Definition of archetypical neighborhoods for residential flexibility analyses

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Definition of archetypical neighborhoods for residential flexibility analyses

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Management summary

Every neighborhood and every network section in the Netherlands is different. In order to quickly gain insights into the potential of energy flexibility, the MOOI GO-e project defined archetypical neighborhoods as a starting point. This document provides the basis for the 8 defined archetypes at a neighborhood level, it describes how they were defined and generated for the entire area of the Netherlands, as well as the descriptions of each of the archetypes with respect to the chosen parameters. The archetypes follow from a data analysis by TNO in collaboration with ElaadNL, after various discussions with the regional grid operators and other partners within the GO-e project.

Figure 1.1 shows most of the over 13.000 neighborhoods in the Netherlands and which archetype they are best represented with. Table 1.1 shows the according number of neighborhoods per archetype.

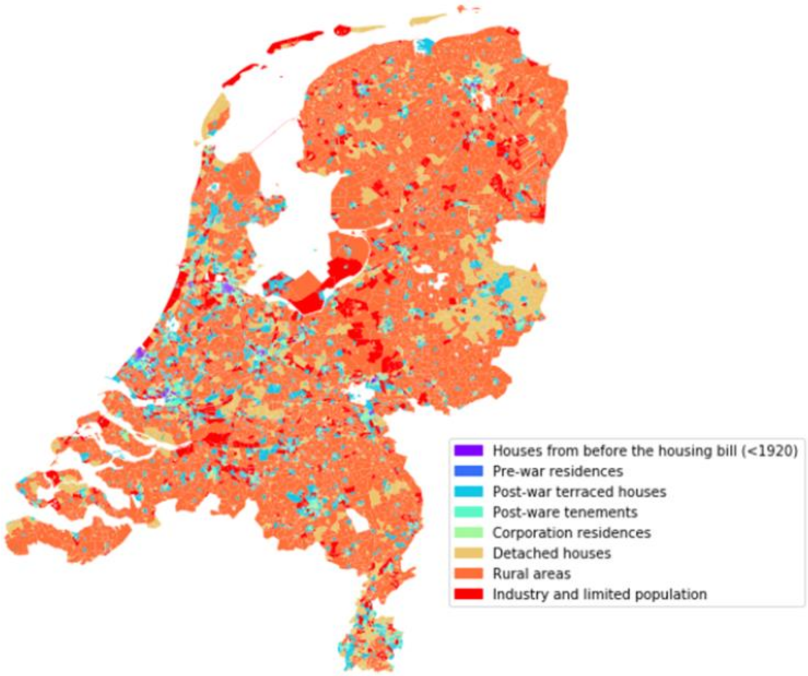

Figure 1.1: Map of Dutch neighborhoods and their archetypes

Table 1.1: Number of neighborhoods per archetype

Archetype	# Neighborhoods	% of total neighborhoods
1 Houses from before the housing bill (<1920)	304	2%
2 Pre-war residencies	179	1%
3 Post-war terraced houses	3.407	26%
4 Post-war tenements	1.088	8%
5 Corporation residences	740	6%

Archetype	# Neighborhoods	% of total neighborhoods
6 Detached houses	2.606	20%
7 Rural areas	3.469	26%
8 Industry and limited population	1.442	11%

As shown in Figure 1.2, based on the current data analysis, archetypes 1 to 5 are best defined. Due to its large presence and distribution, archetype 7 (rural, orange on the map in Figure 1.1) is the least well-defined. This means that within all the neighborhoods linked to the archetype there is a lot of variation.

