Geometric Characteristic Study of Current Building Selection for Numerical Modelling

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Editors Jan van Elk & Dirk Doornhof

General Introduction

The assessment of seismic risk in the Groningen area requires knowledge of the building stock in this area. Description of all buildings in this area is collected in the Exposure Database, maintained by ARUP.

The buildings in Groningen have been assigned to a number of different building typologies. In this report, the geometric characteristics (e.g. building volume, gutter height, building age, footprint area) for selected typologies have been analysed to select the index buildings for numerical modelling of the seismic response (Ref. 1).

References

1. Development of v2 fragility and consequence functions for the Groningen Field, H. Crowley, R. Pinho, B. Polidoro, P. Stafford, October 2015.

NAM

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Directliy linked research	(1) Modelling of seismic response of buildings (2) Development of Fragility Curves (for non-URM and URM buildings) (3) Risk Assessment			
Used data				
Associated organisation	NAM			
Assurance	ARUP			

Technical Note

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Subject	Geometric Characteristic Study of Current Building Selection for Numerical Modelling		

1 Introduction

1.1 Background

Arup is a consultant of NAM's Hazard & Risk Team with regards to the development of the Risk Model of the Groningen region.

The development of the Risk Model for the Groningen region's building stock classifies the region's buildings into typologies, expected to have distinct structural performance and failure consequences. Arup is contributing to this process primarily through the development of the GIS Exposure Database (EDB).

This report has been requested in order to present the comparison of the characteristics of the numerical models currently used by NAM's Hazard & Risk team for the development of the Risk Model, against the distribution of these characteristics within clusters of buildings expected to be structurally similar. This is done in order to inform on the expected spread of geometric characteristics of similar buildings within the building stock.

2 Methodology

2.1 Approach

Arup is currently studying the Groningen region building stock by combining and analysing different available information sources and datasets (see Figure 1).

Technical Note

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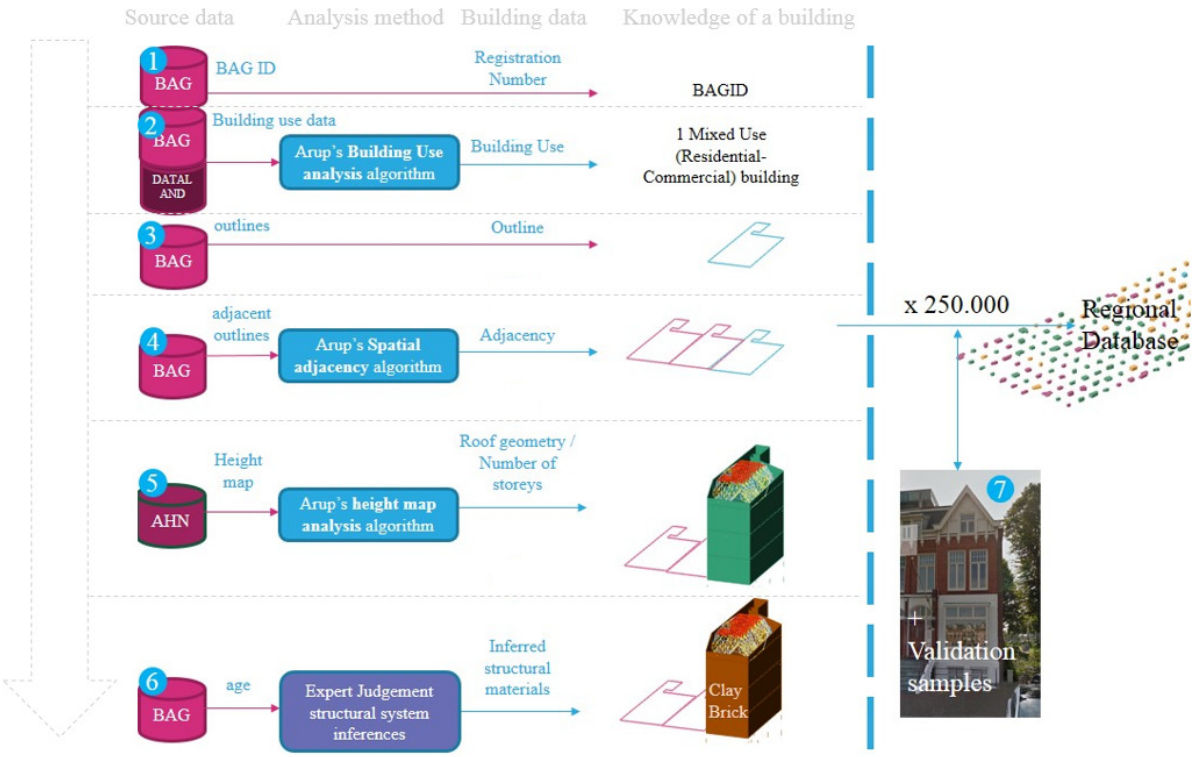


Figure 1 Schematic representation of the data sources and Arup's algorithmic analysis and their effect on increasing the knowledge on the region's building stock.

This study aims to demonstrate how Arup's current numerical models used for version 3 of the Risk Model compare to the characteristics of the building stock subset they belong to. Ideally this comparison is done against the building characteristic distribution of a corresponding homogenous set of buildings, belonging to distinct EDB typologies. In the current EDB, the building stock is classified according to function, adjacency, material and finally structural system[5], as graphically summarised in Figure 2.

A more detailed description on the typologies of EDB V3 is provided in Arup's EDB V3 tech note [4]

