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DEVELOPMENT OF INDUSTRIAL FACILITY MODELS USING MODERN GEODETIC MEASUREMENT AND GEOINFORMATION TECHNOLOGIES
(A CASE STUDY OF THE FERGANA REGION)

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Abstract

This article develops a scientific and methodological framework for modeling industrial facilities by integrating modern geodetic measurement technologies with geoinformation systems. The study is based on the third chapter of a PhD dissertation devoted to improving the use of GIS in industrial facility modeling in the Fergana region. The proposed methodology combines total station measurements, GNSS control, UAV photogrammetry, terrestrial laser scanning, CREDO-based office processing and GIS-based visualization in a unified data environment. Particular attention is given to the transformation of raw measurement results into 3D point clouds, digital industrial models, deformation maps, monitoring indicators and forecasting outputs. The article systematizes the role of CREDO software in geodetic data processing, defines a geodatabase structure for industrial objects, compares different measurement sources according to their operational role and accuracy, and proposes a decision-support workflow for deformation monitoring. The results indicate that the integration of GNSS, total station, UAV, laser scanning and GIS technologies is more effective than using separate measurement methods, because it enables spatially consistent modeling, early detection of deformations, visualization of risk zones and evidence-based engineering decisions. The methodological framework can be applied in the design, construction, reconstruction and operational monitoring of industrial facilities.

Keywords: Industrial facility, geodetic monitoring, total station, GNSS, UAV, terrestrial laser scanning, CREDO, ArcGIS, geodatabase, 3D model, deformation forecasting.

1. INTRODUCTION

Industrial facilities are complex engineering systems that include production buildings, technological lines, pipelines, foundations, chimneys, tanks, transport corridors and auxiliary infrastructure. Their safe operation depends not only on the quality of construction materials and structural design, but also on the geometric accuracy of spatial positioning and the reliability of deformation monitoring. In construction and reconstruction projects, even a small deviation in coordinates, elevation or axis alignment may lead to technological disruptions, additional repair costs and safety risks. Therefore, geodetic measurements and geoinformation technologies have become a critical component of modern industrial engineering.

The relevance of this research is determined by the rapid modernization of industrial infrastructure and the increasing demand for dynamic 3D models of facilities. The dissertation on which this article is based emphasizes that traditional geodetic measurement approaches are often time-consuming and resource-intensive under fast-changing construction conditions. It therefore argues that the integration of GNSS, photogrammetry, UAV platforms and GIS makes it possible to develop accurate and dynamic digital models of industrial facilities [1].

The transition from isolated measurement reports to integrated digital spatial models changes the logic of geodetic support. In a traditional workflow, measurements are mainly converted into paper plans, tables and separate technical reports. In a digital workflow, the same measurement data are transformed into a geodatabase, a 3D point cloud, a textured model, GIS layers, deformation diagrams and predictive indicators. This makes the information visual, comparable and suitable for engineering decision-making.

The objective of this article is to present a scientifically grounded English-language research paper based on the third chapter of the dissertation. The article focuses on the use of geoinformation systems in industrial facility modeling, CREDO-based data processing, comparison of GIS software environments and forecasting of building and structure deformations from geodetic observation results. The main research question is how modern geodetic data can be transformed into a functional GIS-based industrial model that supports monitoring, analysis and decision-making.

The contribution of the article consists of four components: first, an integrated workflow for industrial facility modeling is proposed; second, a geodatabase-oriented structure for geodetic and engineering data is systematized; third, a monitoring approach based on control points, point clouds and GIS analysis is formulated; fourth, the role of deformation forecasting as a basis for preventive engineering management is explained.

2. THEORETICAL BACKGROUND

The theoretical basis of industrial geodetic monitoring is the concept of repeated spatial observations of stable and potentially deformable points. Monitoring includes determination of horizontal displacement, vertical settlement, inclination, rotation and local changes in structural elements. In the context of industrial facilities, monitoring must account for the influence of equipment vibration, temperature changes, technological loads, foundation behavior and construction or reconstruction activities. As a result, a single measurement method is rarely sufficient for a complete evaluation of the object.

