Hochschule für Technik Stuttgart
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Photogrammetry and Geoinformatics

Hochschule für Technik Stuttgart

Master of Photogrammetry and Geoinformatics
GROUP Project

Geodatabase Design: Facility documentation and management for a gas network

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Table of Contents

1. INTRODUCTION

This project delves into the detailed process of conceptualizing, designing, and deploying a Geodatabase tailored explicitly for ArcGIS Pro using Enterprise Architect. The primary goal behind this initiative is to modernize and streamline the operational workflows of "City Gas of A Town," a prominent gas supply company. Currently, the company relies the analog documentation comprising of analogy maps, lists, and cadastral maps, providing information about plots and buildings in their network.

Within the existing infrastructure, the gas facilities are categorized into three distinct types. Firstly, there are high-pressure mains responsible for regional gas distribution. Secondly, main supply systems are employed to disseminate gas within the community. Lastly, house supply pipes connect the gas mains to individual buildings, forming an intricate network.

As a GIS consulting group, we have been entrusted with the pivotal task of harnessing the available data and crafting an entirely digitalized system that seamlessly integrates with the company's existing facilities. This mandate necessitates a comprehensive understanding of the gas supply network, including its high-pressure mains, supply systems, and house supply pipes, which culminate in gas meters associated with individual customers.

Leveraging from the provided data, which includes cadastral maps, building outlines, land parcel attributes, and gas facility details, our group is poised to design and implement an intricate Geodatabase system. This system will capture the spatial relationships between gas facilities, buildings, and plots.

The methodology adopted for this project involves utilizing Sparx's Enterprise Architect for the creation of an Entity-Relationship (ER) diagram that encapsulates the conceptual model. Subsequently, a logical data schema for the ArcGIS geodatabase will be devised, keeping in mind the specific requirements outlined in the assignment. The final phase of the project encompasses the implementation of the geodatabase, where data will be loaded into feature, object, and relationship classes. Rigorous testing will ensure the robustness and accuracy of the system, aligning it seamlessly with the gas supply company's operational needs.

In essence, this assignment serves as a transformative endeavour, transitioning the gas supply company from an analog documentation system to a state-of-the-art digitalized solution, fostering efficiency, accuracy, and a comprehensive understanding of their intricate gas supply network.

2. METHODOLOGY

A comprehensive evaluation of the available data is imperative. This involves the analysis of the provided datasets, ensuring a solid foundation for subsequent phases. Our approach to the project is organized into three phases:

1. Designing an Entity Relationship Diagram (ER-Diagram): This phase involves the creation of a conceptual model, specifically an Entity Relationship Diagram (ERDiagram), using Sparx's Enterprise Architect. The ER-Diagram serves as the blueprint, delineating the relationships between various entities within the gas supply

network. Key attributes such as pressure levels, diameters, and connection dates are incorporated into the design. This phase lays the groundwork for the subsequent steps in the project.

2. Logical Model Development: Building upon the conceptual model, a logical data schema is crafted within a specialized ArcGIS workspace in Enterprise Architect. This model is instrumental in defining crucial elements, including expected feature classes, object classes (tables), and relationships between entities and objects. The culmination of this phase involves exporting the model to XML format, facilitating seamless integration into ArcGIS Pro for project implementation.

3. Implementation in ArcGIS Pro: In the subsequent phase, the exported XML model is imported into a geodatabase within ArcGIS Pro. While the exported XML file generally functions smoothly if all steps in the second phase are accurately defined, occasional errors may arise during the import process. Fortunately, in our project, the importation was executed successfully. This marks the concluding phase where the meticulously designed structure comes into practical application.

3. PART 1: DESIGNING THE ER-DIAGRAM

Our initial phase centres on the creation of an Entity Relationship Diagram (ER-Diagram), a pivotal step that structures the entities, object classes, and relationship classes integral to the gas supply project. Employing Sparx's Enterprise Architect, we meticulously outline the geodatabase structure through this graphical representation.

Based on the information from the provided data, our ER-Diagram encapsulates 14 entities, each with varying significance.

