Enrico Borgogno-Mondino
Paola Zamperlin (Eds.)

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Geomatics for Green and Digital Transition

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Editors

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Editors
Enrico Borgogno-Mondino
University of Torino
Grugliasco, Italy

Paola Zamperlin
University of Firenze
Florence, Italy

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Preface

The Italian Conference on Geomatics and Geospatial Technologies is a biennial event whose 2024 edition was held in Padua (Italy) from the 9th to the 13th of December 2024, offering an important opportunity to share the latest developments in Geomatics, with a particular reflection on the Italian context in terms of technology transfer and innovation proposals.

Participation exceeded expectations and involved prestigious representatives of official institutions and public administration (at various levels of governance), the public and private research sector, and the business world. Over 130 speakers animated the parallel sessions and the poster session with their contributions.

Some remarkable contents were as follows: (i) the initial findings from the ongoing national projects developed within the Next Generation EU framework (Piano Nazionale di Ripresa e Resilienza - PNRR in Italy); (ii) transferability and exploitability of new official geographical products and services provided by institutional entities (e.g., Copernicus); (iii) the need for a definition of adequate standardized procedures for producing and validating geographical and Earth Observation data, products, and services with special concerns about their potential roles in monitoring and control activities from institutional players; (iv) concerns about the disruptive role of Artificial Intelligence in Geomatics-related applications and human job markets.

These two volumes collect 54 selected articles organized into five sections, presenting an in-depth exploration of innovative geospatial analysis and technology in tackling key natural or human environmental challenges, including climate change impacts, urban ecosystem planning and management, emergency response effectiveness, and advancements in complex systems monitoring.

With its particular perspective, each paper contributes to the broader objective of supporting technology transfer of innovative methodologies to improve understanding, preparedness, and response to environmental, cultural heritage, and urban management.

Collectively, these studies emphasize the integration of advanced remote sensing technologies, spatial analysis and GIS, and photogrammetry, always highlighting the critical role of data accuracy, standardization, and accessibility.

In the first chapter, **Natural Hazards and Emergencies**, the papers explore innovative geomatic techniques and remote sensing technologies for environmental monitoring, disaster management, and risk assessment. Key topics include soil moisture estimation, wildfire and flood mapping, landslide susceptibility, and ground deformation analysis using InSAR and GIS-based methods. Applications range from UAV support in firefighting to geospatial assessments of antimicrobial resistance and out-of-hospital cardiac arrests. All works are based on the integration of advanced data processing, satellite monitoring, and field sensors to enhance emergency response, infrastructure resilience, and environmental sustainability.

Studies collected in the second chapter, **Urban Systems: Structures, Cities, and Infrastructure**, present innovative geomatic techniques and approaches for urban planning, sustainability, and public safety. Key themes include digital twins, urban heat island analysis, accessibility evaluation, and crime mapping, alongside assessments of ecosystem services and industrial recycling dynamics. Advanced methodologies, such as AI-driven spatial analysis, groupware planning tools, and satellite data integration for urban efficiency, environmental resilience, and safety perception, are presented here. These approaches contribute to sustainable urban development, inclusive design, and data-driven decision-making for city planning and regeneration.

The third chapter, **Cultural Heritage and Landscape Management**, groups papers where geomatics, GIS, and remote sensing are used for historical, cultural, and environmental preservation and interpretation. Key topics include digitalizing World War I cartography, participatory mapping for education, and advanced surveying of cultural heritage sites using BIM-GIS integration and multispectral imaging. Innovative methods for monitoring coastal and marine areas and changes in land use with artificial intelligence-based techniques are central to the research presented. The interdisciplinary approach that characterizes the articles enhances historical research, urban planning, and conservation efforts through advanced geospatial technologies.

The fourth chapter, **Agriculture and Forests**, collects articles related to the application of remote sensing, UAVs, and satellite imagery in agriculture and environmental monitoring. The main topics include crop stress analysis, drought impact assessment, soil erosion mapping, and irrigation modeling using advanced geospatial technologies, highlighting the integration of LiDAR, multispectral data, and satellite analysis to support sustainable farming and land management.