Modern geodetic technologies provide complementary advantages. GNSS gives a stable coordinate framework and supports connection to external reference systems. Total station measurements provide high-precision local coordinates and are suitable for detailed engineering layout. UAV photogrammetry provides orthophotos, dense point clouds and visual models for large areas. Terrestrial laser scanning captures millions of surface points and allows identification of geometric deviations over the entire object surface. GIS platforms, in turn, organize all these results as spatial layers with attributes, temporal records and analytical functions.

The dissertation identifies the development of GIS-based industrial object models as an insufficiently studied problem in the local research context. The research goal is to improve methods for creating accurate and functional digital models of industrial facilities using modern geodetic measurement and geoinformation technologies. It also highlights the practical need for visual interpretation of geodetic results, because measurement data should be understandable not only for geodesists but also for engineers, project managers and industrial operators [1].

The third chapter of the dissertation is directly related to the methodology of using GIS in industrial facility modeling. It covers accuracy assessment using total stations, scanners and GPS; improvement of geodetic data processing in CREDO; processing and comparison of geodetic measurements in GIS software; and prediction of building and structure deformation based on geodetic observations [1]. These components form the logical basis of the article.

Table 1. Research basis and dissertation-derived methodological parameters

Parameter	**Content used in the article**	**Methodological meaning**
Research object	Engineering structures of existing industrial facilities in the Fergana region	Defines the spatial and technological context of the case study
Research subject	Integration of GNSS, UAV, total station, laser scanning and GIS for digital industrial models	Defines the methodological scope of the modeling process
Main software tools	CREDO, ArcGIS, AutoCAD, Agisoft Metashape and GIS environments	Ensures processing, visualization and analytical comparison
Key scientific novelty	Scientifically grounded integration of modern geodetic measurements and GIS data	Forms the basis for a reproducible modeling algorithm
Expected accuracy effect	Improvement of measurement reliability up to approximately 3-5 cm in applied monitoring tasks	Provides practical justification for integrated geodetic-GIS workflows
Practical output	3D model, deformation map, monitoring database and engineering report	Transforms measurement results into decision-support information

3. MATERIALS AND METHODS

3.1. Study area and research object

The study area is represented by industrial facilities located in the Fergana region. This region is characterized by a combination of industrial zones, agricultural processing enterprises, engineering networks and construction-reconstruction activities. For such objects, geodetic support is needed during the entire life cycle: site selection, design, construction, installation of engineering communications, reconstruction, operational monitoring and preparation of executive documentation.

Industrial objects differ from ordinary civil buildings because they contain technologically connected structures. A chimney, tank foundation, processing line, workshop building and pipeline corridor may operate as parts of a single technological chain. Therefore, geodetic errors cannot be considered separately. They must be analyzed as part of a spatial system in which coordinates, elevations, axes, surfaces and deformations are connected.

3.2. Data acquisition and measurement technologies

The methodological framework uses several categories of geodetic data. Control coordinates are obtained from GNSS observations and total station networks. Detailed spatial information is collected by total station and terrestrial laser scanning. UAV-based imagery provides orthophoto coverage and supports visual control of object surroundings. Laser scanning is especially important for industrial facilities because it provides dense 3D point clouds of surfaces, structural elements and complex technological objects.

Each instrument has a different function in the integrated model. Total station measurements are used for high-precision engineering control, axes, corners and local displacement points. GNSS provides a reference frame and connects the industrial object to the national or local coordinate system. UAV surveys support the generation of orthophotos, site models and broad visual context. Terrestrial laser scanning supports surface deformation analysis, 3D reconstruction and comparison between different observation epochs.

Table 2. Functional role of geodetic technologies in industrial facility modeling

Technology	Data produced	Main use in the model	Strength	Limitation
GNSS	Reference coordinates, baseline positions	Control network and coordinate framework	Fast positioning and external reference	Limited under metal structures or obstructed sky
Total station	Precise local coordinates and angles	Engineering layout and detailed control points	High local accuracy	Point-by-point measurement process
UAV photogrammetry	Orthophoto, DSM, textured model	Site mapping and visual 3D context	Covers large areas quickly	Accuracy depends on GCPs and image quality
Terrestrial laser scanner	Dense 3D point cloud	Surface model, deformation and geometry control	Captures complex shapes and surfaces	Large data volume and processing demands
CREDO software	Adjusted networks, topographic plans, 3D surfaces	Office processing and engineering model preparation	Supports geodetic workflows	Requires correct data structuring
GIS platform	Layers, attributes, risk maps and dashboards	Analysis, visualization and decision support	Integrates spatial and semantic data	Quality depends on database design

Figure 1. General workflow for industrial facility modeling and deformation monitoring.

