FROM SURVEYING TO CONSTRUCTION LAYOUT: AN INTEGRATED DIGITAL GEODETIC WORKFLOW FOR A KARTING COMPLEX

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ABSTRACT: *The rapid development of digital technologies is transforming engineering design and geodetic practice. Within the concept of Geodesy 4.0, geospatial information is increasingly integrated into digital workflows supporting infrastructure planning and design. This paper presents an integrated digital geodetic workflow applied to the design of a karting complex near the village of Vratitsa, Bulgaria. The workflow combines geodetic surveying, terrain modelling, design development, and construction layout planning within a common digital environment using Autodesk Civil 3D. The results demonstrate that the use of a digital terrain model as a unified spatial basis improves data continuity, reduces repeated processing of geospatial information, and supports efficient coordination between project stages. The study confirms the applicability of Geodesy 4.0 principles to sports infrastructure design.*

KEYWORDS: *digital geodetic workflow; sports infrastructure; digital terrain model; engineering geodesy; construction layout; Autodesk Civil 3D; Geodesy 4.0*

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1 Introduction

The ongoing digital transformation of engineering and geospatial disciplines has led to the emergence of new approaches for the acquisition, processing, management, and application of spatial data. The concept of Geodesy 4.0 reflects this transition by integrating digital technologies, geospatial information systems, automation, and intelligent digital environments into contemporary geodetic practice [11].

In modern infrastructure projects, geodetic activities extend beyond data acquisition and geometric control to support planning, design, construction, and spatial information management [3, 12]. Geodetic information, therefore, serves as a fundamental component throughout the project lifecycle, from terrain surveying and digital terrain modelling to project implementation. The integration of geodetic and engineering activities within digital environments improves data consistency and supports more efficient decision-making [8].

Sports infrastructure projects represent a specific category of engineering facilities where accurate terrain representation and coordinated geometric design are essential. Karting complexes, in particular, require precise control of horizontal and vertical geometry, surface grading, and stormwater runoff management, making them suitable case studies for evaluating the application of integrated digital geodetic technologies.

This study presents an integrated digital geodetic workflow applied to the design of a karting complex located near the village of Vratitsa, Bulgaria. The study demonstrates how geodetic and engineering activities can be integrated within a digital design workflow, contributing to the implementation of Geodesy 4.0 principles in sports infrastructure design [11].

2 Study Area and Project Characteristics

The study was conducted for the design of a karting complex located near the village of Vratitsa, Kameno Municipality, Burgas Region, Bulgaria. The project area encompasses three cadastral properties (12245.18.53, 12245.18.11, and 12245.18.12) situated in the locality “Kayata”, with a total area of approximately 110 decares (11 ha).

The selected site is characterized by relatively steep and variable terrain, creating specific challenges for infrastructure planning and requiring detailed geodetic analysis. Terrain conditions significantly influence the design of the transport network, drainage system, vertical planning, and the geometric configuration of the karting track and associated facilities.

The proposed sports complex includes a karting track as the primary functional element, together with supporting infrastructure such as parking areas, service roads, pedestrian zones, green spaces, administrative and service buildings, commercial facilities, and recreational areas.

The spatial organization of the proposed karting complex is presented in Figure 1. The figure illustrates the functional layout of the karting track and its associated facilities, adapted to the existing terrain conditions.

