of the locations is defined differently in different sources. In Gröger *et al.* (2012) the position is proposed to be 2 m or better. In official documents in Germany like AdV (2021b) the location accuracy it is often equated with the accuracy of used cadaster. In case of real estate cadaster, Alkis (2022) defines different levels of accuracy depending on the *collection method* and estimates the accuracy in the range of ñcentimeters to decimetersò.

Figure 1: Capturing methods of CityGML.

The *roof height* data source defines the method used to estimate the height of a building. One method is *laser scanning* while the most used sub method is ALS (Airborne Laser Scanning) which is described in Ressl, Mandlburger and Pfeifer (2009). The point clouds resulting from laser scanning are the starting point for the creation of digital surface models and digital terrain models as well as for 3D city models. Alternatively, automated and manual photogrammetry can be used to estimate the roof height by stereoscopic image analysis methods. The product of automated photogrammetry is the image-based digital surface model, which is described in more detail in ATKIS-DOP (2022). The *manual method* describes the measurement procedure, which is carried out by a surveyor on site. The characteristics *level* and *standard* are estimation methods, which are used if no measuring point is available. One opportunity in the standard

3. Different methods of generating BIM-information and -models

In the context of this work, different approaches are presented that allow a partially automated transfer of information about individual buildings from façade images and city models into building information and BIM models, thus creating an extended database at the building level.

3.1 Façade image-based building information

In order to validate and enrich the information contained in CityGML LOD2 buildings, the application "ABBA" (German: "Automatisierte -Bild Bemaßungs- Anwendung", ñautomated image measuring appò) has been developed. It combines different types of data sources and uses computer vision algorithms to (semi-automatically) collect building information that produces CityGML LOD3 level information such as external dimensions and window/door geometry. The application uses a combination of semantic and geometric map data and images of building façades. The following paragraphs describe the different data sources that can be used by ABBA and the structure -197(a)4(nf/unurc)4(ti)-3(9(a)-ppli)-t(by 20116(of)9699(the)-19[a)4(ppl

converted into real

read into the CityGML based tool. For this purpose, the façade image-based approach is used as usual. The resulting building information, stored in a proprietary data format, is integrated into the existing pipeline. The addition of an extra step after the building information extraction allows the integration of building information extracted from façade

manual method as sources of information. The proportions for *laser scan* and *standard method* are similar to the results for LOD1 in Schwarz (2021). In contrast, *photogrammetry* and *manual methods* are also used for a small number of buildings for LOD2 data. The test study includes ten buildings with 40 façades. According to the previous results, the *ground level height* information for all buildings is derived from the *Digital Terrain Model 1* and the location information for all buildings is based on the cadastre. On the other hand, the source of the *roof height* data is approximately equal between the *laser scan* and the *standard method*. The purpose of the test study is to answer the following questions: Is it possible to achieve the same geometric accuracy with the help of façade image-based approach like in the CityGML approach regarding height and ground dimension information? Further is investigated: How far deviates the same geometric information form CityGML from the real building by comparison with plan data and is the deviation of one meter always fulfilled?

Figure 6: Data sources of regarded CityGML models.

5. Results and discussion of (in)accuracies

The results of the test study are shown in Table 1. The results are differentiated for the façade image-based approach using ABBA and the CityGML based approach. In addition, the results of CityGML are further separated for the two different data sources for height information. The results are shown as absolute values and as a percentage of the *as-planned* values from the plan.

the application ABBA were verified by a test study and the results and the (in)accuracy and its dependencies were discussed. The next steps would be to further automate the data collection process. Images could be automatically analyzed from street images such as Google Maps or Mapillary based on their geo-information. The image processing pipeline could be further automated by using computer vision algorithms to detect the corners of the façade and the parts of the building. As an alternative to the introduced image processing pipeline, photogrammetry and multiple images could be used to generate 3D information about the building façades and the roof type including its geometry. To verify the accuracy of the selected information, with a larger database of available building plans, the geometry could be automatically read from the plans, automating the verification process.

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