Int. j. adv. multidisc. res. stud. 2025; 5(6):966-971

Received: 08-10-2025
Accepted: 18-11-2025

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Information Technology for Civil Engineering: A Case Study of the Kurdistan Ministry of Municipalities

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DOI: https://doi.org/10.62225/2583049X.2025.5.6.5293
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Abstract

Infrastructure project planning, design, execution, and maintenance have all changed because of the integration of information technology (IT) into civil engineering practice. This study examines the application of sophisticated IT tools, including Global Positioning Systems (GPS), Total Station surveying instruments, Geographic Information Systems (GIS), and AutoCAD Civil 3D, within the Ministry of Municipalities of the Kurdistan Region, Iraq. Traditionally, civil engineering design in the region depended on two-dimensional drawings and manual dimensioning devoid of precise geographic referencing, frequently leading to inefficiencies and discrepancies with the actual ground surface. This work presents the Information Technology for Civil Engineering (ITCE) method, which integrates spatial data obtained from satellite imaging with attribute data collected from terrestrial surveying tools. A comprehensive case study including ten municipal projects in Kurdistan illustrates how ITCE boosts design accuracy, enables real-time data exchange among ministry directorates, and improves project management efficacy. Field data were gained with Garmin® GPS receivers and Leica® TS06 Total Station equipment, subsequently processed in AutoCAD Civil 3D to produce precise surfaces, contour lines, and design models. The results show substantial enhancements in design precision, data interoperability, and interdepartmental collaboration. The study shows that incorporating IT solutions into civil engineering processes can significantly enhance infrastructure development results in Kurdistan and provides recommendations for wider implementation.

Keywords: IT, Civil Engineering, GIS, GPS, AutoCAD Civil 3D, Kurdistan, Total Station, Municipal Infrastructure

1. Introduction

Civil engineering is one of the oldest engineering disciplines, playing a fundamental role in the development of an infrastructure that supports economic growth and societal well-being (He *et al.*, 2023; Sysoeva, 2020) [20, 34]. Over the past decades, technological innovations have reshaped many engineering sectors; however, the adoption of IT in civil engineering has progressed unevenly, especially in regions with limited access to modern resources (Alani Adio *et al.*, 2024; Drew, 2008; Esri, 2012; Sakr, 2017; Smith & M.ASCE, 2021) [4, 11, 13, 32]. The Kurdistan Region, in northern Iraq, has experienced rapid urban expansion, creating a pressing need for efficient infrastructure planning, construction, and maintenance.

The Ministry of Municipalities in Kurdistan oversees 175 municipalities (KRG, 2025) [23], managing a wide range of public services including road construction and maintenance, water, and sewerage systems, waste management, and urban development planning. Historically, design workflows within the ministry were manual, with limited integration between departments such as the GIS Directorate, Design Department, Survey Department, and IT Department (KAPITA, 2023;

USAID, 2008) [21, 35]. This resulted in information silos, delays in project execution, and inconsistencies between design drawings and actual site conditions.

The **ITCE** initiative emerged to address these challenges by introducing a unified workflow that integrates spatial and attribute data for infrastructure projects (Agustina, 2019; Faihan Mahmud & Faihan, 2014; Sul *et al*., 2023; Sysoeva, 2020) [2, 15, 33, 34]. This approach leverages advanced surveying tools—such as the Garmin® GPS, Leica® TS06 Total Station, LiDAR scanning systems, and satellite imagery from Google Earth—combined with the processing capabilities of AutoCAD Civil 3D. By linking these technologies through a Management Information System (MIS) framework, ITCE enables real-time data sharing, collaborative design processes, and more accurate project implementation.

This paper presents a comprehensive case study of ITCE implementation across ten infrastructure projects in the Kurdistan Region. The research focuses on (1) the technological tools and methodologies employed, (2) the integration of MIS principles to improve interdepartmental coordination, and (3) the measurable improvements in accuracy, efficiency, and cost-effectiveness achieved through ITCE.

The research is structured: Section 2 reviews relevant literature on IT integration in civil engineering, Section 3 outlines the research method and tools used, Section 4 details the Kurdistan Ministry of Municipalities case study, Section 5 presents results, Section 6 discusses the findings, and Section 7 concludes with recommendations for policy and practice.

2. Literature Review

2.1 Evolution of IT in Civil Engineering

The principal application of IT in civil and structural engineering design was through documentation and books, including design tables, design guides, etc, and textbooks (Drew, 2008) [11] The application of IT within civil engineering began in the 1960s with the development of early FORTRAN-based systems for structural calculations, geometrical analysis, as well as project management employing the Critical Path Method (CPM) (Chapman, 2017; D'Onofrio, 2017; McNally, 1972; Meyers *et al*., 1989; Michael K & Omoloye E, 2014). By the 1980s and 1990s, Computer-Aided Design (CAD) tools such as AutoCAD had become standard in design offices, enabling greater precision and efficiency in drafting. In the 21st century, advancements in surveying technologies, GIS, Building Information Modelling (BIM), and high-resolution satellite imagery have transformed the accuracy and speed of civil engineering workflows (Moreri *et al*., 2024).