The works grouped in the fifth and last chapter, **Environmental Applications of Geomatics**, refer to vertical domains of applications of Geomatics with special concerns about automated habitat mapping, glacier and coastal monitoring, deformation analysis of the MOSE system in Venice, and marine pollution response.

The importance and effectiveness of collaborative approaches among groups and skills can be explicitly recognized in all the selected papers, demonstrating the high added value that such approaches, based on interdisciplinarity and plurality of players from different institutions/academies/companies, can bring.

As Editors and members of the Italian and International community of geomaticians, we hope for the continuation of this trend in the future. We further recognize that only a wise and open dialogue among research, politics, and companies can drive a proper response to the global challenges that different human communities are facing.

As Editors of the 4th collection of ASITA Proceedings in Springer's CCIS series, we warmly express our thanks to all those who have contributed, as authors and reviewers, to make both the Conference and these Proceedings successful.

March 2025

Enrico Borgogno-Mondino
Paola Zamperlin

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BASIC CORE South Tyrol – A Project to Solve the Topographical Complexity of the National Spatial Data Catalogue

Edoardo Scepi[1](✉), Tarcisio Coianiz[1], Pierpaolo Milan[2], Judith Oberlechner[3], David Colmano[3], Günther Gummerer[4], Pietro d'Orio[4], and Stefan Putzer[4]

[1] Consorzio dei Comuni della Provincia di Bolzano SocCoop, Via Canonico Michael Gamper, 10 - 39100 Bolzano (BZ), Italy

[2] Consulente, Via Jacopo Crescini, 83 - 35126 Padova (PD), Italy

[3] Provincia Autonoma di Bolzano, Ripartizione Natura, Paesaggio e Sviluppo del territorio - Ufficio Pianificazione territoriale e cartografia, Palazzo 11, via Renon 4, 39100 Bolzano (BZ), Italy

[4] Informatica Alto Adige SpA, Via Werner Von Siemens, 29 - 39100 Bolzano (BZ), Italy

Abstract. The project originates from a precise and simplified cartographic updating methodology introduced by the Consortium of Municipalities of the Province of Bolzano in the early 2000s. Over time, this methodology became well-established but could no longer be applied after the adoption of the Territorial Data Catalogue (Ministerial Decree 10.11.2011, "Technical rules for defining the content specifications of geotopographic databases," and subsequent amendments) due to the complexity and structure of the new national model. The primary objective of the project was to identify and define a minimal set of information capable of adequately describing the territory for the typical use cases of public administration. This approach aimed to ensure sustainability by enabling consistent updates and alignment with territorial transformations. A crucial step in supporting territorial management was simplifying the definition and comprehension of the fundamental technical layer required for geotopographic databases, which public administrations producing geographic data must guarantee as part of their institutional activities. The Basic Core (BC) specification was developed by reorganizing and simplifying the information layers outlined in the National Territorial Data Catalogue. This process focused on a minimum subset of information, referred to as the National Core (NC), while excluding content already managed by the Provincial Administration within existing archives or sectoral Information Systems. Additionally, data considered three-dimensional—now more easily obtainable through modern, accurate systems—was also excluded. To enhance practical usability, the Basic Core specification includes only themes that are both objectively useful and straightforward to update. This streamlined approach ensures alignment with existing maintenance workflows and supports efficient territorial management.

Keywords: BASIC CORE · NATIONAL CORE · MapView · FME · Territorial Data Catalogue · QGIS

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1 Introduction

Directive 2007/2/EC, also known as the INSPIRE Directive, was adopted by the European Parliament and the Council on 14 March 2007. Its primary goal is to create a European-wide infrastructure for spatial information, known as the Infrastructure for Spatial Information in the European Community (INSPIRE). The directive aims to improve the access to, sharing, and use of geographic or spatial information across Europe, facilitating the development of policies and activities that require spatial data, such as environmental protection, land use, and climate change monitoring [1].