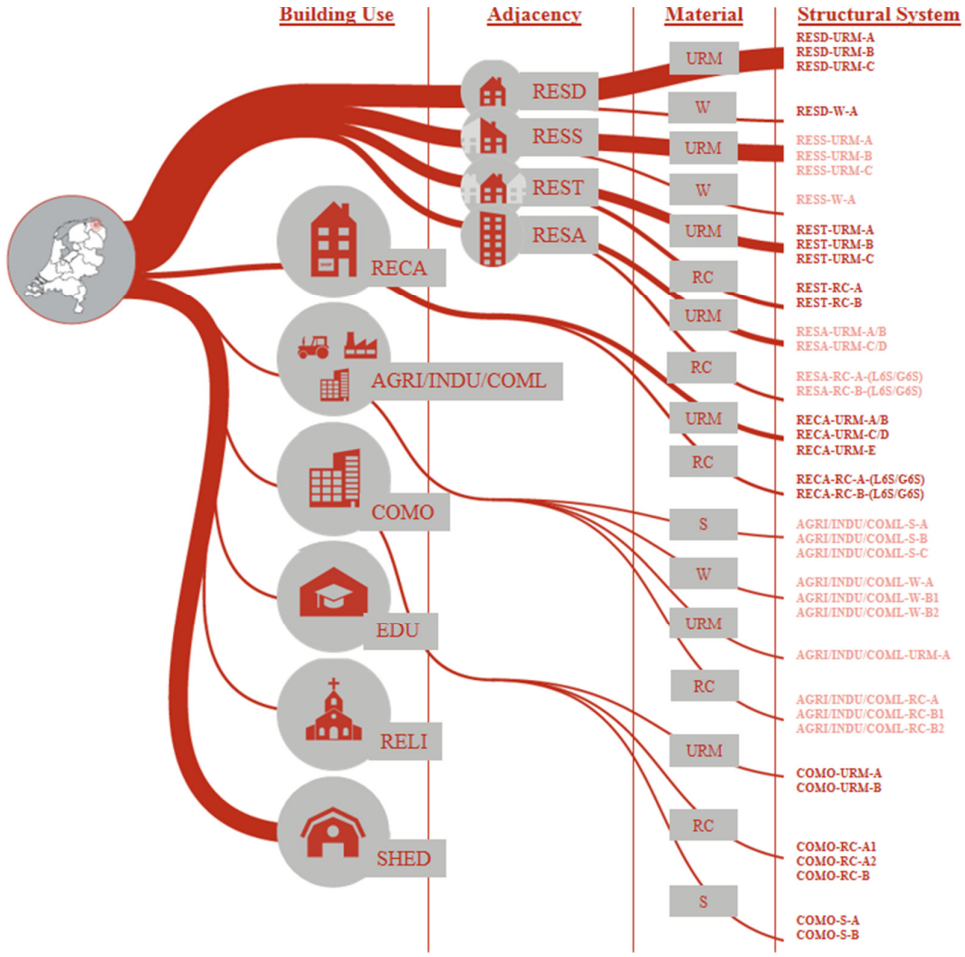


Figure 2 Diagram demonstrating the building typology classification process in EDB V3 [4].

At the time of this study, the EDB probabilistically infers the structural system and material of a building based on its construction year. As a consequence, the number of buildings verified to belong to a specific EDB typology are limited.

For this reason, the building characteristics of the currently used numerical models were compared to the respective intermediate classes, i.e. buildings of the same building use and adjacency, but with varying structural systems. For example a numerical model belonging to REST-URM-A[1], is compared to a sample of REST(Residential-Terraced) buildings, without further differentiation to REST-URM-A, B or C buildings. An overview of the numerical models analysed and the samples they were compared to can be found in Table 1. The naming of each sample represents the intermediate class and the number of samples used, e.g. RESD300 is a random sample of 300 Residential Detached buildings of the Exposure Model's study region.

[1] REST-URM-A typology contains terraced residential buildings with timber diaphragms and solid URM walls [4].

Table 1 Numerical models and the respective samples their characteristics were compared to for this study

Numerical Model Name	Building Typology V2	Building Typology V3	Sample Compared
Nieuwstraat	RESD-URM-A	RESD-URM-A	RESD300
Type C	REST-URM-C	REST-URM-C	REST300
Kwelder	RESD-URM-C	RESD-URM-C	RESD300
Zijlvest	REST-URM-F	REST-URM-C	REST300
Julianalaan	RESS-URM-B	RESS-URM-B	RESS300/ REST300
Schuitenzand	RESA-URM-B	RESA-URM-C/D	RESA300
De Haver	RESD-URM-A	RECA-URM-E	RESD300
Koeriersterweg	RESA-URM-A	RESA-URM-A/B	RESA300

The values of the building characteristics for the aforementioned samples are automatically calculated through Arup's computational algorithms, while the values for the numerical models are calculated per building using the structural drawings used for the numerical modelling of the buildings (Figure 3).

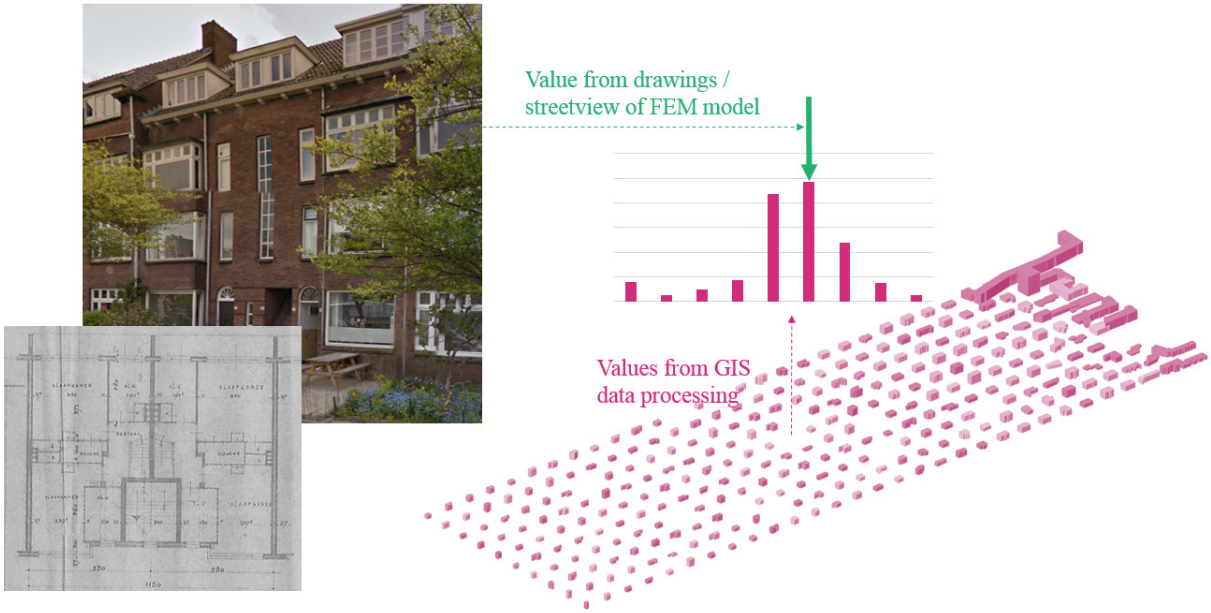


Figure 3 Schematic representation of the different calculation sources for the sample characteristic and distribution and the calculated numerical model characteristic values.

2.2 Parameter definitions

The parameters selected to be analysed for this study are the following:

Table 2 Definitions of parameters analysed in this study

Category Name	Data Type	Description
Building Year	Integer	The building year as provided by BAG.
Building Height	Double	Height of the highest point of a building's geometry from the ground level (excluding chimneys).
Volume	Double	Enclosed volume within the building envelope.
Façade Area	Double	Sum of areas of all vertical surfaces of the building envelope. In terraced buildings and older apartments this can refer includes also the interfaces between adjacent units.
Gutter Height	Double	The distance of the lengthiest linear horizontal roof-wall connection to the ground level.
Footprint Area	Double	Area of the building's outline polygon (e.g. as provided by BAG).
Presence of Gable Walls	Binary	Flag demonstrating the presence or not of an identified gable wall.
Shape in Plan	Text (40)	Shape type of a building's footprint. For this study footprints were divided into 4 types: RECT (Rectangular), L (L-shaped), S/T/U (S/T/U-shaped), Complex (not within the above footprint categories).
Presence of Extensions	Binary	Flag demonstrating the presence or not of an identified extension(i.e. a flat roof extension of the main building geometry, possibly built at a later stage than the building's initial construction).