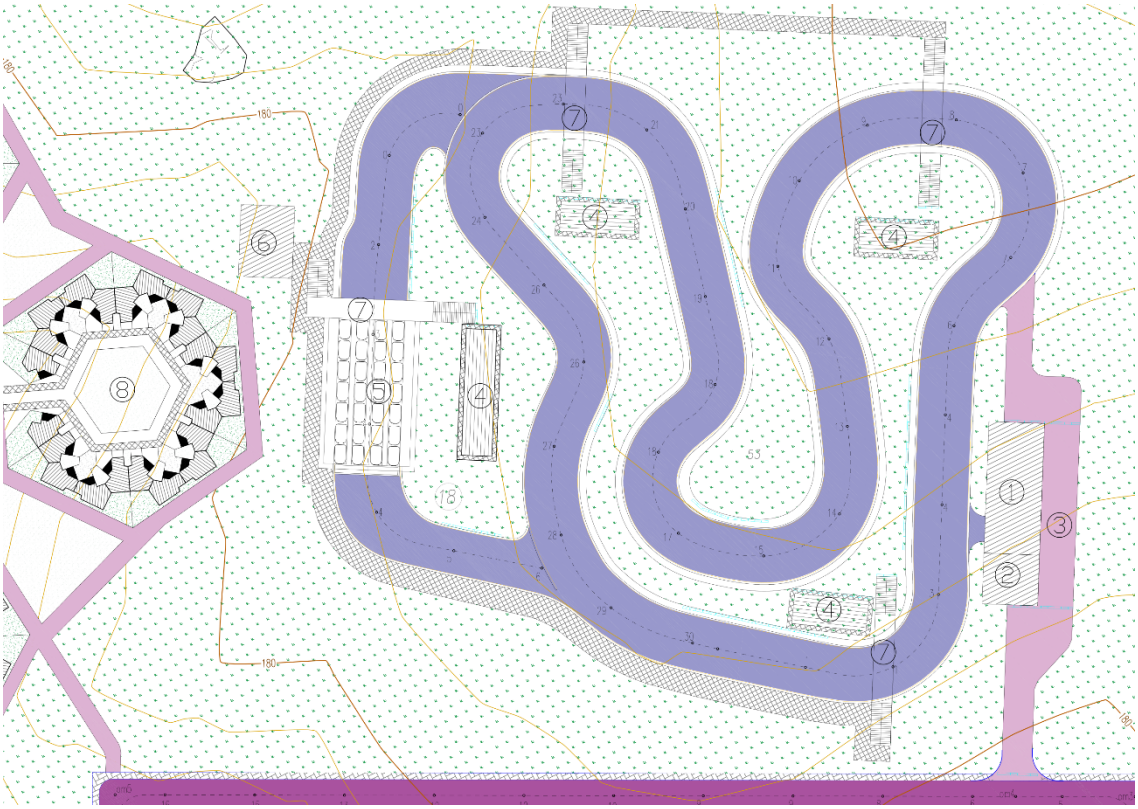


Figure 1. Functional layout of the karting track and associated facilities.

3 Geodetic Data Acquisition and Terrain Modelling

The digital workflow was initiated through geodetic surveying and processing of spatial data describing the existing terrain conditions within the project area. The acquired data formed the basis for all subsequent design activities [9, 12].

The geodetic survey included characteristic terrain points, contour information, and boundary elements required for generating the digital terrain model. The acquired spatial data were referenced to the Bulgarian Geodetic System 2005 (BGS2005) and the Baltic Height System. Based on the survey data, a digital terrain model (DTM) was generated and used as the primary spatial dataset for design and planning activities [2, 6].

The model enabled the assessment of slope conditions, elevation differences, drainage patterns, and terrain-related constraints affecting the proposed infrastructure. A triangulated irregular network (TIN) was used to represent the terrain surface, preserving significant terrain

features while providing an efficient basis for subsequent engineering analyses and design operations [6, 7].

The resulting digital terrain model served as the foundation for all subsequent design and geodetic activities, ensuring a consistent spatial basis throughout the project.

4 Integrated Digital Geodetic Workflow

The integrated digital workflow developed for the design of the karting complex consists of several sequential but interconnected stages. Each stage generates geodetic and engineering outputs that serve as input data for subsequent project activities. The workflow structure is summarized in Table 1.

Table 1
Main stages and outputs of the integrated digital geodetic workflow

Stage	Main Activity	Output
1	Geodetic survey	Topographic survey dataset
2	Terrain modelling	Digital Terrain Model (TIN)
3	General planning	General site plan
4	Profile design	Longitudinal profiles
5	Vertical planning	Grading and elevation model
6	Geodetic control network design	Engineering geodetic control network
7	Construction layout planning	Staking out documentation

The outputs generated at each stage are integrated within a common digital environment, ensuring data consistency and supporting efficient information exchange throughout the project lifecycle.

4.1. General Plan Development

The general plan was developed following the creation of the digital terrain model.

The planning process considered both the existing terrain conditions and the functional requirements of the future sports facility. The karting track was established as the central element of the development. At the same time, the remaining components, including parking areas, service roads, pedestrian zones, green spaces, commercial facilities, and supporting infrastructure, were arranged to ensure efficient circulation, accessibility, and operational functionality.

The arrangement of the functional zones was optimized according to terrain morphology, accessibility requirements, and future traffic circulation. The digital terrain model facilitated the evaluation of alternative spatial configurations and supported the selection of the final layout solution. Particular attention was paid to minimizing earthworks and ensuring compatibility with the existing terrain.