Italy has worked to establish a national Spatial Data Infrastructure (SDI) that aligns with the requirements set forth by INSPIRE, while also tailoring the implementation to its own national needs and resources [2].

It became very clear from the beginning that the proposed SDI structure was quite complex and resource-intensive, especially for smaller public authorities or organizations. Over the years, there have been ongoing efforts to simplify the requirements and processes related to the directive's implementation, in order to reduce the burden on stakeholders, improve compliance, and make spatial data infrastructure more user-friendly. The Basic Core (BC) falls into this line of simplification proposals [8].

Simplification measures have focused on streamlining Data Specifications without compromising on interoperability.

A modular approach was also introduced. Instead of requiring compliance with all expected data, we defined a common subset of information that was relevant to the daily use of the local government. All other themes lay on the core, as further detail in specific thematic contexts. This drastically reduced the complexity of implementation for stakeholders.

The Basic Core (BC) represents a synthesized and reorganized technical content specification, developed by redistributing and simplifying the spatial model currently employed in the National Spatial Data Catalogue. The project originated from a precise and streamlined cartographic updating methodology introduced by the Consortium of Municipalities of the Province of Bolzano in the early 2000s. Over time, this methodology became well-established but could no longer be applied following the adoption of the Territorial Data Catalogue (Ministerial Decree 10.11.2011, "Technical rules for defining the content specifications of geotopographic databases," and subsequent amendments [2]). This limitation arose from the increased complexity and structural requirements of the new national model. The primary goal of the project was to identify and define a minimal set of information that could effectively describe the territory within the typical use contexts of public administration. A key priority was ensuring the sustainability of this dataset, enabling it to remain up to date and aligned with ongoing territorial transformations [3, 7]. To adapt and optimize spatial data management for the Provincial Administration, the simplification process excluded data already integrated into established provincial or national archives and information systems. Examples of these systems include the Sistema Informativo Nazionale Federato delle Infrastrutture (SINFI), the Archivio Nazionale Numeri Civici delle Strade Urbane (ANNCSU), the Archivio Informatico Nazionale delle Opere Pubbliche (AINOP), and the Sistema Informativo Catastale. The Basic Core specification specifically omits certain layers and datasets to streamline management and improve interoperability. Excluded layers include:

o Layer 00: Geodesy and Photogrammetry
o Layer 03: Addresses
o Layer 07: Underground Networks
o Layer 08: Toponymy
o Layer 09: Administrative Areas
o Digital Elevation Models (DEM)

Additionally, grid structures from Layer 01 (Transport) and Layer 04 (Hydrography) have been excluded. This focused approach simplifies information management and facilitates efficient data exchange with higher levels of public administration. The content of the Basic Core is directly mapped to the specifications of the National Spatial Data Catalogue. Simplifying the way different levels of government and authorities collaborate can make the process more efficient. Clearer guidance on roles, responsibilities, and timelines has been part of these efforts.

Ultimately, one of the key goals of simplification is to ensure that end users (e.g., citizens, businesses, policymakers) benefit from more accessible, usable, and timely spatial data. This includes Easier Access to Data and Better Communication of Data Value.

2 Materials and Methods

The operational choices made in defining the Basic Core specifications addressed both the informational content and the spatial model. For the spatial model, a two-dimensional management approach was adopted for the geometries of object classes in the Topographical Database. Where possible, Z-coordinate information was transferred from the geometric component to specific attributes. This approach is particularly relevant for classes such as Volumetric Unit, Building Block, Partition Element, and Endeavour. When necessary, elevation data is managed using digital elevation models (DTM and DSM), particularly for object classes contributing to land cover. To further simplify the spatial model, a single geometric component was adopted for each object class. This approach reduces complexity while still allowing synthetic geometries to be derived from those with higher levels of detail. For instance, the geometry of a building's floor surface can be derived from the geometries of the volumetric units that compose it. Additionally, an attribute called "Level Relative to Ground" was introduced to represent the position of objects in relation to the lowest level of an artifact.