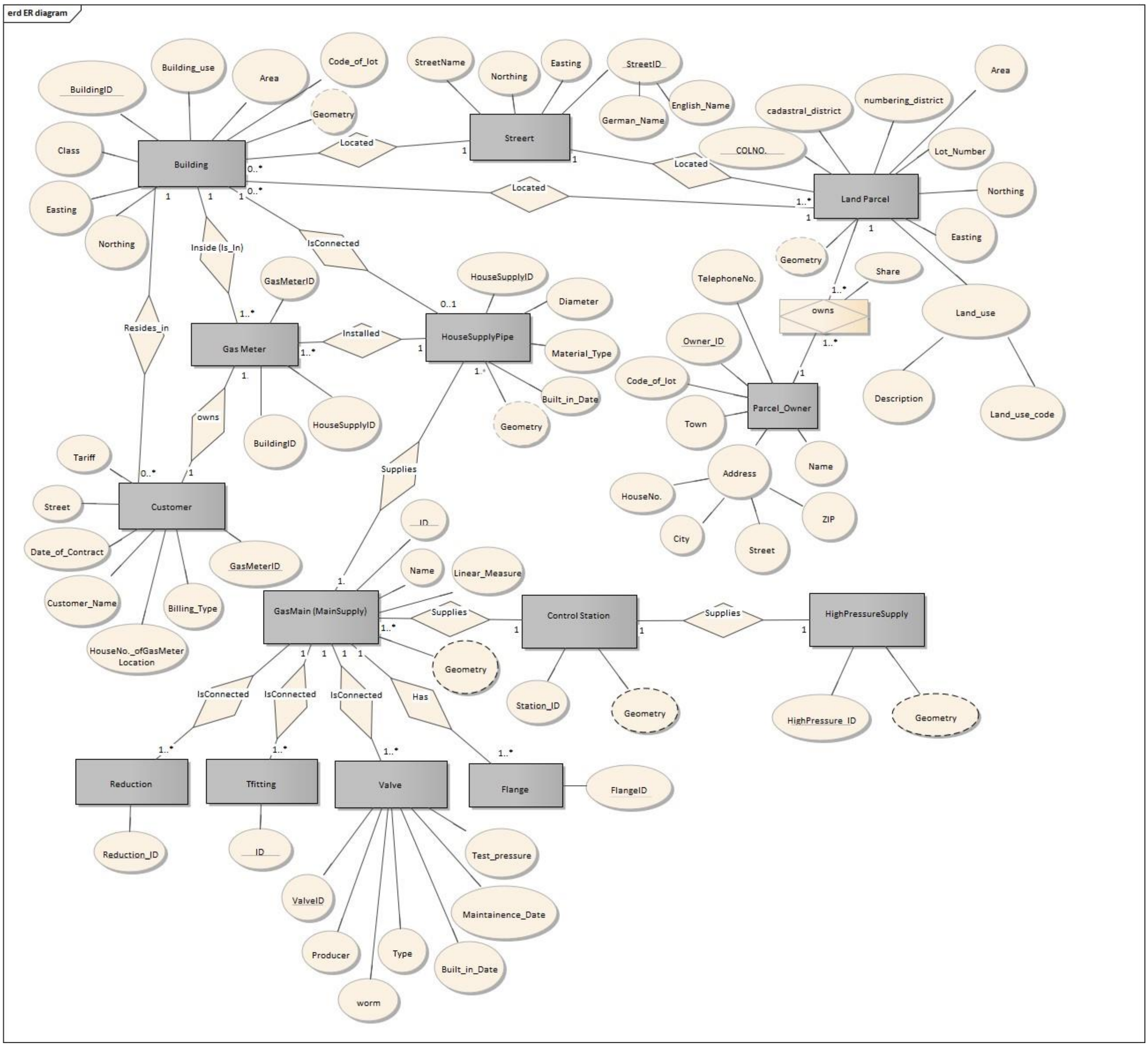


Figure 1. ER Diagram

Briefly introducing the entities in our ER-Diagram and their relationships:

a) Land Parcel and Building: A one-to-many relationship is established, signifying that within one land parcel, none or many buildings could be built, and one building is associated with one land parcel.
b) Land Parcel and Parcel Owner: A many-to-many relationship is articulated, as one land parcel can have one or many owners, and conversely, one owner can possess many land parcels.
c) Land Parcel and Street: The relationship is one to many, indicating that a land parcel is related to only one street, and in one street, multiple land parcels can be situated.
d) Building and Street: Similarly, a one-to-many relationship is defined, indicating that in one street, many or zero buildings can be located, and a building is associated with only one street.

e) Building and Customer: The cardinality between building and customer is one to many, accommodating scenarios where zero or many customers associate within one building, while one customer belongs to only one building.
f) Building and House Supply Pipe: This relationship is denoted as one to 0..1, as one building can have one or zero supply pipes, ensuring each building has, at most, one supply pipe.
g) Building and Gas meter: The relationship between the Building and Gas Meter is one to many relationships, indicating that each building is associated with one to many gas meter and each gas meter is inside only one building.
h) Gas Meter and Customer: The relationship between the Customer and Gas Meter is one to one relationships, indicating that each Customer is associated with only one gas meter and vice versa.
i) Gas Meter and House Supply Pipe: The relationship between the house supply pipe and gas meter is one to many relationships, indicating that each house supply pipe is associated with one to many gas meter.
j) Gas Main (Main Supply) and House Supply Pipe: The relationship is one to many, illustrating that many house supply pipes are connected to one main supply, and one house supply pipe can be connected to one main supply.
k) Main Supply and Reduction: A one-to-many relationship is established, showcasing that several reductions are associated with one main supply pipe.
l) Main Supply and Tfitting: T-fittings act as junction points in the gas mains, facilitating the branching of the pipeline network. A one-to-many relationship is established, showcasing that several reductions are associated with one main supply pipe.
m) Main Supply and Valves: This relationship is one to many, highlighting that many valves are used on one main supply pipe, and one main supply can have many or zero valves.
n) Main Supply and Flange: This relationship is one to many, highlighting that many valves are used on one main supply pipe, and one main supply can have many or zero valves.
o) Main Supply and Control Station: This relationship is one to many, indicating that many main supplies can be connected to a control station, and a control station can have one or many main supplies.
p) Control Station and High-Pressure Supply Pipe: A one-to-one relationship is defined, signifying that one high-pressure pipe is associated with only one control station.

This phase forms the cornerstone for subsequent logical model development and practical implementation in ArcGIS Pro.

4. LOGICAL MODEL – LOGICAL DATA SCHEMA FOR ARCGIS GEODATABASE

After creating our ER-Diagram we created a logical data schema for an ArcGIS geo-database using the ArcGIS Extension of Enterprise Architect (ArcGIS Workspace). We defined the structure of our spatial and attribute data in a way that aligns with the requirements of the GIS application. Below is a simplified demonstration of how we structured our logical data schema for a basic geo-database using Enterprise Architect.

4.1. FEATURE CLASS

In this class we defined feature classes to represent different types of geographic features (e.g., points, polylines, polygons).

For our project, we used:

- Point features to represent **Gas Meter, T-fitting, Reductions,** and **Valves.**

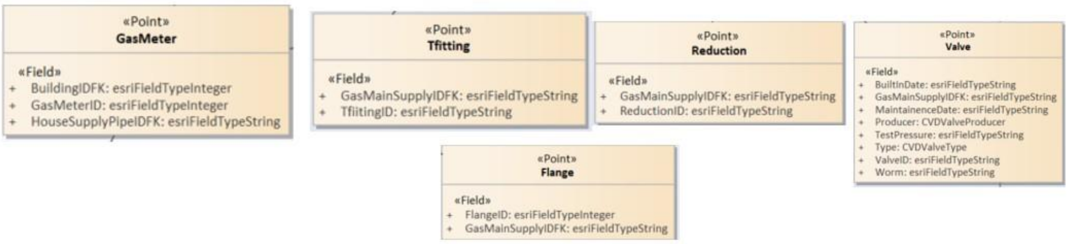


Figure 2 Point Features

- Polyline features to represent **Gas Main Supply pipes, House Supply pipes,** and **High-pressure supply pipes.**

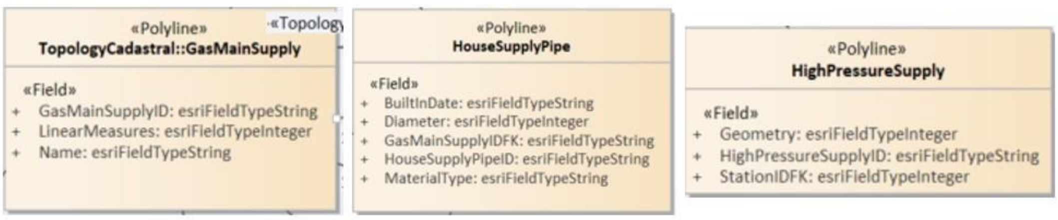


Figure 3 Polyline features

- Polygon features to represent **Buildings, Land parcel,** and **Control stations.**

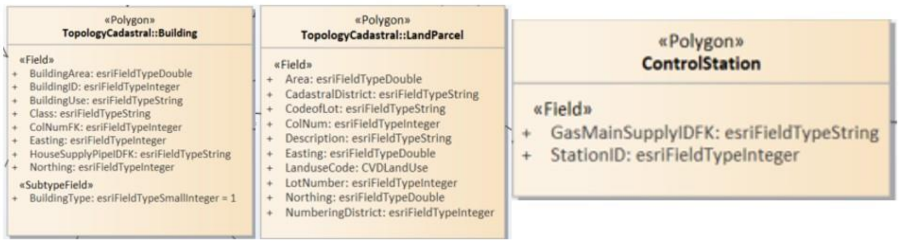


Figure 4 Polygon features

4.2. OBJECT CLASS

In this class, we defined non-spatial data, such as those that were representing entities like customers, parcel owners, and Street ID in a GIS database.

