released 12/2013		No		
072	Inspection Possible	RVS	Observed		released 12/2013		No		
073	Abandonment	RVS	Observed		released 12/2013		No		

074	Reason inspection not performed	RVS	Observed		released 12/2013		No		
075	Address ID	GIS			released 12/2013		No		
076	Premises ID	GIS			released 12/2013		No		
077	Latitude (Y)	GIS			released 12/2013		No		
078	Longitude (X)	GIS			released 12/2013		No		
079	PGA	GIS			released 12/2013		Yes	Definitio n	From December 2014 till June 29th 2015 (batch 1-6) KNMI values were provided; for earlier records (Loppersum) and batches after June 29th 2015 (batch 7 ff.) Shell values were given.
080	Address Use 1	GIS			released 12/2013		No		
081	Address Use 2	GIS			released 12/2013		No		
082	BAG Address Use	GIS			released 12/2013		No		
083	Status of Premises	GIS			released 12/2013		No		
084	Building Year	GIS			released 12/2013		No		
085	Importance Class	GIS			released 12/2013		No		
086	Occupancy Class	GIS			released 12/2013		No		
087	Address Use 1 (manual)	RVS	Observed		released 11/03/20 14		Yes	Extra/ modified choice list items	
088	Address Use 2 (manual)	RVS	Observed		released 11/03/20 14		Yes	Other	Made obsolete.
089	Address Use 2 (list)	RVS	Observed		released 19/03/20 14		Yes	Other	Made obsolete.

090	BAG Address Use (manual)	RVS	Observed		released 12/2013		No		
091	Status of Premises (manual)	RVS	Observed		released 12/2013		No		
092	Building Year (manual)	RVS	Assumed		released 12/2013		No		
093	Importance Class (manual)	RVS	Observed		released 12/2013		No		
094	Occupancy Class (manual)	RVS	Assumed		released 12/2013		No		
095	Main Wall Material	GIS			released 12/2013		Yes	Other	Value no longer provided.
096	Main Wall Material (manual)	RVS	Assumed		released 12/2013		No		
097	Ground Floor Material	GIS			released 12/2013		Yes	Other	Value no longer provided.
098	Ground Floor Material (manual)	RVS	Assumed		released 12/2013		No		
099	Higher Floor Material	GIS			released 12/2013		Yes	Other	Value no longer provided.
100	Higher Floor Material (manual)	RVS	Assumed		released 12/2013		No		
101	Area Building Footprint	GIS			released 12/2013		No		
102	Building Height	GIS			released 12/2013		No		
103	Number of Storeys	GIS			released 12/2013		No		
104	Area Building Footprint (manual)	RVS	Observed		released 12/2013		Yes	Inspection instructions	Initially the footprint of the whole premise was accounted for; after the change only the footprint of the 'main' building is assessed (implications on S-score).

105	Building Height (manual)	RVS	Observed		released 12/2013		Yes	Inspection instructions	In some cases the building height provided by GIS might include chimneys; the change only needs to be registered if the difference is >1m.
106	Number of Storeys (manual)	RVS	Observed		released 12/2013		Yes	Field type	Double to integer > attic storeys that were previously counted as half storeys are now added as full storeys.
107	Horizontal Irregularity	RVS	Observed		released 12/2013		No		
108	Vertical Irregularity	RVS	Observed		released 12/2013		No		
109	Storey Height	RVS	Observed		released 11/03/2014		No		
110	Basement present	RVS	Assumed		released 11/03/2014		No		
111	Emergency confirmed?	RVS	n/a		released 29/07/2014		No		
112	Safety Label	RVS	Observed		released 04/06/2014		No		
113	Emergency Situation	RVS	Observed		released 11/03/2014		No		
114	Emergency intervention	RVS	Assumed		released 04/06/2014		No		
115	S-Curve Value In Plane	RVS	Assumed		released 12/2013		No		
116	S-Curve Value Out of Plane	RVS	Assumed		released 11/03/2014		No		
117	S-Curve version	RVS	n/a		released 21/05/2014		No		

118	Presence of Adequate Wall Ties	RVS	Assumed		released 12/2013		No		
119	Joint Structure	RVS	Assumed		released 12/2013		Yes	Inspection instructions	All terraced, semi-detached and linked buildings are reported as joint structures. In 2013 it is only set to linked when a solid/joined party wall was expected, since this cannot be observed, a different approach is used
120	Foundation Type	RVS	Assumed		released 12/2013		No		
121	Structure Certainty	RVS	manual		released 12/2013		No		
122	Roof Type	RVS	Assumed		released 12/2013		No		
123	Cavity Walls	RVS	Assumed		released 12/2013		No		
124	Presence of Wall Floor/Roof Ties	RVS	Assumed		released 12/2013		No		
125	Wall Thickness	RVS	Assumed		released 11/03/2014		No		
126	Thickness of Inner Leaf	RVS	Assumed		released 12/2013		No		
127	Thickness of Outer Leaf	RVS	Assumed		released 12/2013		No		
128	Maintenance Level	RVS	Observed		released 12/2013		No		
129	Deterioration of masonry	RVS	Observed		released 12/2013		No		
130	Deterioration of mortar over joints	RVS	Observed		released 12/2013		No		
131	Deterioration of concrete elements	RVS	Observed		released 11/03/2014		No		
132	Deterioration of metal connections	RVS	Observed		released 12/2013		No		

133	Deterioration of wooden elements	RVS	Observed		released 12/2013		No		
134	Solar Cells Present	RVS	Observed		released 12/2013		No		
135	Roof suitable for Solar Cells	RVS	Observed		released 11/03/2014		Yes	Other	Bug fix: if 134 was set to "Yes", it was not possible to fill this field.
136	Consequence class	GIS			released 16/03/2015		No		
137	Consequence class (manual)	RVS	Observed		released 16/03/2015		No		
138	Slender chimney(s) - Height [m]	RVS	Observed		released 16/03/2015		No		
139	Slender chimney(s) - Short side [m]	RVS	Observed		released 16/03/2015		No		
140	Slender chimney(s) - Long side [m]	RVS	Observed		released 16/03/2015		No		
141	HRBE 7 - Slenderness ratio	RVS	Observed		released 16/03/2015		No		
142	Sloped chimney flue - Probability	RVS	Assumed		released 16/03/2015		No		
143	Sloped chimney flue - Additional recommendations	RVS	Assumed		released 16/03/2015		No		

A2 EVS Data Schema

This appendix describes the data schema of the EVS dataset, described in Section 4.2.

Table 39 EVS Schema.

Field ID	Field Name	Field Type	Field Description	Comments
001	Building name (if applicable)	Text	Denomination of public or historic buildings.	
002	Street	Text	Street name.	
003	Street number	Text	House number.	
004	Post code	Text	Postal code.	
005	Town	Text	Name of village/town in municipalities.	
012	BAG object-ID	Text	Unique identification code assigned per building by BAG.	
013	Building year	Text	building construction year.	
014	Address use	Menu	Main use of the building.	
015	Mixed use?	Menu	Building with two or more use functions.	
016	Adjacency	Menu	Spatial relation between separate buildings.	
017	Apartment?	Menu	Building with two or more addresses.	
018	Aggregation	Menu	Connection between immediately adjacent but separate buildings.	
019	Presence of secondary buildings	Text	Number of secondary buildings (Sheds, garages etc.).	
020	Presence of extension	Text	Extension built later than the main building.	
022	Shape in plan	Menu	Building geometry in section.	
024	Presence of basement	Menu	Presence of a building layer which is fully or partially below ground.	
025	Foundation type	Menu	Distinction between shallow and deep foundation.	
026	Foundation system	Menu	Specification of the main foundation system.	
027	Number of storeys above ground, excluding attic	Text	Number of building layers.	A building consisting of one storey means a building in which only the ground floor provides habitable space.
028	Number of habitable attic storeys	Text	Number of habitable building layers which are fully or partially under the roof.	

029	Gutter height - Above ground excluding roof	Text	Average height from ground level to gutter of the main building.	
030	Building height - Above ground to top of roof (excluding chimneys etc)	Text	Average height from ground level to ridge of the roof of the main building.	
031	Ground storey - Inter-storey height	Text	Height of the first storey.	
032	Roof form	Menu	Shape of the main roof.	
034	Roof type	Menu	Predominant construction material of the main roof.	
035	Roof system	Menu	Specification of the structural system of the main roof.	
036	Presence of gable walls	Text	Number of gables on the building.	
037	Presence of dormer	Text	Number of dormers on the building.	
039	Vertical load-bearing system	Menu	Main vertical support system.	
040	Vertical load-bearing material	Menu	Main structural material of vertical support system.	
041	Stability system	Menu	Main lateral stability system.	
042	Stability material	Menu	Main structural material of lateral stability system.	
043	Presence of internal load bearing walls	Text	Number of internal load-bearing walls.	
044	Presence of internal non load-bearing walls	Text	Number of internal non load-bearing walls.	
045	Floor system - Ground floor	Menu	Main structural system of the ground floor.	
047	Floor system - Upper floors	Menu	Main structural system of the higher floors.	

A3 Drawing Data Schema

This appendix describes the data schema of the drawing dataset, described in Section 4.3.

Table 40 Drawing Data Schema.

Field ID	Field Name	Field Type	Field Description	Comments
1000	IntendedUse	Text	Intended Use / address use of the building	List
1015	Construction_Year	Numeric	Construction year	
1025	MultipleAddressBuilding	Boolean	Flag to whether it is a multiple address building	
1040	Architect	Text	Architect noted in the drawings	
1045	StructuralEngineer	Text	Structural engineer noted in the drawings	
1050	ConstructionCompany	Text	Construction company noted in the drawings	
1060	ArchitectType	Text	Architectural type as noted in the drawings	
1061	TypeMain	Text	Architectural type class as defined by the drawing data collection team	
1062	TypeSub1	Text	Architectural type subclass as defined by the drawing data collection team	
3000	Adjacency	Text	Adjacency	List
3010	HorzIrregularities	Text	Horizontal Irregularities / Shape in Plan	List
3015	VerticalIrregularitiess	Text	Vertical Irregularities	List
3200	BuildingUnitHeight	Numeric	Building / Unit Height	
3205	StoreyHeightGroundFloor	Numeric	Storey Height - Ground Floor	
3206	StoreyHeightFirstFloor	Numeric	Storey Height - First Floor	
3207	StoreyHeightAttic	Numeric	Storey Height - Attic	
3208	StoreyHeight_SecondFloor	Numeric	Storey Height – Second Floor	
3209	StoreyHeight_SecondAttic	Numeric	Storey Height – Second Attic	
3210	GutterHeight	Numeric	Gutter Height	
3216	LoadBearingSpaceWidth	Numeric	Building / Unit Width	

3217	NumberofLoadBearingSpaces	Integer	Load-Bearing Space (centre to centre, mm)	
3221	AreaBuildingFootprint	Numeric	Area building footprint	
3225	RoofInclination	Integer	Inclination / Slope of Roof	
3250	NumberofStoreysNonAttic	Integer	Number of Storeys (above ground, excluding attic)	
3255	NumberofStoreysAttic	Integer	Number of Attic storeys	
3265	NumberofBasementLevels	Integer	Number of basement levels	
3405	PresenceofExtensions	Boolean	Presence of Extensions	List
3410	PresenceofBasement	Boolean	Presence of basement	List
3411	PresenceofSouterain	Boolean	Presence of souterrain	List
3412	PresenceofSoftStorey	Boolean	Presence of soft storey	List
3415	PresenceofDormer	Boolean	Presence of dormer	List
3418	Presence_of_Parapet	Boolean	Presence of parapet	
3419	Height_of_Parapet	Numeric	Height of parapet	
3420	PresenceofGableWall	Boolean	Presence of gable wall	List
3421	PresenceofURMChimney	Boolean	Presence of URM Chimney	List
3422	ChimneyHeight	Numeric	Chimney Height	
3423	ChimneyLength	Numeric	Chimney Length	
3424	ChimneyWidth	Numeric	Chimney Width	
3425	RoofShape	Text	Roof Shape	List
3430	RoofType	Text	Roof Type	List
3435	RoofSystem	Text	Roof System	List
3438	Roof_Cladding	Text	Roof Cladding	List
3440	FloorTypeGroundFloor	Text	Floor type - Ground Floor	List
3445	FloorSystemGroundFloor	Text	Floor system - Ground Floor	List
3451	FloorTypeFirstFloor	Text	Floor type - First Floor	List
3452	FloorSystemFirstFloor	Text	Floor system - First Floor	List
3453	FloorTypeSecondFloor	Text	Floor type - Second Floor	List
3454	FloorSystemSecondFloor	Text	Floor system - Second Floor	List
3456	FloorTypeAtticFloor	Text	Floor type - Attic Floor	List
3457	FloorSystemAtticFloor	Text	Floor system - Attic Floor	List

3458	FloorTypeSecondAtticFloor	Text	Floor type - Second Attic Floor	List
3459	FloorSystemSecondAtticFloor	Text	Floor system -Second Attic Floor	List
3465	PresenceofWallTiesFloorRoof	Boolean	Wall ties floor/roof	
3470	FoundationType	Text	Foundation Type	List
3475	FoundationSystem	Text	Foundation System	List
3480	VerticalSupportSystemType	Text	Vertical support system / Gravity Load support system	List
3485	VerticalSupportSystemSystem	Text	Vertical support system / Gravity load support system - Material	List
3490	LateralSupportSystemTypeFrontBack	Text	Lateral support system – Front Back	List
3495	LateralSupportSystemSystemFrontBack	Text	Lateral support system Material – Front Back	List
3500	LateralSupportSystemTypeLeftRight	Text	Lateral support system – Left Right	List
3505	LateralSupportSystemSystemLeftRight	Text	Lateral support system Material – Left Right	List
3510	PresenceofInternalLoadBeauringWalls	Boolean	Presence of internal structural walls	
3515	PresenceofInternalNonLoadBearingWalls	Boolean	Presence of internal non-structural (partition) walls	
3530	WallTypeExteriorWall	Text	Exterior Wall Type	List
3531	WallSystemInnerLeafExteriorWall	Text	Exterior Wall System Inner Leaf	List
3532	WallSystemOuterLeafExteriorWall	Text	Exterior Wall System Outer Leaf	List
3533	WallTypePartyWall	Text	Party Wall Type	List
3534	WallSystemPartyWall	Text	Party Wall System	List
3535	WallTypeInternalWall	Text	Internal Wall Type	List
3536	WallSystemInternalWall	Text	Internal Wall System	List
3550	ExternalWall_InnerLeaf_Thickness	Numeric	Thickness of the inner leaf of the external wall	
3551	ExternalWall_OuterLeaf_Thickness	Numeric	Thickness of the outer leaf of the external wall	
3555	InternalWall_Thickness	Numeric	Internal wall thickness	
3789	LengthInternalWall _GroundFloor_FrontBack	Numeric	Length of the internal walls in front back direction	
3790	LengthInternalWall _GroundFloor_LeftRight	Numeric	Length of the internal walls in left right direction	

3805	GroundLevelOpeningPercFront	Numeric	Ground level opening percentage Front	Calculated based of corresponding redrawn elevation
3810	GroundLevelOpeningPercBack	Numeric	Ground level opening percentage Back	Calculated based of corresponding redrawn elevation
3815	GroundLevelOpeningPercLeft	Numeric	Ground level opening percentage Left	Calculated based of corresponding redrawn elevation
3820	GroundLevelOpeningPercRight	Numeric	Ground level opening percentage Right	Calculated based of corresponding redrawn elevation
4200	TotalWallLength_Longitudinal_External	Numeric	Total wall length of the external wall in longitudinal direction	
4201	TotalWallLength_Transverse_External	Numeric	Total wall length of the external wall in transverse direction	
4210	FloorLoadCombination	Numeric	Floor load combination	
4310	GableHeight	Numeric	Gable Height	
4311	GableLength	Numeric	Gable Length	

A4 Data Collection Schema

This appendix describes the data schema of the data collection dataset, described in Section 4.4.

Table 41 Data collection Schema.

Field ID	Field Name	Field Type	Field Description	Comments
[-]	HR_ParentBuilding	Numeric	Premise ID of parent building, value listed at child	
[-]	HR_Notes	Text	Notes for data collection, general comments	
[-]	HR_Architectural_Comments	Text	Assign type of building: e.g. mill, water tower, church etc.	
[-]	HR_DrawingStatus	Text	Status drawing collection	List
[-]	HR_Structural_Layout	Text	Assigned Structural Layout. Further information refer to EDB	List
3000	Adjacency	Text	Spatial relationship between neighbouring buildings	List
1015	Construction_Year	Numeric	Year of construction	
[-]	HR_Upgrade_Present	Boolean	Indicates the presence of building upgrades	
[-]	HR_Upgrade_Year	Numeric	Indication of year of execution	
[-]	HR_Renovation_Present	Boolean	Indicates the presence of building renovations	
[-]	HR_Renovation_Year	Numeric	Indication of year of execution	
[-]	HR_Number_of_storeys_NonAttic	Numeric	Number of Non Attic storeys (H&R definition)	
[-]	HR_Number_of_Storeys_Attic	Numeric	Number of Attic storeys (H&R definition)	
3451	FloorType_FirstFloor	Text	Floor Type First Floor	List
3452	FloorSystem_FirstFloor	Text	Floor System First Floor	List
3456	FloorType_AtticFloor	Text	Floor Type Attic Floor	List
3457	FloorSystem_AtticFloor	Text	Floor System Attic Floor	List
3530	WallType_ExteriorWall	Text	Exterior wall type	List
3532	WallSystem_OuterLeaf_ExteriorWall	Text	Exterior wall system outer leaf	List
3531	WallSystem_InnerLeaf_ExteriorWall	Text	Exterior wall system inner leaf	List

[-]	Horizontal_Irregularity	Text	Structural horizontal irregularities of the building.	List
[-]	Vertical_Irregularities	Text	Structural vertical irregularities of the building.	List
3490	LateralSupportType_FrontBack	Text	Lateral support type in front back direction	List
3495	3495_LateralSupportSystem_FrontBack	Text	Lateral support system material in front back direction	List
3500	3500_LateralSupportType_LeftRight	Text	Lateral support type	List
3505	3505_LateralSupportSystem_LeftRight	Text	Lateral support system Material	List
[-]	HR_Groundlevel_MaxOpeningPerc	Numeric	Maximum opening percentage Ground Floor	
[-]	HR_Groundlevel_Estimated_MaxOpeningPerc	Numeric	Estimated maximum opening percentage Ground Floor	
[-]	Dx_Type_LateralLoadResistingSystem	Text	Type of lateral load resisting system in Dx direction	List
[-]	Dx_Material_LateralLoadResistingSystem	Text	Material of lateral load resisting system in Dx direction	List
[-]	Dy_Type_LateralLoadResistingSystem	Text	Type of lateral load resisting system in Dy direction	List
[-]	Dy_Material_LateralLoadResistingSystem	Text	Material of lateral load resisting system in Dy direction	List
[-]	GEM_ExteriorWall	Text	GEM code for exterior wall	List
[-]	GEM_FloorSystem	Text	Code for GEM floor system	List
[-]	HR_TorsionFlag	Boolean	Indication of torsion	
[-]	HR_DriveInFlag	Boolean	indication of Drive In building	

A5 Desktop Visual Inspections Schema

This appendix describes the data schema of the visual inspections dataset, described in Section 334.5.

Table 42 Desktop Visual Inspections Schema.

Description (Field)	Type of Field	Prefill	High level Definition	Source
Visual validation possible	List		Indicates whether it was possible to perform the visual the inspection.	Google Streetview or Horus photograph
Original building type	List		Type of building at construction.	Google Streetview or Horus photograph
Original building subtype	List		Sub-type of building at construction.	Google Streetview or Horus photograph
Current building Use (population)	List		Current use of the building.	Google Streetview or Horus photograph
Additional use in the same building (population)	List		Secondary use of the building.	Google Streetview or Horus photograph
Construction year	Number	Y	Building construction year.	Google Streetview or Horus photograph
Multiple address building	List	Y	Presence of more than one address in the building.	Google Streetview or Horus photograph
Adjacency	List		High level spatial relationship of the building to other buildings.	All
Touching other buildings	Number	Y	Number of buildings touching the inspected building.	All
Touching same building	Number	Y	Number of buildings touching the inspected building which appear the same as the inspected building.	Google Streetview or Horus photograph
Shape in Plan	List		Shape of building footprint.	BAGviewer
Presence of soft storey	List		Presence of a soft storey	Google Streetview or Horus photograph
Presence of souterrain	List		Presence of a split basement level	Google Streetview or Horus photograph
Number of storeys (above ground, excluding attic)	Number		Number of building layers above ground, excluding attic.	Google Streetview or Horus photograph
Number of attic storeys	Number		Number of building layers within the roof.	Google Streetview or Horus photograph
Number of chimneys	Number		Number of chimneys.	Google Streetview or Horus photograph

Number of gable wall	Number		Number of gable walls, defined as triangular wall area delimited by inclined roof planes.	Google Streetview or Horus photograph
Number of parapets (trapgevels)	Number		Number of parapets.	Google Streetview or Horus photograph
Dominant roof shape	List		Dominant roof shape of the building.	Google Streetview or Horus photograph
Dominant roof shape in plan	List		Dominant roof shape of the building in plan.	All
Secondary roof shape	List		Secondary roof shape of the building.	Google Streetview or Horus photograph
Secondary roof shape in plan	List		Secondary roof shape of the building in plan.	All
Exterior material	List		Main façade material.	Google Streetview or Horus photograph
Presence of secondary buildings	Number		Presence of additional buildings on the plot.	All
Related BAG ID of secondary buildings	Number		building ID of related, non-touching buildings. Multiple values/field possible.	BAGviewer

A6 PDBC Mapping Tables

The following table describes the translation between the values of the various project datasets used and the assigned GEM tag per building attribute as described in Section 5.1.

Table 43 GEM tag per building attribute: Dx / Dy: Material of lateral load resisting system

Dx / Dy: Material of lateral load resisting system Position 1 & 3					
GEM Tag	**Description**	**EVS Mapping**	**Data Collection / Drawing Data Mapping**	**RVS Mapping**	**Visual Inspection Mapping**
MAT99	Unknown material				
MATO	Other material	Mixed	Other	Other	Other
MUR	Masonry unreinforced				URM/RC
					URM/Steel
			URM	URM	URM
		Brick (clay)	URM - Clay Bricks		Masonry_B_temp
		Brick (calcium silicate)	URM - Calcium Silicate Bricks		Masonry_A_temp
		Brick (mixed)			
		Other URM (e.g. stone)	URM-Other		
			Aereated concrete		
			Clay brickwork		
			Calcium silicate brickwork		
			Concrete brickwork	Limestone	
			Calcium silicate elements glued		
					URM/Wood
CR	Concrete, reinforced		Concrete (type unknown)	Concrete	RC
CR+CIP	Concrete, reinforced - Cast-in-place concrete	Concrete (in situ)	Concrete		
			Concrete insitu		
CR+PC	Concrete reinforced –	Concrete (precast)	Precast concrete		

	precast concrete		Concrete precast		
S	Steel	Steel	Steel	Steel	Steel
			Steel frame		
W	Wood	Timber	Timber	Wood	Wood
			Timber frame		

Table 44 GEM tag per building attribute: Dx / Dy: Type of lateral load resisting system

Dx / Dy: Type of lateral load resisting system Position 2 & 4					
GEM Tag	**Description**	**EVS Mapping**	**Data Collection / Drawing Data Mapping**	**RVS Mapping**	**Visual Inspection Mapping**
L99	Unknown lateral load-resisting system				
LO	Other lateral load-resisting system		Other		
LDUAL	Dual frame-wall system				
LFBR	Braced frame	Braced frame	Bracings		
LFM	Moment frame	Moment frame	Moment Frame		
LH	Hybrid lateral load-resisting system		Hybrid (HR) (LH20)		
			Hybrid (HR) (LH5)		
			Hybrid (HR) (LH4)		
			Hybrid (HR) (LH2)		URM/Wood
			Hybrid (HR) (LH3)		URM/Steel
			Hybrid (HR) (LH10)		
		Hybrid	Hybrid (HR) (LH1)		URM/RC
			Mixed		
LN	No lateral load-resisting system		No lateral load resisting system		
LPB	Post and beam		Post and beam		
		Shear walls (distributed)	Shear Walls		
		Shear walls (core)	Central core		

Table 45 GEM tag per building attribute: exterior wall material

Exterior Wall Material Position 5					
GEM Tag	**Description**	**EVS Mapping**	**Data Collection / Drawing Data Mapping**	**RVS Mapping**	**Visual Inspection Mapping**
EW99	Unknown material of exterior wall		Unknown		
EW	Exterior walls		Clay brickwork		
			Timber frame		
			URM		Masonry_A_temp
			Aereated concrete		
			Calcium silicate elements glued		
			Concrete (type unknown)		
			Concrete brickwork		
			Concrete precast		
			Masonry-Timber Frame		
			Masonry - TypeA		
			Steel		
			Steel frame		
			Wood		
			Other		
			Composed		
		Cavity walls	Cavity	TRUE	
			Calcium silicate brickwork		
EWN	No outer leaf cavity walls	Columns	Single Layer		
		Mixed	Solid		
		Solid walls		FALSE	

Table 46 GEM tag per building attribute: material of floor system. Note that the Visual Inspection dataset did not include a floor system parameter.

Floor system material Position 6				
GEM Tag	**Description**	**EVS Mapping**	**Data Collection / Drawing Data Mapping**	**RVS Mapping**
F99	Unknown floor material			
FN	No elevated floor material (single storey)		Not present	
FC	Concrete floor		Concrete	Concrete
			Beam and block	
		Concrete in situ 1 way	Concrete in situ 1 way	
		Concrete in situ 2 way	Concrete in situ 2 way	
		Concrete precast (Hollowcore), With topping	Precast concrete (Hollowcore) 1 way, With topping	
			Precast concrete (Hollowcore) 2 way, With topping	
		Concrete precast (Hollowcore), No topping	Precast concrete floor system (Dato)	
			Precast concrete ribbed slab floor	
			Precast concrete (Hollowcore) 1 way, No topping	
			Precast concrete (Hollowcore) 2 way, No topping	
			Precast concrete 1 way with lateral beam	
			Precast concrete 2 way	
			Composite (steel + concrete)	
			Concrete in situ 1 way with lateral beam	
		Other (NeHoBo, Kwaaitaal, Manta etc.)	Kwaaitaal	
FM	Masonry floor		Nehobo	
			One of: NeHoBo, Kwaaitaal, Manta, PS-isolatievloer	
			Masonry	
FME	Metal floor		Steel	Steel

FO	Floor material, other		Mixed	
		Other	Other	Other
FW	Wooden floor	Timber joists and boards	Timber joists and boards	
		Timber joists and planks	Timber joists and planks	
			Timber joist floor	
			Timber sandwich panel	
			Timber	Timber

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Job number 229746

Arup bv
Postal address:
PO Box 57145
1040 BA Amsterdam
Visitor address:
Naritaweg 118
1043 CA Amsterdam
The Netherlands
www.arup.com

ARUP

Contents

Acronyms

A list of acronyms (abbreviations) used in the document can be found in Table 1.

Table 1: List of acronyms used in the report.

Acronym	**Description**
AHN	*Actueel Hoogtebestand Nederland* Height map of the Netherlands
BAG	*Basisregistratie Adressen en Gebouwen* Key registry of Addresses and Buildings
CVW	Centrum Veilig Wonen
EDB	Exposure Database
EVS	Extended Visual Screening
GEM	Global Earthquake Model
JBG	*Jorritsma Bouw Groningen*
H&R	Hazard & Risk
MLSS	Material and Lateral Support System
NAM	*Nederlands Aardolie Maatschappij*
RVS	Rapid Visual Screening
TA	Ticinum Aerospace

Definition

Building: The building is the unit at which the Exposure Database V7 is analysed. A building in EDB V7 is the equivalent of the object type *pand* in the *Basisregistratie Adressen en Gebouwen* (BAG) [21]. According to BAG, a *pand* is the smallest functional and structural independent unit that is directly and permanently connected to the earth which can be accessed and locked. Note that a *pand* in BAG corresponds to one unit in a terraced row of houses and to a full apartment block within modern construction. Examples of *panden*, each with a unique id as assigned by BAG, can be found in Figure 1.

Further information on BAG including *pand* and other object types can be found in V7 Data Documentation [16].

Figure 1: Examples of *panden* as identified by BAG which represent a building in EDB V7.

