University of Applied Sciences and Arts Northwestern Switzerland
School of Architecture, Civil Engineering and Geomatics

MASTER OF SCIENCE
IN ENGINEERING

Datum transition and cartographic projection for Perù

A workflow for transforming cadastral data from PSAD56 to WGS 84 and a proposal for a uniform national projection.

Peru is seeking to modernise its urban cadastral system within an international project led by the World Bank and co-financed by Switzerland. The Institute of Geomatics at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) supports this initiative through technical expertise, training and applied research, to which this master's thesis contributes.

Initial situation

Geodesy, surveying and cadastre in Peru are based on two different reference systems:

- **World Geodetic System 1984 (WGS 84)**
  The modern global reference system is used in GNSS and contemporary geospatial applications.
- **Provisional South American Datum 1956 (PSAD56)**
  An outdated local reference system that is still used for a large number of cadastral data sets.

More than two million land parcels are still registered in PSAD56, leading to inconsistencies and land conflicts. Additionally, Peru extends over three UTM zones, which complicates nationwide data integration (Fig. 1).

Fig. 1: Location of Peru in South America (Encyclopaedia Britannica, 2025)

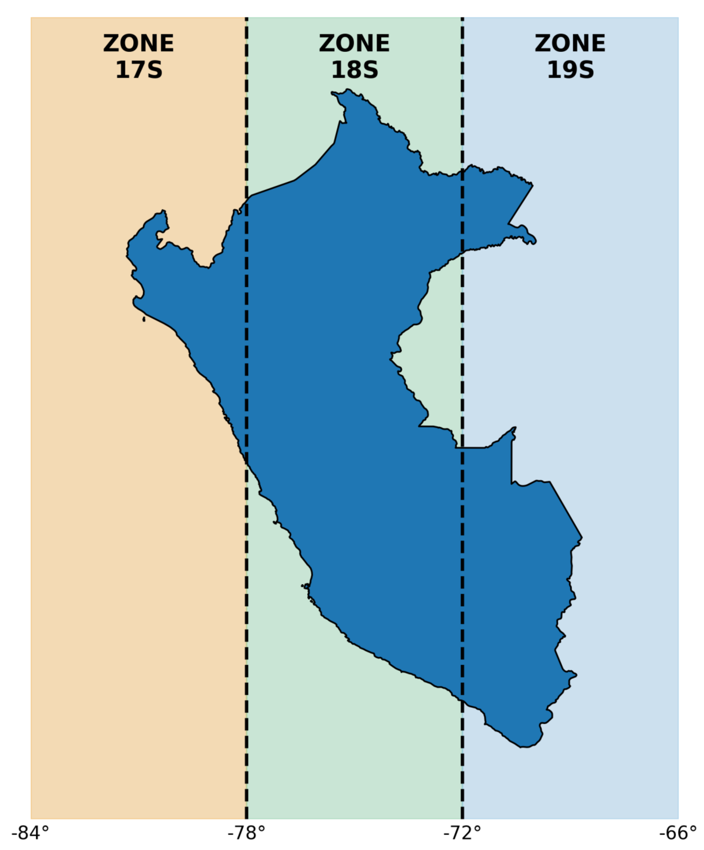

Fig. 2: Peru's extent across three UTM zones (17S, 18S and 19S)

Data analysis

The analysis is based on data sets from two districts in Lima: Surquillo and Los Olivos.

The existing transformation tools include the datum transformation in ArcGIS Pro and QGIS, as well as the GEOCATMIN tool developed by the Institute of Geology, Mining and Metallurgy (INGEMMET) in Peru. ArcGIS Pro and QGIS use the same transformation parameters and therefore produce the same results. Overall, these tools are not suitable for cadastral applications, with GEOCATMIN showing the largest deviations.

The transformation analysis was carried out in the software GeoSuite (TRANSINT) by the Federal Office of Topography swisstopo (2025). The similarity transformations applied are based on the standard theory of geodetic adjustment (Niemeier, 2008). The results of the local transformation analyses demonstrate the importance of using an appropriate spatial extent. While the pueblos are suitable for this purpose, their boundaries must be adjusted in advance to ensure they do not pass through blocks of houses. Approximately five control points should be selected for each pueblo and distributed across its entire perimeter. These control points are then used to determine the transformation parameters.