The parameters Building Year and Footprint Area are extracted directly from Arup's regional GIS database, while for the rest of the parameters are calculated through Arup's extended building data analysis algorithms currently in development. More information on the algorithms is provided in a dedicated tech note [6].

Example of the analysis algorithms and the way the parameters like façade area, volume, presence of gable walls and shape in plan are calculated is shown in Figure 4.

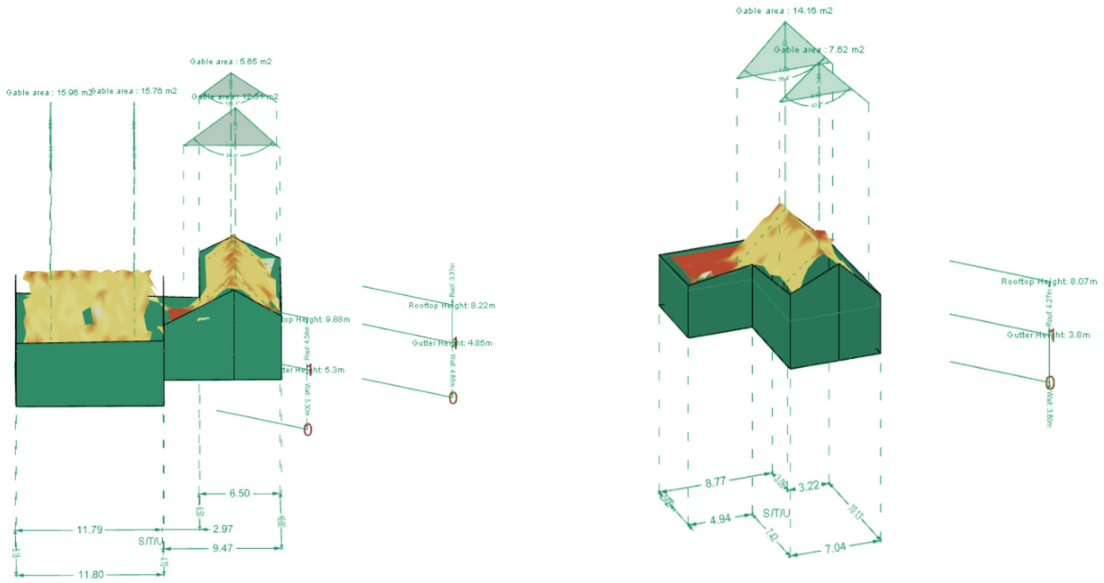


Figure 4 Arup's building data analysis algorithms

Despite the fact that the value assignments were done through different means for the sampled buildings and the numerical models, both assignments followed the same definitions, aiming to maximise the comparability of the two value sources. This might result in some visual assignments, e.g. for Shape in Plan, being not always intuitive: Visually small irregularities in an outline could be considered unimportant from an engineering point of view, but were kept as significant in the Shape in Plan assignment, to match what the current algorithm would assign in each case.

2.3 Assumptions and Limitations

The characteristic values for the numerical models are assigned through calculation based on drawings while the values that they're compared to are calculated through building data analysis algorithms (as demonstrated on Figure 3 above). This approximation could be affecting the study findings.

The random set of buildings have been generated in September 2015 and were therefore based on the intermediate classes of EDB V1. The new findings and improved knowledge recently achieved might suggest a further refinement/revision of the sample study based on the EDB V3[4].

The numerically modelled buildings are also characterised by details that can be typical (roof systems, anchorages, wall types). These are not currently considered into this study although considered to be relevant when assessing building performances.

Due to the aforementioned reasons, and given the different data sources and validation levels of the computational algorithms used for this study, the information provided here should be used only as a first understanding of the distribution of the building characteristics in their respective intermediate class.

2.4 Traceability

To verify the traceability of this study, the BAG ID's of the random sample for the RESA, REST and RESD buildings are stored, along with the data exported from the GIS database and the algorithms that produced additional building data.

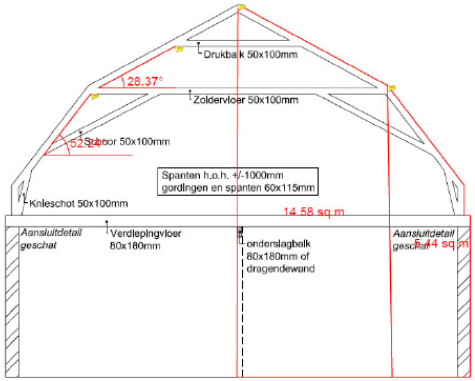
Due to the fact that the characteristic values for the numerical models have been calculated based on drawings, the assigned values are provided in Annex A, for future reference.

3 Implementation

This chapter contains the graphs showing the geometric comparison between current numerical model building characteristics to their respective intermediate class.

The discussion on the presented graphs follows in chapter 4.

3.1 Nieuwstraat 8 (RESD)



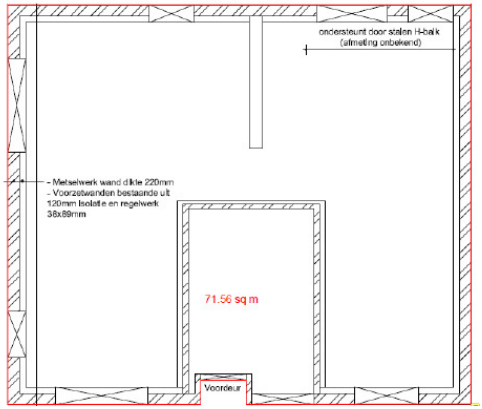


Figure 5 Section, floor plan and street-view images of Nieuwstraat 8 building

3.1.1 Comparison to RESD300 characteristic distribution

Figure 6 Comparison of Nieuwstraat 8 building's characteristic values to the histograms of the RESD300 sample. Vertical axis represents the building count within the sample.