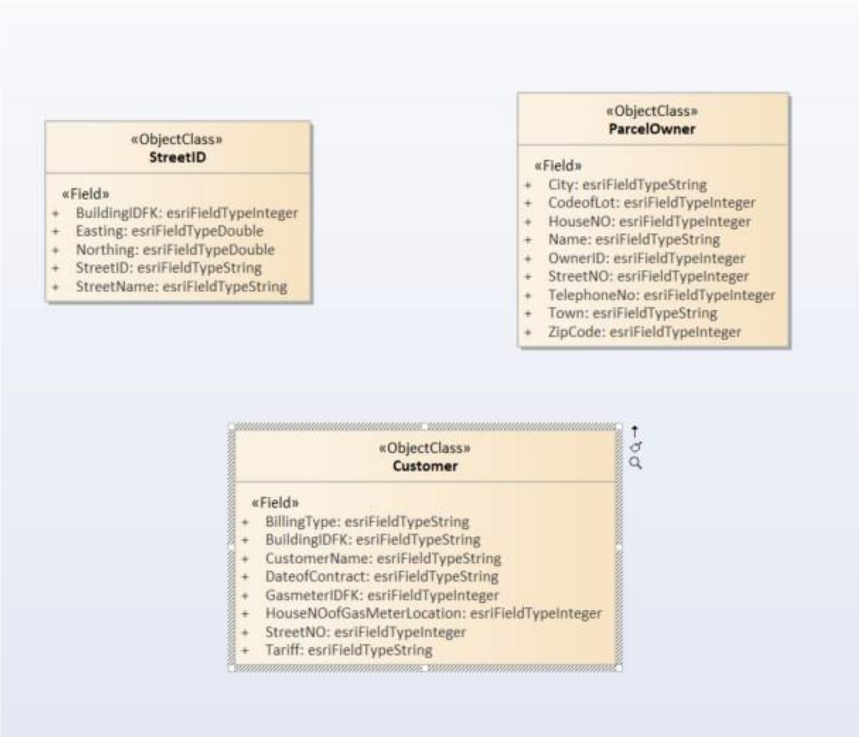


Figure 5 Object classes

4.3. DOMAINS

We defined domains to ensure data quality, consistency, and integrity by enforcing constraints on attribute values. For our project, we only used the **Coded Value Domains,** where each valid value is assigned a code. This was very useful for maintaining consistency and standardizing data entry.

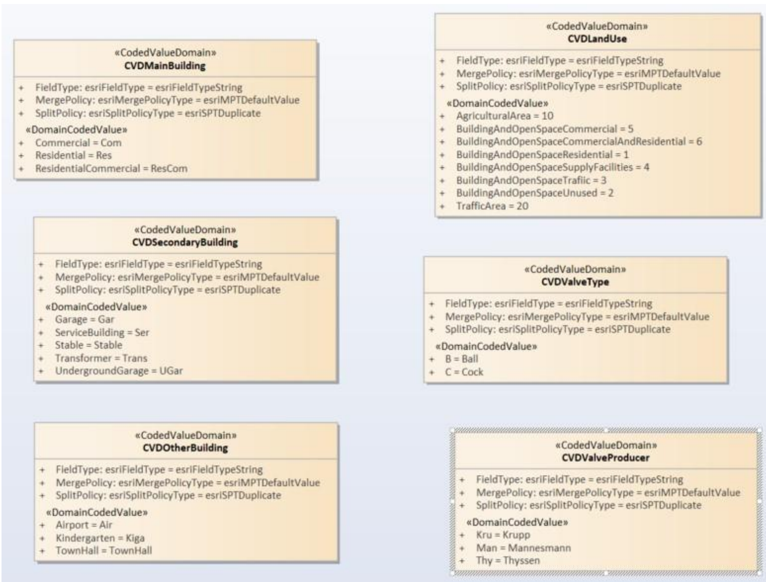


Figure 6 Domains

4.4. TOPOLOGY RULES

We use the topology rules to define and enforce spatial relationships between features in a geodatabase. They are useful in managing and editing spatial data to prevent common geometric errors and inconsistencies. For our projects we used the rules below:

- Land parcels should cover buildings.
- Land parcels should not overlap by themselves.

- land parcels should not have gaps.
- Supply main pipes should not intersect with themselves.
- Supply main pipes should not self-overlap with themselves.

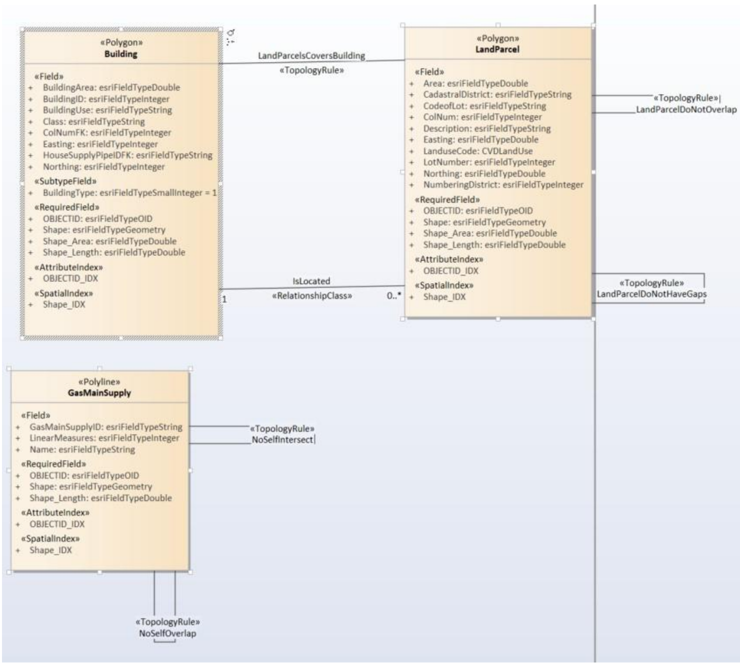


Figure 7 Topology Rules

4.5. SPATIAL REFERENCES

We Specified the coordinate system for the geo-database. For this stage we used Gauß-Krüger projection zone 3, geodetic datum Deutsches Hauptdreiecksnetz (DHDN),EPSG:31467.