1 Executive Summary

An exposure model is a key component of seismic risk assessment and is combined with hazard and vulnerability models to estimate seismic outcomes over a region or portfolio. An exposure model should identify the location of buildings (and possibly other structures), assign building typologies that are linked to fragility and vulnerability models, and quantify the number of occupants expected at different times of the day. Depending on the end use of the risk assessment model and the data available, exposure can be aggregated at different geographical scales (often corresponding to civic administrative units or postal codes), on a building-by-building basis or by typologies.

Arup has developed a building-by-building exposure model for the Groningen Earthquake region, according to specifications defined by NAM’s H&R consultants. The exposure model is shared in the form of an exposure database (EDB) containing the typology classification and the number of occupants for all 263,399 buildings within a 5 km buffer around the Groningen gas field outline defined by NAM.

The deployment of the EDB required the combination of numerous building data sources, including physical and desktop inspection data, open and licensed data related to the geometry, function and building construction attributes per building and additional processed building data derived by Arup and by third parties subcontracted by NAM.

To verify data consistency, a clear taxonomy system was implemented, based on the system and definitions developed by the Global Earthquake Model foundation [16].

The inspection data from various inspection sources was mapped into the EDB V7 taxonomy, so it could be consistently processed. In total, inspection data for 25,608 buildings were processed, according to which structural typologies could be assigned.

For buildings without available inspection data at the time of delivery, a methodical structural system inference system was applied, according to which the construction year, together with other known properties for each building, defined the likelihood of different structural systems. Earlier versions of the EDB structural system inference systems were predominantly based on expert judgement inferences. Since EDB V6, Arup has implemented a Bayesian inference update methodology which automatically updates the earlier judgement-based inferences, given evidence from available inspection data for a specific typology.

To perform the assignment of structural typologies to each building in the region, an intermediate classification to five geometric layout classes, further subdivided into nine structural layout classes has been performed. Considering the numerous combinations possible between important structural parameters, the final count of unique structural systems assigned in EDB V7 was 495.

Given the different sources that can define different elements of the EDB V7 structural systems, Arup has included in the exposure database several source flags that can be used to help identify the basis of each building's structural system attributes.

2 Introduction

Arup BV (Arup) was appointed by Nederlands Aardolie Maatschappij (NAM) to produce the Exposure Database (EDB). The EDB is used by NAM in their Groningen Earthquake Structural Upgrading (GESU) Hazard & Risk (H&R) model [18].

Arup has developed a building-by-building exposure model for the Groningen region of study. The model is shared in the form of an EDB extract containing the building typology classifications and the number of occupants for all buildings within a 5 km buffer around the Groningen gas field.

The EDB is updated periodically in line with key dates provided by NAM. The development of each EDB is a collaboration between Arup's GESU risk team and NAM's consultants Pinho and Crowley, with feedback from the client (NAM). This is the sixth update of the EDB and supersedes the earlier versions:

- V0 (July 2014) [10],
- V1 (March 2015) [13],
- V2 (September 2015) [6],
- V3 (March 2016) [7],
- V5 (September 2017) [9] and
- V6 (February 2019) [14].

This report documents the process of creating EDB V7 [15] dated December 2019 for its use in NAM's H&R model V7. Further supporting documentation around the data used and created for EDB V7 is provided in the EDB V7 Data Documentation [16].

2.1 Key Features

The regional exposure model has been the product of a continuous development improvement of the regional H&R model, since 2014. The most relevant features introduced over the years are:

1. The EDB makes use of the Global Earthquake Model (GEM) taxonomy [16], which is a model used to consistently characterise buildings globally. This makes the defined typologies directly readable and interpretable using the definitions of GEM, except for a limited number of region-specific elements that have been added.
2. Arup's regional exposure model presents the built environment in a detailed building-by-building resolution.
3. EDB V7 incorporates the latest available inspection data from various sources and level of details at the time of delivery.

4. Arup developed a methodology based on Bayes' probabilistic inference theorem, allowing initial typology inferences to be modified according to inspection from the field.
5. Efforts in the consistent algorithmic calculation of geometric properties allow for the definition of classes of relative geometric uniformity and allows the assessment of the geometric similarity between each building in the EDB and the index fragility and vulnerability models that are linked to them.
6. The EDB model has been assessed by an expert panel appointed by NAM [29].

3 Deliverable Description

3.1 EDB V7 Deliverables

EDB V7 Extract [15]

The EDB V7 extract contains building attribute information arranged per building including the assigned structural systems and population data. It includes this information for all buildings within the H&R scope area. The overview of the format and contents of the extract can be found in Table 2 of section 3.2

Structural System Reference Extract

The Structural System reference extract provides the index string referred to in the EDB V7 Extract based on the Global Earthquake Model (GEM) [20] taxonomy labels. A description of the taxonomy elements is provided in the EDB V7 Data Documentation [16]. This extract also provides a summary of the expected number of buildings per taxonomy string based on the sum of individual buildings probabilities in the EDB V7 Extract.

3.2 Extract Overviews

The tables below provide the descriptions of the fields which are included in the EDB V7 deliverables. More information on the data sources listed, including information on limitations related to versioning and availability of updates on certain key data sources, can be found in a dedicated data documentation [16].

Table 2: Exposure Database V7 Extract schema

EDB V7 Extract					
Category Name	**Field Name**	**Data Type**	**Description**	**Data source**	**Reference date**
Building ID	BAG_BUILDING_ID	Text	The identification number provided by the Basisregistratie Adressen en Gebouwen (BAG) for *panden* (buildings).	BAG	2019
Building coordinates (RD New, EPSG:28992)	POINT_X	Double	The x-coordinate of the building centroid in the Rijksdriehoekstelsel coordinate system.		
	POINT_Y	Double	The y-coordinate of the building centroid in the Rijksdriehoekstelsel coordinate system.		
Building use	MAIN_USE	Text	The main building function. For buildings with multiple functions, the one corresponding to the largest floor area is listed. Further information can be found in Data Documentation [16].	Arup	2019
	SECONDARY_USE	Text	The second building function. For buildings with multiple functions, the one corresponding to the second largest floor area is listed. Further information can be found in Data Documentation [16].		
Structural Systems	SYSTEM_n	Text	Most likely structural systems as per assigned probability where 'n' denotes ranking. Further information on this field can be found in Section 4.2.3.	Arup	2019
	S_PROBABILITY_n	Double	Assigned probability for a building to belong to a Structural System n, based on currently available information, where 'n' denotes ranking.		
	SSY_SOURCE_FLAG	Text	Indicator of how the building has been assigned a structural system.		
	HBET_SOURCE_FLAG	Integer	Indicator of how the building has been assigned a range of storey count.		
	IR_SOURCE_FLAG	Integer	Indicator of how the building has been assigned an irregularity.		
Upgrading Flag	UPGRADING_FLAG	Integer	A flag indicating whether a building has been upgraded or built in compliance with	NAM/ CVW	2019

			NEN-NPR 9998. This is flagged using the Strengthened List and Nieuwbouwregeling List identified as 1 and 2 respectively [5].		
Community	COMMUNITY	Text	The community which the building belongs to as part of the calculation of *Maatschappelijk Veiligheidsrisico*.	Arup	2019
Population	SUM_POP_IN_NIGHT	Double	An estimate of the occupancy (number of people) during the night, inside the building.	NAM[1]	2019
	SUM_POP_IN_DAY	Double	An estimate of the occupancy (number of people) during the day, inside the building.		
	SUM_POP_OUT_PAS_DAY	Double	An estimate of the number of people passing by or present in the at-risk zone from debris falling outside a building during daytime.		
	SUM_POP_OUT_PAS_NIGHT	Double	An estimate of the number of people passing by or present in the at-risk zone from debris falling outside a building during night time.		
	SUM_POP_RUNNERS_OUT_DAY	Double	An estimate of the number of people running outside in the event of an earthquake that are estimated to be in the at-risk zone from debris falling outside a building during daytime.		
	SUM_POP_RUNNERS_OUT_NIGHT	Double	An estimate of the number of people running outside in the event of an earthquake that are estimated to be in the at-risk zone from debris falling outside a building during night time.		

The Structural System Reference Extract has the schema shown in Table 3.

[1] The population methodology had been developed by NAM and processed by Arup.

Table 3: Structural Systems Reference Extract Schema.

Structural System Reference Extract		
Field Name	**Data Type**	**Description**
GEM_TAXONOMY	Text	The structural system as described using the GEM taxonomy. See Section 4.6.
SUM_OF_PROBABILITIES	Double	Expected number of buildings per taxonomy string based on the sum of individual building's probabilities.

3.3 Scope Area

The area of interest for the H&R analysis is based on the Groningen gas field outline. The extract boundary for the EDB V7 is a 5 km buffer around the gas field outline as seen in the risk assessment boundary in Figure 2. The resulting number of buildings included in EDB V7 is 263,399. This includes both populated and unpopulated buildings.

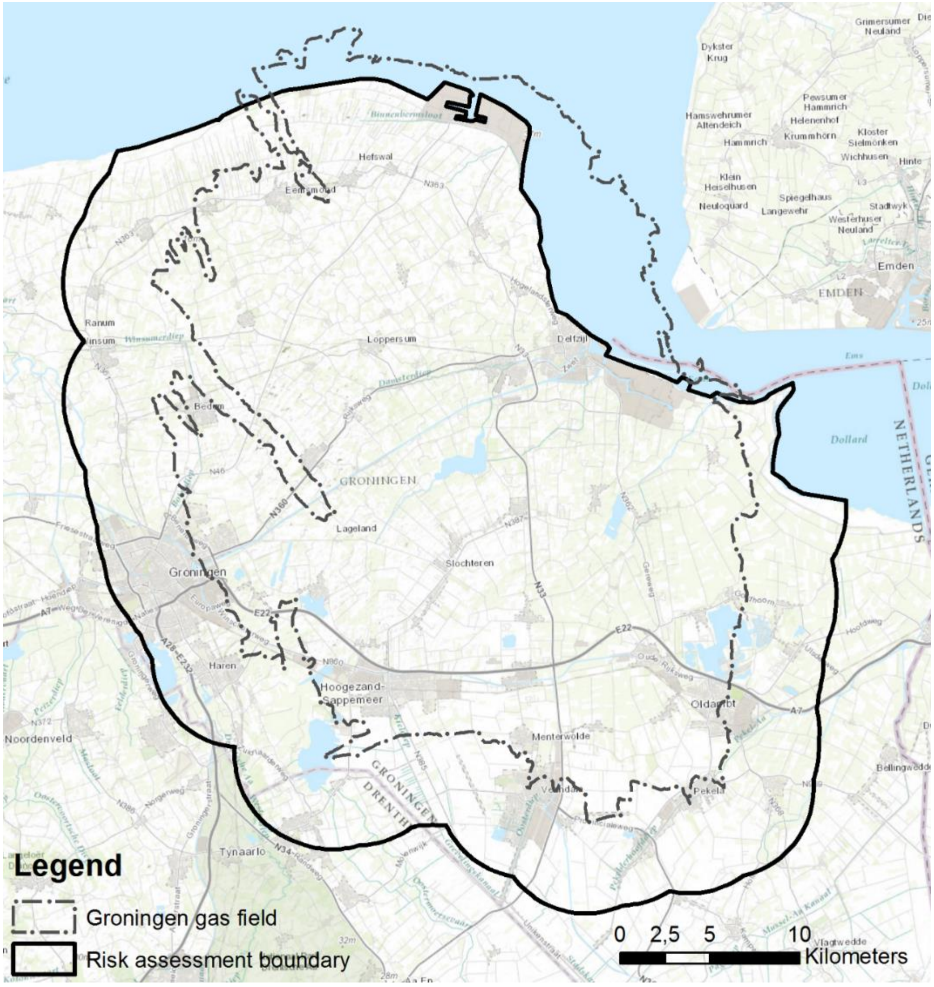


Figure 2 Risk assessment boundary used for the Exposure Database scope.

4 Building Classification

4.1 Introduction

The structural system fields of Table 2, listed separately below in Table 5, are the data fields assigning a structural typology to each building.

Table 4 Structural system fields in EDB V7

Category Name	Field Name	Data Type	Description
Structural Systems	SYSTEM_n	Text	Most likely structural systems as per assigned probability where 'n' denotes ranking.
	S_PROBABILITY_n	Double	Corresponding probability to the structural systems where 'n' denotes ranking.
	SSY_SOURCE_FLAG	Text	Indicator of how the building has been assigned a structural system.
	HBET_SOURCE_FLAG	Integer	Indicator of how the building has been assigned a range of storey count.
	IR_SOURCE_FLAG	Integer	Indicator of how the building has been assigned an irregularity.

For buildings where the data evidence is not yet conclusive the probability is distributed to multiple possible structural systems.

4.1.1 Structural System Taxonomy

Buildings in the regional EDB model are characterised by structural typologies consisting of nine attributes. These are the following:

1) main geometric class,
2) structural material in the primary direction,
3) lateral load resisting system in the primary direction,
4) structural material in the secondary direction,
5) lateral load resisting system in the secondary direction,
6) presence of external walls,
7) floor material,
8) number of floors and
9) irregularity class.

The element names for each attribute were defined according to the GEM building taxonomy [14]. Eight custom taxonomy additions (which are not currently described in GEM) were created for elements related to regional characteristics or important features highlighted by the H&R model [18]. The full list of GEM tags used in EDB V7 is listed in Table 6, with the custom additions shown in italics.

Table 5 Directory of GEM fields used in EDB V7

Geometric Layout - Position 1		
element_type	element_subtype	element_code[2]
Geometric layout class: S	n/a	*S*
Geometric layout class: U	n/a	*U*
Geometric layout class: B	n/a	*B*
Geometric layout class: W	n/a	*W*
Geometric layout class: W	*Aggregate*	*WA*
Geometric layout class: W	*Continuous*	*WC*
Geometric layout class: T	n/a	*T*
Dx / Dy: Material of lateral load resisting system - Positions 2 and 4		
element_type	element_subtype	element_code
Unknown material	n/a	MAT99
Other material	n/a	MATO
Concrete, reinforced	n/a	CR
Concrete, reinforced	Precast concrete	CR+PC
Concrete, reinforced	Cast-in-place concrete	CR+CIP
Masonry, unreinforced	n/a	MUR
Wood	n/a	W
Steel	n/a	S
Dx / Dy: Type of lateral load resisting system - Positions 3 and 5		
element_type	element_subtype	element_code
Unknown lateral load-resisting system	n/a	L99
Other lateral-load resisting system	n/a	LO
No lateral load-resisting system	n/a	LN
Dual frame-wall system	n/a	LDUAL
Post and beam	n/a	LPB
Moment frame	n/a	LFM
Braced frame	n/a	LFBR
Hybrid lateral load-resisting system	n/a	LH

[2] Elements written in Italic letters are custom additions to the GEM taxonomy tags, for important characteristics that are currently not included in the standard GEM taxonomy (e.g. FM, OPL, DIB).

Wall	n/a	LWAL
Exterior wall material – Position 6		
element_type	element_subtype	element_code
Unknown material of exterior wall	n/a	EW99
Exterior walls	n/a	EW
No exterior wall or outer leaf	n/a	*EWN*
Material of floor system – Position 7		
element_type	element_subtype	element_code
Floor material, unknown	n/a	F99
Floor material, other	n/a	FO
No elevated or suspended floor material	n/a	FN
Concrete floor	n/a	FC
Masonry floor	n/a	FM
Wooden floor	n/a	FW
Metal Floor	n/a	FME
Range of number of storeys above ground – Position 8		
element_type	element_subtype	element_code
Unknown number of storeys	n/a	H99
Range of the building's number of storeys above ground: 1 to 2 storeys.	n/a	HBET:2;1[3]
Range of the number of storeys above ground: 3 to 20 storeys.	n/a	HBET:20;3
Range of the number of storeys above ground: 1 to 20 storeys.	n/a	HBET:20;1
Irregularity – Position 9		
element_type	element_subtype	element_code
Unknown structural irregularity	n/a	IR99
Vertical Structural Irregularity - Primary	*Opening percentage on ground floor larger than the defined threshold (see Section 4.5.2).*	*IRVP+OPL*
Vertical Structural Irregularity - Primary	*Building with a garage on the ground floor (Drive-in).*	*IRVP+DIB*
Vertical Structural Irregularity - Primary	Soft Storey	IRVP+SOS

The GEM taxonomy is based on the concatenation of respective GEM textual tags in a defined order. This concatenation is referred to in EDB as a Structural System. For example, a building belonging to the Structural System U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IR99 has

[3] The original comma which is separating the numbers of the HBET range according to GEM has been replaced by a semi-colon (;) to facilitate the parsing of csv files.

1) U – Main geometric layout class of U (unit),
2) MUR – Unreinforced masonry as the main structural material in the primary direction,
3) LWAL – Wall-based lateral load resisting system in the primary direction,
4) MUR - Unreinforced masonry as the main structural material in the secondary direction,
5) LN – No lateral load resisting system in the secondary direction,
6) EW – Presence of external walls,
7) FC – Reinforced concrete floors,
8) HBET:2;1 – 1 or 2 floors,
9) IR99 – Unknown irregularity class.

The Material & Lateral Support System (MLSS) class contains only fields 2 to 7. The MLSS in this example is MUR/LWAL/MUR/LN/EW/FC.

No single data source provides the nine required structural elements within a Structural System for all buildings in the study. The methodology for inferring the missing structural typologies is described below.

4.1.2 Definitions

A glossary of the most recurrent terms of the classification process is presented below:

Geometric Layout: A classification of buildings according to their main geometric features (characteristic width and length of the maximum enclosed rectangle within a building's footprint and the average gutter height). Further insight on the calculation of these parameters can be found in the accompanying EDB V7 Data Documentation [16].

Structural Layouts: Further classification of the Geometric Layout classes into sub-classes, based on additional features, like the number of addresses, the presence of a residential function and the relation of a building to nearby buildings.

Inference Rule: The inference of unknown properties given a set of known properties. In EDB V7 the unknown property is the structural system of each building while the known properties are Structural Layout, building year and height where applicable.

Material & Lateral Support System (MLSS): A subset of the Structural Systems covering six out of the nine features. The MLSS includes structural material in the primary and secondary direction, lateral load resisting system in the primary and secondary direction, presence of external walls and floor material.

Structural System: An assembly of nine structurally important features as listed in Section 4.1.1 which together describe a structural typology, as defined by the Hazard and Risk Model [18].

4.1.3 Classification Overview

The process of classifying the building stock into Structural Systems involves multiple steps. This process can be divided into six key classification steps:

1) Geometric Layout
2) Structural Layout
3) MLSS
4) Storey Count class
5) Irregularity class
6) Final Structural System assignment

An overview of these steps is provided in the workflow diagram in Figure 3. Each of these classification steps are described in further detail in the subsequent sections.

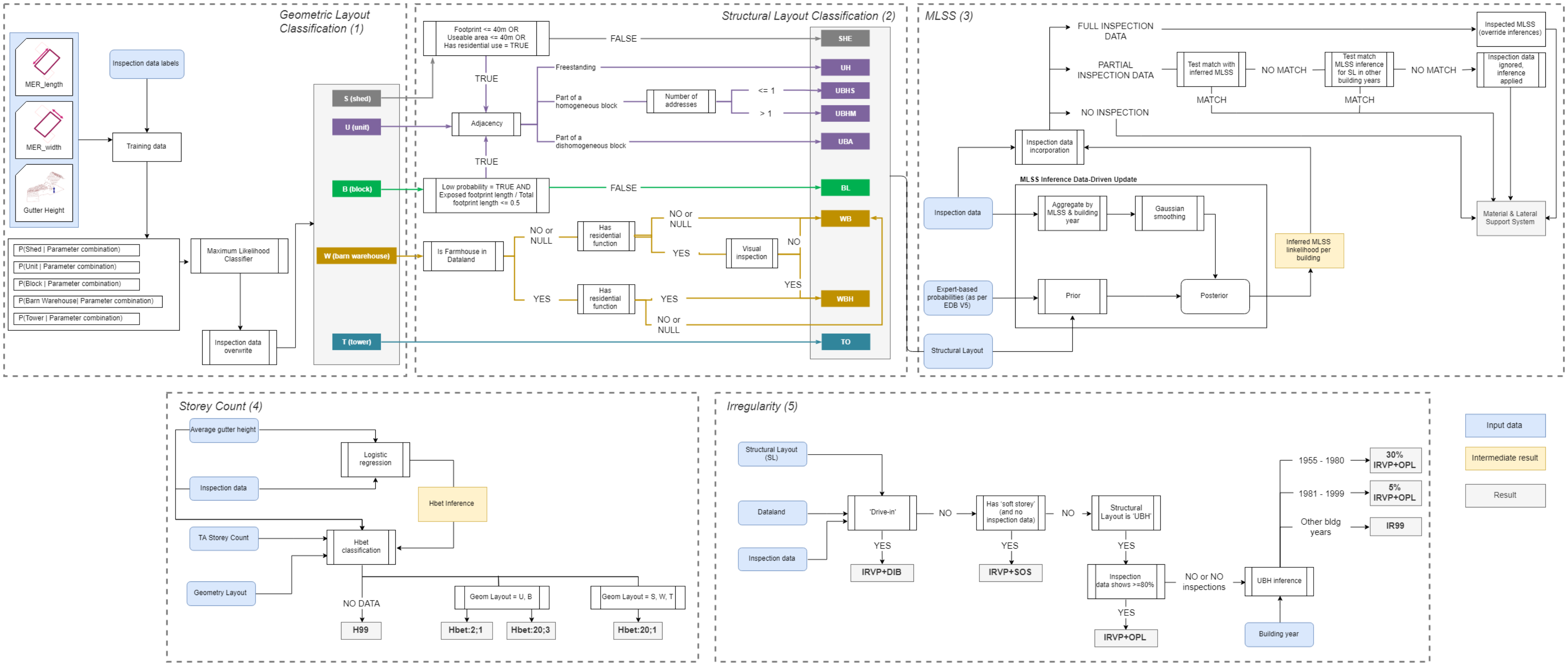


Figure 3 Structural System classification flowchart. Presented in higher resolution in Appendix A4

4.1.4 Data Inputs

The datasets required for the building classification are categorised into the following categories:

- **Source data**

  External datasets maintained by external parties such as government departments.

- **Project data**

  Datasets which have been produced within the project such as inspection datasets and desktop studies produced by Arup and other consultants.

- **Processed data**

  Datasets which Arup has generated utilizing source datasets, project specific assumptions and analysis to provide information that is not directly available from external sources.

All data inputs are detailed in EDB V7 Data Documentation [16]. Table 6 to Table 8 give an overview of the data sources categories.

Table 6 Source data used in the Structural System Classification

Data provider	**Reference date**	**Dataset**	**Description**
Dataland	2018	Architectural and Building descriptions	Real estate information on addresses.
Kadaster	2019	Basisregistratie Adressen en Gebouwen (BAG)	Dutch building and address registry providing data on registered buildings and addresses including geometries and building year.
Ticinum Aerospace (TA)	2019	Storey Count	Dataset containing values on the storey count of buildings calculated based on automatic Streetview image processing. Data as delivered on September 2019 [23]

Table 7 Project Data used in the Structural System Classification

Data provider	Reference date	Dataset	Description
Arup	2019	Drawing Data	Building information collected from drawings for several studies including apartments, terraced and semi-detached buildings.
Arup	2019	Data Collection	Building information collected from drawings, focusing on parameters relevant to assessing seismic risk at a regional scale.
Arup / CVW	2015	Extended Visual Screening (EVS)	Building information collected through visual inspections of the building interior and exterior for structural assessment. For EDB V7, only data collected up to 2015 has been included.
Arup	2015	Rapid Visual Screening (RVS)	Building information collected from the public realm (i.e. without entering the property) as part of a preliminary building assessment process.
Jorritsma Bouw Groningen (JBG)	2017	Desktop Visual Inspections	Building information collected from visual inspections by external NAM subcontractor JBG.

Table 8 Processed Data used in the Structural System Classification

Analysis dataset	Description
Adjacency	Parameters describing the relationship of a building to adjacent and nearby buildings.
Average Gutter Height	Parameter estimating the average height of a building's walls based on AHN and BAG.
Building Use	Parameters describing the main and secondary function of a building based on BAG.
Exposed Footprint Length	Parameter calculating the percentage of a building footprint that is not shared with an adjacent building.
Footprint Area	Calculation of the area enclosed in the building footprints, as provided in BAG.
Gutter height proxy	Parameter estimating the gutter height of a building given the usable area and the footprint area of a building.
Maximum Enclosed Rectangle (MER)	Parameters describing the dimensions of the largest rectangle which can fit within a building footprint.
Usable Area	Parameter describing the amount of area that is registered in a function according to BAG.
Project Data Building Characterisation	Provides the MLSS of buildings with project data in the convention used for EDB V7.

4.1.5 Evaluation method and terminology

To quantitatively assess the accuracy of applied models in the process of the building classification the following measures are introduced.

4.1.5.1 Confusion matrix and overall accuracy

The confusion matrix shows labelled ground truth data against the classification result derived by the model. An example of a confusion matrix is shown in Figure 4. The diagonal cells (shaded in gray) contain the number of correctly identified items. The sum of correctly identified items divided by the sum of all items results in the overall accuracy of the model. In the example below, the overall accuracy would be 29 / 32 = 0.91.

Labelled \ Predicted	Shed	Unit	Tower
Shed	11	2	0
Unit	1	8	0
Tower	0	0	10

Predicted

Figure 4: Example of a confusion matrix

4.1.5.2 Precision, recall and F1

The overall accuracy does not give any information on the performance of specific classes. Especially for imbalanced classification problems where specific categories represent most data points, it is possible that some classes perform very well and therefore bias the overall accuracy. Therefore, it is important to derive more class specific information to have a full overview of the classification performance.

Precision describes the proportion of samples that have been classified correctly (true positive) to the sum of samples that have been classified correctly and samples that have been classified to the same class but do not belong to the class (false positive). The measure gives the likelihood of a given class being classified correctly i.e. if a building has been classified as shed, what is the likelihood that is classified correctly? It is a good measure when the cost of false positive (i.e. assigning a building to shed when it is a unit) is high. In the example of the confusion matrix this would be: 11/12 = 0.92

$$\text{Precision} = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

Labelled \ Predicted	Shed	Unit	Tower	Total
Shed	11	2	0	13
Unit	1	8	0	9
Tower	0	0	10	10
Total	12	10	10	32

Predicted

Precision
Recall

Figure 5: Confusion matrix with calculation of precision and recall parameters

Recall describes the proportion of samples that have been classified correctly (true-positive) to the sum of samples that have been classified correctly and samples that have been classified as a different class but belong to the class in question (false-negatives). The measure describes the ability of a model to identify all relevant cases within a dataset and answers the question as to whether there are any cases that have not been captured; i.e. how much of all sheds are classified correctly? Recall is a good measure when there is a high cost in false negatives (i.e. assigning a building to unit when it should have been shed). In the example of the confusion matrix this would be: 11/13 = 0.85

$$\text{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negative}$$

F1-score takes into consideration both precision and recall. The metric is a harmonic mean of precision and recall and should be used if precision and recall are of equal importance for the problem statement.

$$F1\ Score = 2 * \frac{Precision * Recall}{Precision + Recall}$$

4.2 Geometric Layout

All buildings in EDB V7 are classified into five Geometric Layout classes:

1) S (shed)
2) U (unit)
3) B (block)
4) W (barn_warehouse)
5) T (tower)

This distinction is made because certain Structural Systems are more likely to exist within certain dimensional boundaries such as:

- Buildings close to the dimensions of a residential unit, as captured by the Geometric Layout U, are more likely to have an unreinforced masonry shear wall-based structural system.
- Long-span frame systems are more likely to be found in buildings of larger width and length captured by the Geometric Layout W.
- Tall buildings with a height of more than six storeys are captured by the Geometric Layout T as they are typically combined with special structural system considerations related to their height.
- Buildings that are lower than T but have a length much larger than their width are captured by the Geometric Layout B and are much more likely to have a short span system repetition on one axis.
- Buildings with dimensions much lower than U are captured by the Geometric Layout S.

The Geometric Layout also provides structural context for the MLSS which can have a different structural meaning in different Geometric Layouts.

4.2.1 Data

The geometric layout classification process requires geometric parameters and a learning / training dataset which informs the classification model.

4.2.1.1 Input building data

Below lists the parameters and their sources which were used in the process. Further information on the parameters can be found in the Data Documentation [16].

- Length of maximum enclosed rectangle, Arup
- Width of maximum enclosed rectangle, Arup
- Gutter height, Arup

- Gutter height proxy, Arup
- Storey count, TA

There are three height related parameters to ensure as many buildings could be assigned a gutter height related parameter. In the case where the gutter height data was not available, or a gutter height is deemed unreliable (i.e. when lower than 2.0m), the gutter height proxy was used to estimate the height of the building. If the gutter height proxy was not available as the data only covered buildings with addresses, the storey count, combined with an average height of a storey was used to calculate an estimated gutter height.