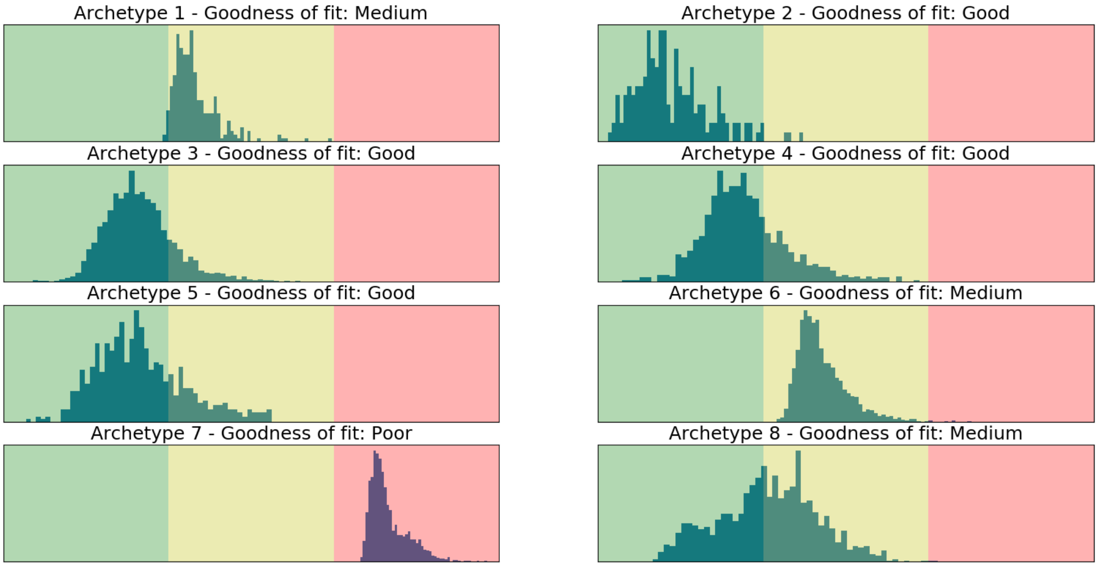

Figure 1.2: Quality of fit for the archetypes

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1 Introduction

The definition of archetypical neighborhoods in the Netherlands for residential flexibility analyses was part of the MOOI project GO-e (Built Environment Electrification). The purpose of this project was to investigate whether smart flexibility services can offer an alternative for strengthening the electricity grid in the built environment.

As every neighborhood and every network section in the Netherlands is different concerning its energy needs and characteristics, the diversity would be too big to include all necessary data in long-term analyses and forecasts to be able to create a nationwide, representative and workable picture with a clear distinction between benefits and effectiveness of flex solutions for congestion management.

In order to be able to still develop usable knowledge and to get a grip on the flex potential in the Netherlands, it was decided to define archetypical neighborhoods, as a starting point for more detailed analyses of individual neighborhoods.

Besides we aimed to create knowledge and means for further academic research in an anonymous setting.

This report explains the approach and results of this approach.

Acknowledgments

The authors of this report extent their gratitude to all of those who have contributed in any way to this work and publication. They would specifically like to acknowledge the contributions of Gijs van der Poel and Elwyn van Zanten of ElaadNL for their expertise and provided data. During the data analysis and data drive approach TNO colleagues Shreshtha Sharma, Pieter Verstraten and Marianne Schaaphok played an invaluable role.

Furthermore during the process many GO-E partners contributed in finetuning the approach, the authors extent their gratitude to Stedin, Liander and Enexis as the partner distribution system operators and preparations of the future use of archetypes within GO-E and beyond. The contributions of Technolution and Phase to Phase were highly relevant in aligning the GO-E modelling chain activities and selection of archetypical electricity grid topologies linked to the archetypical neighborhoods. The authors also thank the PhD students of TU/e for formalizing parts of the methodology in academical papers.

The MOOI project GO-e as a whole was executed by a consortium representing the entire chain of stakeholders concerning the operation of the electricity grid in the built environment. energy system. The project was partly realized with Topsector Energy Subsidy from the Dutch Ministry of Economic Affairs and Climate. The specific subsidy for this project concerns the MOOI subsidy round 2020, which is implemented by the Netherlands Enterprise Agency.

2 Methodology and data collection

2.1 Goal

The goal of defining and identifying archetypes in GO-e is to create knowledge for the potential of flexibility in archetypical neighborhoods, as a starting point for more detailed analyses of individual neighborhoods, and to create knowledge and means for academic research in an anonymous setting.

2.2 Available data

For neighborhoods there are several high quality datasets available, which were crucial to the methodology developed. In the Netherlands the national Central Bureau of Statistics collects and combines a lot of data on neighborhood level, that could be used as a solid basis for the project's purposes. This data was supplemented by two other datasets, with data from individual buildings, as performed by ElaadNL, and data from the regional grid operators on connection sizes. The resulting dataset consisted of approximately 120 parameters for all 13.235 Dutch neighborhoods and was based on the original data from:

- Public neighborhood data from Central Bureau of Statistics (Centraal Bureau voor de Statistiek - CBS)[1]
- Public building information from the Dutch key register of addresses and buildings (Basisregistratie Adressen en Gebouwen - BAG) [2]
- Public data on small scale consumers from the regional grid operators at PC6 level (postal code with letters)

2.3 Methodology

After this initial selection of 120 parameters, a data refining process was performed by experts from TNO and ElaadNL; Figure 2.1 shows an overview of the methodology used to generate a final set of neighborhood archetypes.