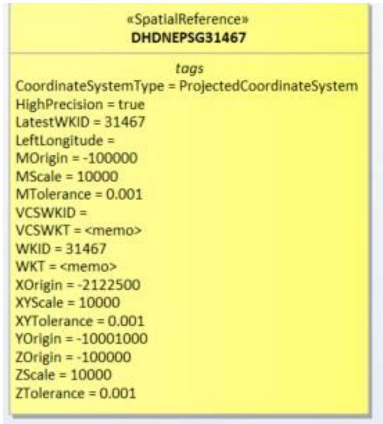


Figure 8 Spatial References

4.6. SUB – TYPES

In general, subtypes are used to represent different categories or types within a feature class. It allows us to model variations within a single feature class by defining subsets that share common characteristics or attributes. For our case, we had to create subtypes of our building feature class as it had a lot of features within itself. From the figure below our subtypes with the building entity can be seen.

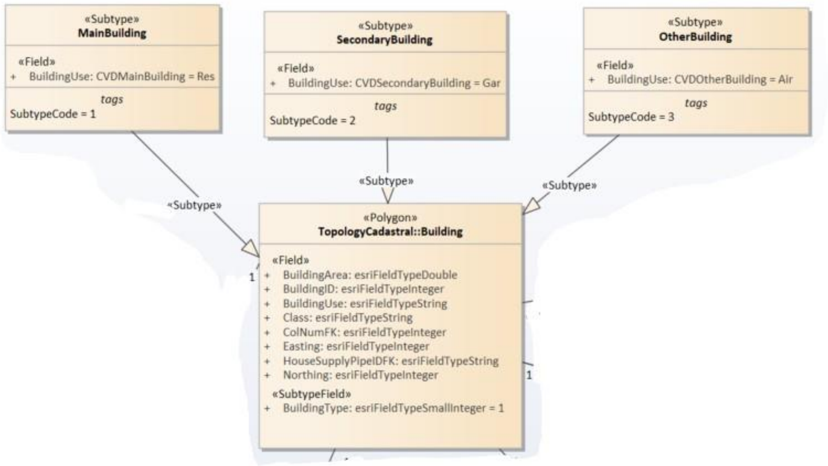


Figure 9 Sub-Types

4.7. RELATIONSHIPS

We used relationships, to associate different feature classes or tables based on common fields. It allowed us to connect data, perform spatial and attribute queries, and as well as model realworld interactions between geographic features or non-spatial entities. Similar to ER diagram the relationship of 1:1, 1:n, and 0:n, one primary key and one foreign key is sufficient however, with n:n a unique relationship needs to be created as seen in figure below.

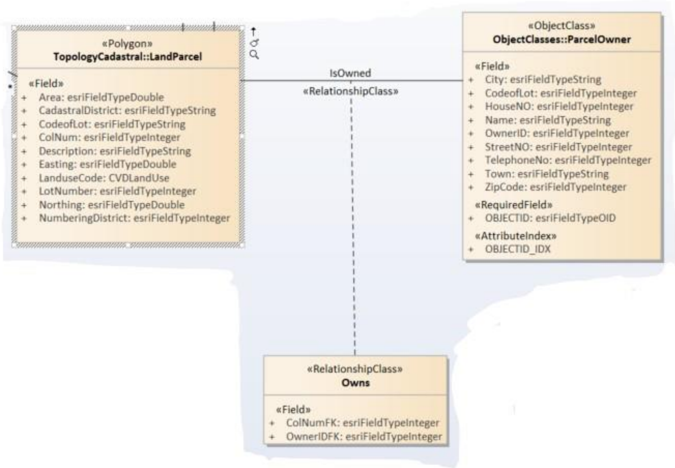


Figure 10 Relationships

4.8. VALIDATION OF ARCGIS MODEL

We use the validate tool, to ensure that our model meet the requirements of our organization, and that it supports accurate and reliable spatial analysis. With this one we had to make sure that after validation we had 0 errors and warnings.