3.3. Data processing workflow

The processing workflow starts from data acquisition and quality control. The first step is to verify the coordinate system, measurement epochs, instrument settings and metadata. The second step is office processing: adjustment of geodetic networks, filtering of point clouds, georeferencing of UAV models and preparation of topographic or engineering plans. The third step is 3D modeling, where point clouds and engineering features are transformed into a structured industrial model. The fourth step is GIS integration, where geometry is connected with attributes, temporal information and monitoring indicators.

The dissertation pays special attention to the role of CREDO software in geodetic data processing. The CREDO environment supports processing of field data, creation of topographic plans, terrain models, earthwork calculations and preparation of data for layout tasks. When used together with GIS platforms, CREDO becomes part of a larger geoinformation workflow rather than an isolated calculation tool.

A key methodological requirement is the preservation of topology and semantic attributes. Coordinates alone are insufficient for industrial decision-making. Each monitoring point must be connected to the object type, observation epoch, instrument, accuracy class, deformation indicator and decision status. This is why the proposed workflow emphasizes a unified geodatabase.

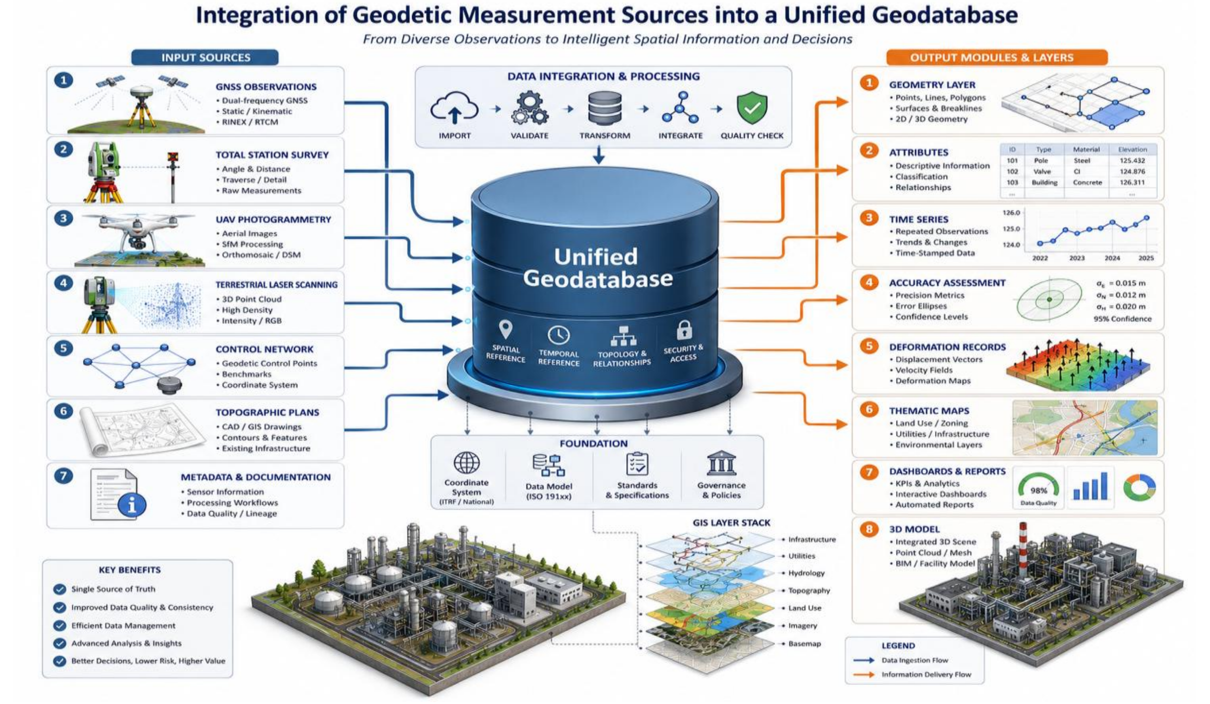


Figure 2. Integration of geodetic measurement sources into a unified geodatabase.