Regarding informational content, the Basic Core introduced a significant reduction in the number of object classes by amalgamating related types and reorganizing enumerated attribute domains systematically and hierarchically. This approach enabled scalable information management across various levels of detail, including municipal, provincial, regional, and national. For instance, six classes from the National Spatial Data Catalogue were consolidated into a single class named Endeavour, while the classes Industrial Artefact, Monumental and Urban Design Artefact, Sports Equipment, Transport Infrastructure Artefact, and Duct Line were merged into a new class called Artefact. The number of attributes per class was also reduced following an analysis of their actual use in municipal and provincial topographic databases. Much of the content is already sourced from certified specialized systems, such as SINFI, ANNCSU, and AINOP, making duplication unnecessary. This aligns with the adopted 'once-only' principle and further simplified the information model. Another major simplification involved spatial integrity constraints, which were reduced to the minimum necessary to ensure logical congruence of geometric and topological aspects. The adoption of a two-dimensional spatial model further streamlined this process, simplifying the management and maintenance of topographic databases. Table 1 below illustrates the comparison between the Basic Core classes and the National Core classes from the National Spatial Data Catalogue, highlighting the reduction in the number of object classes.

Table 1. Difference of object classes between National Core and Basic Core.

LAYERS	National Core Classes	Basic Core Classes
Mobility/Road Network	6	4
Properties	26	8
Hydrography	6	4
Orography	4	2
Vegetation	8	4
Settlement pertinences	9	1
Total	**59**	**23**

In summary, the Basic Core represents a significant advancement in the management and organization of spatial data, enhancing the efficiency and effectiveness of information handling across multiple administrative levels.

2.1 ETL Procedures Development

Following the completion of the technical summary specification and its mapping to the National Spatial Data Catalogue, a major development of ETL (Extract, Transform, Load) procedures was undertaken. These procedures were critical for migrating objects from Municipal and Provincial Topographic Databases based on the National Core to the new Basic Core content specification. This migration ensured consistency, up-to-date spatial data management, and optimized integration with the national framework at both local and provincial levels.

To manage the Basic Core, tools from the GeoUML Methodology were employed, specifically the GeoUML Catalogue and the GeoUML Validator [4–7]. These tools, which played a central role in defining the content specification of the National Spatial Data Catalogue, continue to be instrumental in managing and validating the new technical specification. The GeoUML Catalogue facilitates precise cataloging of spatial object classes, while the GeoUML Validator ensures that data adhere to spatial integrity constraints and comply with the specifications.

The Basic Core is published in two distinct formats to cater to diverse user needs.

Content Specification in Natural Language: Presented as a detailed descriptive document, this format lists the spatial object classes and their spatial integrity constraints. It serves as a key resource for users seeking a comprehensive understanding of the Basic Core's structure and rules.

Formal Specification Files (.SCS): These files are used to generate implementation models such as Shape Flat, PostGIS, and Oracle, which are essential for practical application. Moreover, the.SCS files are critical for validating data, ensuring it aligns with the Content Specification and adheres to the intended implementation models.

This dual-format approach ensures that the Basic Core is accessible and usable by both technical professionals and stakeholders involved in spatial data management, enhancing its practical applicability and comprehensibility.

2.2 From National Core to Basic Core (Automatic Transformation)

Following the detailed definition of the new Basic Core specification, an automatic conversion of the basic spatial information layer for the entire South Tyrol region—previously based on the National Core—was successfully carried out. This critical process was made possible through the support of our technology partner, Informatica Alto Adige S.p.A. (SIAG). By developing multiple dedicated FME (Feature Manipulation Engine) scripts, SIAG effectively completed this essential task.

As anticipated, the automatic conversion process relied on a series of FME scripts, designed to translate the format and data structure of the information layer from the National Core specification to that of the Basic Core. The main requirements these scripts had to fulfill are outlined below.