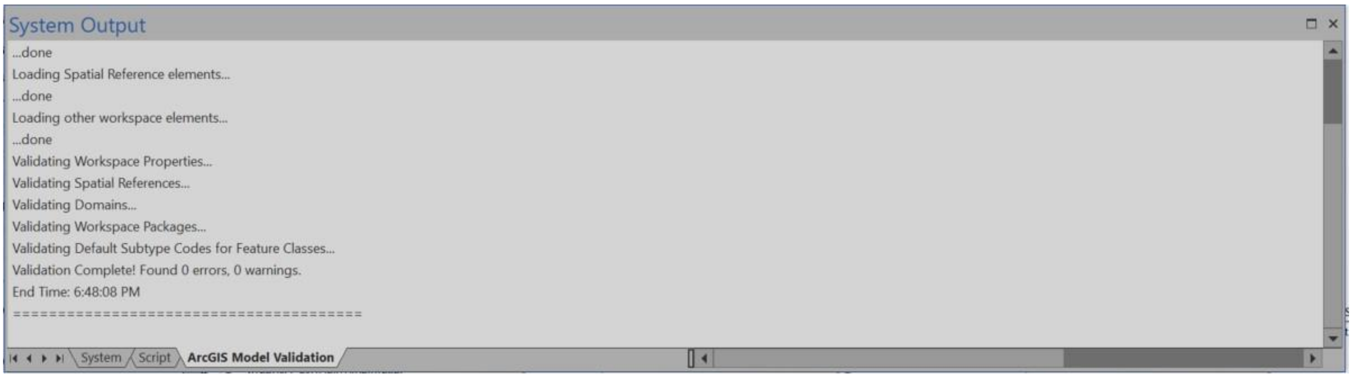


Figure 11 Validation Model

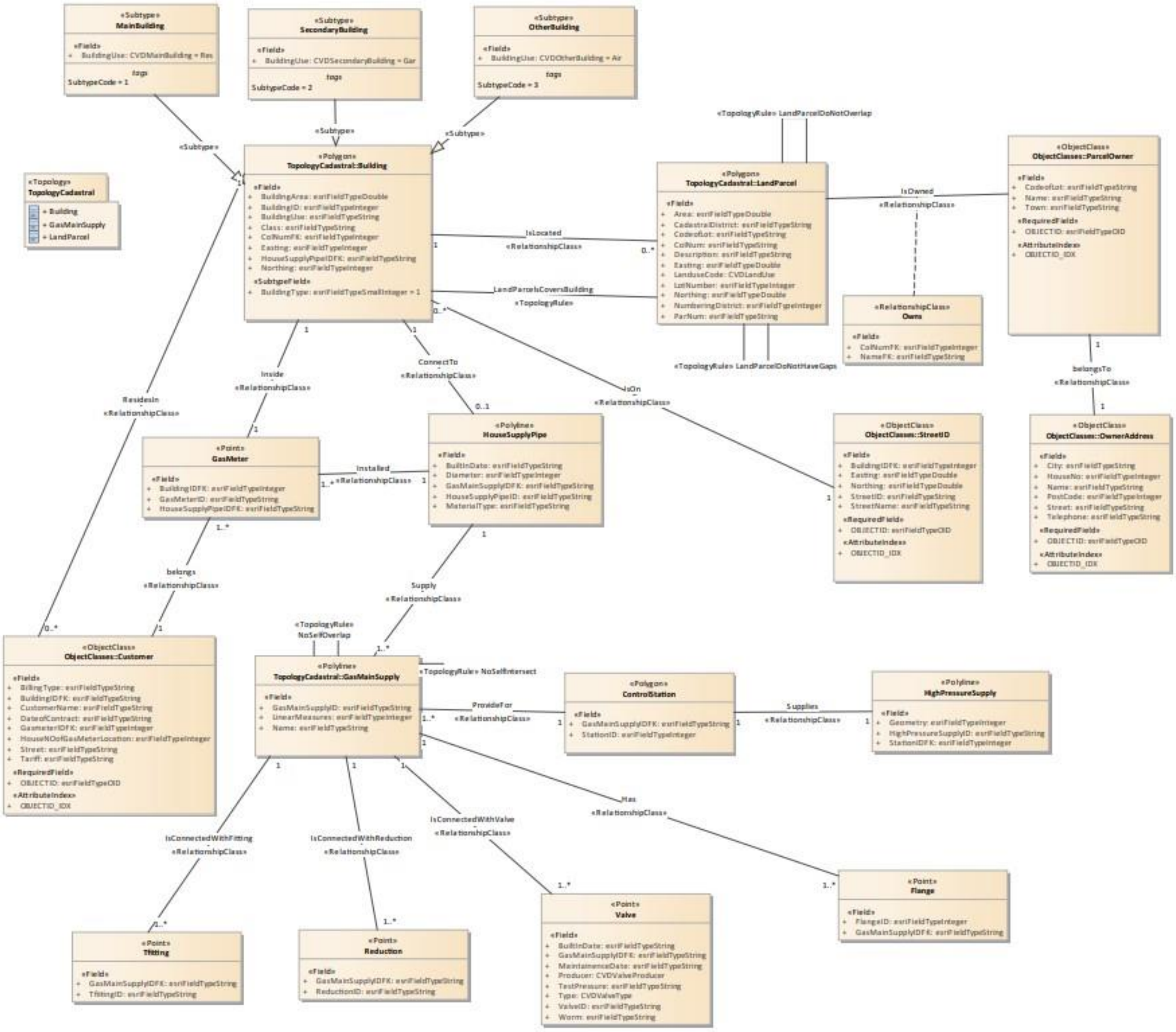


Figure 12 Logical model

5. IMPLEMENTATION OF GEODATABASE IN ARCGIS AND WORKING PROCESS

Initially, we chose the DHDN Zone 3 Gauss Kruger projection for our project, but the file we received was in ETRS89 coordinate system. Since ArcGIS doesn't support DGN CAD-based files, we labeled the coordinate system as ETRS89 in ArcGIS. Afterward, we used ArcGIS projection tools to convert parcels and buildings from ETRS89 to DHDN Zone 3.

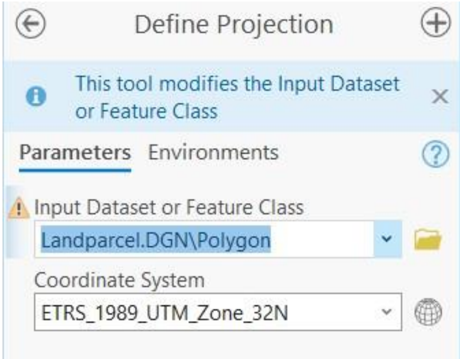
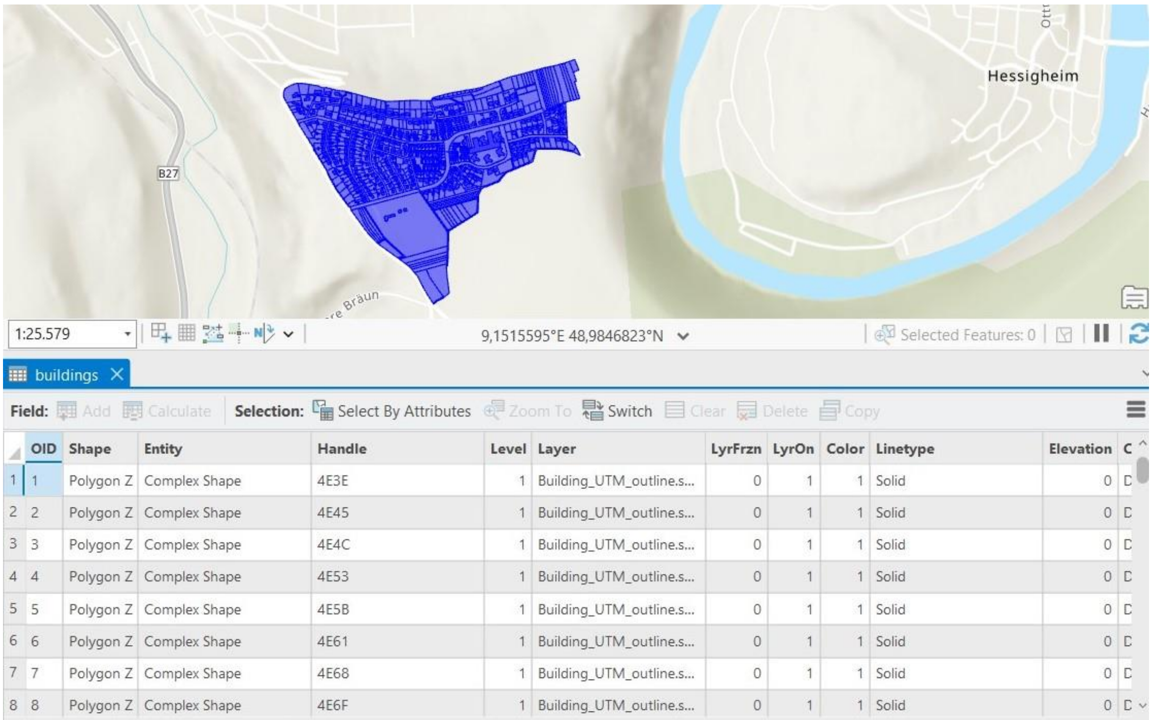