4.2.1.2 Training and validation data

A dataset was collected to train the geometric layout classifier. These buildings were visually assessed to be characteristic of the five classes described in Section 4.2. A total of 363 buildings were part of the training dataset which was predominately defined in EDB V5 [8].

The training dataset aimed for a fair coverage of the Geometric Layouts with regards to the geometric variability and recurrence of the geometric characteristics. The average dimensions of Geometric Layouts, resulting from buildings in the Learning Set, are shown in Figure 6.

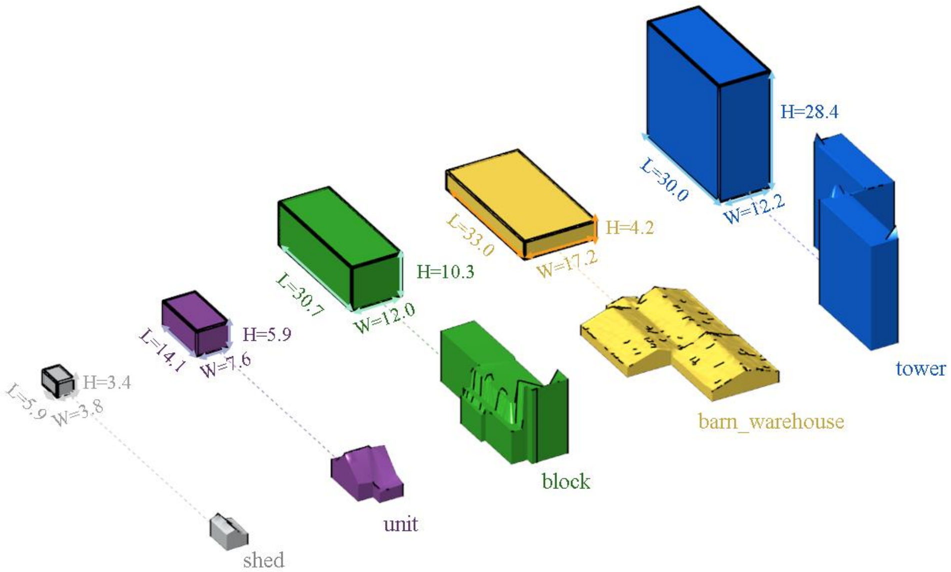


Figure 6 Average learning set dimensions (length-L, width-W and gutter height-H) for each Geometric Layout

A validation dataset was set up based on various data collection efforts around ad-hoc studies such as for terraced buildings or farmhouses. This resulted in 3,893 buildings available for validation for V7. Figure 7 shows the distribution of samples across the geometric layout classes for both training and validation data. The number of samples per class is imbalanced due to several reasons:

- The building profile of the region indicates that there are a low number of towers which is reflected in the low number of tower samples.

- Studies with data collection that contribute to the validation dataset were predominately around terraced buildings; i.e. U (units) and W (barn warehouse) buildings. This results in more samples in the two classes. Sheds have limited validation samples as they are considered low risk and not studied specifically.

As there are limited amounts of inspected data, the data available was taken as is rather than removing for equal distribution of class samples.

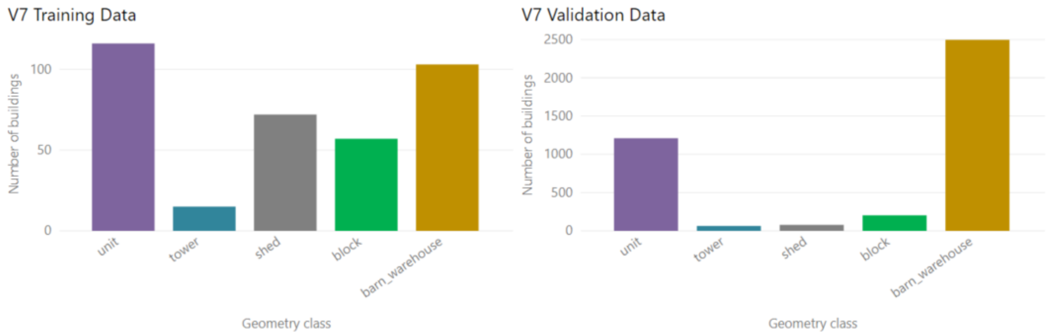


Figure 7 Training and validation data for geometric layout classification

4.2.2 Methodology and implementation

The Geometric Layout classification methodology used in EDB V7 is based on the methodology developed since EDB V5 [9]. The following provides an overview of the process including a diagram shown in Figure 10. Further information on the development and rationale can be found in EDB V5 and V6 documentation [9][14].

Step 1 – Geometric parameter selection and data transformation

The building geometric parameters were selected based on expert judgement. Statistical testing on variable importance using recursive feature selection and random forest confirmed the importance of the variables for the classification of geometry. The selected parameters include:

- Length of maximum enclosed rectangle
- Width of maximum enclosed rectangle
- Average gutter height.

The selected geometric parameters show an asymmetric, positive skewed distribution in the learning set. The application of a logarithmic transformation on the geometric parameter values addresses the skewed distribution and reduces the effect of extreme values.

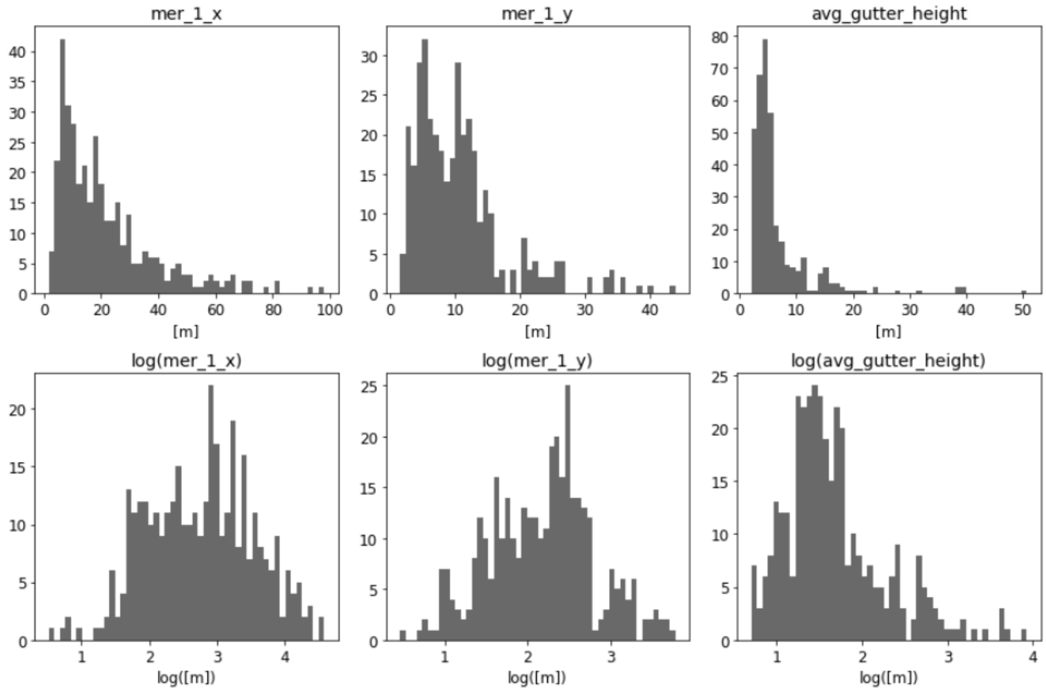


Figure 8: Histogram of selected geometric parameters and log-transformation.

Step 2 – **Model development**

The buildings within the training set and their respective geometric parameters are used to fit a lognormal probability density function for each of the three geometric parameters and for each Geometric Layout. The resulting probability density functions are shown in Figure 9.

As expected the T (tower) Geometric Layout becomes the most likely for gutter heights greater than 18 metres, while buildings that are long in both x and y direction are more likely to be classified in the W (barn_warehouse) Geometric layout.

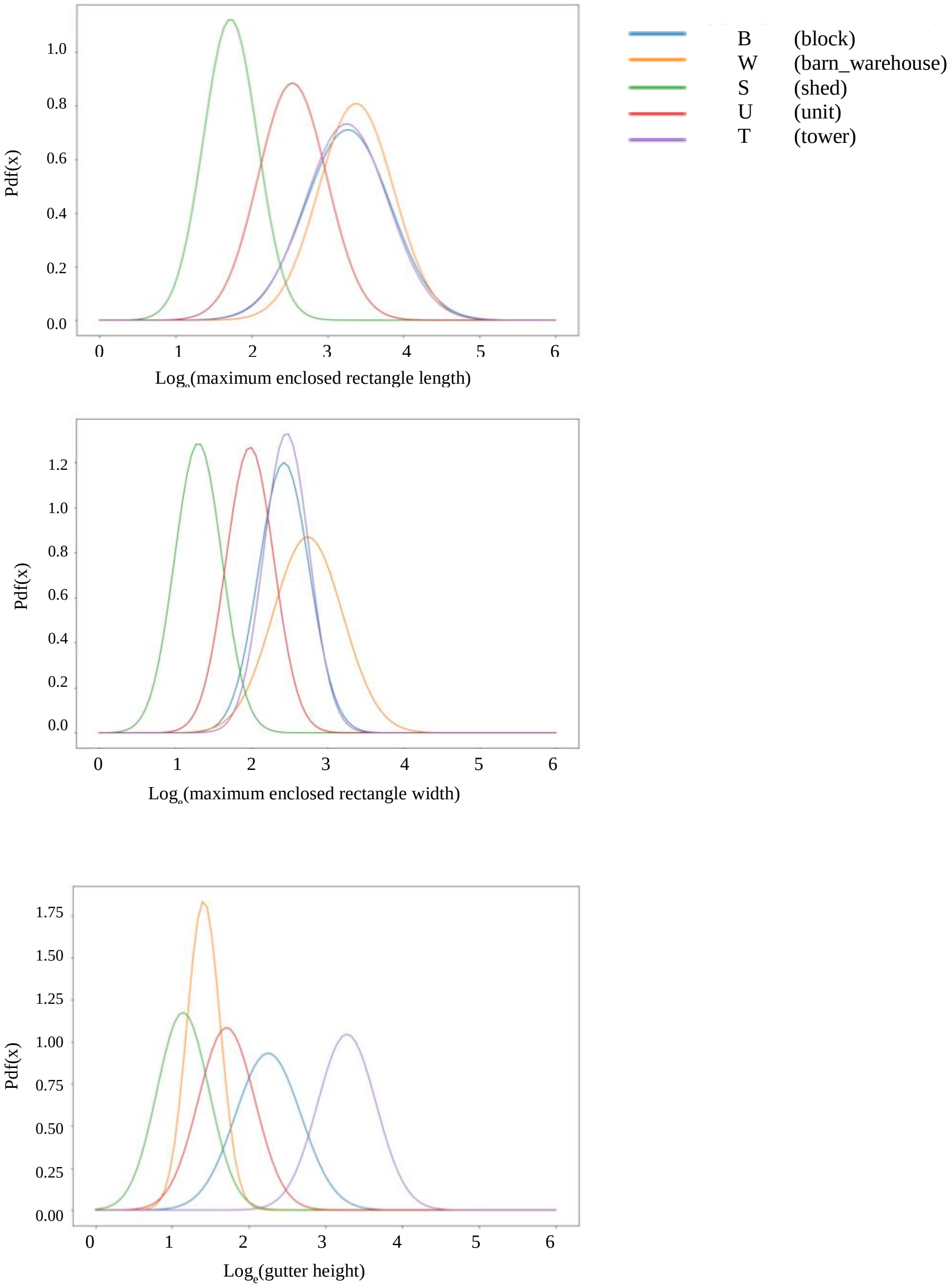


Figure 9: Probability density function per geometrical layout based on the length (top plot), width (middle) and gutter height (bottom) of the maximum enclosed rectangle.

Step 3 − Assignment of Geometric Layout

Each building is classified to the most likely Geometric Layout based on its geometric parameters and the corresponding likelihood of each Geometric Layout.

Based on these probability density functions the rest of the building stock is subsequently classified. This is done by multiplying the likelihood of a building having each of its three geometric parameters and sorting the resultant probability products.

Step 4 – **Inspection Overwrite**

A selection of inspection data which provided Geometry Layout was used to overwrite the classification.

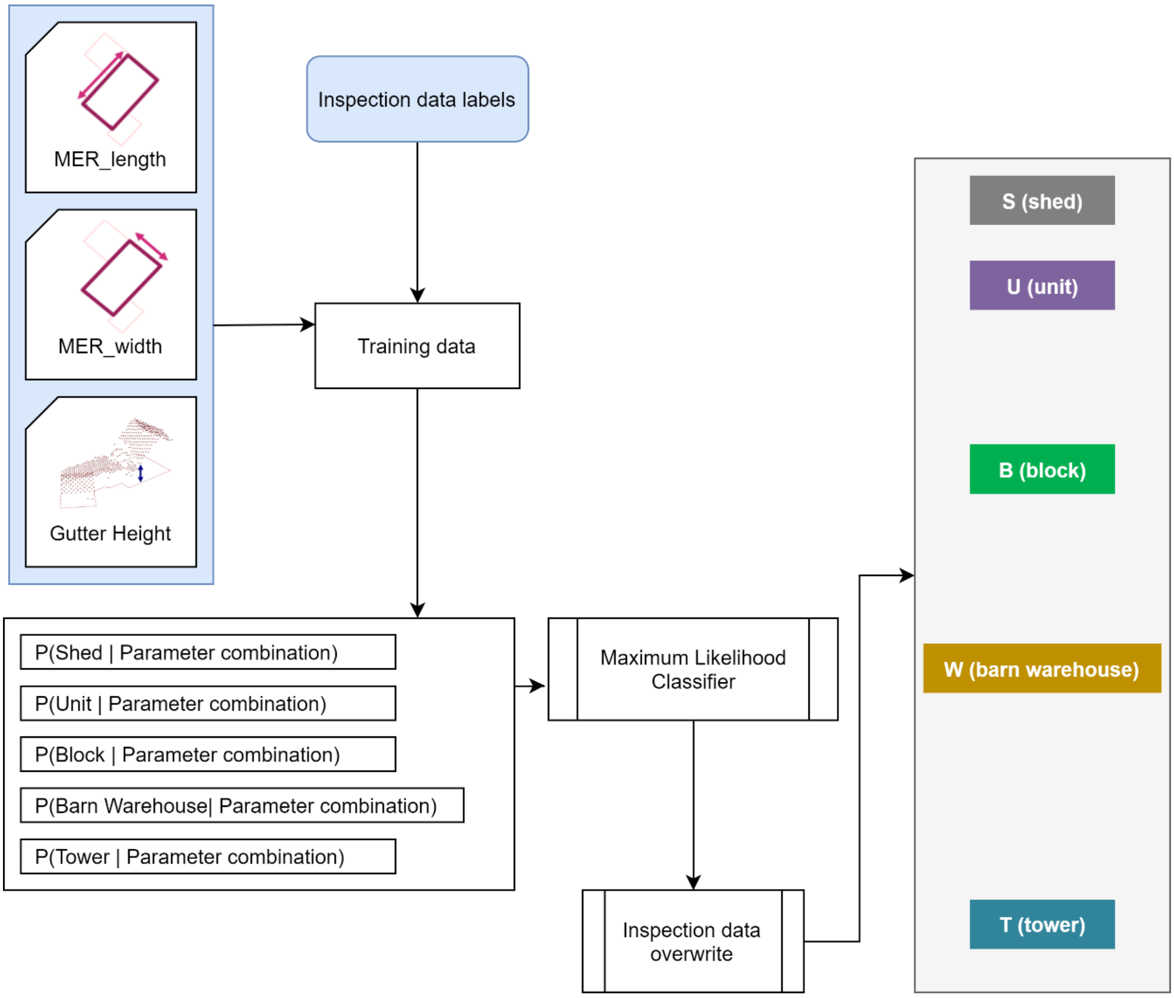


Figure 10 Geometric Layout classification flowchart

4.2.3 Result and evaluation

4.2.3.1 Result

The geometric layout classification results can be found in Figure 11 and Table 9. The results indicate that a high percentage of buildings within the region are small with the top two class being Units and Sheds.

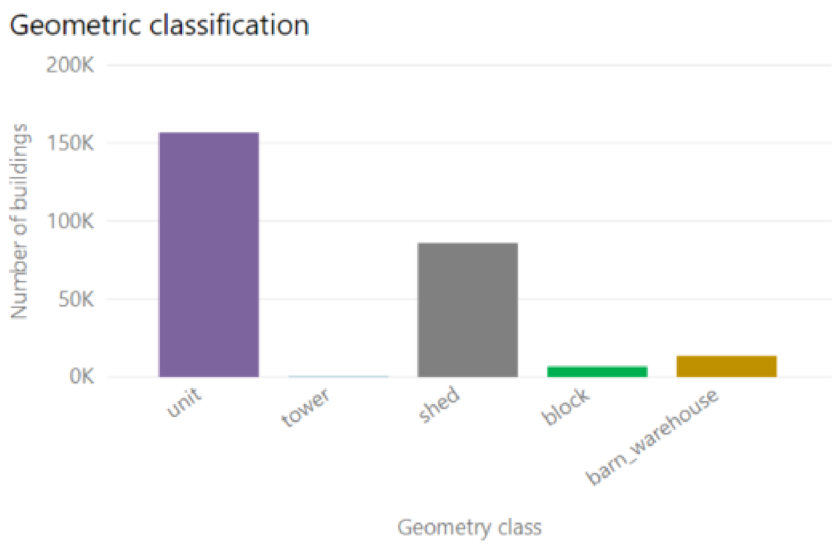


Figure 11 Total counts of buildings per Geometry Class

Table 9 Address count and building count per Geometry Class

	Total Address Count	**Percentage of Total Address Count**	**Total Building Count**	**Percentage of Total Building Count**
Barn / warehouse	18,531	7.35%	13,536	5.14%
Block	54,796	21.75%	6,749	2.56%
Shed	11,762	4.67%	85,970	32.64%
Tower	9,385	3.72%	327	0.12%
Unit	157,115	62.35%	156,817	59.54%
Total	251,589	100.0%	263,399	100.0%

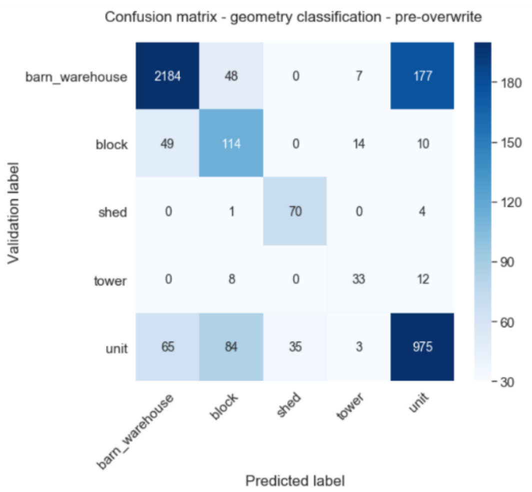
4.2.3.2 Evaluation

A total of 3893 labels were used to evaluate the model results. The evaluation is split into pre and post inspection overwrite to allow for the model (pre-overwrite) and the final Geometry Layout results (post-overwrite) to be assessed. The model achieves an overall accuracy of 86.7 % with the inspection overwrite increasing this to 88.5 %.

Figure 12 and 13 provides the confusion matrix and related evaluation measures for each of the Geometry Layouts. Sheds and barn_warehouses perform relatively well with precision and recall above 0.90 indicating that most of the cases have been classified correctly. The probability that barn_warehouses and sheds have been classified incorrectly is below 10%. Blocks and towers do not perform as well with F1-values around 0.5 to 0.6. This is likely due to the blocks and towers having very similar probability density curves for two of the classifying geometry parameters as seen in Figure 9.

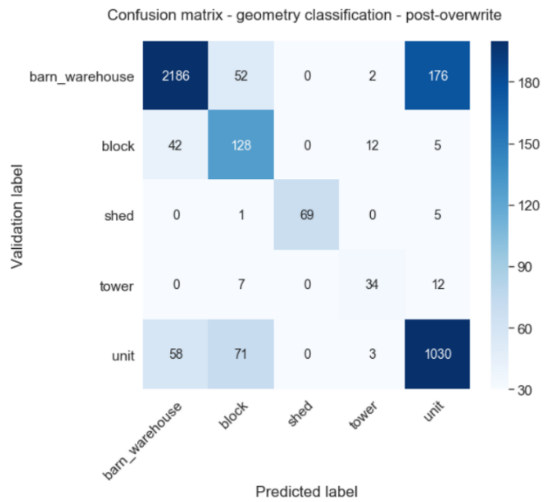
It needs to be highlighted that the distribution of samples throughout the classes is biased. The overall result is thereby highly impacted by classes with a high number of validation samples.

Pre-overwrite



	Precision	Recall	F1	Samples
Barn warehouse	0.95	0.90	0.93	2416
Block	0.45	0.61	0.52	187
Shed	0.67	0.93	0.78	75
Tower	0.58	0.62	0.60	53
Unit	0.83	0.84	0.83	1162
			Total	3893
			Overall Accuracy	86.7 %

Post-overwrite



	Precision	Recall	F1	Samples
Barn warehouse	0.96	0.90	0.93	2416
Block	0.49	0.68	0.57	187
Shed	1.00	0.92	0.96	75
Tower	0.67	0.64	0.65	53
Unit	0.84	0.89	0.86	1162
			Total	3893
			Overall Accuracy	88.5 %

Figure 12 and Figure 13: Confusion matrix and evaluation measures for the Geometry Layout results for both pre-inspection overwrite and post-inspection overwrite.

4.3 Structural Layout

The Geometric Layouts are classified into subclasses based on a set of expert-based rules to form a decision tree. These subclasses are referred to as Structural Layouts as they were defined to align with the Structural Systems assignment. This includes U (units) which are further classified to help distinguish whether the buildings are within a terrace row or detached and W (barn warehouses) to distinguish between warehouse or barn like structures and barn with house buildings.

In V7, the following Structural Layouts were identified:

1) SHE (shed)
2) UH (house)
3) UBHS (block unit single address)
4) UBHM (block unit multiple address)
5) UBA (block unit aggregate)
6) BL (block)
7) WB (barn warehouse)
8) WBH (barn with house)
9) TO (tower)

4.3.1 Data

4.3.1.1 Input data

The following lists the datasets and their sources which were used in the Structural Layout classification. Further information on the parameters can be found in the Data Documentation [16].

- Geometry Layout, Arup (see Section 4.2)
- Adjacency, Arup
- Exposed Footprint Length, Arup
- Building Use, Arup
- Basisregistratie Adressen en Gebouwen (BAG), Kadaster
- WBH inspection data, Arup

The WBH inspection data was collected as part of the development of EDB V7 to provide better confidence in the assignment of WBH buildings and the identification of sub-types. The collection was predominately through desktop studies including visual inspections using Google Streetview.

4.3.1.2 Validation data

A validation dataset was set up based on data collection efforts for validation and was not used in inspection overwrites. This resulted in 882 buildings available for validation for V7.

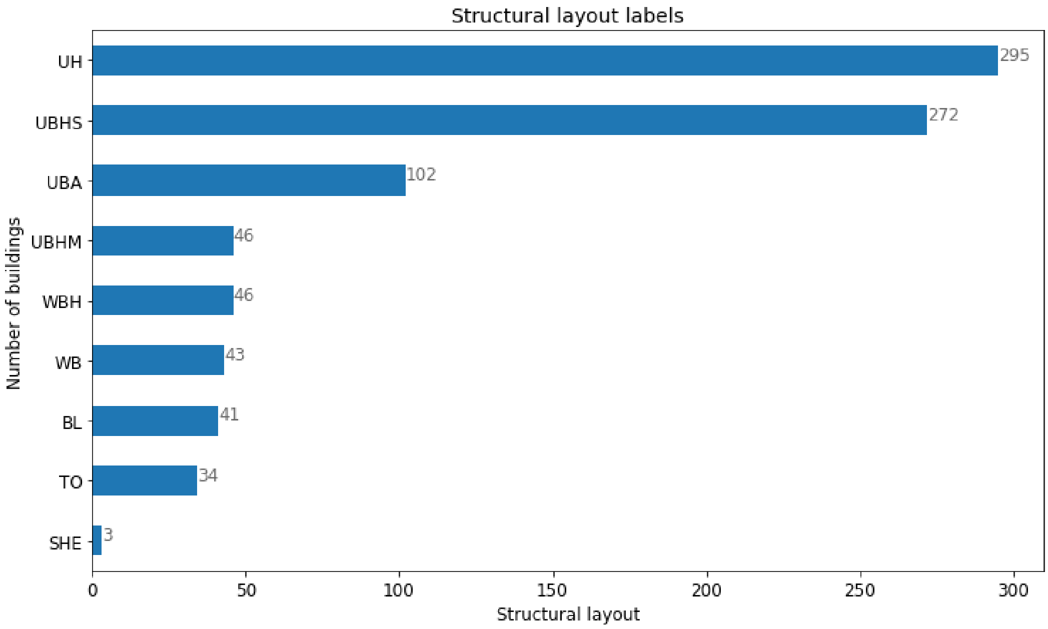


Figure 14: Distribution of available structural layout labels

4.3.2 Methodology and Implementation

The Structural Layout classification methodology used in EDB V7 is based on the methodology developed since EDB V5 [9]. The key update for EDB V7 includes a refinement of the assignment of WBH (barn + house) and WB (barn_warehouse).

The classification of the structural layout is based on an expert derived decision tree approach which is described below. An overview of the decision tree can be found in Figure 15.

- For S (shed) buildings, if a building has a footprint or usable area larger than $40m^2$ or if it is registered to have residential function it is reclassified to Unit, else it is assigned to the SHE (shed) Structural Layout
- For U (unit) buildings:
    - If a building is identified as freestanding according to the adjacency analysis [16] then the building is assigned to the UH (house) Structural Layout.
    - If a building is identified as part of a homogenous block according to the adjacency analysis [16] and is listed with only one address in BAG, then the building is assigned to the Structural Layout UBHS (block

unit single). If listed with multiple addresses in BAG, it is assigned to the Structural Layout UBHM (block unit multiple).

- If a building is identified as part of a inhomogeneous block according to the adjacency analysis [5] then the building is assigned to the Structural Layout UBA (block unit aggregate).

- For B (block) buildings, where a building has been classified to this Geometric Layout with low confidence[4], then an additional check is performed. If the building's exposed footprint length (i.e. length of the footprint which is not shared with other buildings) is greater than 50% of the total footprint length it remains a B (block) Geometric Layout. Otherwise it is assigned to a U (unit) Geometric Layout and is then classified according to its adjacency parameters. This additional check was implemented since some buildings in dense historic urban areas can have width and length similar to a block. However if they have a short exposed façade with the long sides touching other buildings; these buildings are better represented by the Structural Layout UBA (block unit aggregate).

- For W (barn_warehouse) buildings:

    - If it is designated as a 'farmhouse' according to Dataland and has a residential function then it is assigned to 'WBH' (barn + house).

    - If Dataland does not designate as a farmhouse or does not have a description and it does not have a residential function, then it is assigned to WB (barn_warehouse).

    - If Dataland does not designate as a farmhouse or does not have a description and has a residential function, then it is visually inspected to determine whether it is assigned to WBH or WB.

  A description of the values used to identify 'farmhouse' from Dataland can be found in Appendix 1.

- Buildings assigned to the T (tower) Geometric Layout are directly assigned to Structural Layout TOW without any additional algorithmic checks.

[4] Low confidence in the Geometric Layout classification was flagged within the EDB algorithm when the most likely Geometric Layout is less than 5 times more likely than the second most likely Geometric Layout.