[1] https://www.cbs.nl/
[2] https://www.kadaster.nl/zakelijk/registraties/basisregistraties/bag

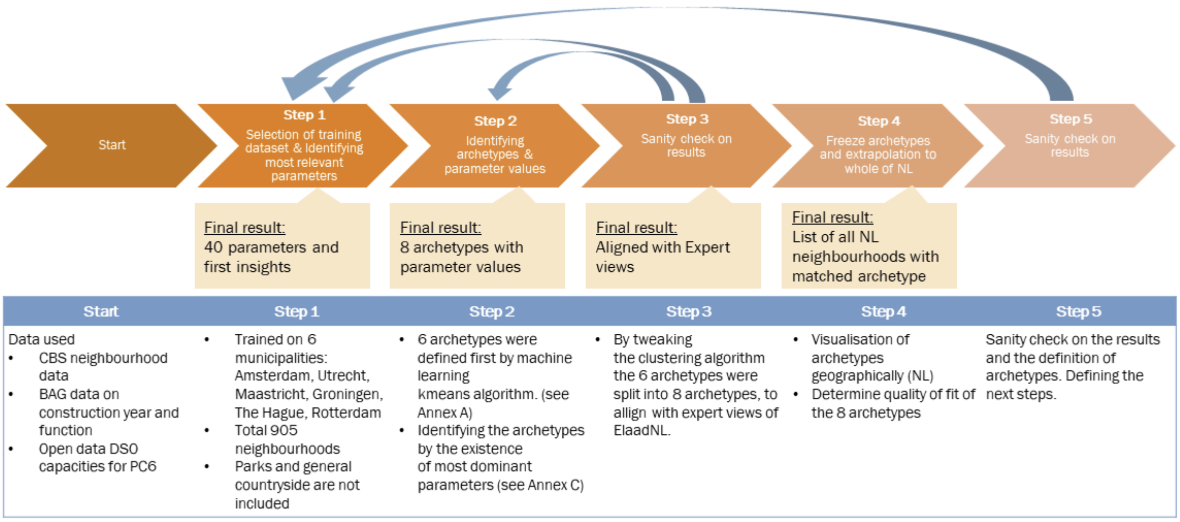

Figure 2.1: Methodology overview (Constructing Neighborhood archetypes via Machine Learning)

First duplicates and correlated features were removed and categorical features with many similar categories were combined. Next, parameters that could logically be converted into percentages were converted accordingly and other parameters were normalized by max-normalization. Finally, a principal component analysis (Pearson, 2010) was applied to reduce the number of parameters to 40 (Verhoeven, van der Holst, Sharma, & Kok, 2022).

Figure 2.2 visualizes the principle of the clusters for a simplified example when only 2 parameters would be used in the methodology.