Figure 13 Define Projection and coordinate system preference

Upon examination, we discovered that the attributes table only included data imported from CAD files, lacking any project-related information. Recognizing this gap, our next move was to inspect the topology. However, since DGN files do not support topology checking, we needed to be careful for potential topology errors at this stage.



	OID	Shape	Entity	Handle	Level	Layer	LyrFrzn	LyrOn	Color	Linetype	Elevation	C
1	1	Polygon Z	Complex Shape	4E3E	1	Building_UTM_outline.s...	0	1	1	Solid	0	D
2	2	Polygon Z	Complex Shape	4E45	1	Building_UTM_outline.s...	0	1	1	Solid	0	D
3	3	Polygon Z	Complex Shape	4E4C	1	Building_UTM_outline.s...	0	1	1	Solid	0	D
4	4	Polygon Z	Complex Shape	4E53	1	Building_UTM_outline.s...	0	1	1	Solid	0	D
5	5	Polygon Z	Complex Shape	4E5B	1	Building_UTM_outline.s...	0	1	1	Solid	0	D
6	6	Polygon Z	Complex Shape	4E61	1	Building_UTM_outline.s...	0	1	1	Solid	0	D
7	7	Polygon Z	Complex Shape	4E68	1	Building_UTM_outline.s...	0	1	1	Solid	0	D
8	8	Polygon Z	Complex Shape	4E6F	1	Building_UTM_outline.s...	0	1	1	Solid	0	D

Figure 14 Checking DGN file in ArcGIS

Upon comparing the row numbers and parcel owner rows from the provided text files, we observed discrepancies that seemed to be inadequate. We suspected that this discrepancy might be related to a topology error. When uploading the files into ArcGIS, arbitrary parcel creation may have occurred, leading to the possibility that ArcGIS generated more parcels than what is reflected in our parcel owner table.

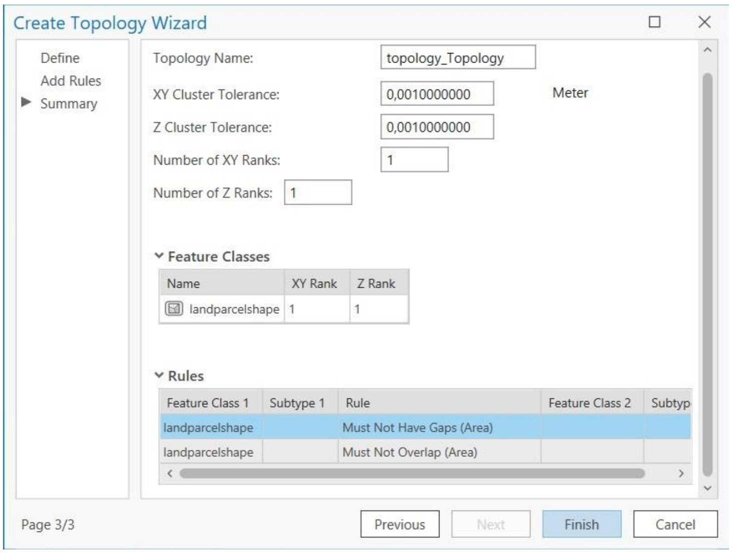


Figure 15 Topology Rules Determination

During our topology check, our focus was particularly on identifying overlapped parcels and those with gaps. Consequently, we formulated topology rules specifying that parcels "must not have gaps" and "must not overlap."

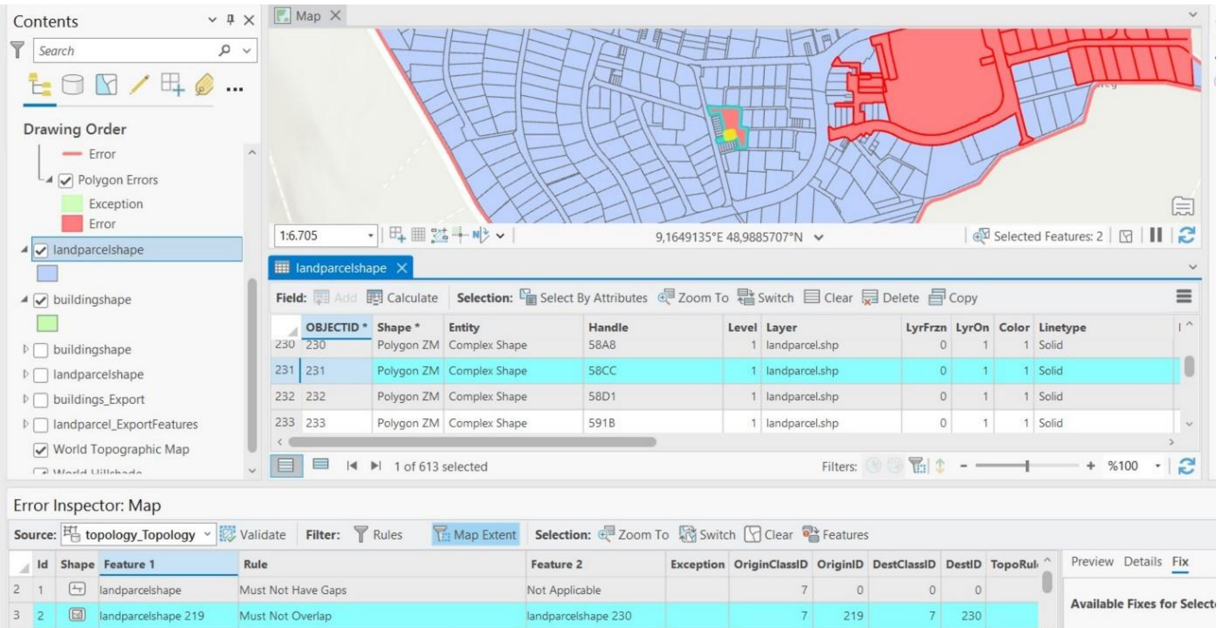


Figure 16 Parcel 230 one out of four parcels that has topology error

Upon scrutinizing parcels with incorrect topology, we uncovered an overlap error involving parcels numbered 230, 231, 232, and 233. It became evident that these specific parcels were positioned under numerous smaller parcels, caused to the overlap issue. Only one of erroneous parcel had smaller parcels in it.