3.4. Proposed geodatabase structure

The geodatabase is the central element of the proposed methodology. It functions as a structured storage and analysis environment for geometry, attributes, time series and quality indicators. In industrial facility monitoring, a geodatabase should contain at least six groups of data: reference control points, measured monitoring points, engineering objects, point cloud indexes, deformation indicators and document outputs.

The conceptual advantage of the geodatabase approach is that it supports comparison across time. The same point can be measured in different epochs, and each observation can be stored with a timestamp, instrument type, operator information, adjustment residuals and quality class. This allows not only mapping of current deformation but also trend analysis and prediction.

Table 3. Recommended geodatabase structure for industrial geodetic monitoring

Layer / table	Geometry type	Main attributes	Analytical function
Control network	Point	Point ID, X, Y, H, accuracy, stability class	Reference framework and coordinate control
Monitoring points	Point	Point ID, object ID, epoch, instrument, displacement values	Time-series deformation analysis
Industrial objects	Polygon / 3D multipatch	Facility type, construction material, function, risk category	Object-based spatial modeling
Point cloud index	Tile / polygon	Scan date, scanner, density, registration error	Management of laser scanning data
Engineering networks	Line	Network type, diameter, depth, protection zone	Infrastructure and safety analysis
Risk zones	Polygon	Risk level, deformation threshold, recommended action	Decision support and maintenance planning
Reports and documents	Non-spatial table	Document ID, date, author, linked object, conclusion	Technical documentation and audit trail

4. RESULTS

4.1. Integrated industrial facility modeling model

The first result is the formulation of an integrated model that connects field geodetic measurements with GIS-based industrial modeling. This model includes data acquisition, office processing, spatial database construction, 3D modeling, deformation assessment, forecasting and engineering decision-making. Unlike a traditional workflow, the proposed model is cyclic: monitoring results return to the geodatabase and update the digital representation of the object.

The integrated model has three layers. The measurement layer contains GNSS, total station, UAV and laser scanning data. The processing layer includes CREDO, photogrammetric software and point-cloud processing. The analytical layer includes GIS operations, deformation maps, risk zones and forecast values. These layers together create a digital representation of the industrial facility that can support design, construction control and operational monitoring.