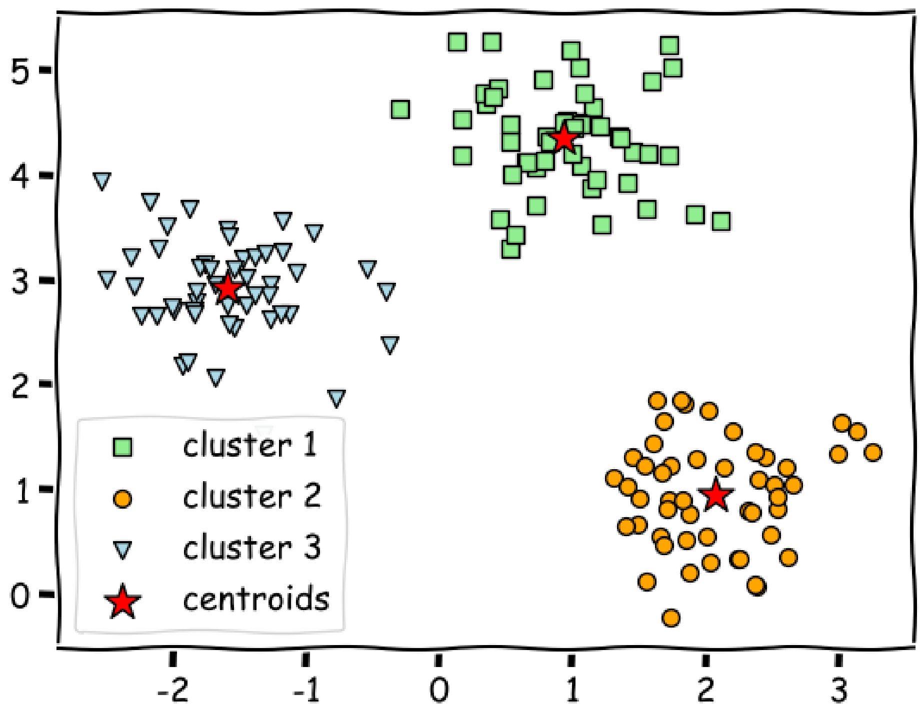

Figure 2.2: Quality of fit example based on two parameters (x and y axis)

Next an unsupervised machine learning algorithm (K-means Clustering), was used to identify dominant parameters and to further cluster the data sets into *k* different groups (clusters). The algorithm was then trained and tuned on a selection of neighborhoods from several larger cities, i.e. Amsterdam, Utrecht, Maastricht, Groningen, the Hague and Rotterdam, see Figure 2.3.

After training of the algorithm, it was run on the neighborhood dataset. This resulted in 6 clusters (k=6), as an entirely data-driven outcome. In order to optimize for usability in the GO-E project, applying an expert judgement by TNO and ElaadNL, for 2 of the 6 clusters another split was made which ultimately resulted in 8 final archetypes.

The result of this methodology was a list of all Dutch neighborhoods, indicating by which archetype that neighborhood is best represented.

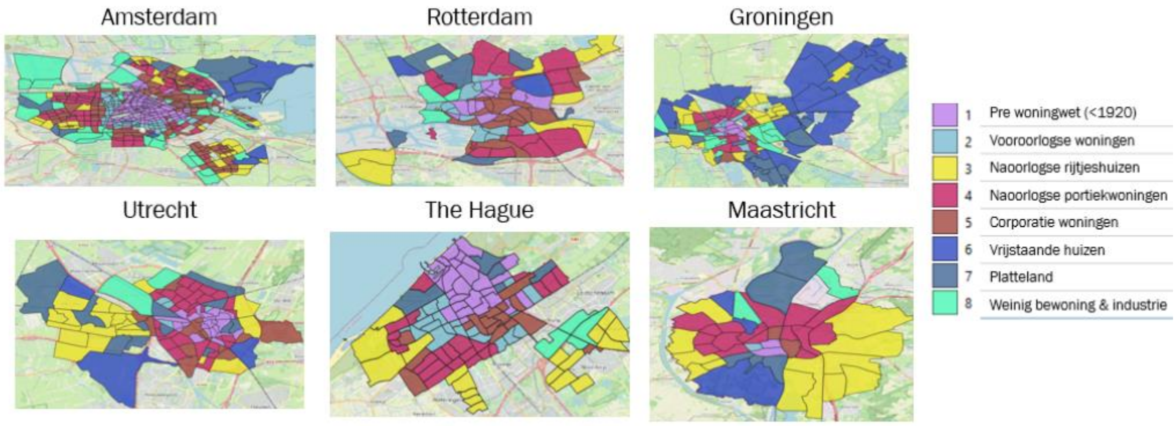

Figure 2.3: Training data set

2.4 Dominant parameters used for final archetype definition

Table 2.1 shows the 18 dominant parameters based on which the archetypes differ the most.

Table 2.1: Parameters explaining most of the variance between the 8 archetypes

#	Parameters	#	
1	Multiple-family-residences [%]	10	Building year 1874-1920 [%]
2	High energy label [%]	11	Building year 1920-1946 [%]
3	Medium energy label [%]	12	Building year 1946-1960 [%]
4	Apartment houses [%]	13	Building year 1960-1970 [%]
5	Chained houses [%]	14	Building year 1960-1970 [%]
6	Average household size	15	Houses connected to heat networks [%]
7	Houses part of a housing cooperations [%]	16	Gas connections [%]
8	Sale [%]	17	>3×25A grid connection [%]
9	Rent [%]	18	Density of addresses [km^2]

3 Results - Archetypes

This section describes the results generated by the approach above, in terms of each of the neighborhood archetypes. The archetypes denote the most prevalent type of housing in a neighborhood according to the dominant parameters found by the K-means algorithm.