3.2 Kwelder 1 (RESD)

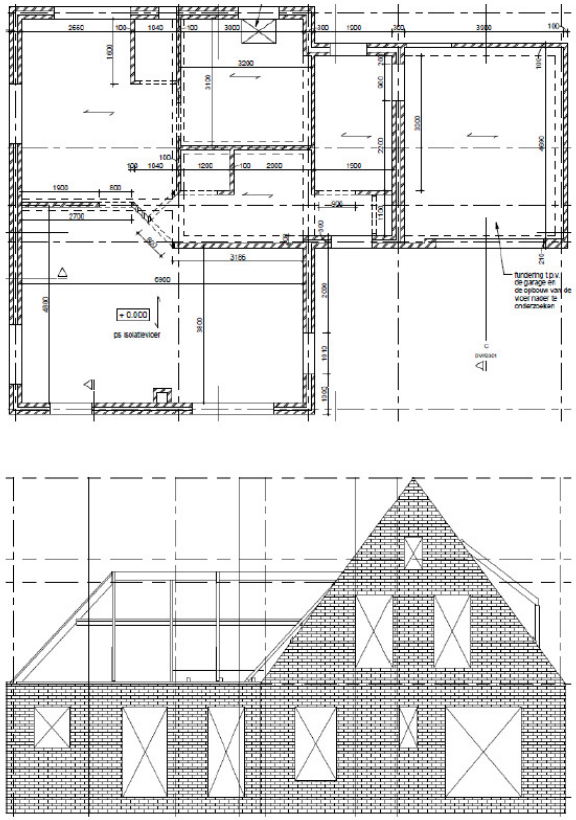


Figure 7 Floor plan, front façade and street-view image of Kwelder 1 building.

3.2.1 Comparison to RESD300 characteristic distribution

Figure 8 Comparison of Kwelder 1 building's characteristic values to the histograms of the RESD300 sample (Vertical axis represents the building count within the sample).

3.3 Type C (REST)

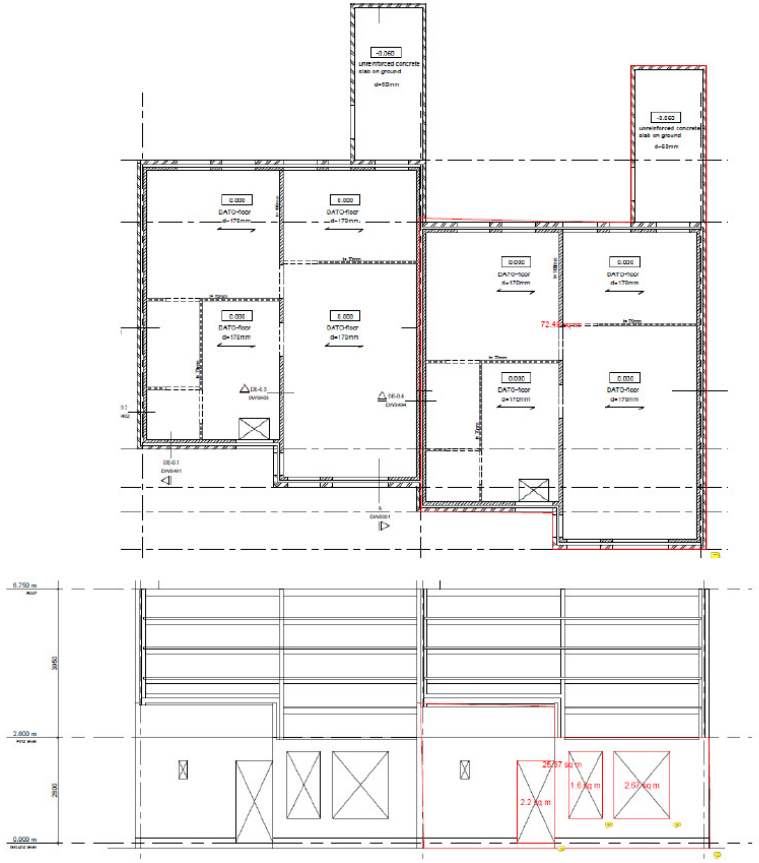


Figure 9 Floor plan, front façade and street-view image of Type C.

3.3.1 Comparison to REST300 characteristic distribution

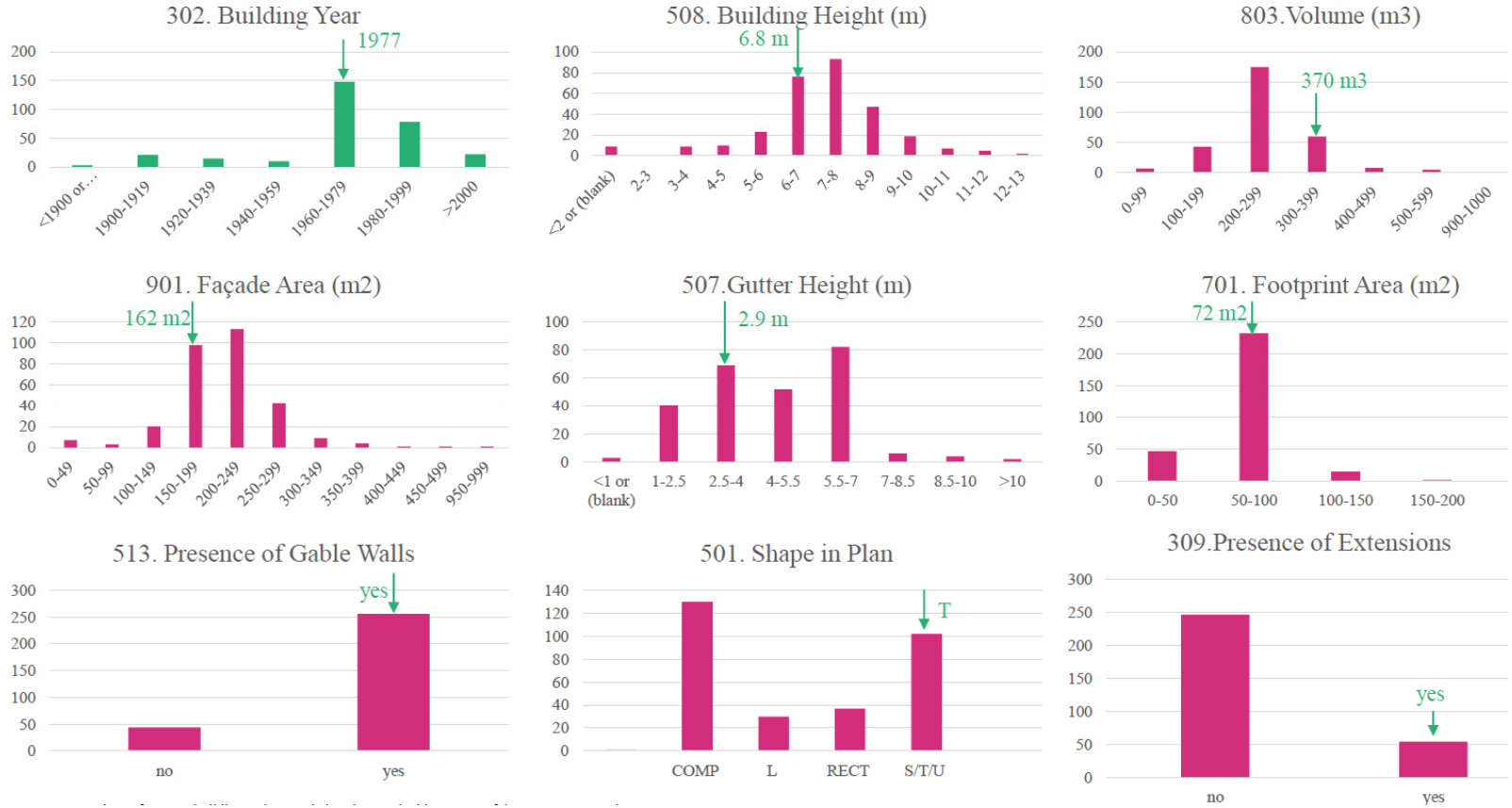


Figure 10 Comparison of Type C building's characteristic values to the histograms of the REST300 sample. Vertical axis represents the building count within the sample.