- o **Import and Mapping:** The script needed to import and interpret data based on the National Core schema, map the entities within it, and subsequently compare them to the corresponding entities in the Basic Core model. This process involved a comprehensive reorganization of the data, whether through grouping or simplifying various pieces of information, to ensure alignment with the new specification.
- o **Geometric and Semantic transformation:** In addition to attribute mapping, the FME scripts needed to support geometric and semantic transformations. Since the Basic Core schema requires a simplified geometric representation—for example, converting complex polygons into simplified polygons or points—the scripts had to handle these transformations seamlessly. Similarly, the semantic content needed to be adjusted to align with the requirements of the target model, ensuring consistency and adherence to the Basic Core specification.
- o **Validation and Data Cleaning:** During the conversion process, the scripts were configured to perform a series of data validation and cleaning checks. These checks included tasks such as eliminating duplicates, correcting topological errors, and adjusting attribute values to align with the Basic Core requirements.
- o **Export and Publication:** Once the transformation was complete, the entire information layer was exported to the new format based on the Basic Core model. This step concluded with the saving of the data (e.g., shapefiles, GeoPackage, GeoJSON) and their subsequent publication on a WebGIS platform for further review and verification of the results.

Clearly, after such a large-scale automatic transformation, and despite the numerous controls applied through the specially developed FME scripts, it was essential to conduct an extensive manual verification, correction, and updating process.

Unfortunately, it was not possible to include images of the developed scripts due to their complexity and size. The software limitations prevent exporting images at the required resolution.

2.3 Basic Core Online Dashboard and QGIS Projects

The next step in the Basic Core project was the creation of a dedicated online environment. This platform, equipped with guided and mostly automated procedures, allowed different types of users to check the data converted according to the new specification.

Built on the new MapView platform (Fig. 1), which was developed to replace the existing MAPS Web GIS system in South Tyrol, an online editing dashboard was created. This dashboard enabled users to visualize, analyze, edit, and/or update data through a web interface. Additionally, it allowed users to create and download custom-tailored QGIS projects, ready for use.

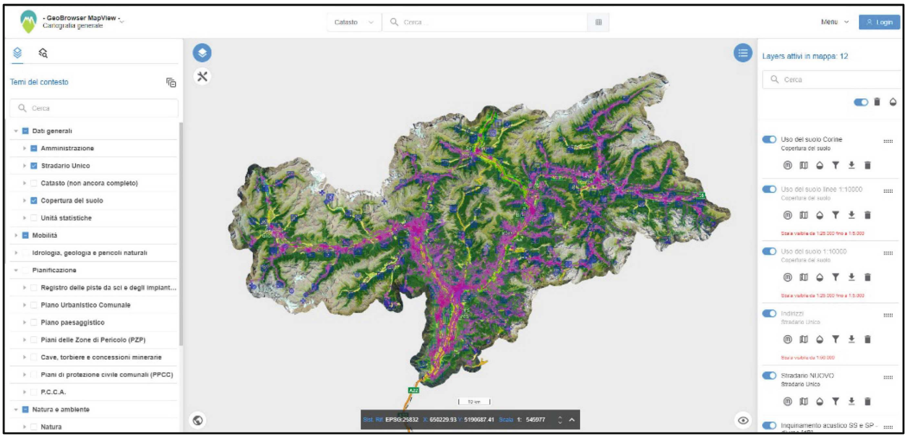

Fig. 1. MapVIEW Platform.

The dashboard features an intuitive UI that allows easy access to all the functionality provided.

- o **Works Session List:** This section of the dashboard displays the number and status of all active, archived, or validated work sessions. Users can import an updated and corrected work session or export one that requires additional checks and/or corrections. This section relies on a set of essential FME scripts, which are responsible for performing all coherence checks before the updated data is integrated into the main Basic Core dataset (Fig. 2, 2).