3.1 Archetype 1 - Houses from before the housing bill (<1920)

This archetype is dominated by residences built before the introduction of the housing act, in the period of 1874-1920. Based on the analysis, 2.3% of the neighborhoods in the Netherlands fall under this archetype. The archetype is densely populated, and mainly consists of purchased apartments with multiple family residences. The energy labels of the buildings are mixed, but C/D labels are more present than A/B. The residence corporations are not very present in this archetype.

Characteristic	This archetype
Dominant construction year	1874-1920
Dominant type of building	Apartments
Single/multiple family building	Multiple family residences
Dominantly rent/bought	Low-medium bought
Density of addresses	High
High-rise	No
Energy labels	Mix (more C/D than A/B)
Presence of residence corporations	Low
Grid connections	Low-medium 3x25A connection

3.2 Archetype 2 – Pre-war residences

This archetype is dominated by pre-war residences, built in the period of 1920-1946. Based on the analysis, 1.35% of the neighborhoods in the Netherlands fall under this archetype. The archetype is densely populated, and mainly consists of purchased apartments with multiple family residences. The energy labels of the buildings are mixed, but A/B labels are more present than C/D. The residence corporations are not very present in this archetype.

Characteristic	This archetype
Dominant construction year	1920-1946
Dominant type of building	Apartments
Single/multiple family building	Multiple family residences
Dominantly rent/bought	Low-medium bought
Density of addresses	High density
High-rise	No
Energy labels	Mix (more A/B than C/D)
Presence of residence corporations	Low
Grid connections	Low-medium 3x25A connection

3.3 Archetype 3 – Post-war terraced houses

This archetype is dominated by post-war tenements, built in the period of 1970-2010. Based on the analysis, 8% of the neighborhoods in the Netherlands fall under this archetype. The archetype is of low-medium population density, and predominantly consists of rented apartments. The energy labels of the buildings are mixed. The residence corporations are moderately present in this archetype.

Characteristic	This archetype
Dominant construction year	1970-2010
Dominant type of building	Mix of predominantly chained houses and apartments
Single/multiple family building	Mostly single family houses
Dominantly rent/bought	Bought
Density of addresses	Relatively low
High-rise	No

Characteristic	This archetype
Energy labels	Mix
Presence of residence corporations	Relatively low
Grid connections	Medium share 3x25

3.4 Archetype 4 – Post-war tenements

This archetype is dominated by post-war tenements, built in the period of 1970-2010. Based on the analysis, 8% of the neighborhoods in the Netherlands fall under this archetype. The archetype is of low-medium population density, and predominantly consists of rented apartments. The energy labels of the buildings are mixed. The residence corporations are moderately present in this archetype.

Characteristic	This archetype
Dominant construction year	1970-2010
Dominant type of building	Mostly apartments
Single/multiple family building	Multiple family residences
Dominantly rent/bought	Rent
Density of addresses	Low-medium
High-rise	Almost no high-rise
Energy labels	Mix
Presence of residence corporations	Medium
Grid connections	Medium share 3x25

3.5 Archetype 5 – Corporation residences

This archetype is dominated by corporation residences, built in the period mix of 1920-2010 and newer. Based on the analysis, 5.5% of the neighborhoods in the Netherlands fall under this archetype. The archetype is of medium population density, and predominantly consists of rented residences (mainly for multiple families). The hallmark of this archetype is that there are no detached houses. The most present energy labels in this archetype are C-D-E. The residence corporations are very present in this archetype.

Characteristic	This archetype
Dominant construction year	Mix of 1920-2010 and newer buildings
Dominant type of building	No detached houses
Single/multiple family building	Relatively many multiple family residences
Dominantly rent/bought	Predominantly rent
Density of addresses	Medium
High-rise	No
Energy labels	High percentage of energy labels C-D-E
Presence of residence corporations	Large
Grid connections	Low share 3x25

3.6 Archetype 6 – Detached houses

This archetype is dominated by detached houses, built in the period of 1874-1920 and 1946-1960. Based on the analysis, 19.6% of the neighborhoods in the Netherlands fall under this archetype. The archetype is of low population density, and predominantly consists of detached houses. The energy labels of the houses are low, mainly F/G. The residence corporations are not present in this archetype, and the number of rental houses is very low.