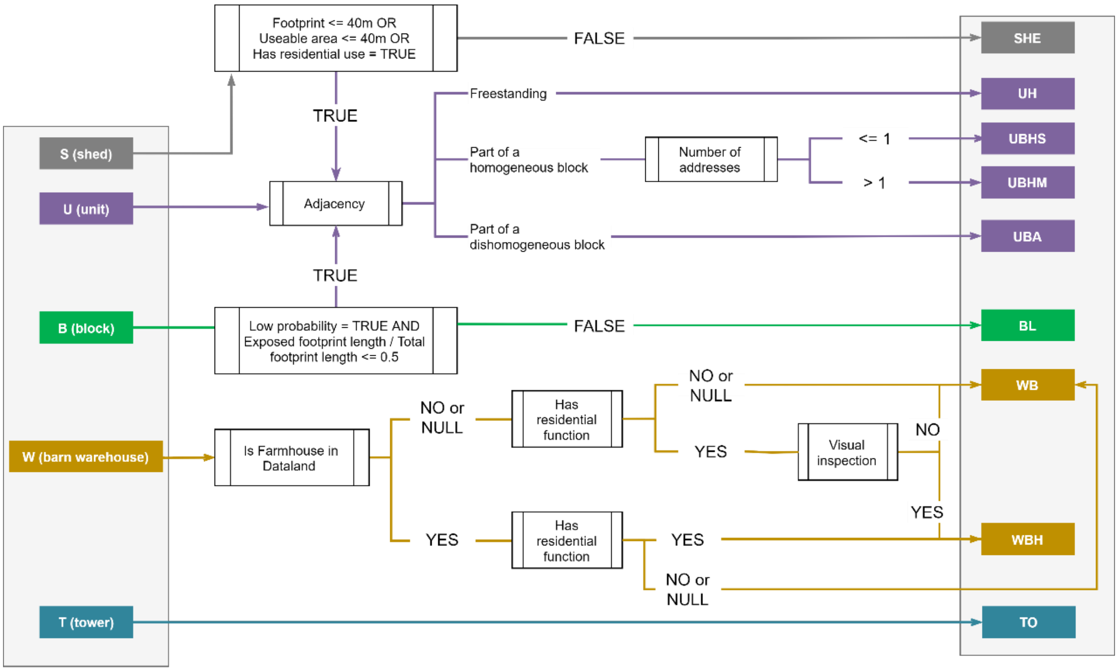


Figure 15 Decision tree for the sub-classification of Geometric Layouts into Structural Layouts

4.3.3 Results and evaluation

4.3.3.1 Results

The total building counts per Structural Layout are shown in Figure 16. In this figure it is apparent that the SHE (shed) buildings are the most predominant in the region with approximately 86,000 buildings, followed by UBHS (block unit single) with approximately 77,000 buildings and UH (house unit) with approximately 55,000 buildings. At the other extreme, only 338 buildings were classified as TO (tower) buildings.

Most Unit buildings feature a single residential unit with a single address, while BL (block) and T (tower) buildings can feature a larger number of residential addresses. The total count of addresses and total count of buildings in each Structural Layout is presented in Table 10.

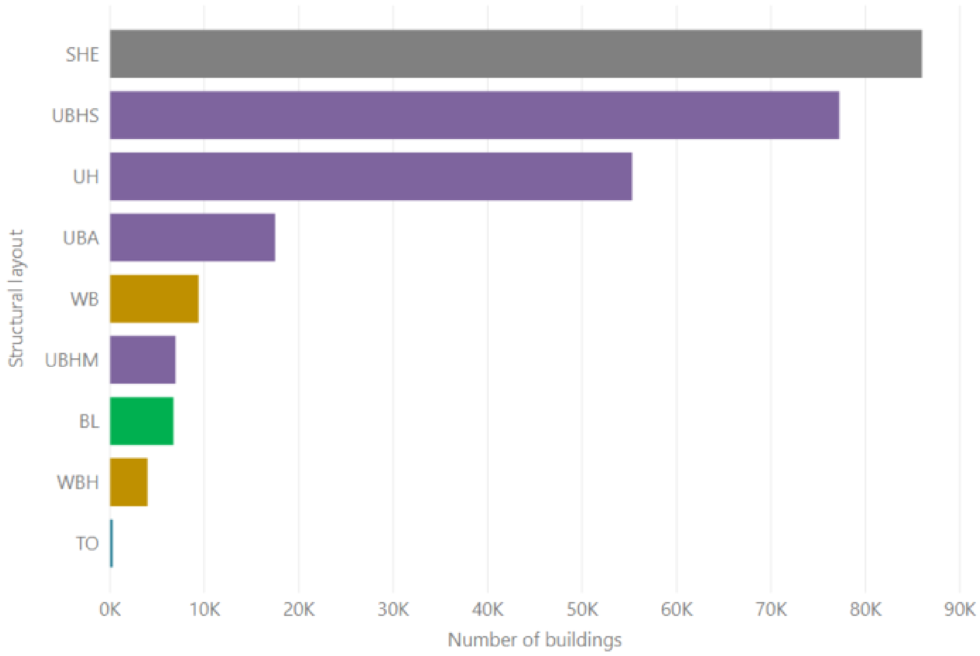


Figure 16 Total counts of buildings per Structural Layout in EDB V7

Table 10 Address count and building count

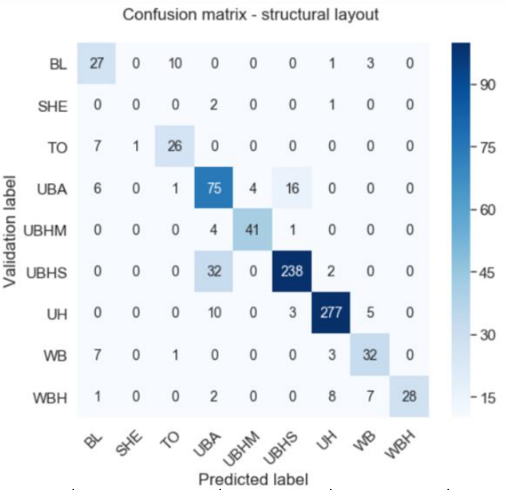
	Total Address Count	**Percentage of Total Address Count**	**Total Building Count**	**Percentage of Total Building Count**
UBHS	77,086	30.63%	77,223	29.32%
BL	57,152	22.71%	6,736	2.56%
UH	40,076	15.92%	55,305	21.00%
UBA	22,512	8.95%	17,487	6.64%
UBHM	17,865	7.10%	6,944	2.64%
SHE	11,762	4.67%	85,973	32.64%
WB	11,186	4.44%	9,392	3.57%
TO	9,560	3.80%	338	0.13%
WBH	4,460	1.77%	4,001	1.52%
Total	251,659	100.0%	263,399	100.0%

4.3.3.2 Evaluation

The overall accuracy of the model is 84%. However the validation samples are not equally distributed across all Structural Layouts and will impact the interpretation of the evaluation measures such as accuracy and precision. SHE in particular has only 3 available labels which are not sufficient to derive any insights about model performance. The available validation samples were still used as available data to indicate acceptable results. The confusion matrix and the evaluation measures can be found in Figure 17 for the results of Structural Layout. TO has only a limited number of 34 labels with an acceptable class accuracy of 72%. UBHS, UH have over 250 available labels and show class accuracies of 90%.

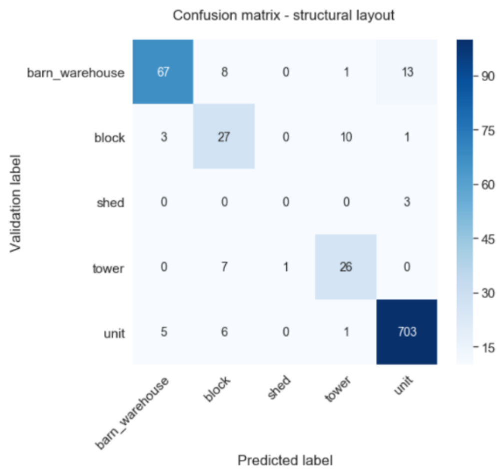
When assigning the Geometry Layout to the final Structural System (further described in Section 4.6), the assignment is derived from the first letter of the Structural Layout to ensure that the expert and inspection overwrites introduced in the Structural Layout classification are captured in the Structural System. Figure 18 shows the performance of the reclassification to Geometry Layout against the aforementioned validation sample set which indicates an overall accuracy of 93%.

Structural Layout



	Precision	Recall	F1-score	Samples
bl	0.56	0.66	0.61	41
she	0.00	0.00	0.00	3
to	0.68	0.76	0.72	34
uba	0.60	0.74	0.66	102
ubhm	0.91	0.89	0.90	46
ubhs	0.92	0.88	0.90	272
uh	0.95	0.94	0.94	295
wb	0.68	0.74	0.71	43
wbh	1.00	0.61	0.76	46
			Total	**882**
			Overall Accuracy	**84%**

Reclassification to Geometry



	Precision	Recall	F1-score	Samples
Barn warehouse	0.89	0.75	0.82	89
Block	0.56	0.66	0.61	41
Shed	0.00	0.00	0.00	3
Tower	0.68	0.76	0.72	34
Unit	0.98	0.98	0.98	715
			Total	**882**
			Overall Accuracy	**93%**

Figure 17 and Figure 18: Confusion matrix and evaluation measures for the Structural Layout results and the reclassification to Geometry Layout from Structural Layout.

4.4 Material and Lateral Support System

Following the assignment of Structural Layouts, the buildings are assigned MLSS and a corresponding probability. The MLSS provides structural properties including structural material in the primary and secondary direction, lateral load resisting system in the primary and secondary direction, presence of external walls and floor material. As buildings can be assigned MLSS through inferences, inspections or a combination of both, a building can have several MLSS in which the sum of probabilities will equal one or only one MLSS with a probability of one.

4.4.1 Data

4.4.1.1 Input data

The following lists the datasets and their sources which were used in the MLSS classification. Further information on the parameters below can be found in the Data Documentation [16].

- Structural Layout, Arup (see Section 4.3)
- Building year (BAG), Kadaster
- Project Building Data Characterisation (PBDC), Arup

The PDBC dataset is the result of mapping the MLSS information from various inspection sources to the convention used in EDB V7. This allows inspection datasets to be used in the classification process. The PDBC dataset contains inspection data from:

- RVS, Arup, Nov 2015
- EVS, Arup/CVW, Dec 2015
- Drawing Data, Arup, Dec 2019
- Data Collection, Arup, Dec 2019
- Visual Inspection, JBG, July 2017

4.4.2 Methodology and implementation

The MLSS classification methodology used in EDB V7 is based on the methodology developed since EDB V6 [14]. Figure 19 provides an overview of the process.

The MLSS classification methodology is described below in two key parts:

- Development of the data driven inference using inspection data,
- Final MLSS assignment from either inference or inspection where available.

Further information on the development and rationale can be found in EDB V6 documentation [14].

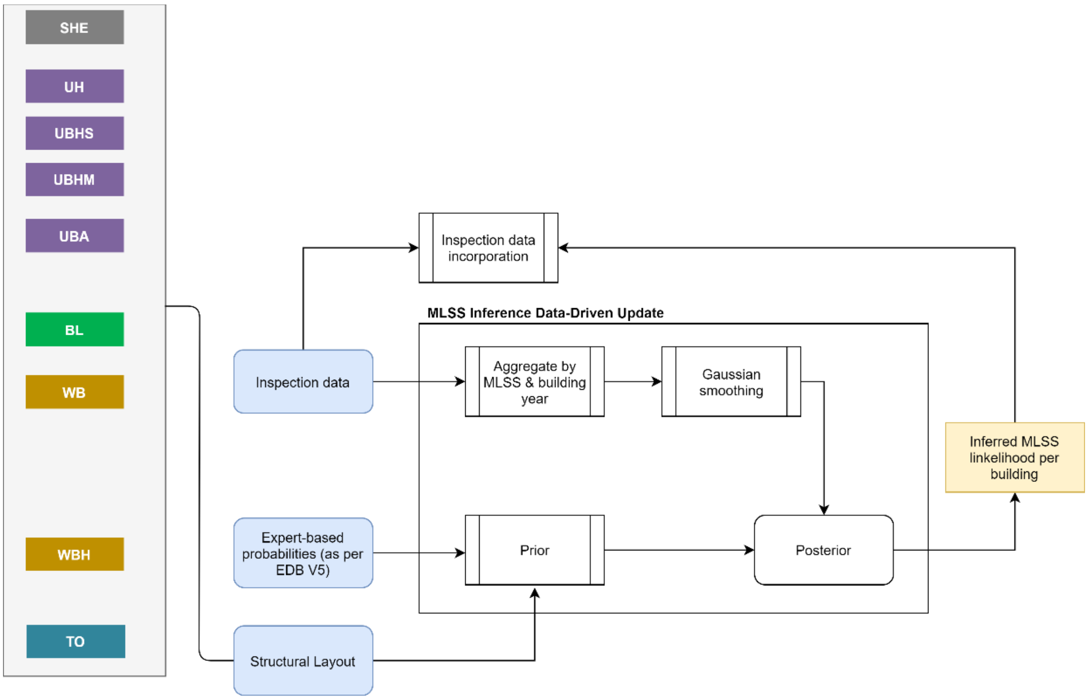


Figure 19 Material & lateral support system (MLSS) inference development methodology.

4.4.2.1 Data driven inferences

The MLSS inferences assigns the relative probability of different MLSS for buildings based on a building's Structural Layout and construction period. The data driven inferences enhances the expert-based inferences of EDB V5 [9] through Bayesian inference updates given available inspection data. This allows the inferences to be updated based on observations (inspection data).

The methodological steps for the data-driven inference updates are outlined below. A detailed description of the process can be found in EDB V6's Technical [14].

Step 1 – Inspection data processing and derivation of synthetic data through Gaussian smoothing

The inspection data is aggregated by MLSS and building year retrieving the number of buildings per construction year and MLSS. A smoothing operation is introduced as there is a strong correlation between the probability of structural systems in successive years. As inspection data is limited, without this step the resulting inferences would be largely different for consecutive building years.

The kernel density methodology developed in EDB V6 smooths the inspected probability for an MLSS in a building year based on Gaussian smoothing parameters and the difference of building years. Each inspection of a given building creates thereby also a likelihood for adjacent building years. Figure 20 shows an example of a Gaussian smoothing curve, that describes the influence of inspection data on adjacent building years. The driving factor of the smoothing operation is the bandwidth of the Gaussian kernel T_0 which defines the shape of the smoothing curve. The dataset resulting from this methodology is further referenced as synthetic dataset.

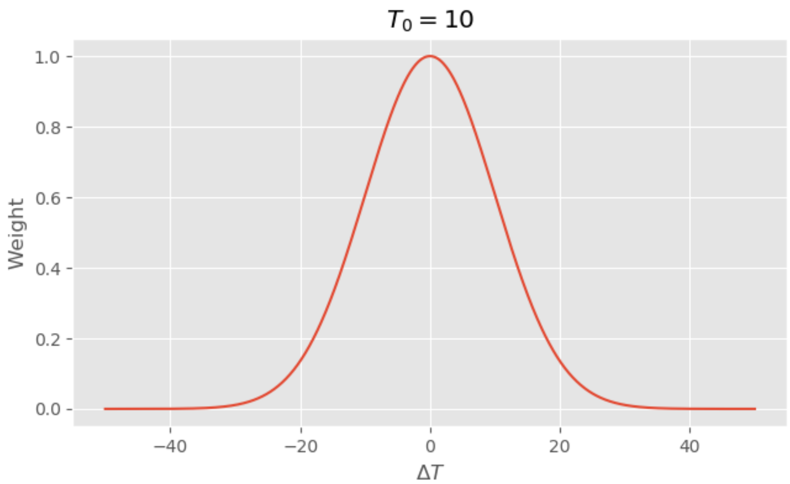


Figure 20 Example of a Gaussian correlation function.

Step 2 − Bayesian inference update

The expert-based probabilities from EDB V5 are updated with the synthetic data created in the previous step.

Step 2.1 – Combining MLSS derived from expert-based probability and inspection data

The MLSS from the expert-based probabilities are compared to the MLSS as defined by the inspection data. MLSS present in the inspection data but not in the expert-driven inferences are assigned an initial probability of 0. This results in example prior inferences as shown in Table 11.

Table 11 Example of MLSS prior probability

	1980 – prior probability
MUR/LWAL/MUR/LWAL/EWN/FW	0.002[5]
S/LFBR/S/LFBR/EWN/FC	0.011
S/LFM/S/LFM/EWN/FC	0.010
MUR/LWAL/MUR/LWAL/EW/FW	0.226
CR+CIP/LFM/CR+CIP/LFM/EWN/FC	0.006
CR+CIP/LWAL/CR+CIP/LWAL/EWN/FC	0.011
MUR/LWAL/MUR/LWAL/EW/FC	0.691
W/LWAL/W/LWAL/EW/FW	0.042

[5] At this stage, the calculations are done with probability values stored to multiple decimal places. The process of rounding up the assigned probabilities takes place in the final step of the Structural System assignment, described in Section 4.6.

W/LWAL/W/LWAL/EWN/FW	0.000

Step 2.2 – Weighting of prior inferences

The probabilities described in Step 2.1 are weighted by a function of the building count in each Structural Layout and a factor agreed in EDB V6 after an evaluation through a sensitivity study. This weighting factor takes into consideration the building stock. A higher presence of a specific Structural Layout results in a heavier weighting of the prior inferences.

Step 2.3 – Calculation of posterior probabilities

The weighted prior inferences of each MLSS for a given building year are added to the corresponding synthetic dataset value from the inspection-based data integration as described in step 1 resulting in the posterior probabilities.

The described process in step 2.1 to 2.3 is repeated separately for all building years to build the data driven inference for a structural layout. This was then repeated for all structural layouts.

The resulting inferences used in EDB V7 is described in Appendix A3 per Structural Layout.

4.4.2.2 MLSS assignment

Depending on the availability of inspection data for each building in EDB V7, three different MLSS assignment processes are followed. This is described below and shown diagrammatically in the flowchart of Figure 21.

1. **MLSS assignment from the data driven inference**

   Buildings for which there is no available inspection data are directly represented by the Inferred MLSS.

2. **MLSS assignment directly from inspections**

   Buildings that have all MLSS fields assigned based on inspection data are directly assigned the inspected MLSS and are not affected by inferences. Full description on how the MLSS are assigned from different inspection sources can be found in the EDB V7 data documentation [16].

3. **MLSS assignment partially from inspection and inference**

   Buildings for which inspections provide only partial information (e.g. assigned presence of the material of external walls but not floor type), then a conditional probability, given the inspection data, is assigned. As an illustrative example, if the following inferences are assigned for a specific building:

   - 60% probability to a Structural System with masonry walls and timber floors,
   - 20% to a Structural System with masonry walls and concrete floors
   - 20% to a Structural System with concrete walls and concrete floors

and an inspection source determines that this building has masonry walls, the probabilities get redistributed as follows:

- 75% probability to the Structural System with masonry walls and timber floors,
- 25% to the structural system with masonry walls and concrete floors and
- 0% to a structural system with concrete walls and concrete floors.

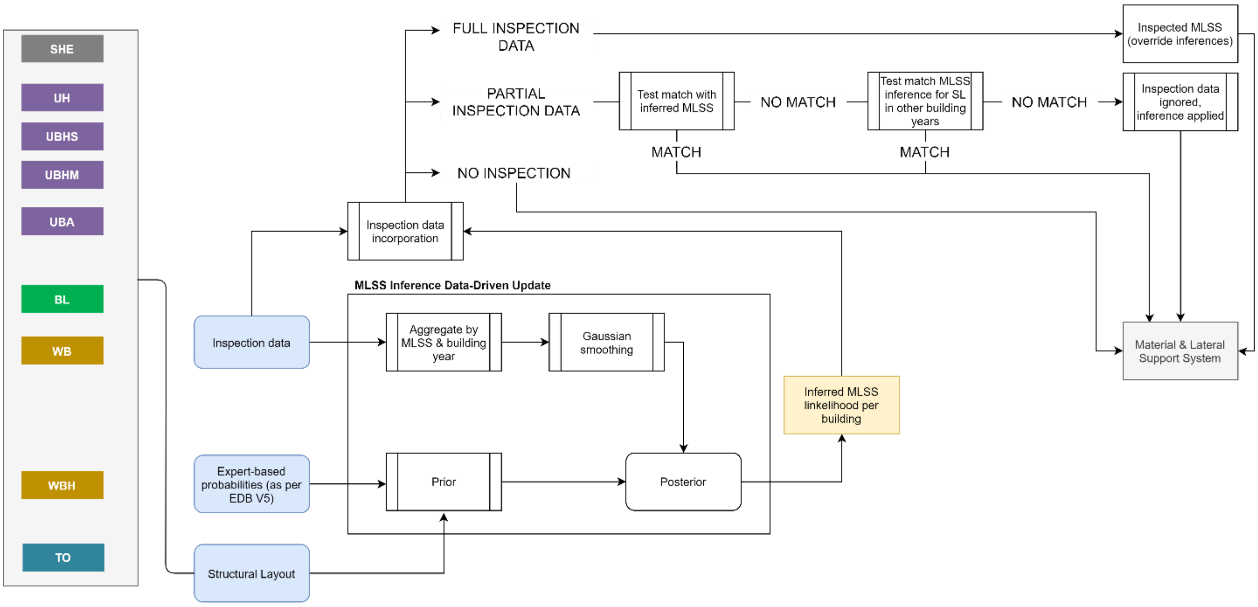


Figure 21 MLSS inspection data incorporation process

4.4.3 Results

The classification process assigns MLSS to all 263,399 buildings in EDB V7.

The top 20 Structural Systems are shown in Figure 22. In this figure it is apparent that the SHE (shed) buildings, the most predominant in the region according to the Structural Layout results, have been assigned to MAT99/LN/MAT99/LN/EW99/F99. The next few MLSS are generally seen in UBHS (block unit single) buildings which was the second most predominant Structural Layout.

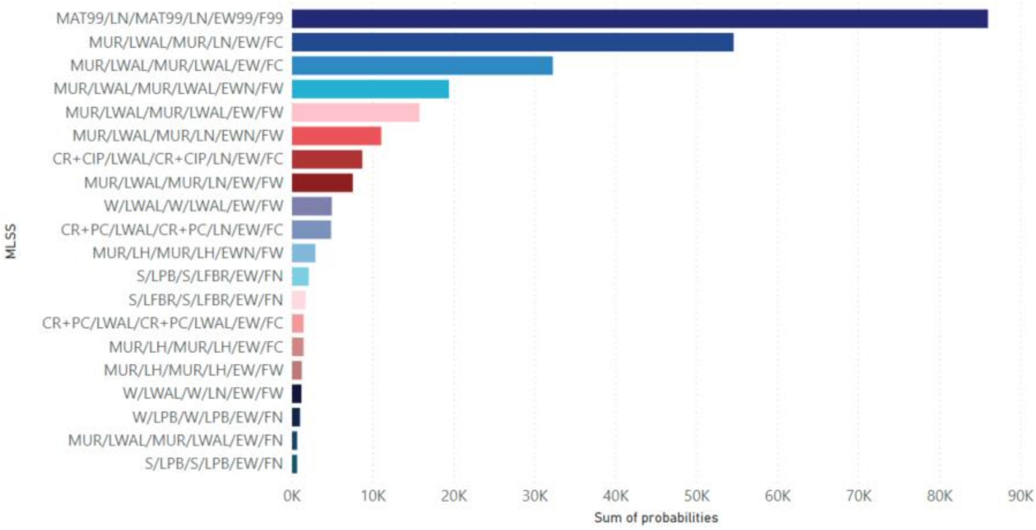


Figure 22 The predominant inspected MLSS's ranked by sum of probabilities.

The number of buildings with available full inspections per Structural Layout and the respective ratio over the total count of buildings per Structural Layout in EDB V7 is presented in Table 12.

The Structural Layout with the highest coverage of inspections is UBHS (block unit single) with approximately 11% of the region's buildings having a full inspection. WB (barn warehouse) and UBHM (block unit multiple) are the Structural Systems with the lowest data coverage with the exclusion of SHE (sheds) which generally represent unoccupied buildings of small dimensions.

Table 12 Availability of full and partial inspections per Structural Layout

Structural Layout	**Total Count EDB V7**	**Count of full inspections**	**Count of partial inspections**	**Coverage of full inspections**	**Coverage partial inspections**	**Coverage of inference**
BL	6,736	237	188	3.52%	2.79%	93.69%
SHE	85,973	4	0	0.00%	0.00%	100.00%
TO	338	16	7	4.73%	2.07%	93.20%
UBA	17,487	1,151	859	6.58%	4.91%	88.51%
UBHM	6,944	135	9	1.94%	0.13%	97.93%
UBHS	77,223	8,797	2,133	11.39%	2.76%	85.85%
UH	55,305	2,150	7,529	3.89%	13.61%	82.50%
WB	9,392	111	553	1.18%	5.89%	92.93%
WBH	4,001	329	1,019	8.22%	25.47%	66.31%
TOTAL	263,399	**12,930**	**12,297**	4.91%	4.67%	90.42%
TOTAL excl. SHE	177,426	**12,926**	**12,297**	7.29%	6.93%	85.78%

4.5 Storey Count and Irregularity

The buildings are assigned a storey count and irregularity class which forms part of the final structural system assignment.

The four possible storey count classes are:

- H99 – Unknown number of storeys
- HBET:2;1 – Number of storeys between 1 and 2
- HBET: 20;3 – Number of storeys between 3 and 20
- HBET: 20;1 – Number of storeys between 1 and 20

HBET:2;1 and HBET20;3 are assigned only to specific Geometry Layouts of B and U as requested by the client. HBET:20;1 is assigned to the remainder of Structural Layouts where building storey count data is available. H99 is applicable to all Structural Layouts when there is no available storey count data.

The four possible vertical structural irregularity classes are:

- IR99 – Unknown structural irregularity
- IRVP+OPL – Presence of opening percentage on the ground floor larger than 85%
- IRVP+DIB – Presence of drive in garage on the ground floor
- IRVP+SOS – Presence of soft storey

IRVP+OPL are assigned only to UBHS and UBHM Structural Layouts as requested by the client. All other irregularity classes could be assigned to all buildings.

4.5.1 Data

4.5.1.1 Input data

Below lists the datasets and their sources which were used in the storey and irregularity class assignment. Further information on the datasets below can be found in the Data Documentation [16].

- Gutter height, Arup
- Architectural Description, Dataland
- Storey count, TA
- Building year (BAG), Kadaster
- Data Collection, Arup
- Drawing data, Arup

- Visual Inspections, JBG
- Soft storey data collection, Arup

4.5.2 Methodology and implementation

The assignment of storey count and irregularity classes used in EDB V7 is based on the methodology developed in EDB V6 [14]. The assignment of irregularity classes has been updated in EDB V7 to include building year inferences instead of the TA dataset's opening percentage which was found to be less reliable than the building year inferences.

4.5.2.1 Storey Count

The storey count classes were assigned as per Figure 24 and the logic described below:

- **H99** is used when there is no information from which the number of storeys can be inferred.
- **HBET:2;1** is only used when required for the respective Geometry Layout (U, B). This tag is assigned when available inspections (drawings or visual inspections) denote that a building has 1 or 2 storeys. If inspection data is not present, the tag is assigned through a dedicated data-driven inference, described below. If gutter height data is not present, then the tag is used if TA data assigned not more than 2 storeys.
- **HBET:20;3** is only used when required for the respective Geometry Layout (U, B). This tag is assigned when available inspections (drawings or visual inspections) denote that a building has more than 2 storeys. If inspection data was not present this tag is assigned through a dedicated data-driven inference, described below. If gutter height data is not present, then the tag is used if TA data assigned more than 2 storeys.
- **HBET:20;1** is used when storey count data or gutter height data is present in EDB V7, but a related distinction for buildings of the respective Geometry Layout (S, W, T) is not required by the current Hazard & Risk Model [22].

Storey Count Class Inferences

As there was limited coverage of storey count data, which are generally from inspections, storey count class inferences were created using the gutter height (which has wider data coverage) parameter as an input.

To create the inferences, inspection data from drawing data of 12,178 buildings were classified into two groups according to the inspected storey count:

- One or two storeys
- More than two storeys

The average gutter height has then been used to model a logistic regression function to derive the probability of a building for the two defined classes. This function gives a data-driven inference of the probability for belonging to the two storey count classes given a building's gutter height. The gutter height-based inference of probability between HBET:2;1 and HBET:20;3, for Structural Layouts where this distinction is required, is defined in Figure 30.