The resulting general plan provided the basis for subsequent design and implementation activities.

4.2. Profile Design

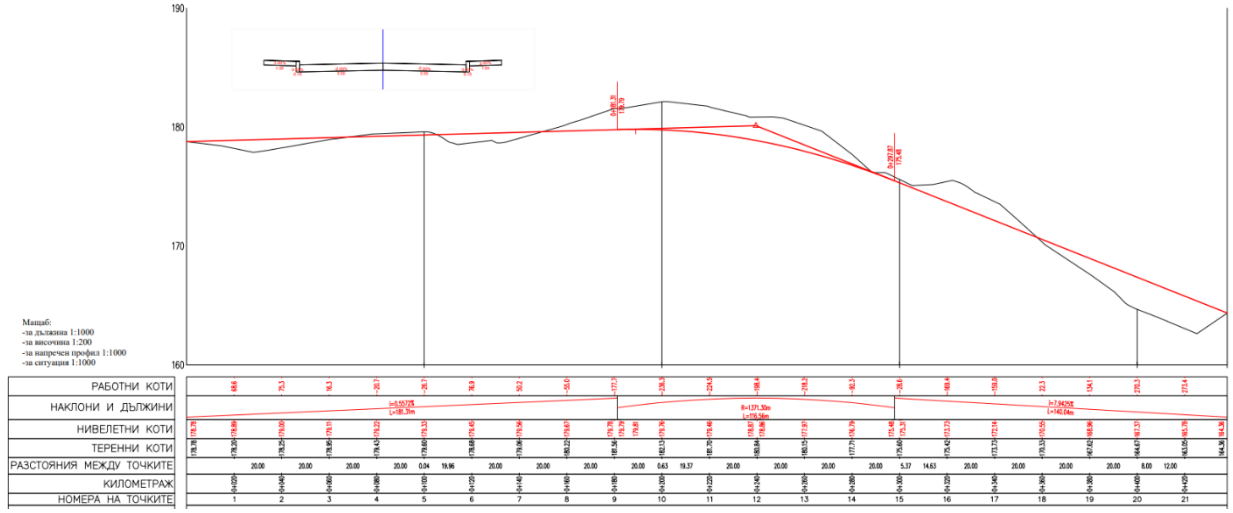
Profile design constituted an important stage within the integrated digital workflow, linking the digital terrain model with the development of project elevations [3]. Longitudinal profiles were prepared for both the karting track and the service road to evaluate terrain variations and support the subsequent vertical planning process.

The generated profiles enabled the assessment of terrain variations, slope conditions, and design elevations for both the karting track and the service road. The analyses supported the

development of vertical geometry compatible with the existing terrain while ensuring operational functionality and drainage requirements.

Representative longitudinal profiles developed for the service road and the karting track are shown in Figure 2. The profiles illustrate the relationship between existing terrain and proposed design elevations along the project alignments.

(a) Service Road



(b) Karting Track

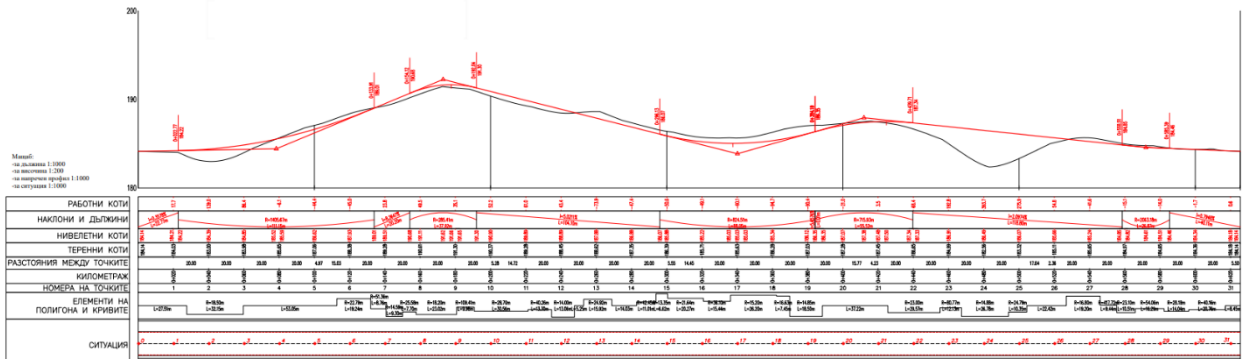


Figure 2. Longitudinal profiles of (a) the service road and (b) the karting track showing the relationship between existing terrain and design elevations.