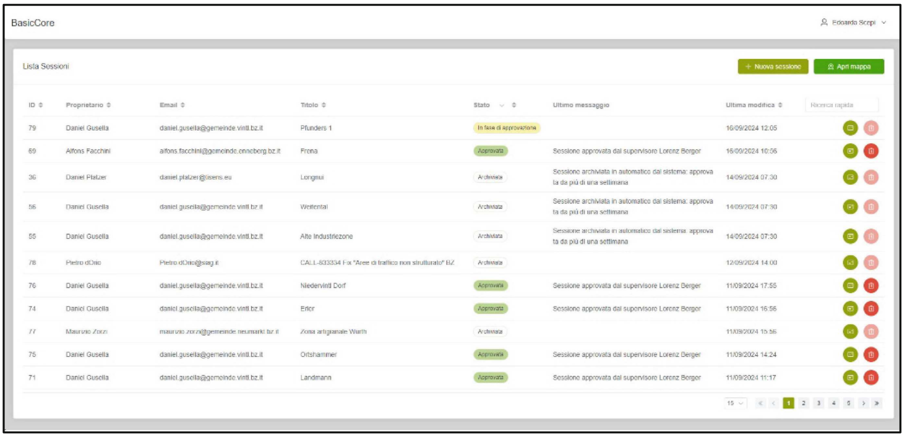

Fig. 2. Dashboard Works Session List.

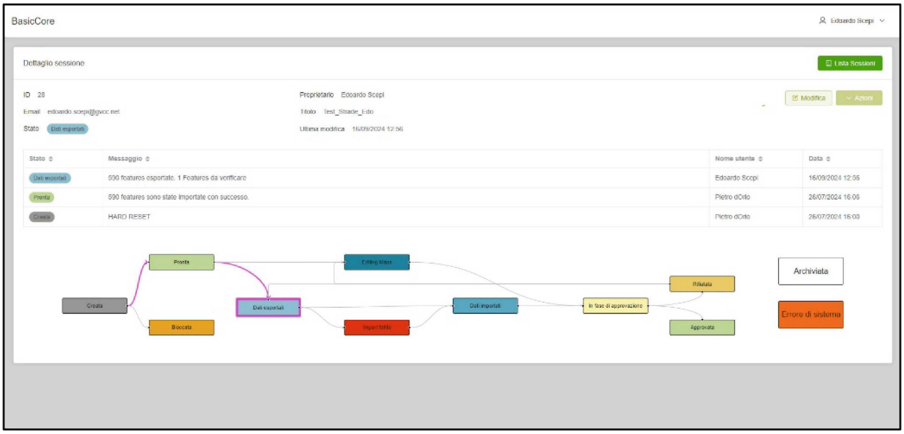

Fig. 3. Dashboard Work Session Detailed View.

Interactive Map: Used to visualize geospatial data. In this section, users can either directly correct or update all BC themes or select specific areas where QGIS work sessions can be created and exported (Fig. 4).

o **Editing Toolbox:** Accessible directly from the interactive map, this section provides a range of tools for editing geospatial data (create, edit, or delete) directly through the web interface. Whether using the online dashboard or QGIS projects, each operation is guided by step-by-step wizards, which help simplify the operator's tasks and significantly reduce the likelihood of errors (Fig. 5).

These controls, to name a few, include the auto-generation of unique IDs, automatic snapping during vector digitization, auto-completion of geographic and/or cadastral information, and the entry of attributes from predefined, unmodifiable lists of values. The second mode of interaction developed for correcting and updating the new technical