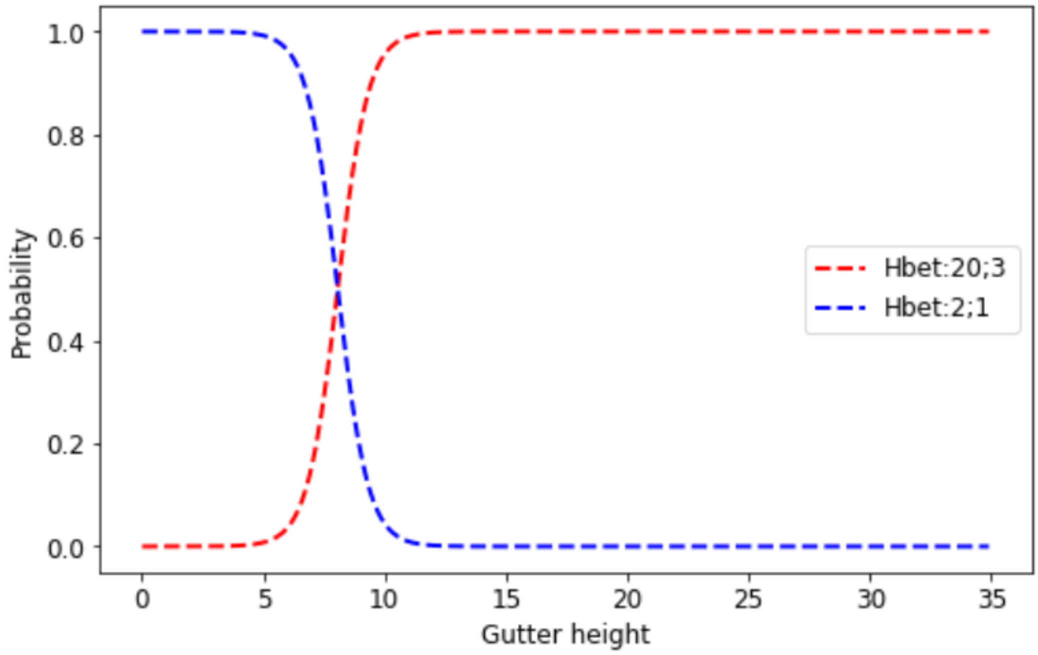


Figure 23 Data-driven inference rule for the storey count class probability assignment.

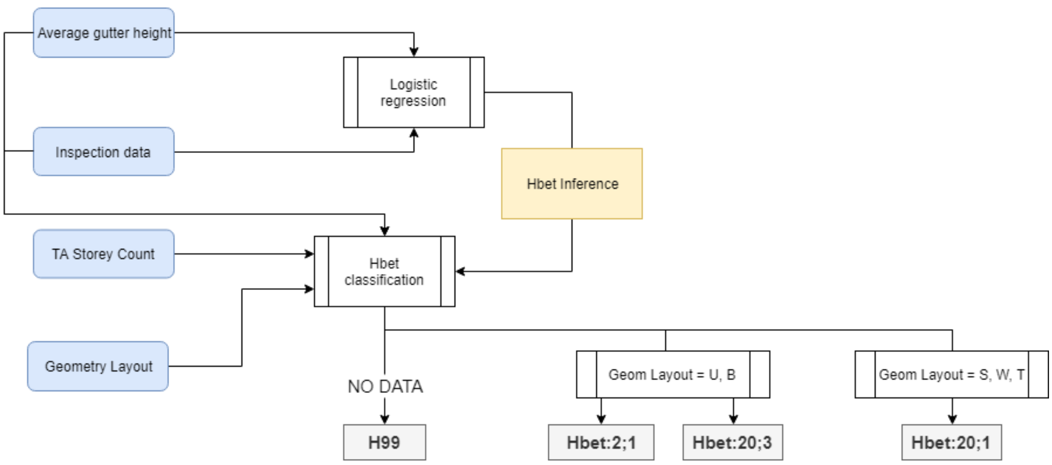


Figure 24: Storey count classification methodology

Storey count source flag

To provide information on how the storey count classes were assigned, a source flag was created called 'hbet_source_flag'. The source flag records the data source based on which the storey count has been assigned. Table 13 provides an overview of the source flag and its corresponding description.

Table 13 Definition of the hbet_source_flag assignment

hbet_source_flag	Description
0	No source processed.
1	Assigned based on the storey count calculated by dividing the total usable area by the footprint area of a building.
2	Assigned based on data from the TA dataset.
3	Assigned based on the inferences using gutter height data.
4	Assigned based on the storey count based on visual inspection via Streetview images.
5	Assigned based on the storey count seen in the inspection of drawings or through physical inspection – with a minimum height for a storey set to 0.5m.
6	Assigned based on the storey count seen in the inspection of drawings or through physical inspection – with a minimum height for a storey set to 1.5m.

4.5.2.2 Irregularity

The four irregularity classes were assigned according to the following logic and priority as described below. This is further visualised in Figure 25.

- **IRVP+DIB** is used when a 'drive in building' is identified through inspection drawing data, visual inspections via Streetview or Dataland's building description is Drive-in. The actual descriptions used by Dataland can be found in Table 14.
- **IRVP+SOS** is used when a visual inspection via Streetview images recorded the presence of more than 1 storey and visible indications of a relative increase in stiffness on the storeys above the ground floor [27].
- **IRVP+OPL** is only used when the related distinction is required for the respective Structural Layout (UBHM and UBHS buildings). This tag was assigned in accordance to the recommendation of the H&R model [18]**.** Therefore, depending on source data availability, it was assigned as follows:
    - When inspection opening percentage data is present, the tag is assigned when measured data is greater than 85%.
    - When visual inspection information indicates a large opening.
    - When inspection data is not available, IRVP+OPL is assigned using building year inferences as agreed with the client [19]. The inferences are as following:
        - Building year before 1955, assign 5% IRVP +OPL and 95% IR99
        - Building year between (and including) 1955 to 1980, assign 25% IRVP+OPL and 75% IR99

    - Building year after 1980, assign 5% IRVP +OPL and 95% IR99

- **IR99** is used when it is not known whether there are any structural irregularities, or what type of irregularities may exist. This tag was assigned as a pre-set to all buildings and it was only altered if one of the clauses for the 3 tags above were True.

Table 14 Descriptions in Dataland that resulted in an IRVP+DIB GEM tag

Dataland's Architectural Descriptions related to Drive-in buildings
2/1 kap drive-in woning
2^1 kap drive-in-woning
Drive-in woning geschakeld
Hoek drive-in-woning
Rij drive-in-woning
Rijwoning drive-in
Rijwoning drive-in hoek
Woning Geschakeld Drive-In
Woning Hoek Drive-In
Woning Rij Drive-In
Woning Studenten Rij Drive-In
Woning Vrijstaand Drive-In

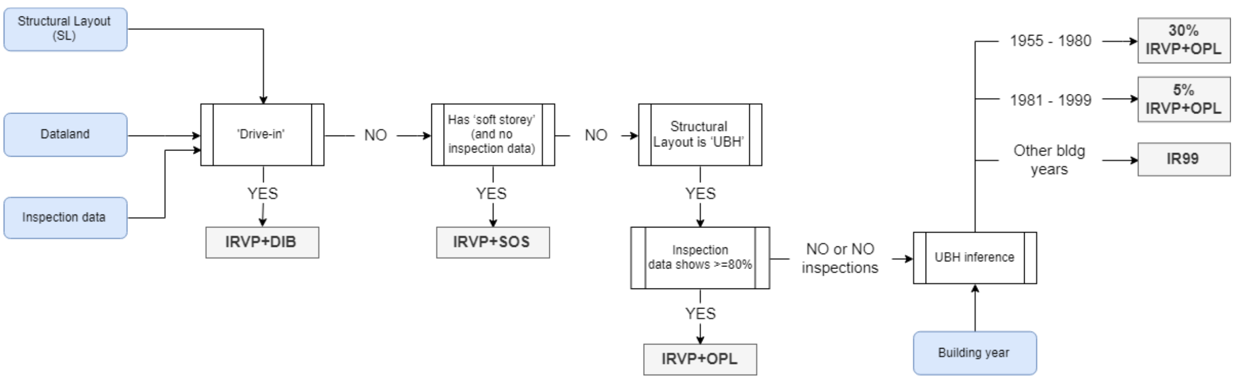


Figure 25: Irregularity assignment methodology.

Irregularity source flag

To provide information on how the irregularity classes were assigned, a source flag was created called 'ir_source_flag'. The source flag records the data source based on which the storey count has been assigned. Table 15 provides an overview of the source flag and its corresponding description.

Table 15 Definition of the ir_source_flag assignment

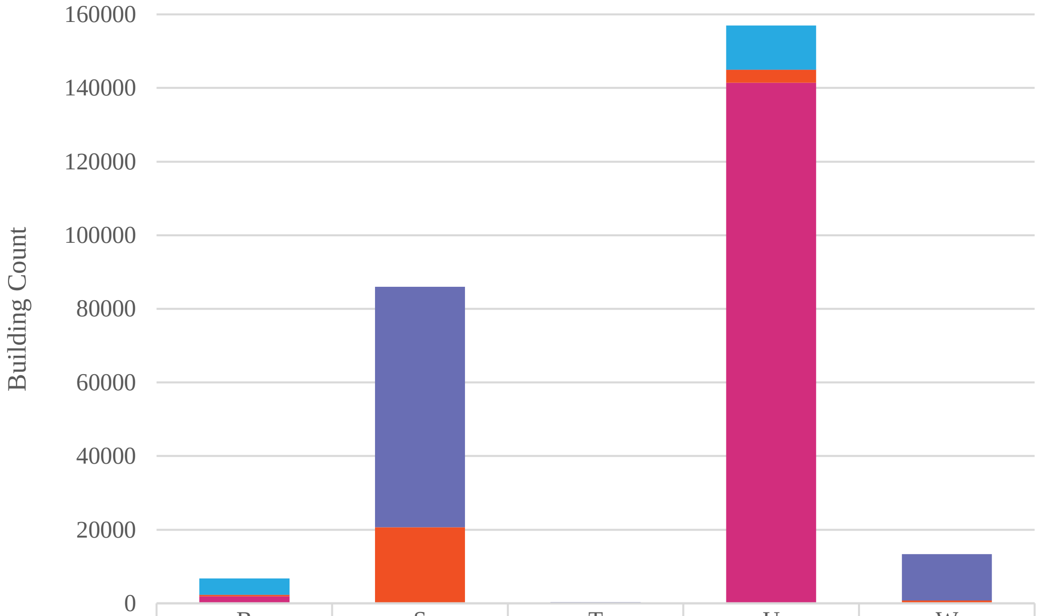
ir_source_flag	Description
0	No source processed.
1	Assigned based on an age-based inference.
2	N/A (previously assigned based on data from the TA dataset in V6)
3	Assigned through Dataland Drive-In Description.
4	Assigned based on the visual assessment of street-view images.
5	Assigned based on the calculated opening percentage from the inspection of drawings or through physical inspection.

4.5.3 Results

4.5.3.1 Storey count

The total counts for each storey count class per Geometry Layout are shown in Figure 26. This is shown as specific storey count classes are only assigned for B and U Geometry Layouts.

There is a total of 3,905 buildings with an assigned Geometry Layout of B and U which were assigned with H99 and thus have no storey count or building height information. This most likely corresponds to newly-built construction for which no height map, inspection data or Streetview images were available.

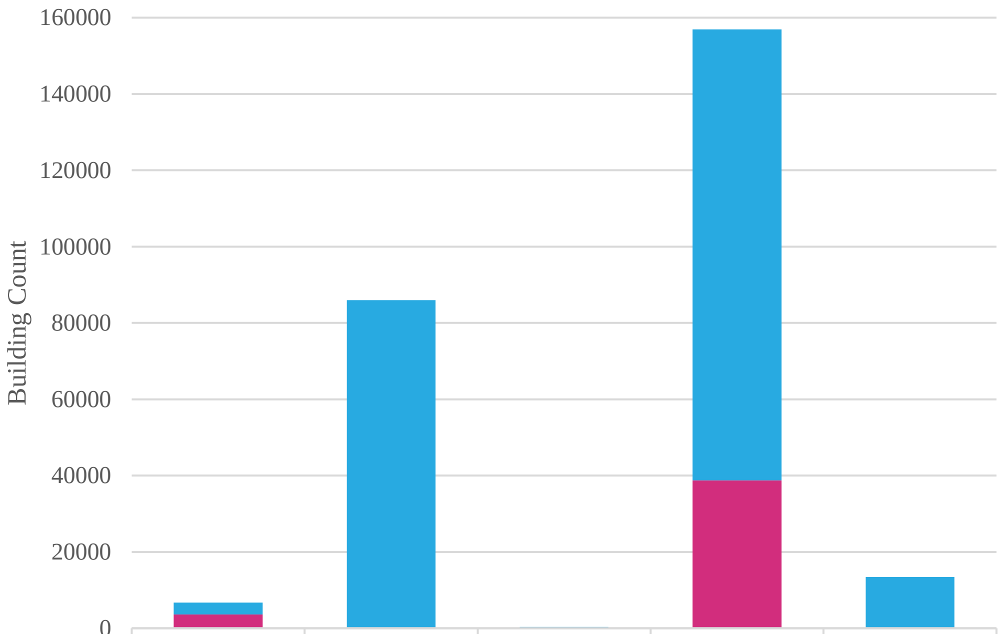


	B	S	T	U	W
HBET:20;3	4430	0	0	12011	0
HBET:20;1	8	65285	338	0	12581
H99	380	20688	0	3525	812
HBET:2;1	1918	0	0	141423	0

Figure 26 Breakdown of storey count class count per Geometry Layout

The current storey count classification methodology, as described in Section 4.5.2, allowed buildings to have a probability for both HBET:2;1 and HBET:20;3. This happens as a consequence of buildings assigned a storey count class based on gutter height with a value whereby both classes have a likelihood.

Figure 27 lists the number of buildings assigned a single and multiple storey count class across their likely Structural Systems. The sum of buildings with an uncertainty related to storey count classification can therefore be calculated to be 42,443.



	B	S	T	U	W
Single	3082	85973	338	118170	13393
Multiple	3654	0	0	38789	0

Figure 27 Count of buildings featuring a single or multiple storey count classes per Structural Layout

The overview of the source flag for the storey count classification can be found in Figure 28. The majority of buildings have been assigned based on average gutter height and inference (source flag ‘3’) while approximately 9% of the total building stock have been assigned a storey count from a direct source (source flag ‘4’, ‘5’, ‘6’).

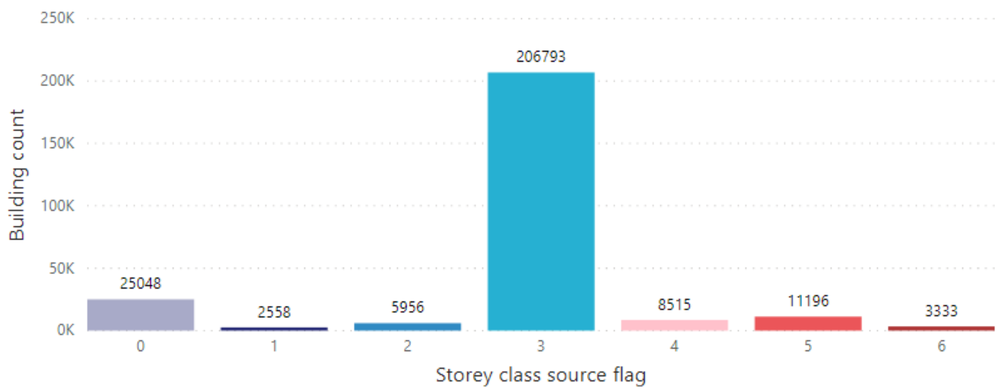


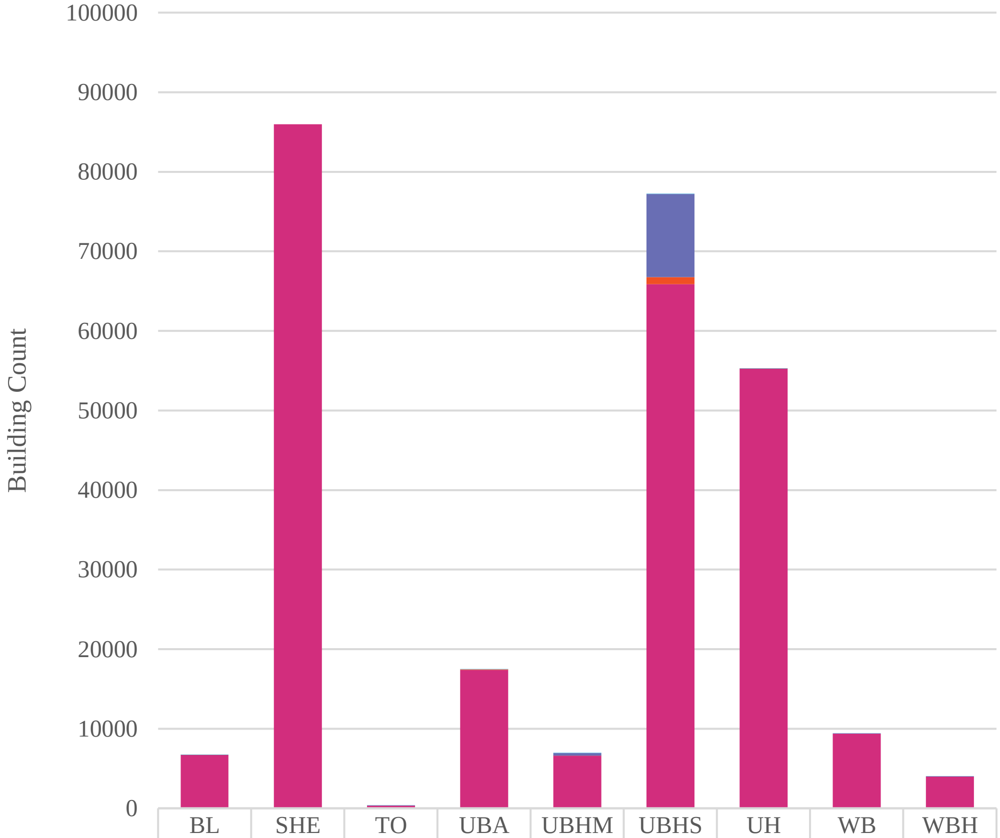
Figure 28 Count of buildings per storey count source flag (hbet_source_flag) in EDB V7

4.5.3.2 Irregularity

The total counts for each storey count class per Structural Layout are shown in Figure 29. This is shown as specific irregularity classes are only assigned for UBHS and UBHM Structural Layout.

As shown there, the majority of buildings in the region has an unknown irregularity tag (IR99) while approximately 966 buildings have an irregularity indication related to the drive-in buildings (i.e. buildings in which the ground floor is a parking garage for cars), and 124 buildings have a visually inspected indication for possible soft storey. The buildings noted to be featuring a large opening were 10,790.

The irregularity distinction is not used for all Structural Layouts in the H&R model [18]. For the Structural Layouts where this is the case the IR99 tag is used. Therefore, some buildings in the IR99 (unknown irregularity) class could also feature irregularities.



	BL	SHE	TO	UBA	UBHM	UBHS	UH	WB	WBH
IRVP+SOS	38	0	5	24	1	3	31	15	7
IRVP+OPL	0	0	0	0	325	10465	0	0	0
IRVP+DIB	3	0	0	64	3	895	1	0	0
IR99	6695	85973	333	17399	6615	65860	55273	9377	3994

Figure 29 Breakdown of irregularity class per Structural Layout

According to the regional H&R model [18], irregularity is only a differentiator for buildings in the UBHS and UBHM Structural Layouts, which reflect terraced buildings. The overview of the source flag for irregularity classification for UBHS and UBHM can be found in Figure 30. The majority of buildings have been assigned by the building year inference (source flag ‘1’) while approximately 10% of UBHS and UBHM are assigned by inspections (source flag ‘5’).

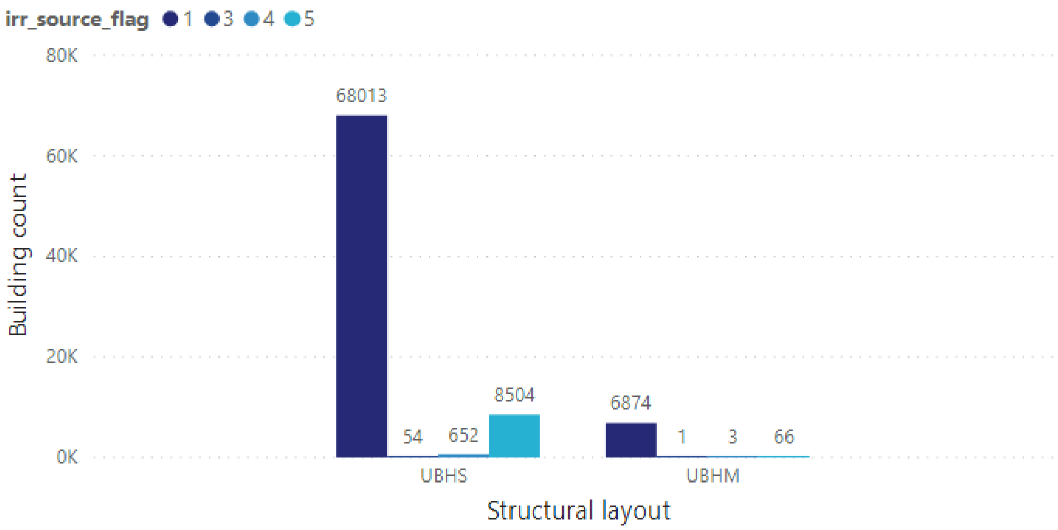


Figure 30 Count of buildings per irregularity source flag (ir_source_flag) for UBHS and UBHM buildings in EDB V7

4.6 Final Structural System Assignment

The Structural System consist of nine attribues which are described in Section 4.1.1. To construct the Structural System and its respective probability, the Geometric Layout, MLSS, storey count and irregularity classes are combined.

4.6.1 Data

Below lists the datasets and their sources which were used in the final Structural System assignment.

- Structural Layout, Arup (see Section 4.3)
- MLSS, Arup (see Section 4.4)
- Storey Count Class, Arup (see Section 4.5)
- Irregularity Class, Arup (see Section 4.5)
- WBH Inspection data, Arup

The WBH inspection data was collected as part of the development of EDB V7 to provide better confidence in the assignment of WBH buildings and the identification of sub-types. The collection was predominately through desktop studies including visual inspections using Google Streetview.

4.6.2 Methodology and impelementation

With the exception of Geometry Layout, a building can be assigned probabilities against multiple MLSS, storey count and irregularity classes. In these cases, the probabilities are multiplied for each of the separate parts of a Structural System. For example, if a building is 50% likely to have two different MLSS's (MLSS1 and MLSS2 for this example) and 50% likely to belong to HBET:2;1 and HBET:20;3, then 25% probability is assigned to the four possible combinations:

- MLSS1/HBET:2;1
- MLSS2/HBET:2;1
- MLSS1/HBET:20;3
- MLSS2/HBET:20;3

This assumes no correlation between the possible MLSS's and storey count and irregularity classes.

As the multiplication of probabilities can introduce small probabilities, any Structural Systems which have a likelihood less than 1% are removed and the sum of all removed Structural System probabilities is distributed equally to the remaining Structural Systems as discussed with the client.

This is done to reduce the number of Structural Systems that are inferred with a very low likelihood which would therefore be having little impact in the Risk calculation while increasing computational processing time.

The Geometry Layout assigned to the Structural System is assigned through the first letter of the Structural Layout to ensure that the expert and inspection overwrites introduced in the Structural Layout classification are captured in the Structural System. There is only one Structural Layout assigned per building so there is no impact on probabilities. Where the Structural Layout is assigned as 'WBH', a corresponding sub-type was assigned through the WBH inspection data. This resulted to either 'WA' or 'WC' which correspond to WBH (barn+house) with aggregate or continuous roof.

After these operations the extract is formatted as described in Table 2 of Section 3.3.

4.6.2.1 Source Flag Assignment Methodology

To provide information on how the structural system classes were assigned, a source flag was created called 'ssy_source_flag'. This records how the MLSS was assigned through recording which input was used. Table 16 provides an overview of the source flag and its corresponding description.

Table 16 Definition of SSy_Source_Flag depending on the presence of full classification data (1), partial classification data (0.5) or absence of classification data (0) per EDB V6 data sources. The dash symbol signifies that the source is not taken into account due to the presence of a source with higher reliability.

SSy_Source_Flag		Building year	Function data	Structural Layout	RVS	Visual Inspection	Drawing Data	EVS
0		1	0	0	0	0	0	0
1		1	1	0	0	0	0	0
2		1	0	1	0	0	0	0
3		1	1	1	0	0	0	0
4	a	1	1	1	0.5	0	0	0
	b	1	1	1	-	0.5	0	0
	c	1	1	1	-	-	0.5	0
	d	1	1	1	-	-	-	0.5
5	a	-	-	-	1	0	0	0
	b	-	-	-	-	1	0	0
	c	-	-	-	-	-	1	0
	d	-	-	-	-	-	-	1

4.6.3 Results

Structural Systems are assigned for all 263,399 buildings within EDB V7 and are delivered to the client according to the schema described in Table 2. To estimate the count of buildings per Structural System in the region, the probabilities per Structural Systems are added. The top 20 Structural Systems are shown in Figure 31 below, while the total list of Structural Systems and their corresponding estimated building count is listed in Appendix A2.

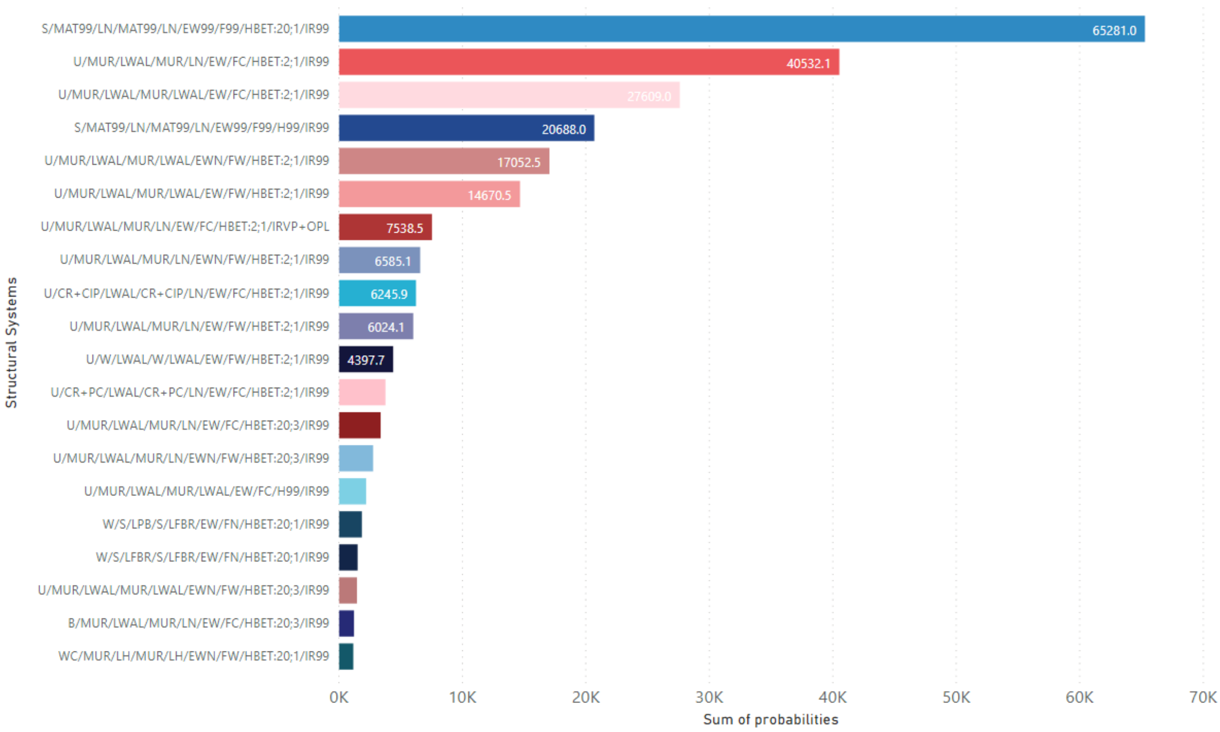


Figure 31 The sum of probabilities per Structural System

The source flags provide a way of assessing the extent to which the different sources were used in the assignment of the Structural System.

The total building count for buildings that were assigned through partial inspection data (source flags ‘4a’, ‘4b’, ‘4c’ and ‘4d’) was 12,297, while the number of buildings assigned through full inspection data (‘5c’ and ‘5d’) was 12,930. These numbers represent approximately 5% each of the total building stock, therefore together about 10% of the total building stock is informed by inspection data.

It should be considered that approximately 36% of the buildings with a source flag ‘3’ are unoccupied. Considering this, the percentage of occupied Buildings that has been assigned through partial or full inspection data is approximately 14%. Further insight on the count of buildings per Structural System source flag for the five Geometric Layouts is given in Section 4.4.3.