3.4 Zijlvest 25 (REST)

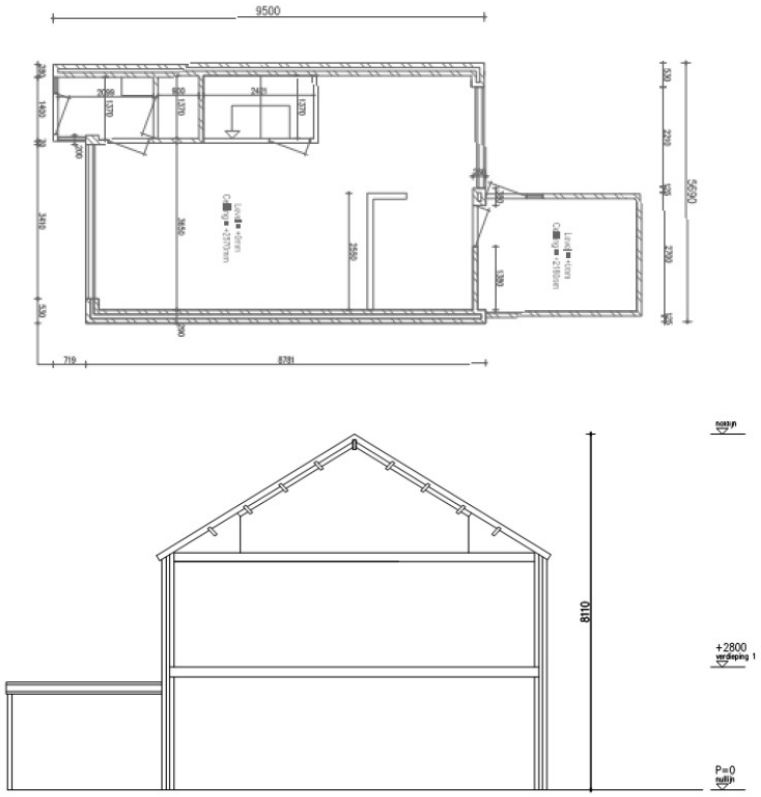


Figure 11 Floor plan, front façade and street-view image of Zijlvest 25.

3.4.1 Comparison to REST300 characteristic distribution

Figure 12 Comparison of the Zijlvest 25 building's characteristic values to the histograms of the REST300 sample. Vertical axis represents the building count within the sample.

3.5 Koningin Julianalaan 52 (RESS-REST)

Figure 13 Floor plan, front façade and street-view image of Koningin Julianalaan 52.

3.5.1 Comparison to RESS300[1] characteristic distribution

Figure 14 Comparison of the Koningin Julianalaan 52 building's characteristic values to the histograms of the RESS300 sample. Vertical axis represents the building count within the sample.

1. Koningin Julianalaan 52 is compared to both RESS300 and REST300 samples. That is because according to EDB V3 typology definitions, the building is RESS(Semi-Detached), but similar buildings can also be considered terraced of 2 units.

3.5.2 Comparison to REST300 characteristic distribution

Figure 15 Comparison of the Koningin Julianalaan 52 building's characteristic values to the histograms of the REST300 sample. Vertical axis represents the building count within the sample.

3.6 Schuitenzand flat (RESA)

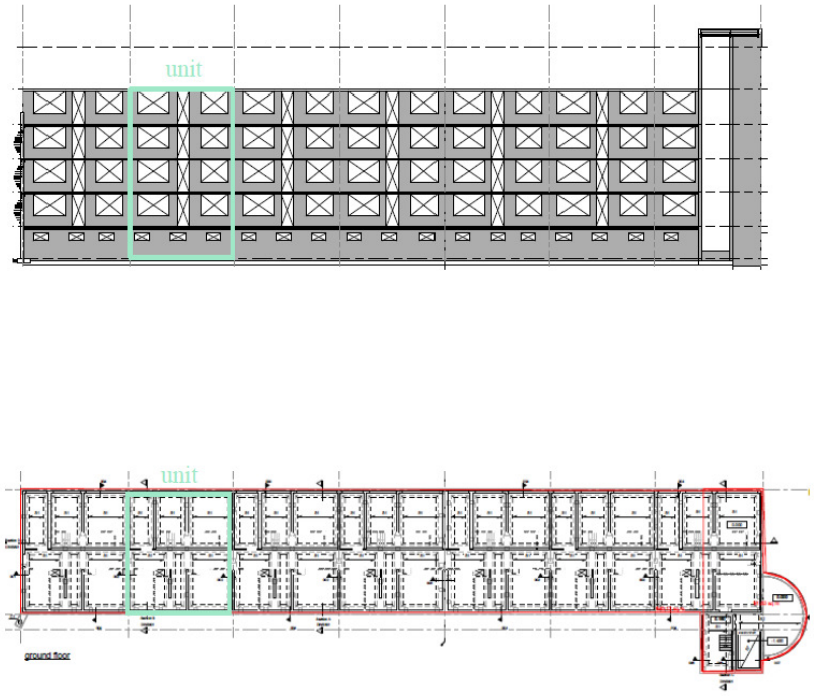


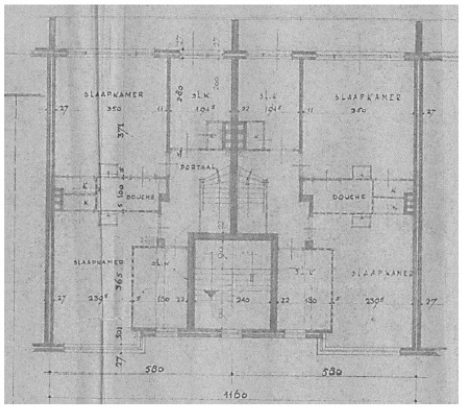
Figure 16 Floor plan, front façade and street-view image of the Schuitenzand-flat.

3.6.1 Comparison to RESA300 characteristic distribution

Figure 17 Comparison of the Schuitenzand flat's characteristic values to the histograms of the RESA300 sample. Vertical axis represents the building count within the sample.