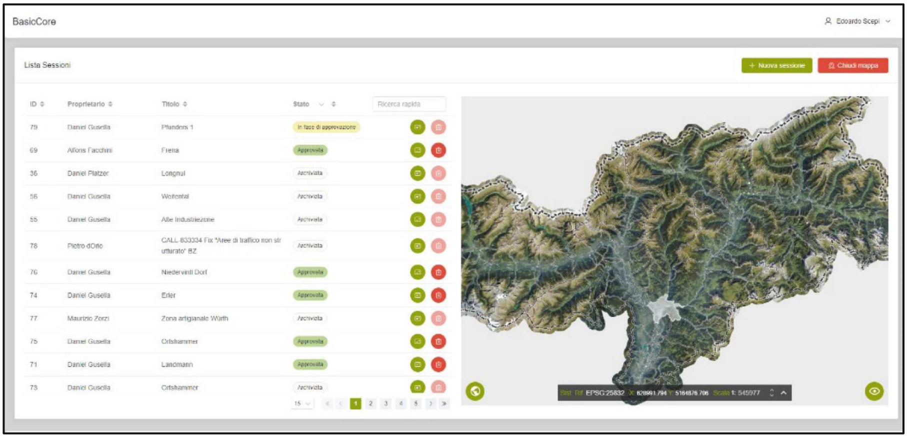

Fig. 4. Dashboard Basic Core Works Sessions Interactive Map.

Fig. 5. Dashboard Editing Section.

information base layer is intended for more complex and substantial changes that go beyond the capabilities of the online interface. This mode utilizes ready-to-use QGIS projects, which can be created and downloaded directly from the dashboard.

These tailor-made QGIS projects were developed to simplify and optimize the management and maintenance of BC cartography. They allow users to work on spatial information layers through the standard QGIS interface, enhanced with advanced controls and dedicated input forms.

The input masks were designed to address specific operational needs, streamlining the data update process and reducing the likelihood of errors. These masks guide the user through a step-by-step procedure for entering or modifying data, with auto-completion features where possible. This approach minimizes the complexity of the required steps while ensuring data consistency (Fig. 6).

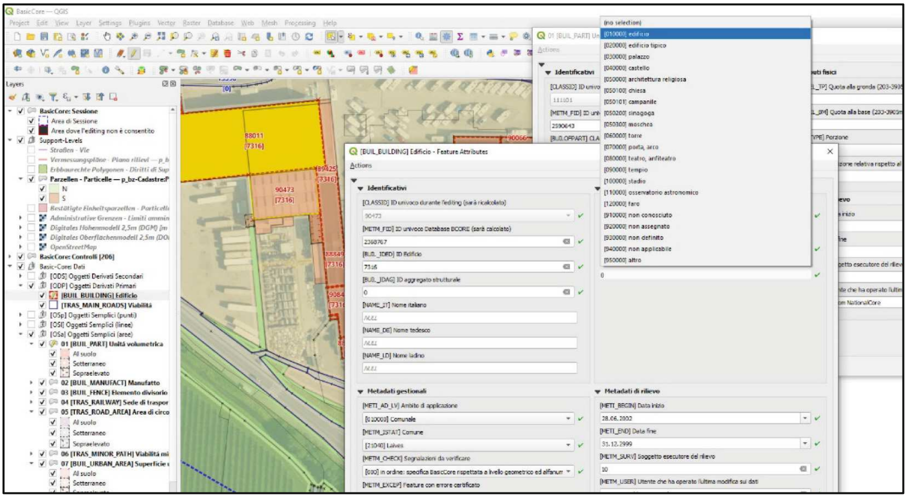

Fig. 6. Basic Core QGIS project control and entry masks.

The project developed this dual interaction approach to provide a flexible and efficient system for different types of users, whether they are "experienced technicians" or users less familiar with GIS technologies. Once the appropriate corrections and updates have been completed—either through the web interface or using QGIS projects—users can proceed with the re-import and data validation process within the dashboard.

These steps are crucial for ensuring that the data can be replaced and published in the official cartography. Using another set of FME scripts, the system performs validation checks to ensure the data conforms to the standards defined by the new technical specification. Special attention is given to:

- **Topological validation** (e.g., contiguity of polygons, absence of multi-polygon objects, no overlaps, and line connectivity),
- **Geometric validation** (e.g., absence of corrupted geometries, effective closure of polygons),
- **Attributive validation** (e.g., consistency of assigned attributes, validity of entered values, and absence of null values).

If the data does not meet the validation criteria, a detailed report is generated and sent to the operator, highlighting any specific errors. The final data update occurs without compromising the integrity of the overall information layer, thanks to cross-checking procedures that prevent errors and unintended overwriting (Fig. 7, 8).