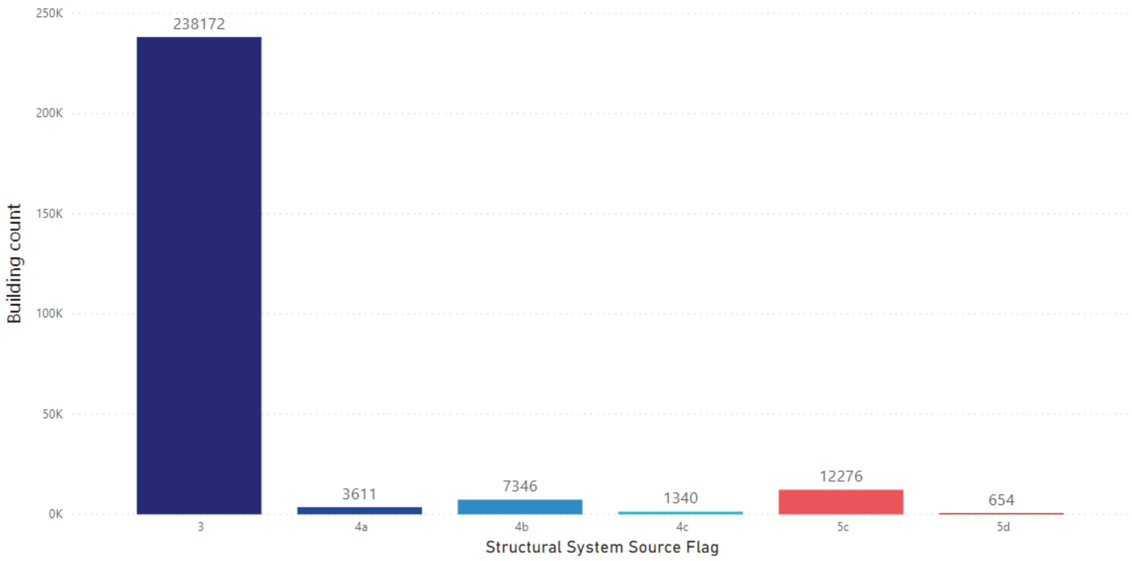


Figure 32 Count of buildings per Structural System source flag (ssy_source_flag) in EDB V7

4.6.4 Version comparison between V6 and V7

To help understand and evaluate the developments of V7, comparisons with the results of EDB V6 were made for Structural Layout, MLSS and the Structural System source flag (ssy_source_flag). These three items were selected as key points in the classification and are discussed in the following sections.

4.6.4.1 Structural Layout

The Structural Layout is a key parameter for MLSS assignment and provides the first part of the Structural System. The comparison of Structural Layout between EDB V6 and V7 revealed minor changes between both versions as shown in Figure 33. The main change include UBA and UBHS buildings in V6 being reclassified to UH and UBA. This mainly reflects the updates to the adjacency analysis which is the main input in assigning a U (unit) to its respective Structural Layout subclasses. V7's adjacency analysis was redeveloped to be stricter in identifying uniform blocks (i.e. UBHS / UBHM) and was adjusted to ensure that non-occupancy buildings (such as sheds or garages) which touched an otherwise freestanding building, would still classify the building as freestanding.

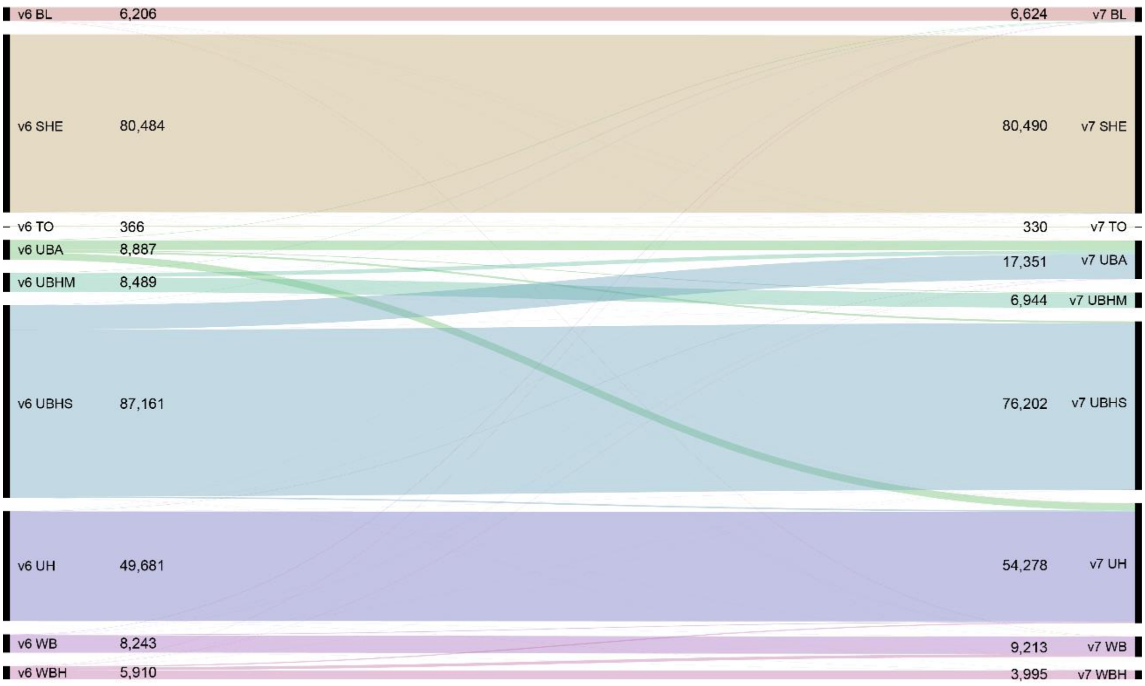


Figure 33: Structural layout comparison between V6 and V7

The other main change in the Structural Layout is the refinement in WB and WBH buildings. Figure 33 shows a reduction of WBH buildings in V7 as stricter rules were introduced in the Structural Layout classification including the WBH visual inspections.

4.6.4.2 Structural System

The Structural System was compared between V6 and V7. While the total number of buildings between V6 and V7 has changed slightly due to new buildings and demolition, it is expected that the distribution of Structural Systems remains largely the same.

The Structural Systems were compared and the top 11, arranged by absolute difference with regards to building count (using sum of probabilities), was assessed. There were some large differences such as approximately 30,900 fewer buildings in V7 compared to V6 for the Structural System U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IRVP+OPL. On closer inspection, it was identified that the reason for these large changes was mainly due to a changed irregularity class. The changed irregularity class is the result of a V7 development which removed a dataset evaluated to be insufficiently reliable to indicate large openings (and thus potential irregularities) and reliance on building year inferences as described in Section 4.5.2. For the top 11 Structural Systems with the largest absolute differences, this change could account for 8 of the Structural Systems. This can be found in Table 17 with the ‘matching’ Structural Systems (with the exception of the irregularity class) highlighted in the same colour.

Table 17: Comparison of Material and Lateral Support System in v6 and v7 arranged by absolute difference.

Structural System	**V6 Count**	**V7 Count**	**Difference**
U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IRVP+OPL	7538.5	38438.5	30900.1
U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IR99	40532.1	11741.9	-28790.2
U/MUR/LWAL/MUR/LN/EW/FW/HBET:2;1/IRVP+OPL	404.3	5937.4	5533.2
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IRVP+OPL	225.8	5578.6	5353.7
S/MAT99/LN/MAT99/LN/EW99/F99/H99/IR99	20688.0	15727.0	-4961.0
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IR99	6585.1	1718.2	-4867.8
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IR99	27609.0	22893.0	-4716.1
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IRVP+OPL	1056.4	5746.6	4689.3
U/MUR/LWAL/MUR/LN/EW/FW/HBET:2;1/IR99	6024.1	1487.4	-4537.7
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IR99	6246.9	1834.0	-4412.9

4.6.4.3 SSy Source Flag

The Structural System Source Flag provides insights into the confidence of the assigned MLSS.

Table 28 shows all the combinations present in this comparison and the respective building counts. On the comment section of the table, the mechanism for the source flag combination is explained. It should be noted that this comparison was performed only for the 255,427 buildings that were present in both datasets, therefore excluding newly-built or demolished buildings.

A total of 254,765 buildings remained the same probability with an additional 616 buildings being assigned a ‘higher’ source flag due to new inspection data. There were also 57 buildings which were assigned a ‘lower’ source flag in V7 compared to V6. This can be due to updated mapping and data input as V6 contained inspection data which had not been yet processed or validated yet. As these inspection datasets have now been processed in V7, some parameters may have been found to be invalid and removed, thus reducing completeness. This may also further impact partial inspections which could not be matched to a corresponding inference.

Table 18 Comparison of the structural system confidence flag from V6 and V7

Ssy_source_flag			
V6	**V7**	**Building Count**	**Comment**
3	3	230154	Same source flag in both versions
4a	3	3	Updating mapping and data input
4b	3	22	Updating mapping and data input
4c	3	20	Updating mapping and data input
5c	3	1	Updating mapping and data input
3	4a	8	Additional inspection data input
4a	4a	3599	Same source flag in both versions
4d	4a	3	Updating mapping and data input
5d	4a	1	Additional inspection data input
3	4b	4	Additional inspection data input
4b	4b	7336	Same source flag in both versions
4c	4b	1	Updating mapping and data input
5c	4b	1	Updating mapping and data input
5d	4b	4	Updating mapping and data input
3	4c	3	Additional inspection data input
4b	4c	2	Additional inspection data input
4c	4c	1333	Same source flag in both versions
5c	4c	2	Updating mapping and data input
3	5c	22	Additional inspection data input
4a	5c	4	Additional inspection data input
4b	5c	42	Additional inspection data input
4c	5c	2	Additional inspection data input
5c	5c	12206	Same source flag in both versions
3	5d	1	Additional inspection data input
4a	5d	42	Additional inspection data input
4b	5d	200	Additional inspection data input
4c	5d	147	Additional inspection data input
4d	5d	2	Additional inspection data input
5c	5d	125	Additional inspection data input
5d	5d	137	Same source flag in both versions

5 Discussion and Recommendations

5.1 Intended Application of Extract

The intended use of the EDB V7 is to feed into the Risk Assessment at a regional level, as presented in the H&R model report [18] for which it categorizes buildings in typologies, based on their inspected or expected characteristics, without including information about the performance of these typologies or individual buildings.

The EDB V7, described in this report, takes into account the particular instructions and requirements of our client in order to facilitate the input to the regional Risk Model calculation [18].

This predominantly algorithmic building classification has been subject to regular checking since EDB V5 [9] and was independently evaluated by an external technical panel [29] to be of satisfactory performance. However, its quality is ultimately bound by the quality and accuracy of its input datasets. A limited number of misclassifications due to proximity of geometric characteristics can result in the assignment of a structural system that is not the actual Structural Systems for specific buildings. However, the impact is expected to be limited, given the regional scale of the Risk assessment to which the EDB V7 feeds into.

5.2 Recommendations

Overall recommendations that can be suggested are with regards to updating data inputs for next versions of the EDB. For example, it is important to continue to update input datasets in future iterations; in particular, the BAG database is probably of highest importance, as it creates the base inventory of buildings.

Another important additional feature can come from the anticipated availability of a new version of AHN Height map data in early 2020. When this is available, the geometric parameters of buildings can be reprocessed in order to have an updated representation of the region as of 2019, and therefore increase largely the coverage of height-related parameters, adding the respective values for buildings built after 2009. The increased density of the forthcoming point cloud dataset also presents opportunities for further improvements of the algorithmic geometric characterisation of buildings in the region.

Other important dataset updates are related to an inventory of strengthened, demolished and newly-built buildings as well as the addition of future inspection data from Arup or third parties.

With regards to inspection data, it is recommended to increase alignment of ongoing inspection campaigns to the EDB taxonomy, so more inspection data can feed into the process. For the present version of the EDB it was not possible to incorporate EVS data shared by CVW, for reasons explained in a dedicated memorandum [28]. If a revised version of the dataset is received, the number of buildings referencing inspection data, instead of the dedicated probabilistic inferences of the EDB, could further increase.

6 References

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A1 Farmhouse Dataland Descriptions

The Dataland descriptions listed in Table 19 were mapped to a WBH (barn+house) Structural Layout (see Section 4.3) in EDB V7.

Table 19 Dataland farmhouse descriptions as part of the Structural Layout classification.

Dataland index	**Dataland description**
1115	Vrijstaande woonboerderij
1125	2/1 kap woonboerderij
1175	Geschakelde woonboerderij
1215	Vrijst. recr. woonboerderij
1515	Woning Bedrijfs Vrijstaand Woonboerderij
1525	2^1 kap bedr. woonboerderij
1575	Gesch. bedr. woonboerderij
1615	Vrijst. prakt. woonboerderij
2211	Akkerbouwbedrijf met woning
2213	Fruitkwekerij
2241	Proefboerderij
2243	Woning + melkveebedrijf
2245	Veehouderij runderen
2246	Veehouderij varkens met woning
2248	Veehouderij pluimvee met woning
2251	Overige veehouderij
2261	Stoeterij/manege/fokkerij
3243	Melkveebedrijf
3245	Veehouderij runderen
3246	Veehouderij varkens
3248	Veehouderij pluimvee
3261	Stoeterij/Manege/Paardenfokkerij

A2 Estimated Building Counts per Structural System

Table 20 presents summation of all Structural System probabilities across the 263,399 buildings of the database, which can provide an estimate of the expected building count for each Structural System.

Table 20 Estimated building count per Structural System

Structural System	Sum of probability
S/MAT99/LN/MAT99/LN/EW99/F99/HBET:20;1/IR99	65,281.0
U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IR99	40,532.1
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IR99	27,609.0
S/MAT99/LN/MAT99/LN/EW99/F99/H99/IR99	20,688.0
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:2;1/IR99	17,052.5
U/MUR/LWAL/MUR/LWAL/EW/FW/HBET:2;1/IR99	14,670.5
U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IRVP+OPL	7,538.5
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IR99	6,585.1
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IR99	6,245.9
U/MUR/LWAL/MUR/LN/EW/FW/HBET:2;1/IR99	6,024.1
U/W/LWAL/W/LWAL/EW/FW/HBET:2;1/IR99	4,397.7
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:2;1/IR99	3,772.5
U/MUR/LWAL/MUR/LN/EW/FC/HBET:20;3/IR99	3,383.7
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:20;3/IR99	2,770.4
U/MUR/LWAL/MUR/LWAL/EW/FC/H99/IR99	2,204.9
W/S/LPB/S/LFBR/EW/FN/HBET:20;1/IR99	1,862.3
W/S/LFBR/S/LFBR/EW/FN/HBET:20;1/IR99	1,518.4
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;3/IR99	1,465.9
B/MUR/LWAL/MUR/LN/EW/FC/HBET:20;3/IR99	1,225.1
WC/MUR/LH/MUR/LH/EWN/FW/HBET:20;1/IR99	1,167.9
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:2;1/IR99	1,057.5
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IRVP+OPL	1,056.4
U/MUR/LWAL/MUR/LN/EW/FW/HBET:20;3/IR99	1,019.7
U/W/LWAL/W/LN/EW/FW/HBET:2;1/IR99	1,004.9
W/W/LPB/W/LPB/EW/FN/HBET:20;1/IR99	963.1
B/MUR/LWAL/MUR/LN/EWN/FW/HBET:20;3/IR99	900.1
WA/MUR/LH/MUR/LH/EWN/FW/HBET:20;1/IR99	891.4
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;3/IR99	720.3
B/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;3/IR99	672.8
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IRVP+OPL	609.5
U/MUR/LWAL/MUR/LN/EW/FC/HBET:20;3/IRVP+DIB	570.2
W/S/LPB/S/LPB/EW/FN/HBET:20;1/IR99	544.2
B/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;3/IR99	529.9
B/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IR99	510.2
W/W/LPB/S/LFBR/EW/FN/HBET:20;1/IR99	504.7

W/MUR/LWAL/MUR/LWAL/EW/FN/HBET:20;1/IR99	489.7
U/W/LWAL/W/LWAL/EW/FW/H99/IR99	447.7
W/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:20;1/IR99	440.0
W/MUR/LH/MUR/LH/EW/FC/HBET:20;1/IR99	412.8
U/MUR/LH/MUR/LH/EWN/FW/HBET:2;1/IR99	407.3
B/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IR99	407.2
U/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;3/IR99	407.2
U/MUR/LWAL/MUR/LN/EW/FW/HBET:2;1/IRVP+OPL	404.3
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:20;3/IR99	398.2
WC/MUR/LH/MUR/LH/EW/FW/HBET:20;1/IR99	398.2
W/W/LPB/MUR/LWAL/EW/FN/HBET:20;1/IR99	395.4
U/MUR/LH/MUR/LH/EW/FW/HBET:2;1/IR99	385.0
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:2;1/IRVP+OPL	383.6
U/MUR/LWAL/MUR/LWAL/EW/FW/H99/IR99	365.8
W/CR+CIP/LPB/CR+CIP/LPB/EW/FN/HBET:20;1/IR99	364.0
U/MUR/LWAL/MUR/LWAL/EW/FM/HBET:2;1/IR99	348.9
WA/MUR/LH/MUR/LH/EW/FW/HBET:20;1/IR99	343.8
B/MUR/LH/MUR/LH/EW/FC/HBET:20;3/IR99	311.2
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;3/IR99	310.0
WC/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;1/IR99	298.7
U/MUR/LWAL/MUR/LN/EW/FC/HBET:20;3/IRVP+OPL	273.9
U/MUR/LWAL/MUR/LN/EW/FC/H99/IR99	244.0
B/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IR99	240.6
W/CR+PC/LPB/CR+PC/LPB/EW/FN/HBET:20;1/IR99	233.8
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IRVP+OPL	225.8
W/S/LPB/S/LFBR/EW/FN/H99/IR99	218.5
WA/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;1/IR99	214.8
B/MUR/LH/MUR/LH/EWN/FW/HBET:20;3/IR99	208.4
B/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IR99	200.7
WA/MUR/LH/MUR/LH/EW/FC/HBET:20;1/IR99	195.5
W/CR+PC/LWAL/CR+PC/LWAL/EW/FN/HBET:20;1/IR99	187.7
W/S/LFBR/S/LFBR/EW/FN/H99/IR99	169.5
U/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:2;1/IR99	164.4
WC/MUR/LH/MUR/LH/EW/FC/HBET:20;1/IR99	160.8
B/MUR/LWAL/MUR/LN/EW/FC/H99/IR99	158.3
U/W/LWAL/W/LN/EW/FW/HBET:20;3/IR99	139.3
B/MUR/LH/MUR/LH/EW/FC/HBET:2;1/IR99	139.0
B/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;3/IR99	134.6
U/MUR/LH/MUR/LH/EW/FC/HBET:2;1/IR99	132.7
U/MUR/LWAL/MUR/LWAL/EW/FN/HBET:2;1/IR99	120.3
B/MUR/LH/MUR/LH/EWN/FW/HBET:2;1/IR99	115.3
W/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;1/IR99	108.7
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:20;3/IRVP+OPL	107.0
U/MUR/LWAL/MUR/LN/EW/FM/HBET:2;1/IRVP+OPL	96.0
W/S/LPB/S/LPB/EW/FN/H99/IR99	95.0
B/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:20;3/IR99	93.5

B/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:20;3/IR99	89.7
WC/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;1/IR99	85.5
U/W/LWAL/W/LWAL/EW/FW/HBET:20;3/IR99	85.2
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/H99/IR99	85.0
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;3/IRVP+DIB	84.5
WA/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;1/IR99	81.6
B/CR+CIP/LWAL/CR+CIP/LN/EW/FC/H99/IR99	81.4
T/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;1/IR99	80.5
W/MUR/LH/MUR/LH/EW/FW/HBET:20;1/IR99	79.4
U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IRVP+DIB	75.1
T/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;1/IR99	74.0
W/W/LPB/S/LFBR/EW/FN/H99/IR99	70.1
B/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;3/IR99	67.5
B/S/LFBR/S/LFBR/EW/FC/HBET:20;3/IR99	61.6
T/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;1/IR99	60.9
U/S/LFBR/S/LFBR/EW/FC/HBET:2;1/IR99	60.1
B/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:2;1/IR99	59.0
W/MUR/LH/MUR/LH/EW/FN/HBET:20;1/IR99	58.4
W/MUR/LH/MUR/LH/EWN/FW/HBET:20;1/IR99	56.8
B/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:2;1/IR99	54.1
U/MUR/LWAL/MUR/LWAL/EWN/FW/H99/IR99	53.9
W/S/LFBR/S/LFBR/EW/FC/HBET:20;1/IR99	52.5
B/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:2;1/IR99	51.3
W/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;1/IR99	50.5
W/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;1/IR99	50.1
W/S/LFM/S/LFBR/EWN/FN/HBET:20;1/IR99	48.6
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:20;3/IRVP+DIB	47.1
U/MUR/LWAL/MUR/LN/EW/FM/HBET:2;1/IR99	47.0
W/W/LPB/MUR/LWAL/EW/FN/H99/IR99	46.8
U/W/LWAL/W/LWAL/EWN/FW/HBET:2;1/IR99	44.2
W/S/LFM/S/LN/EW/FN/HBET:20;1/IR99	44.2
B/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:2;1/IR99	41.2
W/CR+PC/LWAL/CR+PC/LWAL/EW/FN/H99/IR99	40.6
U/MUR/LWAL/MUR/LN/EW/FW/HBET:20;3/IRVP+DIB	39.4
U/MUR/LH/MUR/LH/EWN/FW/HBET:20;3/IR99	37.7
U/CR+PC/LWAL/CR+PC/LN/EW/FC/H99/IR99	37.6
T/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;1/IR99	37.0
WA/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;1/IR99	36.1
W/W/LPB/W/LPB/EW/FN/H99/IR99	35.8
B/CR+PC/LWAL/CR+PC/LN/EW/FC/H99/IR99	35.7
WC/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;1/IR99	34.4
W/CR+PC/LPB/CR+PC/LPB/EW/FN/H99/IR99	32.9
U/CR+CIP/LWAL/CR+CIP/LN/EW/FW/HBET:2;1/IR99	32.0
B/MUR/LH/MUR/LH/EW/FC/H99/IR99	32.0
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;3/IRVP+DIB	31.8
W/S/LFM/S/LFM/EWN/FN/HBET:20;1/IR99	31.6

B/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;3/IR99	31.3
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/H99/IR99	29.9
W/S/LFM/S/LN/EWN/FN/HBET:20;1/IR99	28.7
B/S/LFBR/S/LFBR/EW/FC/HBET:2;1/IR99	28.2
W/MUR/LWAL/MUR/LWAL/EW/FN/H99/IR99	26.2
U/MUR/LWAL/MUR/LWAL/EW/FO/HBET:2;1/IR99	26.1
B/MUR/LWAL/MUR/LWAL/EW/FC/H99/IR99	25.9
U/MUR/LWAL/MUR/LWAL/EW/FW/HBET:2;1/IRVP+OPL	24.6
U/MUR/LWAL/MUR/LWAL/EWN/FC/HBET:2;1/IR99	22.8
T/S/LFBR/S/LFBR/EW/FC/HBET:20;1/IR99	21.4
B/S/LFM/S/LFM/EW/FC/HBET:20;3/IR99	21.0
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;3/IR99	18.7
B/MUR/LWAL/MUR/LWAL/EW/FM/HBET:20;3/IR99	18.5
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:2;1/IRVP+SOS	18.5
W/MUR/LWAL/MUR/LWAL/EWN/FN/H99/IR99	17.5
B/MUR/LWAL/MUR/LWAL/EW/FW/HBET:2;1/IR99	17.2
U/MUR/LWAL/MUR/LWAL/EW/FM/HBET:2;1/IRVP+OPL	16.9
W/CR+CIP/LPB/CR+CIP/LPB/EW/FN/H99/IR99	16.8
U/MUR/LWAL/MUR/LN/EW/FW/HBET:20;3/IRVP+OPL	16.5
WC/W/LPB/W/LPB/EW/FW/HBET:20;1/IR99	16.3
B/CR+PC/LH/CR+PC/LH/EW/FC/HBET:20;3/IR99	16.1
T/MUR/LH/MUR/LH/EW/FC/HBET:20;1/IR99	15.9
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IRVP+DIB	14.6
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:2;1/IRVP+DIB	14.5
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IRVP+DIB	13.7
W/MUR/LH/MUR/LH/EW/FC/H99/IR99	13.5
U/W/LWAL/W/LN/EW/FW/H99/IR99	13.1
B/CR+CIP/LH/CR+CIP/LH/EW/FC/H99/IR99	12.6
B/CR+PC/LWAL/CR+PC/LWAL/EW/FC/H99/IR99	11.9
U/W/LWAL/W/LN/EW/FW/HBET:20;3/IRVP+DIB	11.8
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:2;1/IRVP+DIB	11.3
W/S/LFM/S/LN/EWN/FN/H99/IR99	11.2
U/W/LFM/W/LN/EWN/FW/HBET:2;1/IR99	10.9
T/S/LFM/S/LFM/EW/FC/HBET:20;1/IR99	10.7
B/MUR/LH/MUR/LH/EWN/FM/HBET:20;3/IR99	10.6
B/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;3/IRVP+SOS	10.4
U/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;3/IR99	9.9
B/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;3/IR99	9.8
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;3/IRVP+DIB	9.8
B/MUR/LWAL/MUR/LN/EW/FC/HBET:20;3/IRVP+SOS	9.7
B/CR+PC/LH/CR+PC/LH/EW/FC/HBET:2;1/IR99	9.4
T/MUR/LWAL/MUR/LN/EW/FC/HBET:20;1/IR99	9.4
U/MUR/LH/MUR/LH/EW/FW/HBET:20;3/IR99	9.2
B/S/LFBR/S/LFBR/EW/FC/H99/IR99	9.1
U/S/LFBR/S/LFBR/EW/FC/H99/IR99	9.0
WA/MUR/LH/MUR/LH/EW/FM/HBET:20;1/IR99	8.9

U/MUR/LWAL/MUR/LWAL/EW/FW/HBET:2;1/IRVP+SOS	8.8
T/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;1/IR99	8.6
B/MUR/LH/MUR/LH/EWN/FM/HBET:2;1/IR99	8.3
U/CR+PC/LWAL/CR+PC/LN/EWN/FC/HBET:2;1/IR99	8.3
U/MUR/LH/MUR/LH/EW/FM/HBET:2;1/IR99	8.1
WC/MUR/LH/MUR/LH/EW/FM/HBET:20;1/IR99	8.0
U/MUR/LWAL/MUR/LWAL/EWN/FO/HBET:2;1/IR99	8.0
U/MUR/LH/MUR/LH/EWN/FC/HBET:2;1/IR99	7.9
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IRVP+DIB	7.6
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:20;3/IRVP+DIB	7.5
U/MUR/LWAL/MUR/LN/EW/FC/H99/IRVP+OPL	7.5
WA/W/LPB/W/LPB/EW/FW/HBET:20;1/IR99	7.3
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:2;1/IRVP+OPL	7.2
T/CR+CIP/LFM/CR+CIP/LFM/EW/FC/HBET:20;1/IR99	7.1
U/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:2;1/IR99	7.0
U/W/LWAL/W/LWAL/EW/FC/HBET:2;1/IR99	7.0
U/MUR/LH/MUR/LH/EW/FN/HBET:2;1/IR99	6.9
B/CR+PC/LH/CR+PC/LH/EW/FC/H99/IR99	6.9
U/MUR/LWAL/MUR/LN/EW/FW/H99/IR99	6.8
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IRVP+SOS	6.5
U/S/LFM/S/LFM/EW/FC/HBET:2;1/IR99	6.5
W/S/LFM/S/LN/EW/FN/H99/IR99	6.5
WC/MUR/LH/MUR/LWAL/EWN/FW/HBET:20;1/IR99	6.3
WA/W/LH/W/LH/EW/FW/HBET:20;1/IR99	6.1
B/S/LFM/S/LFM/EW/FC/HBET:2;1/IR99	6.1
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;3/IRVP+OPL	6.1
U/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/H99/IR99	6.0
U/MUR/LH/MUR/LH/EW/FC/HBET:20;3/IR99	5.9
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IRVP+SOS	5.8
U/MUR/LWAL/MUR/LN/EW/FW/HBET:2;1/IRVP+DIB	5.4
T/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:20;1/IR99	5.3
U/MUR/LWAL/MUR/LWAL/EW/FM/HBET:20;3/IRVP+DIB	4.9
U/MUR/LWAL/MUR/LN/EWN/FW/H99/IR99	4.9
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:2;1/IRVP+OPL	4.6
W/MUR/LH/MUR/LH/EW/FC/HBET:20;1/IRVP+SOS	4.5
W/S/LFM/S/LFM/EWN/FN/H99/IR99	4.5
W/MUR/LWAL/MUR/LN/EW/FC/HBET:20;1/IR99	4.5
U/W/LWAL/W/LN/EW/FW/HBET:2;1/IRVP+DIB	4.4
U/MUR/LH/MUR/LH/EWN/FW/HBET:2;1/IRVP+SOS	4.3
B/MUR/LH/MUR/LH/EWN/FN/HBET:20;1/IR99	4.0
B/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:20;1/IR99	4.0
B/MUR/LH/MUR/LH/EW/FC/HBET:2;1/IRVP+SOS	3.8
U/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;3/IRVP+DIB	3.8
WA/MUR/LH/MUR/LWAL/EWN/FW/HBET:20;1/IR99	3.7
U/W/LFBR/W/LFBR/EWN/FW/HBET:2;1/IR99	3.6
B/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:2;1/IR99	3.5