The comparison between a four-parameter (Helmert) transformation and a three-parameter transformation shows clear differences in terms of adaptability and geometric consistency. The four-parameter transformation achieves smaller residuals thanks to the additional scale factor, allowing for better adaptation to local conditions. However, this results in different scales between the individual transformation perimeters, which can lead to geometric inconsistencies in the overall inventory. The three-parameter transformation is area-preserving, meaning the sizes of the parcels are retained. Nevertheless, this results in slightly larger residuals. Based on this analysis, a workflow for converting from PSAD56 to WGS 84 coordinates was defined.

The concept for a new projection provides a solid basis for implementation and further research. An oblique cylindrical projection based on the geometric extent and orientation of Peru is proposed. This projection is based on the UTM projection, with the strip width adjusted to encompass the entire country. Additionally, the scale factor has been selected to minimise resulting distortions. The concrete implementation of the projection and determination of the numerical parameters are still pending.

Proposed transformation workflow

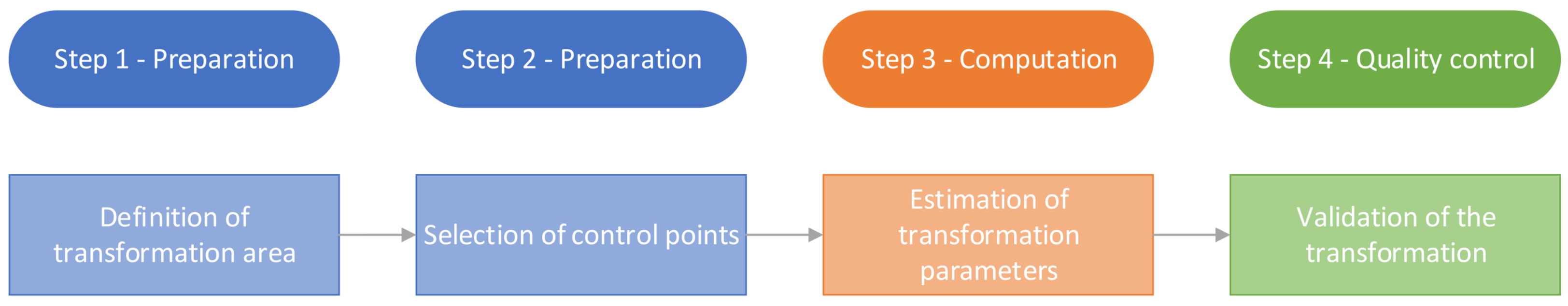

Fig. 3: Workflow for the transformation of cadastral data from PSAD56 to WGS 84, including preparation, parameter estimation and validation

Step 1: Definition of transformation area

The transformation area is defined at the pueblo (settlement) level with minor adjustments when necessary. A clear definition of the transformation area is essential, as the transformation parameters are only valid within this extent.

Step 2: Selection and definition of control points

The control points are evenly distributed along the transformation perimeter. Orthophotos support the identification of suitable points. At least ten points per pueblo are recommended, with a subset used for parameter estimation and the remaining points for validation. This allows the identification of poor control points.

Step 3: Estimation of transformation parameters

The transformation parameters are estimated using a least-squares adjustment based on the selected control points. Both a four- and a three-parameter similarity transformations are evaluated.
The final model selection requires validation using field-measured control points and additional test areas.

Step 4: Validation of the transformation

The transformation is validated using additional control points that were not included in the parameter estimation. These points are transformed to WGS 84 using the derived parameters and compared with their measured coordinates. If available, orthophotos can also be used to assess the quality of the transformation.

Conclusion & Outlook

This work developed a workflow for transforming PSAD56 data to WGS 84. The workflow now needs to be validated using on-site measurements and additional test areas. Based on these results and decisions made by the responsible cadastral authority, the final transformation model can be defined, or alternative approaches considered.
A conceptual projection for Peru was developed, whose implementation and technical evaluation remain for future work.

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