2. Footprint Area, Volume and Façade area and Footprint Type are affected by BAG's ambiguous polygon definition for apartments. In the older apartments the BAG's outline polygon defines one unit of an apartment block while in newer apartments it defines the total block. Thus Schuitenzand's values are given both for the total block as well as per unit.

3.7 Koeriersterweg 18 (RESA)



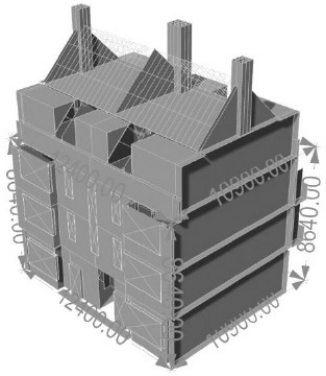
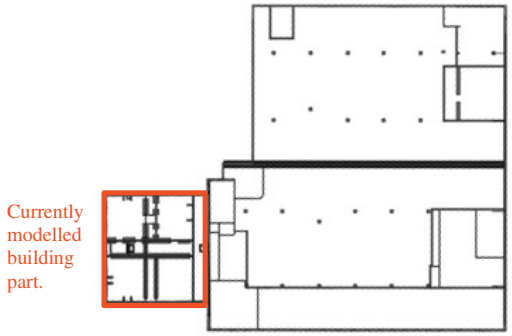


Figure 18 Floor plan, 3d model and street-view image of Koeriersterweg 18.

3.7.1 Comparison to RESA300 characteristic distribution

Figure 19 Comparison of Koeriersterweg 18's characteristic values to the histograms of the RESA300 sample. Vertical axis represents the building count within the sample.

3.8 De Haver (V2 RESD, V3 RECA)



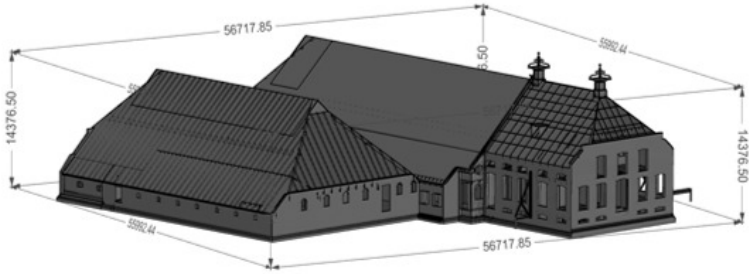


Figure 20 Floor plan, 3d model and street-view image of De Haver.

3.8.1 Comparison to RESD300 characteristic distribution

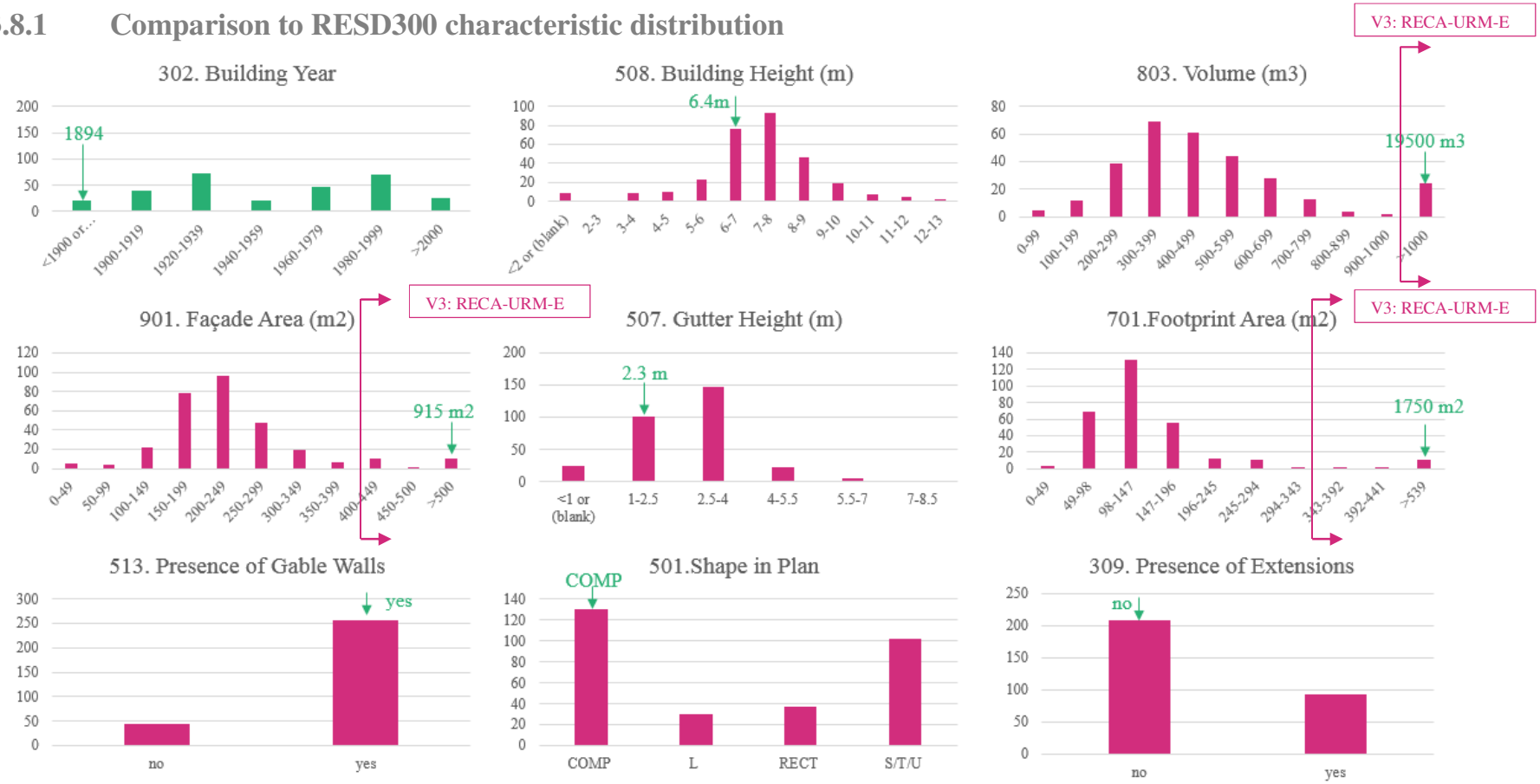


Figure 21 Comparison of De Haver's characteristic values to the histograms of the RESD300 sample. Vertical axis represents the building count within the sample. This type of buildings belong to a Residential-Commercial(RECA) typology in EDB V3.

3. Measurements refer to the total building besides the fact that currently only the residential part is numerically modelled.

4 Discussion

4.1 Nieuwstraat 8

In the current risk model, Nieuwstraat 8 is representing the pre-1940's Residential Detached typology RESD-URM-A. The footprint and the façade area calculated for this building is slightly lower than the most predominant domain, when compared to a random sample of RESD (across all building construction years). Additionally the footprint of this building is rather simple (Rectangular), which seems not in line with the predominant RESD footprint shapes.