In conclusion, the dashboard offers a powerful and flexible environment for managing geospatial data efficiently and, most importantly, collaboratively. It features advanced editing tools and helpful wizards that enhance the user experience.

Fig. 7. Basic Core Cartography Before Editing.

Fig. 8. Basic Core Cartography After Editing.

3 Results

A key outcome of this project was the substantial improvement in the efficiency and accuracy of cartographic updates, directly attributed to the advanced technical implementation described in Sect. 2.3. The interactive dashboard and QGIS project integration streamlined workflows, reduced manual effort, and enhanced data validation procedures.

To evaluate the system's effectiveness, a pilot project involving 20 municipalities in South Tyrol was conducted in the second half of 2024. This initiative not only facilitated the correction and updating of the Basic Core cartography but also served as a real-world load test for the platform. The immediate recognition by municipalities of the system's utility underscores its role in improving spatial planning and decision-making processes.

Key Improvements and Gains:

- **Automated Validation & Error Reduction:** The use of automated coherence checks, topological and geometric validation scripts significantly reduced errors, ensuring higher data integrity compared to previous manual processes.
- **Time Efficiency:** The guided editing toolbox, along with real-time validation and interactive dashboards, accelerated update processes, minimizing the need for extensive post-processing corrections.
- **User Accessibility:** The dual interaction model (web-based dashboard and QGIS projects) enabled a wider range of users to efficiently contribute to data management, from GIS experts to local municipal technicians.
- **Scalability:** The system demonstrated its capability to manage increasing workloads, supporting a standardized and scalable approach to spatial data management across multiple municipalities.

Project Phases:

- **Training:** The municipal technicians involved were trained in the use and understanding of the technical content specification, the system (dashboard and QGIS), and the methods for correcting and updating the Basic Core cartography.
- **Inconsistencies analysis:** Each team from the municipalities reviewed their cartographic data, identifying discrepancies with the actual situation on the ground. In several cases, depending on the municipality, these discrepancies were significant and substantial.
- **Update/Correction:** Data was updated to reflect all spatial changes that had occurred over time, such as new buildings, changes in the road network, and updates to agricultural areas.
- **Data validation and integration:** The task was carried out by fully exploiting and testing the capabilities of the developed system.

The technical advancements embedded in the dashboard and QGIS-based workflows have thus led to a more accurate, efficient, and user-friendly system, setting a benchmark for future spatial data management projects.

4 Conclusions

This pilot project serves as a model for future large-scale interventions and marks the first step towards the standardization of spatial data management throughout the Provincia Autonoma di Bolzano. Thanks to the active participation of the municipalities, a process has been initiated that will lead to the creation of a more reliable technical base map, serving as a foundation for future decisions and interventions. The platform proved to be particularly useful, not only for interacting with the new BC layer, but also for managing GIS data in a simple, fast, and efficient manner.

Future developments will expand and integrate the system further, enabling the monitoring of changes over time and real-time collaboration among all stakeholders responsible for this critical sector. Among the many positive outcomes, we particularly highlight:

- o Improved accuracy of the cartographic data.
- o Constant and autonomous updating of spatial and cartographic information.
- o Streamlining of land use planning
- o Inter-municipal cooperation

Another undeniable benefit of the approach on which this project is based is the significant reduction in costs that each municipality will experience, no longer needing to rely on specialized external consultants or firms.

We are confident that this project will provide concrete benefits in the management of such a fundamentally important information layer as basic technical vector cartography. This represents the minimum information content that administrations, when producing spatial data in the context of their institutional activities, must guarantee for geotopographic databases, ensuring the creation of a homogeneous dataset with national coverage.

In fact, both the simplification and the management system we have implemented will enable the Basic Core to become a practical and effective tool for land management. In contrast to the National Core, which, with its high degree of complexity—59 classes—was too large for what should be a basic technical cartography, the Basic Core offers a more streamlined and applicable model. The National Core ultimately remained more of an academic concept than a practical one, with limited real-world application.

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