Upon further investigation, we noticed that three of the erroneous parcels had sizes identical or smaller to other parcels. Consequently, we made the decision to delete those three parcels. Subsequently, we were left with one parcel exhibiting topology errors, containing smaller parcels within it. However, as this erroneous parcel was situated outside the area of interest, we chose not to delete it to avoid data loss.

After resolving these issues, we conducted a check on the row numbers with parcel owner data, and confirmed that the parcel and owner numbers matched, indicating the successful resolution of the topology errors.

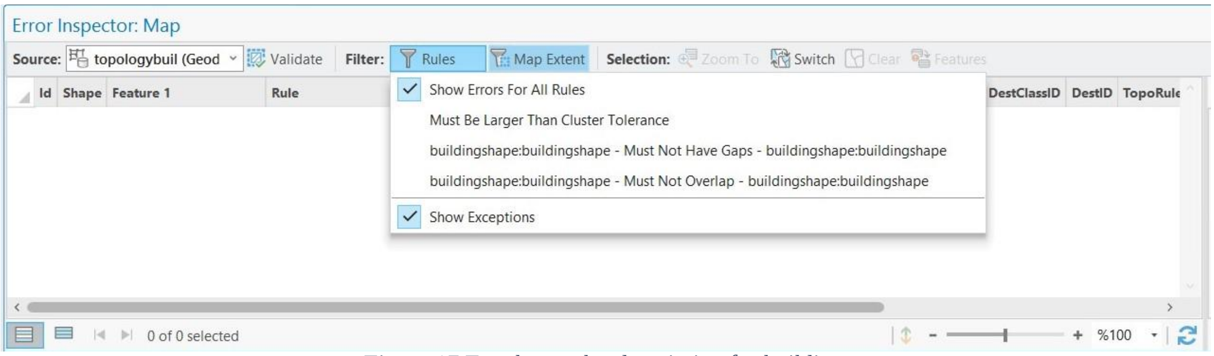


Figure 17 Topology rules description for building

Likewise, we repeated the topology checking process for buildings, employing the "must not have gaps" topology rules. Fortunately, there were no erroneous buildings identified during this assessment.

6. GEOREFERENCING AND DIGITIZATION

We've completed the essential digitization process for the A-town area to establish a database. Initially, we georeferenced the provided jpg format image and exported it as a tiff file. Subsequently, we digitized the data from the legend of map and t-fitting, gas meter which we've chosen to incorporate into the database design although it is not specified in jpg images.

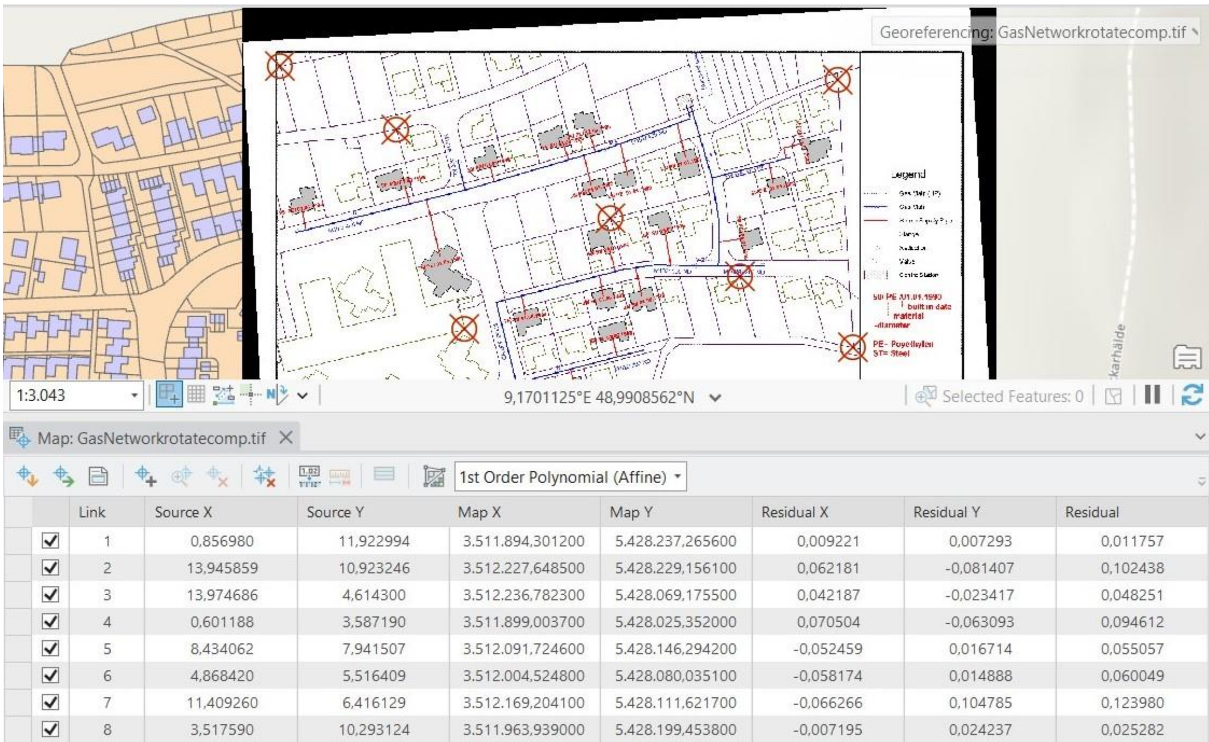


Figure 18 RMS result of Georeferencing

At the end of this stage, we saved the layers created as a result of digitization and the edited building and land parcel files as shapefiles to easily access them.

7. XML EXPORT PROCESS, UPLOADING DATA TO THE DATABASE, JOIN PROCESS

First, we started with the join process. We combined the attribute tables by joining the buildings and parcels, where we fixed the topology error. There were 611 parcels in total. We decided to work only with the parcels in our area of interest. However, if we had used the frame, we obtained by digitizing the jpg file to cut the parcels before joining, the id that we planned to use as the primary key data would also cause data loss. For this reason, we did the join process first.