It is assumed that these characteristics are more common in the older subset of RESD buildings, but further investigation is needed to validate & refine the study of that subset.

4.2 Kwelder 1

Kwelder is currently representing the Residential Detached typology RESD-URM-C. It seems to have a relatively large volume combined with a relatively low façade area due to the low gutter height (2.75m). In general the values of this building are within or adjacent to the most predominant characteristic domains.

A dedicated study should verify if the characteristic combination of Kwelder (relatively large volume but low façade area due to low gutter height and a relatively steep roof), is recurrent in newer Residential Detached buildings of the region.

4.3 Type C

Type C seems to be close to the most predominant domains of the Residential Terraced sample's geometric characteristics.

Most of the Residential Terraced buildings are built after 1960's and have footprints below 100 m2.

The Volume of Type C seems to be on the higher-end of the sample characteristics. This could be partly due to the presence of an extension and partly due to the tendency of terraced buildings having a relatively constant gross floor area, which is either distributed on one storey with a larger footprint, or in two storeys with a smaller footprint area.

4.4 Zijlvest 25

All the building characteristic values of Zijlvest 25, are either within the most predominant domains for terraced buildings or in adjacent domains.

4.5 Koningin Julianalaan 52

This building is a semi-detached house (RESS) but is compared also against the REST sample due to its similarity to terraced buildings.

A first interesting result of the study is that, although Terraced buildings are predominantly built after the 1960's, semi-detached buildings are built after the 20's in a constant rate.

The rest of the characteristics are distributed in similar ways in RESS and REST buildings with Koningin Julianalaan being generally close to the most predominant domains.

The footprint area seems to be on the low-end side of the histograms for this building, due to the domains selected. On chapter 6, different ways of addressing the domain sensitivity of histograms in future versions are discussed.

4.6 Schuitenzand flat

Schuitenzand currently belongs to the modern URM apartments EDB V3 typologies (RESA-URM-C/D).

Footprint Area, Volume and Façade area and Footprint Type are affected by BAG's ambiguous polygon definition for apartments. In the older apartments the polygon defines one unit of an apartment block while in newer apartments it defines the total block, containing multiple units. Thus Schuitenzand's values are given also for the total block as well as after dividing the values by its unit count.

Even if divided by the number of units, the Schuitenzand flat is still on the high-end of the histograms as far as Volume, Façade Area and Height parameters are concerned.

Given that it is expected that RESA-URM-C and RESA-URM-D will be separate typologies in future EDB versions, with Schuitenzand belonging to RESA-URM-D, dedicated studies will determine if Schuitenzand's geometric characteristics are common when compared only to RESA-URM-D buildings.

4.7 Koeriersterweg 18

Koeriersterweg is representing RESA-URM-A/B on V3. On later versions the current intention is that these RESA-URM-A will be separated from RESA-URM-B, in which case Koeriersterweg 18 will represent the latter.

Despite the fact that Koeriersterweg 18 seems to be on the high end of the Volume and Façade Area histograms, this is probably skewed by the predominance of RESA-URM-A's in the sample which are lower in volume than the rest of the RESA typologies. The scatter plot shown in Figure 22 demonstrates that Koeriersterweg is close to the average Building Year–Volume combination of RESA-URM-B buildings.

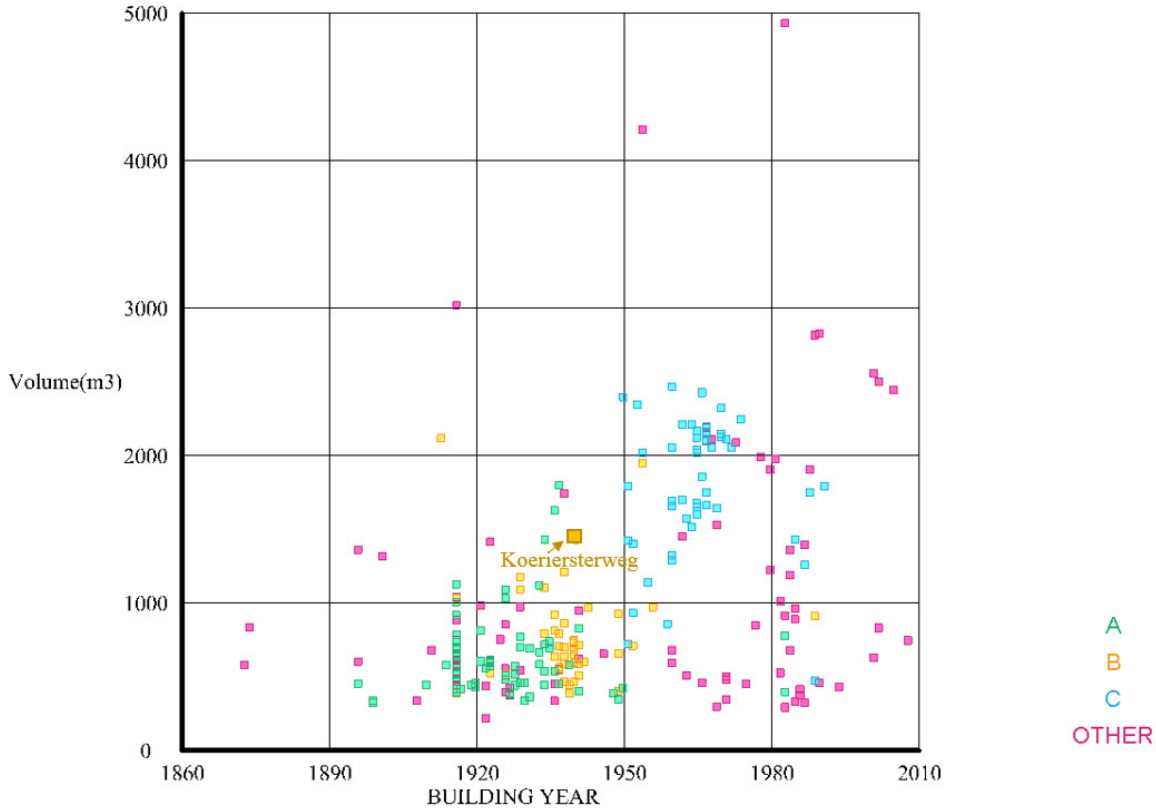


Figure 22 Koeriersterweg plotted against the RESA300 Volume-Building year scatterplot. (289 out of the 300 buildings in the sample are within the domains plotted)

4.8 De Haver

De Haver was compared to Residential Detached buildings, as farmhouse buildings like De Haver would be classified as RESD building at the time the samples were taken (EDB V1).

As shown in the diagrams, the aim of having the new typology RECA-URM-E(farmhouse typology) is to better reflect the characteristics of this type of structures featuring large farm additions in a dedicated typology. This is expected to truncate the upper end of the footprint and volume charts of the RESD, also resulting in more uniform RESD typologies.