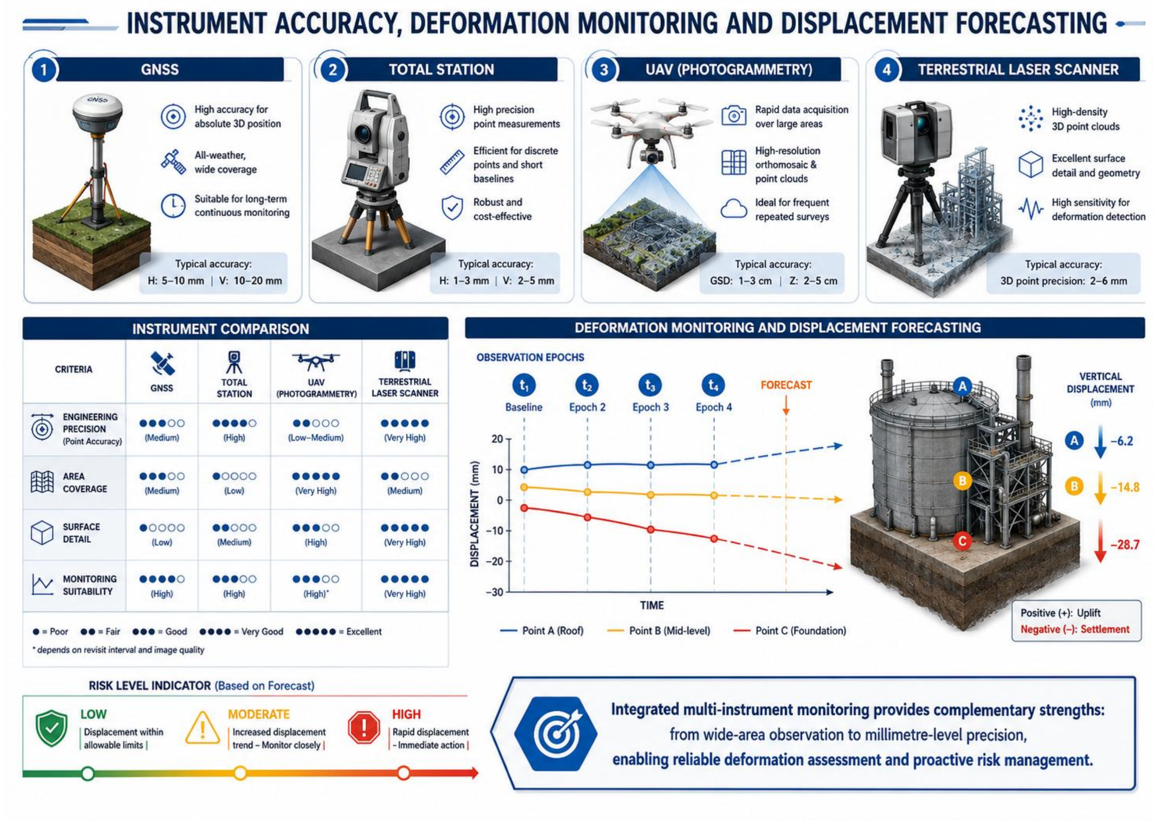
4.2. Accuracy assessment and comparison of measurement methods

Accuracy assessment is essential because the value of a 3D industrial model depends on the reliability of the source measurements. The dissertation highlights that the integrated use of modern geodetic instruments and GIS methods can improve practical accuracy and provide measurement reliability in the range of several centimeters for applied monitoring tasks. The exact accuracy depends on instrument type, observation geometry, control network stability, environmental conditions and processing method.

The proposed comparison framework distinguishes between point accuracy, surface accuracy, model consistency and decision accuracy. Point accuracy refers to the reliability of individual measured coordinates. Surface accuracy refers to the agreement between point clouds or 3D meshes and the real object surface. Model consistency refers to correct integration of datasets from different sources. Decision accuracy refers to whether the model correctly identifies risk zones and supports appropriate maintenance or engineering actions.

Table 4. Accuracy and quality assessment criteria for integrated industrial models

Criterion	**Indicator**	**Recommended evaluation method**	**Interpretation**
Coordinate accuracy	RMS error in X, Y and H	Network adjustment and independent check points	Shows reliability of measured points
Point cloud quality	Registration residual and density	Cloud-to-cloud and cloud-to-control comparison	Shows surface representation quality
Photogrammetric quality	GCP residuals and image overlap	Bundle adjustment report and control points	Shows suitability of UAV model
Topological correctness	Intersection, gaps and duplicate features	GIS topology rules and validation	Shows database consistency
Temporal consistency	Same reference system across epochs	Epoch-to-epoch comparison	Shows reliability of deformation trends
Decision reliability	Risk classification correctness	Expert validation and threshold analysis	Shows usefulness for engineering management



CRITERIA	GNSS	TOTAL STATION	UAV (PHOTOGRAMMETRY)	TERRESTRIAL LASER SCANNER
ENGINEERING PRECISION (Point Accuracy)	●●●○○ (Medium)	●●●●○ (High)	●●○○○ (Low–Medium)	●●●●● (Very High)
AREA COVERAGE	●●●○○ (Medium)	●○○○○ (Low)	●●●●● (Very High)	●●○○○ (Medium)
SURFACE DETAIL	●○○○○ (Low)	●●○○○ (Medium)	●●●○○ (High)	●●●●● (Very High)
MONITORING SUITABILITY	●●●●○ (High)	●●●○○ (High)	●●●○○ (High)*	●●●●● (Very High)

● = Poor ●● = Fair ●●● = Good ●●●● = Very Good ●●●●● = Excellent

* depends on revisit interval and image quality

Figure 3. Instrument accuracy, deformation monitoring and displacement forecasting.