In the join process, we created a "parcelid" column with the same numbers as "objectid" to serve as the primary key. Subsequently, we utilized the Calculate Field tool to transfer the sequence numbers from "objectid" to the "parcelid" column. The attribute table was then joined using "objectid" as the primary key and "id" as the foreign key. Consequently, each parcel acquired associated attribute data.

Following the join process, we conducted the clipping process. During the digitization process, a framework indicating our work area was also created. Parcel and building data were then clipped using this framework. Upon examining the attribute table, despite the "objectid" numbers being listed arithmetically from 1 to the end, we successfully prevented data loss within the defined work area, thanks to the "parcelid" column we created.

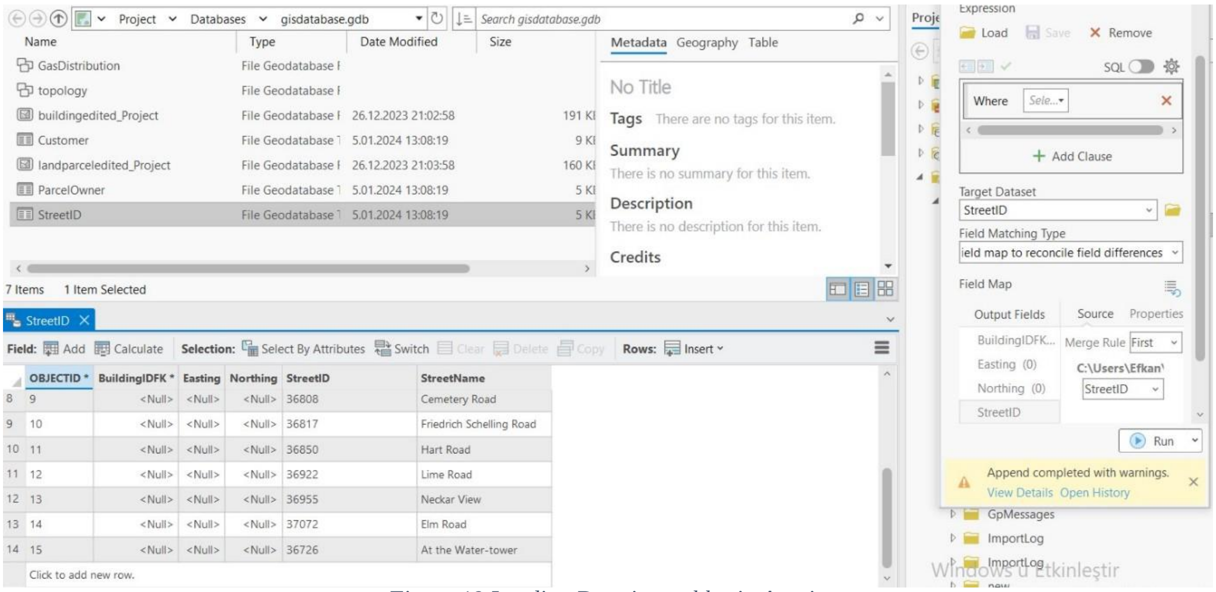


Figure 19 Loading Data into tables in Arcgis

We imported the XML file, generated from the logical model, into the ArcGIS database. During this process, the XML file was brought into the catalog pane, and the necessary files were examined within the catalog. Data was loaded into object class files—StreetID, Parcel, Owner, Address, and Customer—using the "Load Data" function. At this stage, the columns in the TXT files were imported to the corresponding columns in the database.

However, it was observed that some rows in the TXT files were not successfully transferred to the tables. To address this, manual entry of these rows into the tables became necessary. For instance, the second line of the StreetID TXT file was not loaded automatically, so it was entered manually. Consequently, the "ObjectID" was not utilized as the primary key for the StreetID table due to this manual intervention.

Another issue arose due to data type discrepancies. It was discovered that certain numerical data failed to load because the data type was defined as an integer in Enterprise Architecture. To resolve this, the UML was restructured, converting the data type to string, and the model was then exported as XML.

These adjustments and conversions were repeated for various object classes to ensure consistency and accuracy in the data loading process.

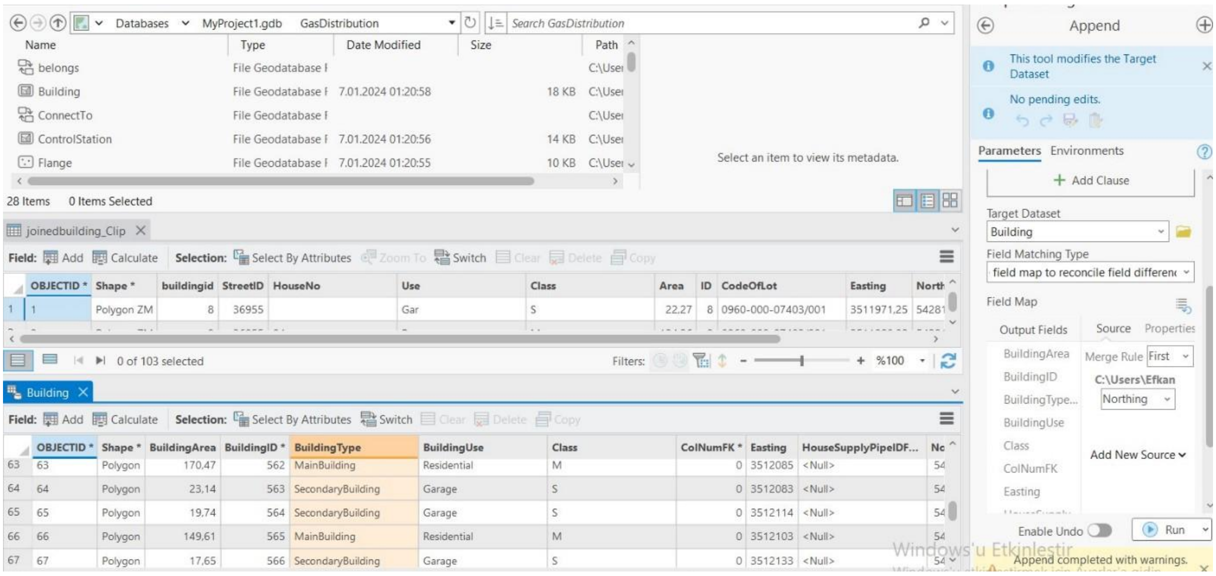


Figure 20 loading data into attribute tables of buildings

We imported data into feature class files using shapefiles to ensure that spatial data aligns with the database. We also matched the relevant columns to facilitate a matching of both spatial and attribute data into the database via load data tool.
Finally, we transferred the data onto the map. We checked the attribute tables.