Characteristic	This archetype
Dominant construction year	Mix of 1946-1960 and 1874-1920
Dominant type of building	Detached houses
Single/multiple family building	Low
Dominantly rent/bought	Rent is low
Density of addresses	Low
High-rise	No
Energy labels	Low (F/G)
Presence of residence corporations	No
Grid connections	High 3x25A
Households with highest income	Low

3.7 Archetype 7 – Rural area

This archetype is dominated by chained houses and apartments in rural area, built in the period of 1874-1920 and 1946-1960. Based on the analysis, 26.21% of the neighborhoods in the Netherlands fall under this archetype. The archetype is of medium population density. The energy labels of the houses are medium, mainly C/D/E. The residence corporations are not present in this archetype, and the number of rental houses is very low.

Characteristic	This archetype
Dominant construction year	Mix of 1946-1960 and 1874-1920
Dominant type of building	Mostly chained houses and apartments
Single/multiple family building	Medium
Dominantly rent/bought	Rent is medium
Density of addresses	Medium
High-rise	No
Energy labels	Medium (C/D/E)
Presence of residence corporations	No
Grid connections	Medium-high 3x25A
Households with highest income	High

3.8 Archetype 8 – Industry and limited population

This archetype is dominated by industrial buildings and has limited population. The commercial use buildings are built in the period of 1970-2010. Based on the analysis, 11% of the neighborhoods in the Netherlands fall under this archetype. The archetype is of low population density. The energy labels are not reported in the analysis.

Characteristic	This archetype
Dominant construction year	1970-2010
Dominant type of building	Commercial use
Single/multiple family building	Not applicable

Characteristic	This archetype
Dominantly rent/bought	low
Density of addresses	Low
High-rise	-
Energy labels	No
Presence of residence corporations	Not applicable
Grid connections	Large share of 3x25

3.9 Quality of fit of the archetypes

As a final step and sanity check, for each archetype all assigned neighborhoods were scored (based on the dominant parameters) on their distance to the centroid of the cluster, as such providing an indication of the coherency of the archetypes.

Based on the current data analysis, archetypes 1 to 5 are best defined, as shown in Figure 3.1. Due to its large presence and distribution, archetype 7 (rural area) is the least well-defined. This means that within all the neighborhoods linked to the archetype there is a lot of variation.

In Figure 3.1, the vertical axis represents the number of occurrences and on the horizontal axis is the distance to the centroid of the cluster of all neighborhoods assigned to the archetype, as such this represents the quality of fit. Neighborhoods in the green area have a small distance to the centroid and for these the archetypes are a good fit. If most occurrences are in the green area, then the quality of fit for this archetype is good.

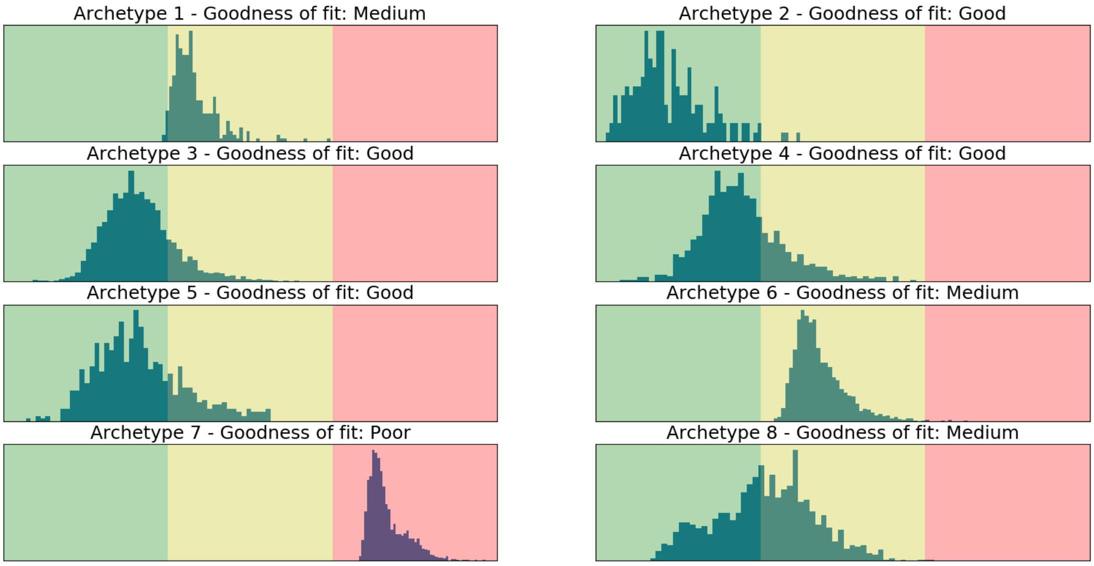

Figure 3.1: Quality of fit for the 8 archetypes

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