4.3. CREDO-based processing and GIS comparison

CREDO software is considered in the dissertation as a key environment for office processing of topographic and geodetic materials. Its value lies in the ability to process field measurements, create digital terrain models, prepare topographic plans and support engineering design tasks. However, for industrial monitoring, CREDO should be integrated with GIS platforms so that measurement results can be analyzed together with object attributes, risk categories and temporal monitoring data.

ArcGIS and QGIS environments extend the analytical capacity of the workflow by enabling spatial overlay, attribute queries, thematic mapping, dashboard preparation and risk zoning. AutoCAD supports engineering drawing and detailed design documentation, while Agisoft Metashape and similar photogrammetric tools support UAV-based 3D reconstruction. The proposed methodology does not replace these programs with a single platform; rather, it defines how they should interact in a consistent data chain.

Table 5. Comparative role of software environments in industrial facility modeling

Software environment	**Primary function**	**Input data**	**Output data**	**Role in integrated methodology**
CREDO	Geodetic office processing and engineering topoplan	Total station, GNSS, survey files	Adjusted coordinates, surfaces, plans	Core geodetic processing
ArcGIS	Spatial analysis and geodatabase management	Vector layers, raster data, attributes	Maps, geodatabases, risk zones	Decision-support and analytical environment
QGIS	Open-source GIS analysis and visualization	Vector/raster layers, databases	Maps, spatial queries, reports	Alternative GIS processing platform
AutoCAD / Civil 3D	Engineering design documentation	Coordinates, plans, design drawings	CAD drawings, construction documentation	Technical drawing and design integration
Agisoft Metashape	UAV photogrammetric reconstruction	Aerial images and GCPs	Orthophoto, dense cloud, 3D mesh	Photogrammetry and textured model generation
Point cloud software	Registration and surface analysis	TLS scans and control points	Registered point cloud, deviations	3D deformation and geometry analysis

4.4. Deformation monitoring and forecasting

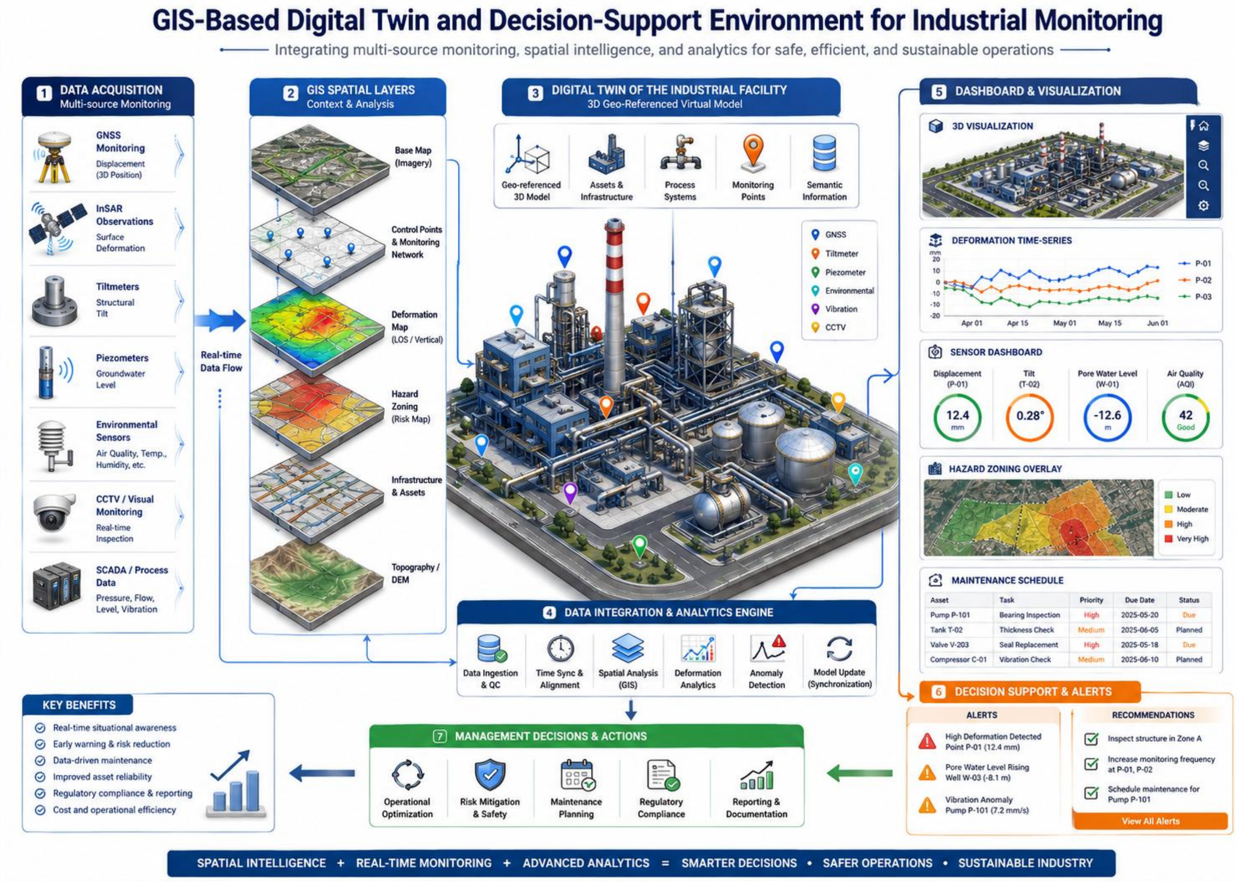
A central result of the third chapter is the methodological transition from simple measurement to complex deformation monitoring. The dissertation proposes an approach that can be summarized as control point plus 3D point cloud plus GIS analysis plus accuracy comparison. This approach evaluates deformation not only as a numerical displacement value but also as a spatial process that has location, direction, rate, risk level and engineering consequence.