4.3. Vertical Planning

Vertical planning represented a key component of the integrated digital workflow, linking the existing terrain conditions with the proposed functional requirements of the karting complex. The importance of vertical planning and surface grading for ensuring proper drainage conditions and functional performance has also been emphasized in studies related to transport infrastructure design [5]. Based on the digital terrain model and the previously developed profiles, project elevations were defined for the karting track, service roads, parking areas, pedestrian zones, and adjacent facilities. The design was supported by the grading and surface modelling functionalities available in Autodesk Civil 3D [1].

The vertical planning solution ensured compatibility between the proposed infrastructure and the existing terrain. Particular attention was paid to the distribution of design elevations,

surface gradients, and water management requirements in order to provide reliable operation of the infrastructure and minimize potential water accumulation within the project area.

Developed at the conceptual design stage, the vertical planning solution was integrated with the terrain model and profile design, providing the basis for defining construction elevations and drainage directions across the site.

The resulting solution for the karting track is illustrated in Figure 3, which demonstrates the distribution of design elevations and grading elements developed to ensure effective runoff control and operational safety.

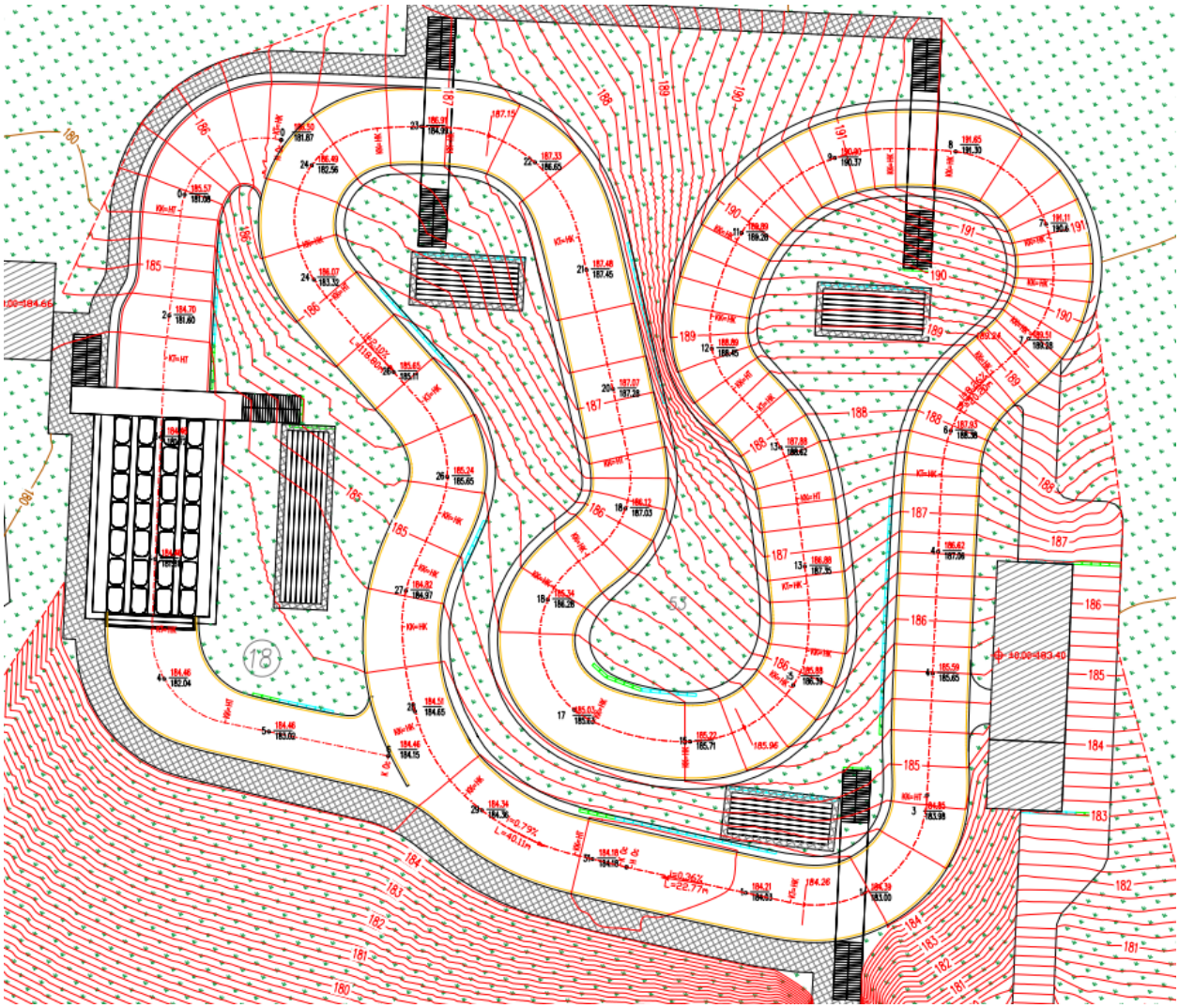


Figure 3. Vertical planning scheme of the karting track illustrating the relationship between design elevations and terrain morphology.

4.4. Engineering Geodetic Control Network

An engineering geodetic control network consisting of horizontal and vertical control elements was designed to support construction layout activities and future monitoring tasks [9, 12]. The network provided the spatial reference framework required for positioning the designed facilities and implementing construction staking operations. Horizontal control points and leveling benchmarks were established to support both planimetric and vertical control throughout the project area.

4.5. Construction Layout Planning

Construction layout planning represented the final stage of the integrated geodetic workflow. Based on the design documentation and the engineering geodetic control network, layout plans were prepared for the principal components of the karting complex, including the karting track, service roads, parking areas, recreational zones, and buildings [3].

The layout documentation included the characteristic points and coordinates required for the accurate transfer of the digital design to the physical terrain. These data supported construction staking and quality control during project implementation [13].

An example of the construction layout documentation is presented in Figure 4.