5 Conclusions

The geometric characteristics of the currently numerically modelled buildings have been compared to the intermediate class characteristic distributions.

This study has been used to inform NAM's Hazard & Risk team throughout the index selection and typology refinement processes for the 3rd Version of the Exposure Model of the Groningen Region.

Despite the fact that index building selection can be influenced by a variety of parameters beyond the ones studied, similar studies provide context to these selections and enhance the understanding of the building typologies of the Region's Exposure Model.

The increasing understanding results in information-based decisions not only on index building selections but also on the rearrangement of typologies and the refinement of the Typology definitions.

6 Recommendations

This study focused on nine parameters that were currently available for the samples used. The addition of other important parameters could result in the enhancement of similar studies in the future, through studies correlating building characteristics to building performances. This will give an indication on the structural relevance of each building characteristic in future studies.

In Chapter 3, some of the comparative charts represented the distribution of continuous variables through histograms, to present data in a uniform and intuitive way. Due to the sensitivity to selected domain subdivision for these variables, alternative chart types could be preferable in the future.

As an example, Figure 23 shows how different domains would affect the impression from the histogram diagrams, for a building of 47.5m^2.

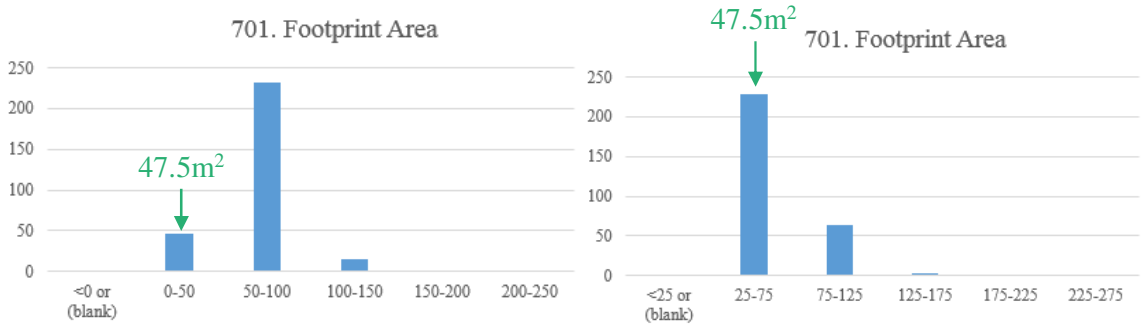


Figure 23 Footprint Area histogram with two different domains selected. Koningin Julianalaan belongs in the most predominant domain in the second histogram.

Arup is currently testing algorithms to better visualise the characteristic distribution and the comparison of a specific building to these distributions (see Figure 24). Gaussian or log-normal distributions are tested for best fit, while an implementation of Kernel Density Estimation is also under consideration. These algorithms are also aiming at providing a ranking of a set of buildings by statistical "representativeness".

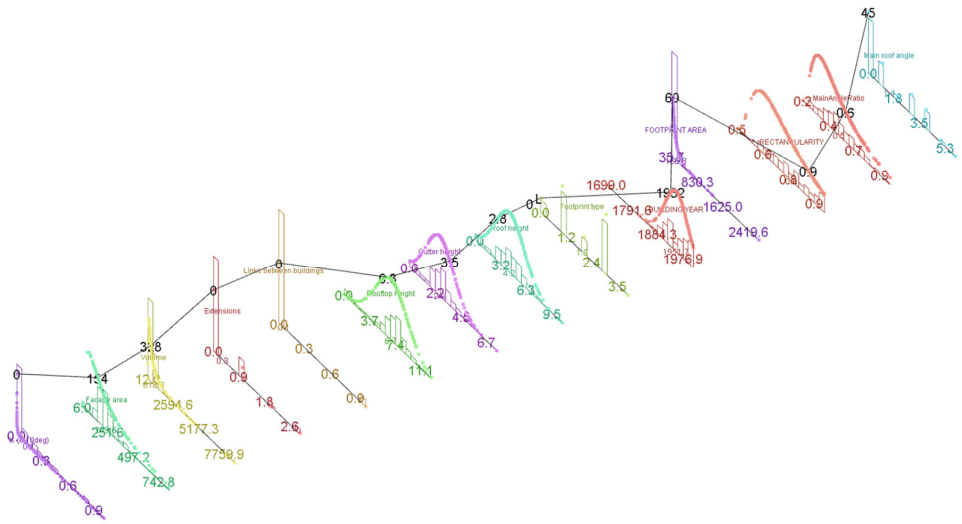


Figure 24 Representativeness ranking algorithm

The further refinement of the input data and the calculation algorithms(e.g. refining cut-off values to better reflect engineering judgement perception of footprint types), along with the enlargement of the sample size and future typology revisions could influence future versions of this document.

7 References

[1] Arup (2015). *White Paper Exposure Database V1*, Arup report number 229746_031.0_REP1001

[2] Arup (2015). *GIS Exposure Database Extract V1*. Arup report number 229746_052.0_NOT134

[3] Arup (2015). *GIS Exposure Database Extract V2*, Arup report number 229746_031.0_REP1003

[4] Arup (2016). *Exposure Database V3*, Arup report number 229746_031.0_REP1010 (forthcoming)

[5] Nederlandse Aardolie Maatschappij BV (2015). *Hazard and Risk Assessment for Induced Seismicity Groningen*. Interim Update 7 November 2015. Available at: http://feitenencijfers.namplatform.nl/onderzoeksrapporten/ [Accessed 1 March 2016]

[6] Arup (2016). Building data analysis methodologies, Arup report number 229746_031.0_NOT1046 (forthcoming)

Annex 1 Numerical Model Building Characteristics

The values assigned to the numerical models were based on structural drawings available (with the exception of building year which was retrieved from Arup's GIS database).

Table 3 Assigned values for the analysed numerical model buildings based on available drawings.

Building Name	302. Building Year	508. Building Height (m)	803. Volume (m3)	901. Façade Area (m2)	507. Gutter Height (m)	701. Footprint Area (m2)	513. Presence of Gable Walls	501. Shape in Plan	309. Presence Extensions
Nieuwstraat	1922	6.4	422	145	3.6	71	1	RECT	0
Kwelder	1996	7.8	520	187	2.75	106	1	T	0
Type C	1977	6.8	370	162	2.9	72	1	T	1
Zijlvest	1976	8.11	340	162	5.5	58.5	1	S	1
Julianalaan	1957	7.1	290	161	5.4	45.4	1	RECT	0
Schuitenzand	1964	19.4	9151	2093	13.8	637	0	L	0
Koeriersterweg	1940	14	1420	509	8.6	116.6	1	RECT	0
De Haver	1894	13.8	19500	915	2.3	1749.6	1	COMP	0

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