The monitoring system should include several types of observations. Vertical settlement is controlled by leveling or high-precision elevation measurement. Horizontal displacement is controlled by total station and coordinate comparison. Surface deformation is analyzed by terrestrial laser scanning and point cloud comparison. GNSS provides the general coordinate framework, UAV provides the site-level visual model, and GIS integrates the results into thematic maps and risk zones.

Forecasting is necessary because industrial safety depends on early warning. If a monitoring point shows continuous displacement over several epochs, the GIS environment can store the time series and support linear or nonlinear prediction. The forecast should not be interpreted mechanically; it must be evaluated together with structural conditions, load changes, environmental factors and expert engineering judgment.

Table 6. Deformation monitoring cycle for industrial facilities

Stage	Operation	Output	Decision meaning
1. Baseline survey	Establish control points and initial 3D model	Reference coordinates and base surface	Defines zero epoch for comparison
2. Periodic measurement	Repeat GNSS, total station, laser scan and UAV observations	Observation epoch dataset	Detects changes in time
3. Data adjustment	Process measurements in CREDO and related tools	Adjusted coordinates and residuals	Ensures numerical reliability
4. GIS comparison	Compare epochs and classify displacement	Deformation map and attribute table	Identifies affected objects and zones
5. Forecasting	Model displacement trend and thresholds	Predicted displacement values	Supports preventive maintenance
6. Engineering decision	Prepare report and recommended actions	Technical conclusion and maintenance plan	Converts geodetic data into management action



Asset	Task	Priority	Due Date	Status
Pump P-101	Bearing Inspection	High	2025-05-20	Due
Tank T-02	Thickness Check	Medium	2025-06-05	Planned
Valve V-203	Seal Replacement	High	2025-05-18	Due
Compressor C-01	Vibration Check	Medium	2025-06-10	Planned

High Deformation Detected Point P-01 (12.4 mm)
Pore Water Level Rising Well W-03 (-8.1 m)
Vibration Anomaly Pump P-101 (7.2 mm/s)

☑ Inspect structure in Zone A
☑ Increase monitoring frequency at P-01, P-02
☑ Schedule maintenance for Pump P-101

Figure 4. GIS-based digital twin and decision-support environment for industrial monitoring.