U/MUR/LH/MUR/LH/EW/FC/H99/IR99	3.4
W/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;1/IR99	3.1
B/MUR/LH/MUR/LH/EW/FC/HBET:20;3/IRVP+SOS	3.0
T/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;1/IRVP+SOS	3.0
U/MUR/LWAL/MUR/LWAL/EW/FO/HBET:2;1/IRVP+OPL	3.0
B/MUR/LH/MUR/LH/EWN/FN/HBET:2;1/IR99	3.0
B/MUR/LWAL/MUR/LN/EWN/FW/H99/IR99	3.0
U/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IRVP+SOS	3.0
W/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:20;1/IR99	2.9
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;3/IRVP+OPL	2.8
U/CR+PC/LWAL/CR+PC/LN/EWN/FC/HBET:2;1/IRVP+OPL	2.8
W/S/LFBR/S/LFBR/EWN/FN/HBET:20;1/IR99	2.7
W/MUR/LH/MUR/LWAL/EW/FW/HBET:20;1/IR99	2.7
B/S/LFM/S/LFM/EW/FN/HBET:2;1/IR99	2.6
WA/MUR/LH/MUR/LH/EWN/FW/HBET:20;1/IRVP+SOS	2.6
B/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:2;1/IR99	2.6
W/MUR/LWAL/MUR/LN/EW/FN/HBET:20;1/IR99	2.5
B/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IRVP+SOS	2.5
U/MUR/LWAL/MUR/LWAL/EW/FW/HBET:2;1/IRVP+DIB	2.4
T/CR+PC/LH/CR+PC/LH/EW/FC/HBET:20;1/IR99	2.3
W/S/LFM/S/LFBR/EW/FN/HBET:20;1/IR99	2.3
W/CR+PC/LH/CR+PC/LH/EWN/FO/HBET:20;1/IR99	2.2
B/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IRVP+SOS	2.2
U/MUR/LWAL/MUR/LWAL/EW/FM/H99/IR99	2.1
W/MUR/LFBR/MUR/LFBR/EWN/FO/HBET:20;1/IR99	2.0
S/MUR/LWAL/MUR/LN/EW/FC/HBET:20;1/IR99	2.0
U/MUR/LWAL/MUR/LWAL/EWN/FC/HBET:20;3/IR99	2.0
W/W/LWAL/W/LWAL/EW/FN/HBET:20;1/IR99	2.0
W/W/LWAL/W/LWAL/EWN/FW/HBET:20;1/IR99	1.9
B/MUR/LWAL/MUR/LWAL/EW/FO/HBET:2;1/IR99	1.9
WC/S/LPB/S/LPB/EW/FW/HBET:20;1/IR99	1.9
U/S/LPB/S/LFBR/EW/FN/HBET:2;1/IR99	1.8
U/S/LFBR/S/LFBR/EW/FC/HBET:20;3/IR99	1.8
WA/MUR/LWAL/MUR/LWAL/EW/FN/HBET:20;1/IR99	1.8
W/S/LFM/S/LFM/EW/FW/HBET:20;1/IR99	1.8
U/S/LFM/S/LFBR/EW/FN/HBET:2;1/IR99	1.8
W/MUR/LWAL/MUR/LWAL/EW/FN/HBET:20;1/IRVP+SOS	1.7
B/MUR/LH/MUR/LH/EWN/FW/HBET:2;1/IRVP+SOS	1.7
U/W/LH/W/LH/EW/FW/HBET:2;1/IR99	1.7
W/S/LPB/S/LFBR/EW/FN/HBET:20;1/IRVP+SOS	1.7
U/S/LPB/S/LPB/EW/FC/HBET:2;1/IR99	1.7
WC/MUR/LWAL/MUR/LWAL/EW/FO/HBET:20;1/IR99	1.7
B/MUR/LWAL/MUR/LWAL/EW/FM/HBET:2;1/IR99	1.7
B/MUR/LH/MUR/LH/EWN/FW/HBET:20;3/IRVP+SOS	1.6
W/MUR/LH/MUR/LH/EW/FW/HBET:20;1/IRVP+SOS	1.6
W/W/LWAL/W/LWAL/EWN/FN/HBET:20;1/IR99	1.6

WC/MUR/LH/MUR/LH/EW/FN/HBET:20;1/IR99	1.5
W/W/LPB/W/LPB/EW/FW/HBET:20;1/IR99	1.5
WA/MUR/LH/MUR/LH/EW/FW/HBET:20;1/IRVP+SOS	1.5
WC/W/LH/W/LH/EW/FW/HBET:20;1/IR99	1.5
WA/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;1/IR99	1.5
WA/W/LH/W/LH/EW/FC/HBET:20;1/IR99	1.5
W/S/LFBR/S/LN/EW/FN/HBET:20;1/IR99	1.5
W/S/LPB/S/LPB/EWN/FME/HBET:20;1/IR99	1.5
U/MUR/LH/MUR/LH/EW/FC/HBET:2;1/IRVP+SOS	1.4
B/S/LFM/S/LFM/EW/FC/H99/IR99	1.4
U/S/LPB/S/LN/EW/FN/HBET:2;1/IR99	1.4
WC/MUR/LH/MUR/LH/EWN/FW/H99/IR99	1.4
W/W/LH/W/LH/EW/FN/HBET:20;1/IR99	1.4
W/S/LFBR/S/LFBR/EW/FC/H99/IR99	1.4
WA/MUR/LH/MUR/LH/EWN/FW/H99/IR99	1.4
W/S/LFBR/S/LFBR/EW/FN/HBET:20;1/IRVP+SOS	1.4
WC/S/LFM/S/LFBR/EWN/FW/HBET:20;1/IR99	1.4
U/S/LFM/S/LN/EW/FW/HBET:2;1/IR99	1.3
U/MUR/LWAL/MUR/LN/EW/FW/HBET:2;1/IRVP+SOS	1.3
U/W/LH/W/LH/EW/FN/HBET:2;1/IR99	1.3
U/W/LH/W/LH/EW/FC/HBET:2;1/IR99	1.3
WC/W/LPB/W/LPB/EW/FM/HBET:20;1/IR99	1.3
U/S/LFBR/S/LN/EWN/FN/HBET:2;1/IR99	1.3
U/W/LH/W/LH/EWN/FW/HBET:2;1/IR99	1.2
U/MUR/LFM/MUR/LFM/EW/FO/HBET:2;1/IR99	1.2
WA/MUR/LWAL/MUR/LWAL/EW/FO/HBET:20;1/IR99	1.2
U/MUR/LH/MUR/LH/EWN/FW/HBET:2;1/IRVP+OPL	1.2
U/W/LWAL/W/LWAL/EW/FO/HBET:2;1/IR99	1.2
W/CR+CIP/LFM/CR+CIP/LH/EW/FW/HBET:20;1/IR99	1.2
WC/MUR/LH/MUR/LH/EW/FC/HBET:20;1/IRVP+SOS	1.2
U/MUR/LWAL/MUR/LWAL/EW/FM/HBET:20;3/IR99	1.2
W/S/LPB/S/LPB/EW/FW/HBET:20;1/IR99	1.2
W/S/LFBR/S/LFM/EWN/FN/HBET:20;1/IR99	1.1
WA/MUR/LWAL/MUR/LWAL/EWN/FC/HBET:20;1/IR99	1.1
U/MUR/LH/MUR/LH/EW/FW/HBET:2;1/IRVP+SOS	1.1
U/W/LWAL/W/LWAL/EW/FN/HBET:2;1/IR99	1.1
W/S/LPB/S/LN/EW/FN/HBET:20;1/IR99	1.1
U/MUR/LWAL/MUR/LH/EW/FN/HBET:2;1/IR99	1.1
WA/MUR/LWAL/MUR/LWAL/EWN/FM/HBET:20;1/IR99	1.1
W/MUR/LH/MUR/LH/EW/FN/HBET:20;1/IRVP+SOS	1.1
W/CR+CIP/LFM/CR+CIP/LFM/EW/FM/HBET:20;1/IR99	1.1
WC/MUR/LWAL/MUR/LWAL/EWN/FO/HBET:20;1/IR99	1.1
WA/MUR/LH/MUR/LH/EWN/FC/HBET:20;1/IR99	1.0
U/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;3/IRVP+SOS	1.0
B/MUR/LWAL/MUR/LWAL/EW/FN/HBET:2;1/IR99	1.0
U/CR+CIP/LFM/CR+CIP/LFM/EWN/FO/HBET:2;1/IR99	1.0

B/MUR/LWAL/MUR/LWAL/EW/FO/HBET:20;3/IR99	1.0
B/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IRVP+SOS	1.0
S/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:20;1/IR99	1.0
S/W/LN/W/LN/EWN/FN/HBET:20;1/IR99	1.0
T/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;1/IRVP+SOS	1.0
T/MUR/LWAL/MUR/LN/EW/FC/HBET:20;1/IRVP+SOS	1.0
U/MUR/LN/MUR/LN/EWN/FW/HBET:2;1/IR99	1.0
U/MUR/LWAL/MUR/LH/EWN/FW/HBET:2;1/IR99	1.0
U/MUR/LWAL/MUR/LWAL/EWN/FO/HBET:2;1/IRVP+SOS	1.0
U/MUR/LWAL/S/LFM/EW/FW/HBET:2;1/IR99	1.0
U/S/LH/MUR/LWAL/EWN/FO/HBET:2;1/IR99	1.0
U/W/LPB/W/LPB/EW/FW/HBET:2;1/IR99	1.0
WA/W/LPB/W/LPB/EW/FN/HBET:20;1/IR99	1.0
WA/MUR/LH/MUR/LH/EW/FN/HBET:20;1/IR99	1.0
U/MUR/LWAL/MUR/LN/EW/FC/HBET:20;3/IRVP+SOS	1.0
W/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:20;1/IRVP+SOS	0.9
U/MUR/LWAL/MUR/LWAL/EWN/FC/H99/IR99	0.9
WA/S/LPB/S/LPB/EW/FW/HBET:20;1/IR99	0.9
U/MUR/LH/MUR/LH/EWN/FW/H99/IR99	0.9
U/MUR/LWAL/MUR/LWAL/EW/FN/H99/IR99	0.8
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;3/IRVP+SOS	0.8
B/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;3/IRVP+SOS	0.7
B/MUR/LWAL/MUR/LN/EWN/FW/HBET:2;1/IRVP+DIB	0.6
U/MUR/LH/MUR/LH/EW/FW/HBET:20;3/IRVP+SOS	0.6
B/MUR/LWAL/MUR/LWAL/EWN/FW/H99/IR99	0.6
B/MUR/LH/MUR/LH/EWN/FW/H99/IR99	0.6
U/MUR/LH/MUR/LH/EWN/FW/HBET:2;1/IRVP+DIB	0.6
WC/MUR/LWAL/MUR/LWAL/EW/FN/HBET:20;1/IR99	0.6
U/MUR/LH/MUR/LH/EWN/FC/HBET:2;1/IRVP+SOS	0.6
U/W/LH/W/LH/EW/FW/HBET:20;3/IR99	0.6
U/MUR/LH/MUR/LH/EW/FW/H99/IR99	0.6
WC/MUR/LH/MUR/LH/EW/FW/HBET:20;1/IRVP+SOS	0.6
U/W/LWAL/W/LN/EW/FW/HBET:2;1/IRVP+OPL	0.6
W/S/LPB/S/LPB/EW/FN/HBET:20;1/IRVP+SOS	0.5
WA/W/LPB/W/LPB/EW/FM/HBET:20;1/IR99	0.5
U/MUR/LWAL/MUR/LWAL/EW/FN/HBET:20;1/IR99	0.5
WA/MUR/LH/MUR/LH/EW/FC/HBET:20;1/IRVP+SOS	0.5
U/CR+CIP/LFM/CR+CIP/LFM/EW/FC/HBET:2;1/IR99	0.4
U/W/LWAL/W/LWAL/EW/FW/HBET:2;1/IRVP+OPL	0.4
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;3/IRVP+SOS	0.4
B/MUR/LWAL/MUR/LN/EW/FC/HBET:2;1/IRVP+DIB	0.4
U/MUR/LH/MUR/LH/EWN/FW/HBET:20;3/IRVP+DIB	0.4
B/MUR/LWAL/MUR/LN/EW/FC/HBET:20;3/IRVP+DIB	0.4
WC/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;1/IR99	0.4
WC/W/LH/W/LH/EW/FC/HBET:20;1/IR99	0.4
WA/MUR/LH/MUR/LH/EW/FC/H99/IR99	0.4

WC/MUR/LH/MUR/LH/EW/FC/H99/IR99	0.4
U/W/LWAL/W/LWAL/EW/FW/HBET:2;1/IRVP+DIB	0.4
U/W/LWAL/W/LWAL/EW/FW/HBET:20;3/IRVP+DIB	0.4
B/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/H99/IR99	0.4
W/S/LFM/S/LFBR/EWN/FN/H99/IR99	0.3
B/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IRVP+SOS	0.3
U/MUR/LH/MUR/LH/EWN/FW/HBET:20;3/IRVP+SOS	0.3
U/MUR/LWAL/MUR/LWAL/EW/FM/HBET:2;1/IRVP+DIB	0.3
B/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:20;3/IRVP+SOS	0.3
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:2;1/IRVP+SOS	0.3
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:20;3/IRVP+OPL	0.3
W/MUR/LWAL/MUR/LWAL/EW/FC/H99/IR99	0.3
U/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;3/IRVP+DIB	0.3
W/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;1/IRVP+SOS	0.3
W/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;1/IRVP+SOS	0.2
B/S/LFM/S/LFM/EW/FN/HBET:20;1/IR99	0.2
U/MUR/LWAL/MUR/LN/EWN/FW/HBET:20;3/IRVP+SOS	0.2
U/W/LWAL/W/LWAL/EW/FW/HBET:2;1/IRVP+SOS	0.2
U/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:2;1/IRVP+SOS	0.2
WA/S/LFM/S/LFBR/EWN/FW/HBET:20;1/IR99	0.2
U/W/LWAL/W/LWAL/EWN/FW/HBET:20;3/IR99	0.2
B/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;3/IRVP+DIB	0.2
B/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IRVP+DIB	0.2
W/MUR/LWAL/MUR/LWAL/EWN/FW/H99/IR99	0.2
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:2;1/IRVP+SOS	0.2
W/MUR/LH/MUR/LH/EW/FN/H99/IR99	0.2
WA/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;1/IRVP+SOS	0.2
W/MUR/LWAL/MUR/LWAL/EW/FW/H99/IR99	0.2
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:2;1/IRVP+SOS	0.2
B/MUR/LH/MUR/LH/EWN/FW/HBET:2;1/IRVP+DIB	0.2
WC/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;1/IRVP+SOS	0.2
U/MUR/LH/MUR/LH/EW/FN/HBET:2;1/IRVP+SOS	0.2
U/MUR/LH/MUR/LH/EW/FC/HBET:20;3/IRVP+DIB	0.2
U/MUR/LH/MUR/LH/EW/FW/HBET:2;1/IRVP+DIB	0.2
U/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;3/IRVP+SOS	0.2
U/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;3/IRVP+SOS	0.2
B/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:2;1/IRVP+SOS	0.2
W/MUR/LWAL/MUR/LWAL/EW/FW/HBET:20;1/IRVP+SOS	0.1
W/S/LFBR/S/LFBR/EW/FC/HBET:20;1/IRVP+SOS	0.1
WA/MUR/LWAL/MUR/LWAL/EWN/FO/HBET:20;1/IR99	0.1
B/MUR/LH/MUR/LH/EWN/FM/HBET:2;1/IRVP+SOS	0.1
WA/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;1/IRVP+SOS	0.1
U/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:2;1/IRVP+DIB	0.1
W/MUR/LWAL/MUR/LN/EW/FC/HBET:20;1/IRVP+SOS	0.1
W/MUR/LH/MUR/LH/EW/FW/H99/IR99	0.1
U/CR+CIP/LFM/CR+CIP/LFM/EW/FC/HBET:2;1/IRVP+SOS	0.1

U/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:2;1/IRVP+SOS	0.1
U/CR+PC/LH/CR+PC/LH/EW/FC/HBET:2;1/IRVP+SOS	0.1
U/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:2;1/IR99	0.1
W/MUR/LH/MUR/LWAL/EW/FW/HBET:20;1/IRVP+SOS	0.1
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:2;1/IRVP+DIB	0.1
B/MUR/LH/MUR/LH/EW/FC/HBET:2;1/IRVP+DIB	0.1
B/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:20;3/IRVP+DIB	0.1
B/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:2;1/IRVP+DIB	0.1
U/MUR/LWAL/MUR/LN/EW/FW/HBET:20;3/IRVP+SOS	0.1
B/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:2;1/IRVP+DIB	0.1
B/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:20;3/IRVP+SOS	0.1
WC/MUR/LWAL/MUR/LWAL/EW/FC/H99/IR99	0.1
WA/MUR/LWAL/MUR/LWAL/EW/FC/H99/IR99	0.1
B/MUR/LWAL/MUR/LWAL/EW/FW/H99/IR99	0.1
B/MUR/LH/MUR/LH/EW/FC/HBET:20;3/IRVP+DIB	0.1
B/MUR/LWAL/MUR/LWAL/EW/FW/HBET:2;1/IRVP+SOS	0.1
U/MUR/LH/MUR/LH/EW/FC/HBET:2;1/IRVP+DIB	0.1
U/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;3/IRVP+DIB	0.1
B/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;3/IRVP+DIB	0.1
W/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;1/IRVP+SOS	0.1
B/MUR/LWAL/MUR/LWAL/EW/FC/HBET:2;1/IRVP+DIB	0.1
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/HBET:20;3/IRVP+SOS	0.1
B/MUR/LH/MUR/LH/EWN/FN/HBET:2;1/IRVP+SOS	0.1
W/S/LFM/S/LN/EW/FN/HBET:20;1/IRVP+SOS	0.1
U/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;3/IRVP+OPL	0.1
WA/MUR/LH/MUR/LH/EW/FW/H99/IR99	0.1
B/MUR/LWAL/MUR/LWAL/EWN/FW/HBET:20;3/IRVP+SOS	0.1
B/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;3/IRVP+SOS	0.1
B/MUR/LWAL/MUR/LWAL/EW/FM/H99/IR99	0.1
WA/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;1/IRVP+SOS	0.1
WC/MUR/LH/MUR/LH/EW/FW/H99/IR99	0.1
WC/MUR/LWAL/MUR/LWAL/EWN/FC/HBET:20;1/IR99	0.1
W/S/LFM/S/LN/EWN/FN/HBET:20;1/IRVP+SOS	0.1
W/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:20;1/IRVP+SOS	0.1
U/MUR/LH/MUR/LH/EWN/FC/H99/IR99	0.1
WC/W/LPB/W/LPB/EW/FN/HBET:20;1/IR99	0.0
W/S/LFM/S/LFM/EWN/FN/HBET:20;1/IRVP+SOS	0.0
B/MUR/LH/MUR/LH/EWN/FM/H99/IR99	0.0
U/MUR/LH/MUR/LH/EW/FC/HBET:20;3/IRVP+SOS	0.0
W/S/LFM/S/LFBR/EWN/FN/HBET:20;1/IRVP+SOS	0.0
B/S/LFBR/S/LFBR/EW/FC/HBET:20;3/IRVP+SOS	0.0
WA/MUR/LWAL/MUR/LWAL/EWN/FW/H99/IR99	0.0
WC/MUR/LWAL/MUR/LWAL/EWN/FW/H99/IR99	0.0
U/MUR/LWAL/MUR/LN/EW/FW/H99/IRVP+OPL	0.0
W/S/LFM/S/LFBR/EW/FN/HBET:20;1/IRVP+SOS	0.0
U/MUR/LH/MUR/LH/EW/FW/HBET:20;3/IRVP+DIB	0.0

WC/MUR/LH/MUR/LH/EWN/FC/HBET:20;1/IR99	0.0
U/CR+PC/LWAL/CR+PC/LN/EW/FC/HBET:20;3/IRVP+SOS	0.0
W/S/LFBR/S/LFBR/EWN/FN/HBET:20;1/IRVP+SOS	0.0
B/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:2;1/IRVP+DIB	0.0
B/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:20;3/IRVP+DIB	0.0
B/CR+PC/LH/CR+PC/LH/EW/FC/HBET:20;3/IRVP+SOS	0.0
B/CR+CIP/LH/CR+CIP/LH/EW/FC/HBET:20;3/IRVP+DIB	0.0
WC/S/LFM/S/LFBR/EWN/FW/H99/IR99	0.0
B/CR+CIP/LFM/CR+CIP/LFM/EW/FC/HBET:20;3/IR99	0.0
WA/S/LFM/S/LFBR/EWN/FW/H99/IR99	0.0
B/CR+PC/LWAL/CR+PC/LWAL/EW/FC/HBET:2;1/IRVP+DIB	0.0
B/CR+CIP/LWAL/CR+CIP/LWAL/EW/FC/HBET:20;3/IRVP+SOS	0.0
B/S/LFBR/S/LFBR/EW/FC/HBET:2;1/IRVP+DIB	0.0
WC/MUR/LWAL/MUR/LWAL/EW/FC/HBET:20;1/IRVP+SOS	0.0
B/MUR/LWAL/MUR/LWAL/EW/FO/HBET:2;1/IRVP+SOS	0.0
B/MUR/LH/MUR/LH/EWN/FM/HBET:2;1/IRVP+DIB	0.0
B/MUR/LH/MUR/LH/EWN/FN/H99/IR99	0.0
B/MUR/LWAL/MUR/LWAL/EWN/FN/H99/IR99	0.0
WA/MUR/LH/MUR/LH/EW/FM/HBET:20;1/IRVP+SOS	0.0
B/S/LFBR/S/LFBR/EW/FC/HBET:20;3/IRVP+DIB	0.0
W/S/LFM/S/LFM/EW/FW/HBET:20;1/IRVP+SOS	0.0
U/MUR/LWAL/MUR/LN/EWN/FW/H99/IRVP+OPL	0.0
B/CR+PC/LH/CR+PC/LH/EW/FC/HBET:2;1/IRVP+DIB	0.0
U/CR+CIP/LFM/CR+CIP/LFM/EW/FC/HBET:20;3/IRVP+SOS	0.0
W/MUR/LH/MUR/LH/EWN/FW/H99/IR99	0.0
WC/MUR/LH/MUR/LH/EW/FM/HBET:20;1/IRVP+SOS	0.0
B/CR+PC/LH/CR+PC/LH/EW/FC/HBET:20;3/IRVP+DIB	0.0
U/CR+CIP/LWAL/CR+CIP/LN/EW/FC/H99/IRVP+OPL	0.0
U/CR+CIP/LFM/CR+CIP/LFM/EWN/FO/HBET:2;1/IRVP+SOS	0.0
B/MUR/LWAL/MUR/LWAL/EW/FM/HBET:2;1/IRVP+SOS	0.0
U/MUR/LWAL/MUR/LWAL/EW/FN/HBET:2;1/IRVP+SOS	0.0
W/S/LFBR/S/LFM/EWN/FN/HBET:20;1/IRVP+SOS	0.0
W/S/LPB/S/LPB/EW/FW/HBET:20;1/IRVP+SOS	0.0
B/MUR/LWAL/MUR/LWAL/EW/FW/HBET:2;1/IRVP+DIB	0.0
W/S/LFBR/S/LN/EW/FN/HBET:20;1/IRVP+SOS	0.0
W/S/LPB/S/LPB/EWN/FME/HBET:20;1/IRVP+SOS	0.0
U/MUR/LWAL/MUR/LWAL/EW/FM/HBET:2;1/IRVP+SOS	0.0
WC/MUR/LWAL/MUR/LWAL/EW/FO/HBET:20;1/IRVP+SOS	0.0
B/MUR/LWAL/MUR/LWAL/EW/FN/HBET:20;1/IR99	0.0
B/MUR/LH/MUR/LH/EWN/FN/HBET:2;1/IRVP+DIB	0.0
B/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:2;1/IRVP+DIB	0.0
B/MUR/LWAL/MUR/LWAL/EWN/FN/HBET:2;1/IRVP+SOS	0.0
U/MUR/LWAL/MUR/LWAL/EW/FC/H99/IRVP+OPL	0.0
U/MUR/LWAL/MUR/LWAL/EW/FO/HBET:20;3/IR99	0.0
B/S/LFM/S/LFM/EW/FC/HBET:2;1/IRVP+DIB	0.0
WC/MUR/LWAL/MUR/LWAL/EWN/FM/HBET:20;1/IR99	0.0

A3 Inference Rules Used in EDB V7

The inference rules used in EDB V7 are presented in the figures below per Structural Layout. The dashed lines show the expert based inference as per EDB V5 [8] while the continuous lines show the resulting inference rules created using inspection data, as described in Section 4.4.2.

The inference rule for the BL (block) Structural Layout is inferring predominantly masonry-based MLSS's, with timber floors in early 20th century construction losing popularity compared to concrete floors and cavity walls after the middle of the century. As shown in Figure 35, the impact of the data-driven inference updates has reduced the probability of both predominant classes, given the variety of less predominant combinations present in the inspection data.

Note that while EDB V5 was inferring an LWAL (wall) system in the y-direction, in EDB V7 the expert-based inference was changed to infer LN (no lateral support system) system. The change was performed to align the BL tagging with the UBHS (block unit single) and UBHM (block unit multiple) buildings which have similar characteristic structural systems in the y direction and are noted LN in this direction.

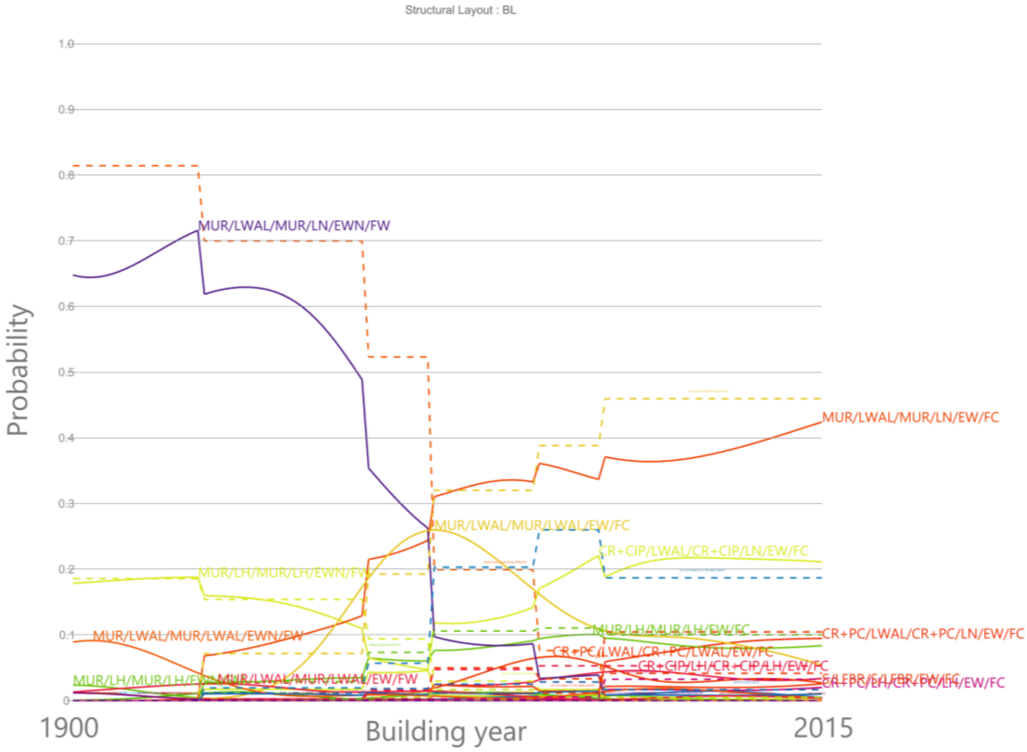

Figure 34 BL (block) Structural Layout inference rule[6]

[6] In these graphical representations, the names of Structural Systems with a maximum inferred probability lower than 5% are not denoted to avoid title cluttering (given that there are multiple inspected typologies with very low counts and, therefore, low resultant probabilities). The dashed lines represent the EDB V5 expert-based inference rules, while the continuous lines represent the data-driven inference updates.