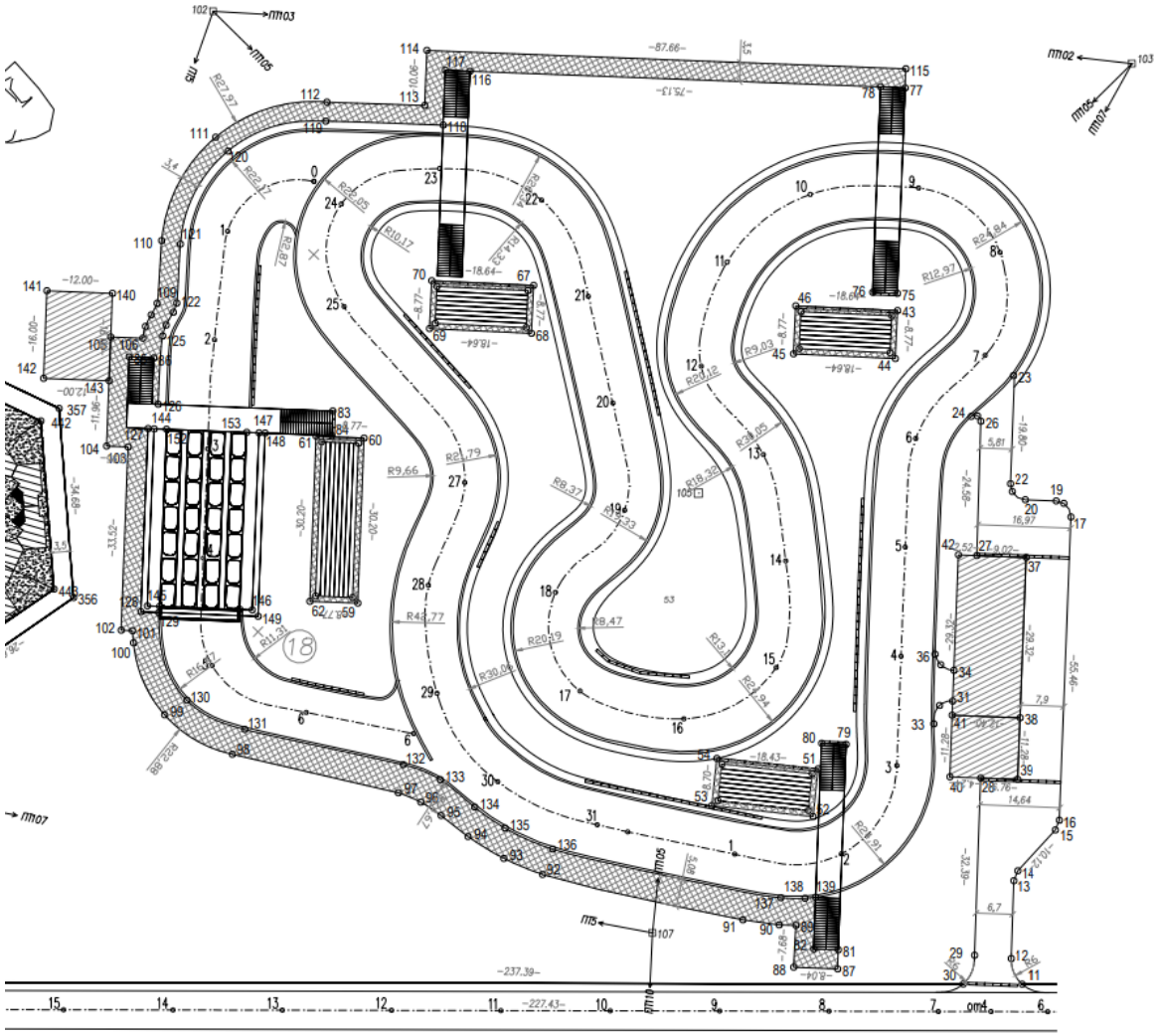


Figure 4. Construction layout plan of the karting track showing characteristic staking-out points.

5 Discussion in the Context of Geodesy 4.0

The presented case study demonstrates the transformation of engineering geodesy into an integral component of digital engineering processes. Consistent with the principles of Geodesy 4.0, geospatial information was integrated with terrain modelling, design development, and construction layout planning within a common digital environment [11].

A key factor in this integration was the use of a unified terrain dataset as the primary spatial reference throughout the project, supporting consistency between project stages and reducing

repeated data processing [4, 6, 11]. The integration of surveying information with digital modelling tools also improved visualization, supported design decision-making, and enhanced coordination between project participants [8].

The case study demonstrates that digital integration reduces information fragmentation between surveying, design, and construction phases, which is one of the central objectives of Geodesy 4.0. Beyond traditional surveying activities, geodetic specialists increasingly contribute to the management, validation, and integration of spatial information throughout the project lifecycle.

The results indicate that Geodesy 4.0 principles apply not only to large-scale infrastructure projects but also to specialized facilities such as sports complexes.

Table 2 summarizes the main differences between traditional geodetic project development and the integrated digital workflow applied in the present study.

Table 2

Comparison between traditional and integrated digital geodetic workflows

Project Stage	Traditional Workflow	Integrated Digital Workflow
Terrain modelling	Independent processing and data exchange between software environments	Common digital terrain model used throughout the project
General planning	Separate design datasets	Direct interaction with the digital terrain model
Profile design	Repeated data transfer and updates	Dynamic connection with terrain and design data