5. DISCUSSION

The results show that the main scientific value of the methodology is not only the use of advanced instruments but also the construction of a coherent data environment. GNSS, total station, UAV and laser scanner data have different spatial resolutions, coordinate properties and error structures. If they are processed separately, the engineering interpretation remains fragmented. If they are integrated into a geodatabase and analyzed through GIS, the same data become part of a unified industrial model.

The proposed methodology corresponds to the digital transformation logic of modern construction and industrial management. A 3D model can represent the real condition of the object, while GIS layers connect this model with coordinates, attributes, observation epochs and risk categories. This is particularly important for industrial facilities where technological systems, construction structures and communication networks overlap spatially.

The use of CREDO as a geodetic processing environment is justified by its ability to process field survey data and create engineering surfaces. However, the dissertation-based analysis indicates that CREDO results should not remain isolated. They need to be exported and integrated into GIS platforms for comparative spatial analysis, visualization and decision support. Such integration reduces the gap between geodetic calculation and engineering management.

The monitoring model also has an important methodological implication: deformation is not a single coordinate difference but a process. A point displacement may be small but dangerous if it continues to increase, if it is located in a critical structural zone, or if it coincides with surface anomalies in the point cloud. GIS-based analysis makes it possible to combine these indicators and classify risk zones more objectively.

The approach has some limitations. First, the quality of the final model depends on the stability of the control network. Second, UAV and laser scanning datasets require careful georeferencing and filtering. Third, deformation forecasting requires multiple observation epochs; a forecast based on only two measurements is not sufficiently reliable. Fourth, the implementation of such a methodology requires trained personnel and clear standards for data storage, metadata and reporting.

Despite these limitations, the integrated approach has practical advantages for industrial facilities in the Fergana region and similar environments. It supports reconstruction planning, safety monitoring, maintenance scheduling, technical documentation and digital transformation. It also allows industrial managers to see geodetic results in a visual form rather than only as tables of coordinates.

6. PRACTICAL RECOMMENDATIONS

First, industrial facilities should create a stable geodetic control network before starting reconstruction or monitoring. Control points must be protected, periodically checked and connected to a common coordinate and elevation system.

Second, measurement data from GNSS, total station, UAV and laser scanning should be stored in a unified geodatabase. The database should include not only coordinates but also metadata: instrument type, observation date, accuracy class, operator, object type and processing status.

Third, CREDO-based processing should be used for adjustment, terrain modeling and engineering plans, while GIS should be used for layer integration, deformation mapping, risk zoning and decision-support outputs.

Fourth, deformation monitoring should be organized as a repeated cycle. At least three observation epochs are recommended before building a reliable trend model. Critical structures such as chimneys, tanks, machine foundations and high-load technological frames should be monitored more frequently.

Fifth, UAV photogrammetry and laser scanning should be used not only for visualization but also for quantitative comparison. Point cloud-to-point cloud and point cloud-to-control point analysis can help identify local deformation zones that are not visible in point measurements alone.

Sixth, reporting should be standardized. Each report should contain the observation scheme, instruments used, coordinate system, adjustment results, deformation tables, risk maps, 3D visualization and engineering recommendations.

7. CONCLUSION

The article presented an English-language scientific interpretation of the third chapter of the dissertation devoted to the improvement of GIS-based methodology for industrial facility modeling. The proposed approach integrates geodetic measurements, CREDO processing, 3D modeling, GIS analysis and deformation forecasting into a single methodological workflow.

The analysis confirms that separate geodetic methods are insufficient for reliable industrial monitoring. GNSS, total station, UAV, terrestrial laser scanning and GIS technologies must be combined in a unified system. Such integration improves the ability to evaluate the real spatial condition of industrial objects, identify deformations, visualize risk zones and support engineering decisions.

The key scientific result is the formulation of a complex monitoring approach based on control points, 3D point clouds, GIS analysis and accuracy comparison.

The key practical result is the possibility of converting measurement outputs into 3D models, deformation maps, forecasts and technical reports. This supports safer and more efficient management of industrial facilities during construction, reconstruction and operation.

Future research should focus on automating the geodatabase update process, developing standardized deformation thresholds for different types of industrial objects, integrating BIM and GIS data structures, and applying machine learning methods to predict deformation dynamics under different environmental and technological conditions.

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