For the UH Structural Layout there is a much smaller variation in the inspected Structural Systems with the main probabilities being divided among six MLSS's. What is notable is that in the data-driven inference updates, shown in Figure 35, timber constructions have been found to be higher than the initially assigned percentage, and therefore their inferred likelihood by the end of the 20th century is largely increased using the inspection data-driven inference update methodology previously described.

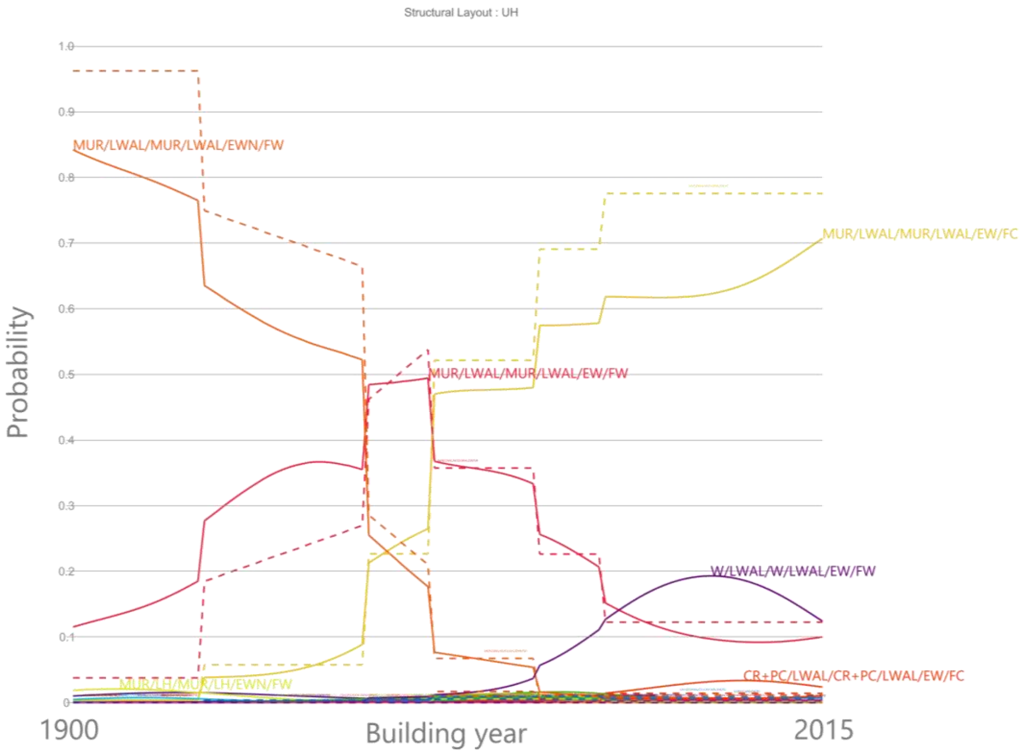

Figure 35 UH (house) Structural Layout inference rule

As shown in Figure 36, UBA (block unit aggregate) inferences present similar trends to the BL and UH, with predominantly masonry-based MLSS's being assigned a larger likelihood. Variations with LWAL, LN and LH on the secondary directions are present in the inspection data and on the previous inferences, resulting in increased numbers of significantly inferred MLSS's for UBA.

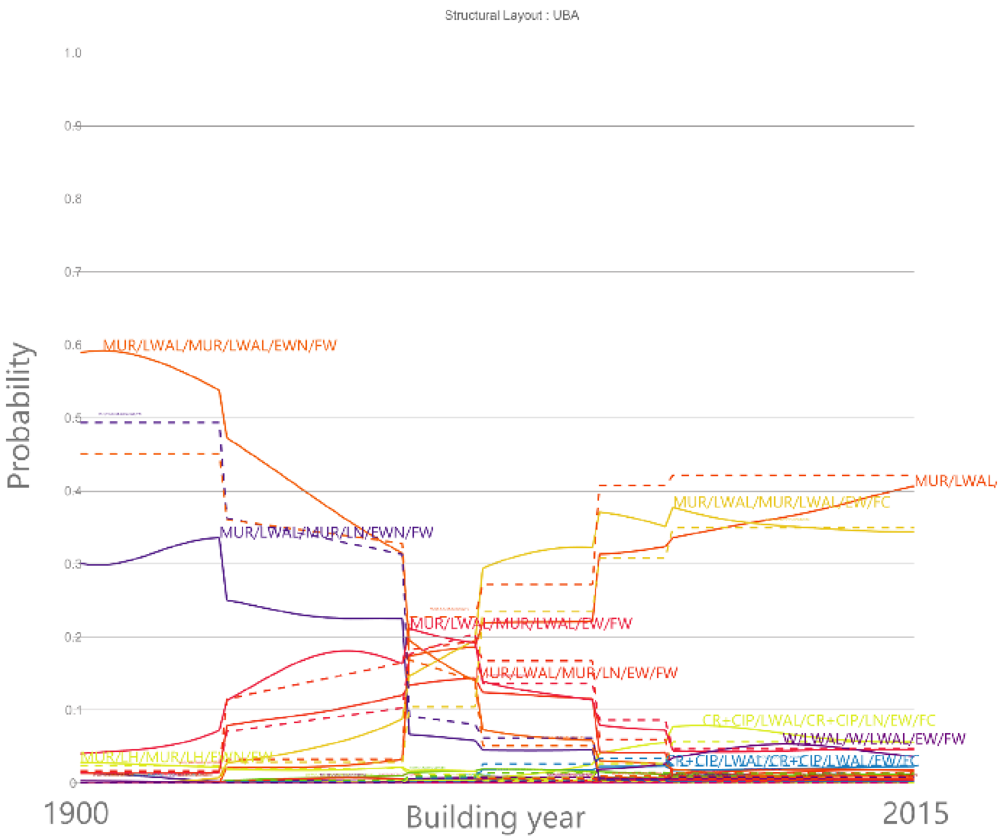

Figure 36 UBA (block unit aggregate) Structural Layout inference rule

The UBHS (block unit single) Structural Layout has the most inspected buildings, which allowed it to be the first Structural Layout to have data-driven inferences already derived in the previous EDB version (EDB V5). The main trends of those inferences are slightly modified with the emergence of buildings being inspected to have LWAL in the secondary direction, resulting in a small likelihood being assigned to corresponding MLSS's (see Figure 37).

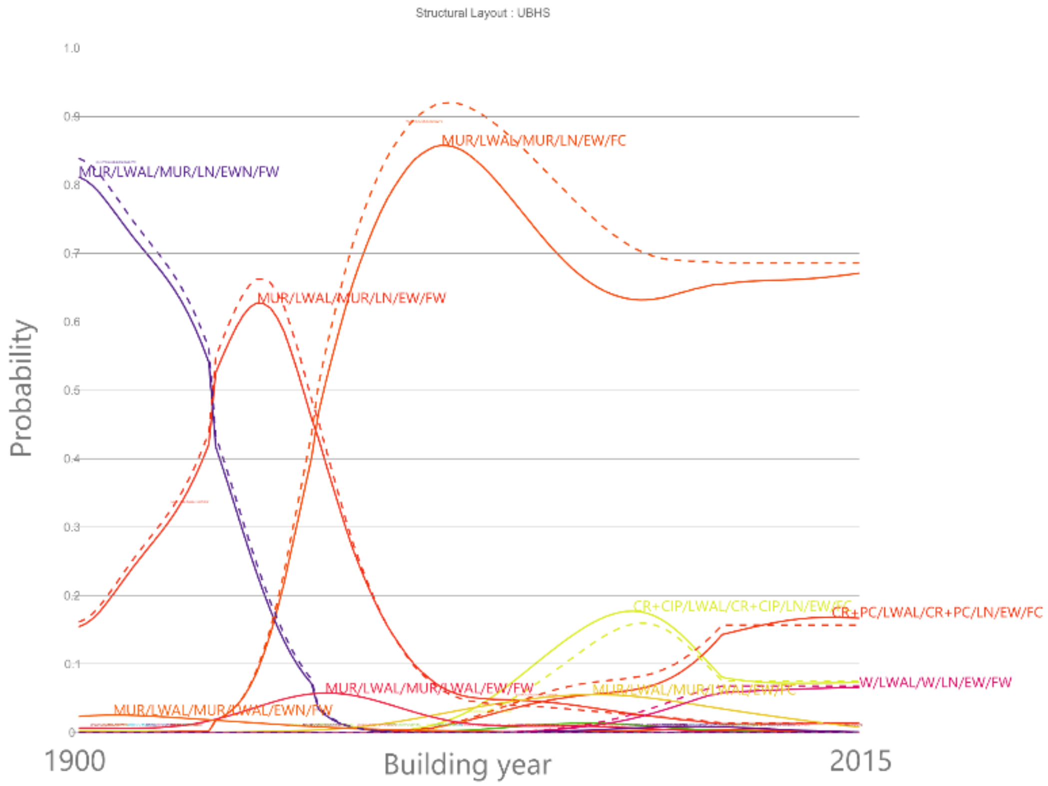

Figure 37 UBHS (block unit single) Structural Layout inference rule

The UBHM (block unit multiple) follows similar trends as UBHS but the MLSS with cavity masonry walls and timber floors does not become predominant in any building period, unlike UBHS. Noteworthy is also the significant emergence of cast-in-place concrete MLSS's in recent years, with higher likelihoods than the ones initially assigned by the expert-based inference rules (see Figure 38).

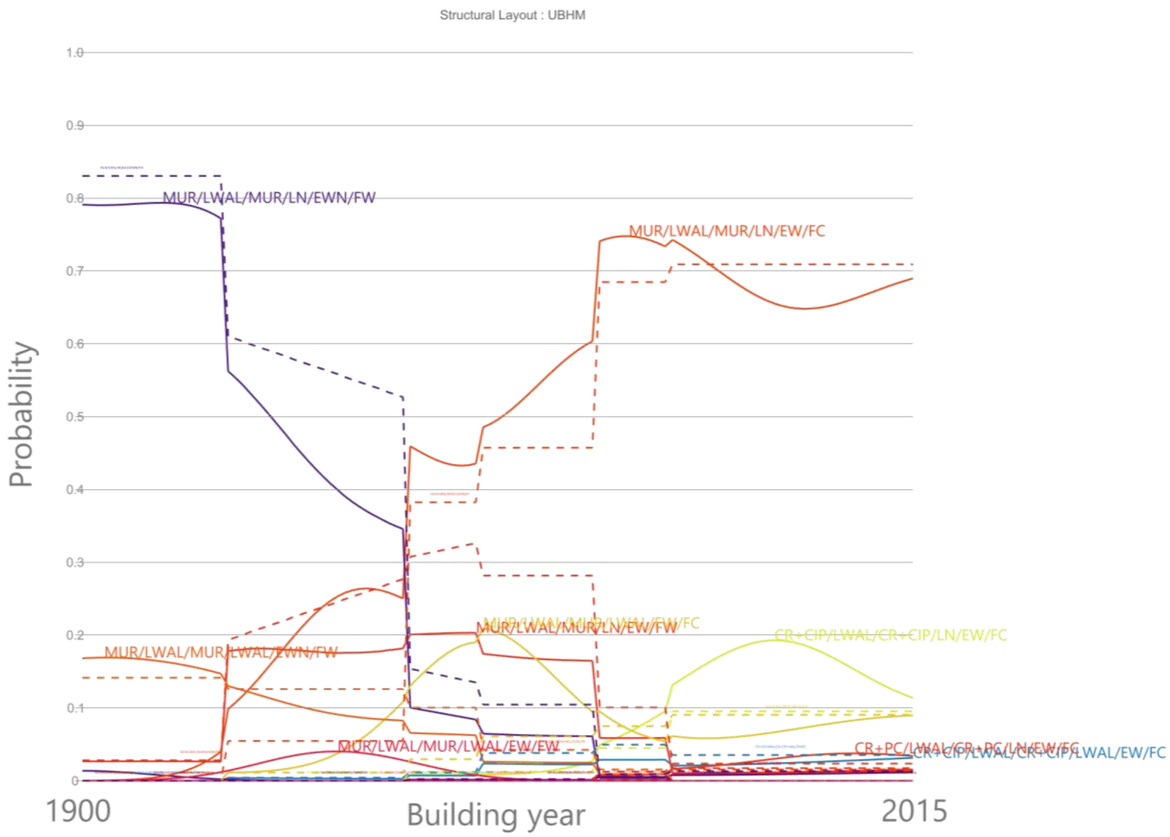

Figure 38 UBHM (block unit multiple) Structural Layout inference rule

As shown in Figure 39, the WB (barn_warehouse) inference update algorithm does not modify the previously assigned inference rules by very much. The main update is the emergence of masonry cavity wall-based construction in larger percentages than the ones previously assigned by the expert-based inferences. These are most likely corresponding to the relatively smaller WB buildings which might not have been taken into account in the development of the expert-based inferences.

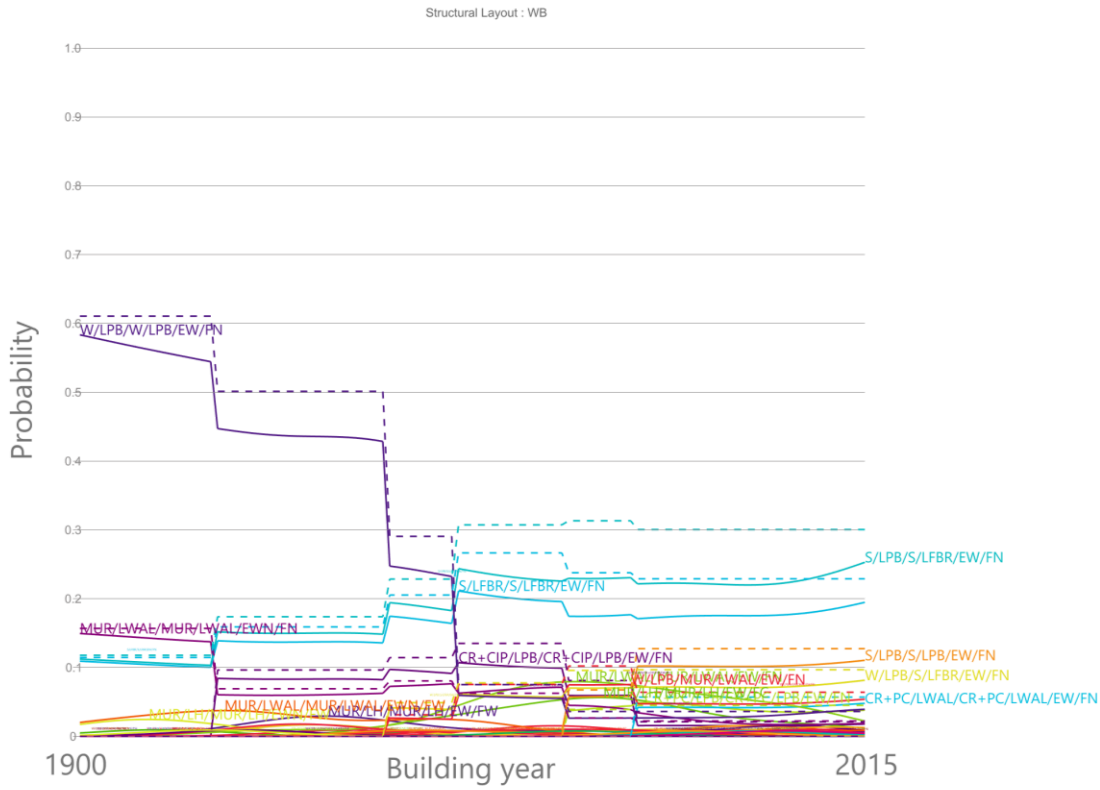

Figure 39 WB (barn_warehouse) Structural Layout inference rule

The WBH (barn+house) inference previously assigned MLSS of MUR/LH/MUR/LH/EWN/FW with a probability of 1, irrespective of the building year, to buildings identified as farmhouses. This inference has now been updated with the emergence of predominantly cavity masonry wall-based MLSS's summing to a likelihood of approximately 0.3 to 0.5 across all building years, as shown in Figure 40.

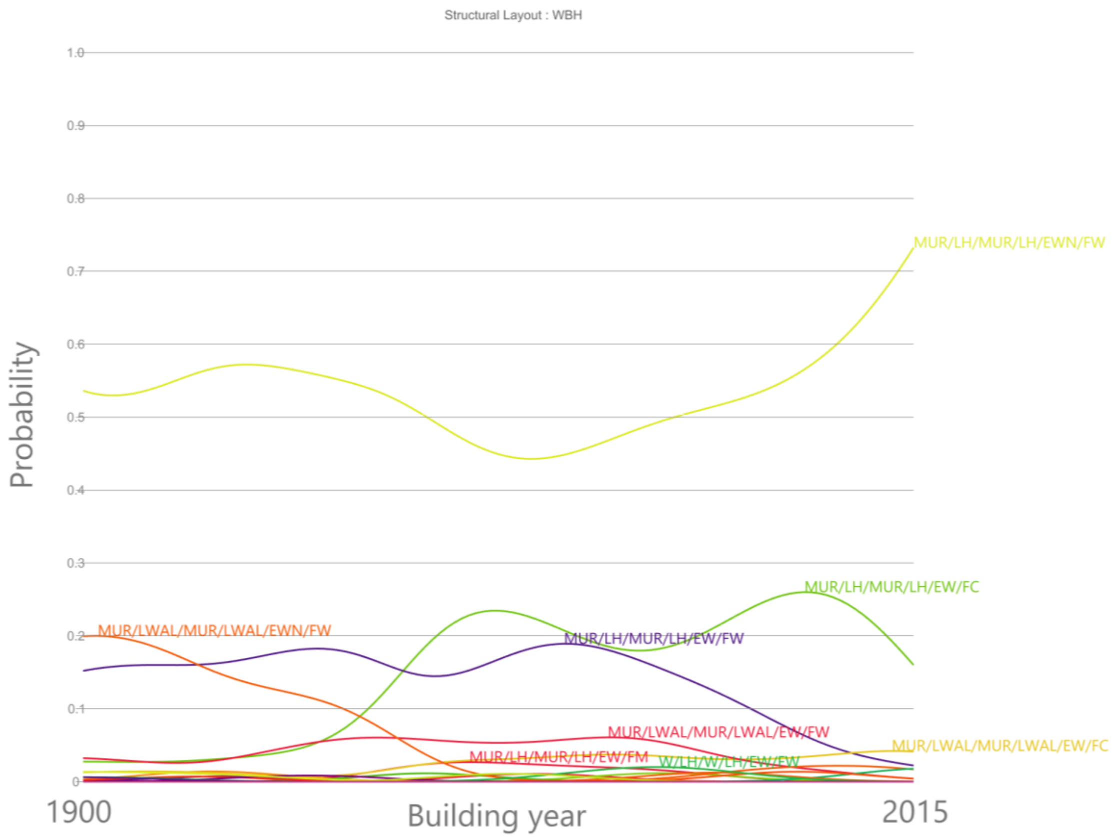

Figure 40 WBH (barn+house) Structural Layout inference rule

Finally, the inference for T (tower) as shown in Figure 41, has been updated with the large emergence of concrete-based construction with LWAL (wall) and LN (no lateral load-resisting system) in the strong and weak direction respectively. This has been the outcome of the inspection data coming from buildings that are similar to BL (block) buildings having more than six storeys and therefore being assigned to T (tower). It is noted that before 1920 there are very few buildings above a height corresponding to six storeys, with most of them corresponding to church towers or similar traditional construction. With this reasoning a solid wall masonry Structural System was assigned to be the one likely system only based on expert-judgement, as related drawing data was not available.

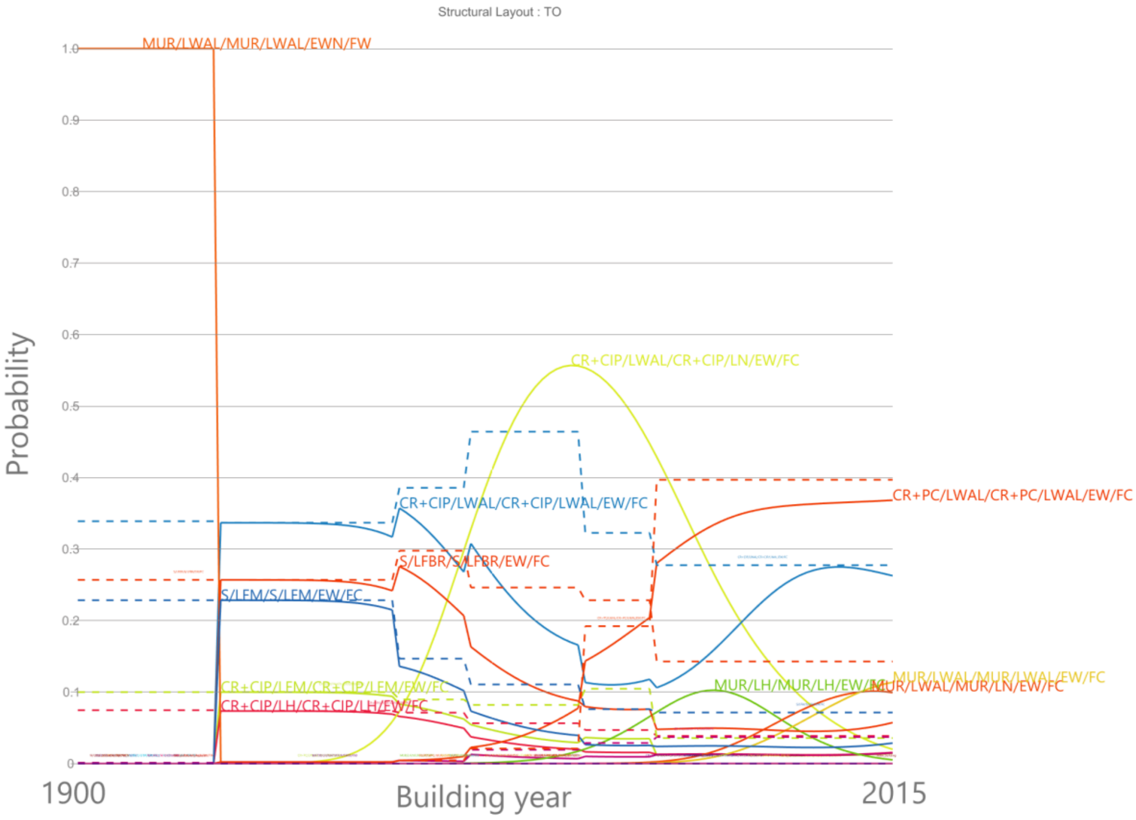

Figure 41 TO (tower) Structural Layout inference rule. [7]

[7] The inference before 1920 has been updated based on expert-judgement due to the lack of data-points. On the previously used TO inference rule there was no probability assigned to masonry structures, possibly due to the experts not considering tall old structures like church towers as part of the Structural Layout.

A4 Building Classification Flowchart

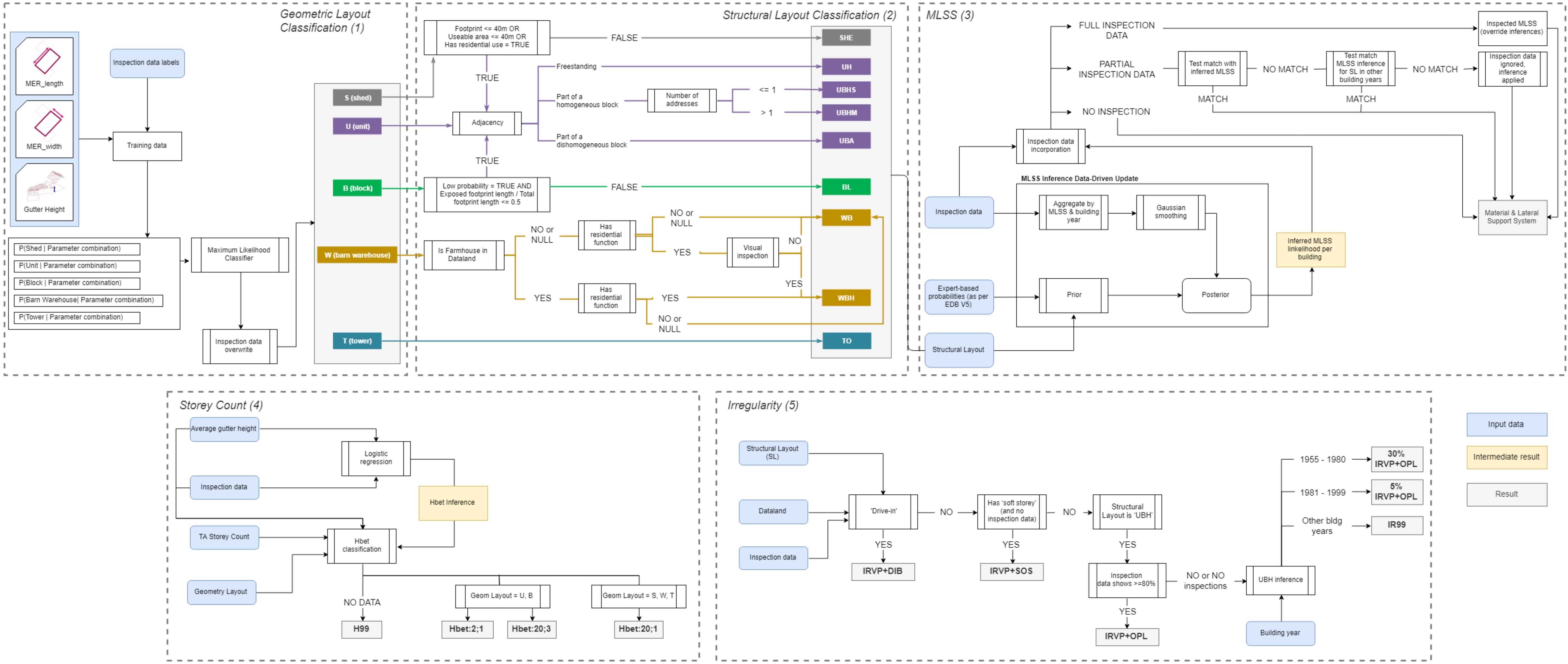

Figure 42 The Stuctural System classification flowchart of Figure 3 presented in higher resolution

Postprocessing the v7 Exposure Database to produce the v7 Exposure Model

By Jeroen Uilenreef, Helen Crowley and Roy Scheefhals

This short memo describes the additional processing steps that were applied to the v7 exposure database (EDB) provided by Arup (Arup, 2020) in order to produce the exposure model input for NAM's HRA2020 risk assessment (March, 2020). A brief summary of each post-processing step is provided below:

1) Filtering of buildings with zero population

The v7 EDB provided by Arup has 263,399 individual buildings, and this was reduced to 153,955 buildings for the purposes of the risk assessment as follows:

- All buildings with blank fields in the indoor daytime population column were removed (97,298 buildings).
- All buildings with "overige gebruiksfunctie" (i.e. 'other use') in the 'main_use' column together with zero indoor daytime population were removed (12,133 buildings).
- Buildings with blank fields in the 'main_use' column together with zero indoor daytime population were removed (13 buildings).

In summary, all buildings with >= 0 people (indoor, daytime) were included in the risk assessment unless their function was 'overige gebruiksfunctie' ('other') or blank (and thus unknown).

2) Manipulation of WA and WC geometric layouts

The entries in the v7 EDB with WA or WC layouts correspond to buildings with both a barn and farmhouse (4,001 buildings). As separate vulnerability models have been developed for the barn and the house in the v7 risk assessment (see Crowley and Pinho, 2020), separate entries for the barn and house were needed in the exposure model. All entries with the WA and WC geometric layouts were first assigned to the URM1F_B vulnerability class and then these entries were then repeated in the database and assigned to either URM1F_HA (for WA layouts) or URM1F_HC (for WC layouts).

3) Mapping of structural systems to vulnerability classes

All other structural systems within the v7 EDB were mapped to vulnerability classes using the table provided in Table B.1 of Crowley and Pinho (2020).

4) Reduction of vulnerability classes per building to a maximum of 10

The v7 version of the risk engine can only read a maximum of 10 distinct vulnerability classes per building. For those buildings for which more than 10 classes were assigned (following the mapping applied in the previous step), these vulnerability classes were removed and their total probability was reassigned to the first 10 vulnerability classes in proportion to the probability of each of the latter.

References

Arup 2020 “Exposure Database V7 Data Documentation” 229746_031.0_REP2015, April 2020

Crowley H. and Pinho R. (2020) “Report on the v7 Fragility and Consequence Models for the Groningen Field,” NAM Platform, March 2020.