Vertical planning	Multiple manual adjustments	Coordinated grading within a common environment
Geodetic control network	Designed separately from design documentation	Integrated with the digital project model
Construction layout planning	Independent preparation of staking-out data	Direct extraction from the integrated digital model
Data consistency	Potential inconsistencies between stages	Continuous spatial data consistency
Project coordination	Limited interoperability	Improved coordination and information exchange

The comparison highlights the benefits of the integrated workflow, including improved data consistency, reduced repeated processing of geospatial information, and enhanced coordination between design and implementation activities.

6 Conclusion

This study presented an integrated digital geodetic workflow for the design of a karting complex located near the village of Vratitsa, Bulgaria. The proposed approach demonstrated how geodetic and engineering activities can be integrated within a unified digital process supporting project planning, design, and implementation.

The results highlight the value of digital geodetic technologies in contemporary engineering practice. The use of a common digital terrain model and an integrated workflow improved data continuity, reduced repeated processing of spatial information, and supported efficient coordination between design and construction-related activities.

The case study demonstrates the practical applicability of integrated digital geodetic workflows, consistent with the principles of Geodesy 4.0, in sports infrastructure projects. The

proposed workflow supports more efficient project development, improved coordination between project stages, and informed engineering decision-making.

Future research may focus on extending the proposed workflow through the integration of emerging intelligent geospatial technologies. A separate direction for future consideration is 3D laser scanning, discussed in [10].

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