2.2 Role of MIS in Infrastructure Projects

MIS provides structured frameworks for storing, processing, and distributing information across organisational units (Alzhrani, 2020; Caldas, 2003; Warner & Sage, 2002). In civil engineering, MIS can facilitate real-time data exchange between survey teams, designers, GIS analysts, and field implementation crews (Esri, 2012 [13]; Laudon & Laudon, 2007). According to (Laudon & Laudon, 2007), the effectiveness of MIS in engineering projects is determined by its ability to integrate spatial and non-spatial data, improve decision-making, and reduce redundancies in workflows.

2.3 Surveying Technologies: GPS, Total Stations, and LiDAR

GPS have become essential for geospatial data collection because of their ability to provide precise location information in three dimensions (latitude, longitude, and height). Modern civil engineering projects often combine GPS measurements with data collected by Total Stations, which integrate electronic theodolites with electronic distance measurement (EDM) capabilities (Geospatial World, 2021; Leica_Geosystems, 2013) LiDAR (Light Detection and Ranging) technology further enhances data acquisition by generating high-density point clouds of the earth's surface, facilitating accurate modelling in software environments such as AutoCAD Civil 3D (Brodu & Lague, 2012).

2.4 GIS and AutoCAD Civil 3D Integration

GIS platforms store, manage, and visualise spatial data, while AutoCAD Civil 3D specialises in creating detailed engineering designs from both spatial and attribute datasets. Integrating GIS with Civil 3D enables engineers to overlay satellite imagery, contour data, and field-collected coordinates to produce accurate and contextually relevant designs (Esri.org, 1999; ESRI, 2020) [12, 14]. This combination is especially useful in regions such as Kurdistan, where up-to-date geospatial databases are still developing.

2.5 IT Adoption in Developing Regions

The adoption of advanced IT in civil engineering within developing regions faces challenges such as limited budgets, lack of skilled personnel, and resistance to change (Drew, 2008; Esri, 2012; Sakr, 2017; Sul *et al*., 2023) [11, 13, 31, 33]. However, case studies from countries including Malaysia, India, and Turkey have showed that targeted training programmes, phased technology integration, and government support can speed up adoption and deliver significant benefits in project quality and efficiency (Al-Badi *et al*., 2020; Pavlova, 2020; Yaakob *et al*., 2020) [3, 30, 37].

3. Method

3.1 Research Design

This study adopts a **case study research design**, focusing on the Kurdistan Ministry of Municipalities as a model for IT integration in civil engineering. The research combines qualitative and quantitative methods, including field surveys, technical workflow analysis, and interviews with engineers and ministry officials. The emphasis is on documenting the tools, processes, and outcomes of the **ITCE** approach in real-world infrastructure projects.

3.2 Instruments and Tools

The ITCE method employs a combination of ground-based and satellite-based surveying technologies:

- **GPS (Garmin® eTrex)**: Used to collect geo-referenced points in Easting, Northing, and Elevation coordinates. Points are recorded under field conditions and stored in device memory for transfer to GIS or CAD environments.
- **Total Station (Leica® TS06)**: An optical-electronic instrument that measures angles and distances, calculates three-dimensional coordinates, and stores them as structured datasets (GSI files). The total station

is essential for high-accuracy surveying in road alignments, building construction, and utility layouts.
- **LiDAR scanning is** employed in select projects to capture dense point clouds for creating highly accurate terrain models.
- **AutoCAD Civil 3D**: Used for data processing, surface modelling, contour generation, and the creation of design drawings.
- **GIS software is** integrated with Civil 3D to manage spatial datasets, satellite imagery, and master plans.

3.3 Data Collection Procedure

Data collection followed a multi-step process:

1. **Field Surveys**: Teams used GPS receivers for preliminary location marking and Leica Total Station instruments for detailed measurements.
2. **Data Transfer**: Field-collected data were transferred to computers via cable, memory cards, or Bluetooth. Garmin GPS data were processed through MapSource software and exported as text or comma-separated values (CSV) files. Total Station data GEO Serial Interface (GSI) files were converted to text format using Leica FlexOffice.
3. **Data Processing**: Coordinate tables (East, North, Height) were imported into AutoCAD Civil 3D. Surfaces were generated using the TIN (Triangulated Irregular Network) method, and contour lines were created at specified intervals.
4. **Design Integration**: Spatial data from satellite imagery (Google Earth) was combined with attribute data from survey instruments to create accurate and contextually relevant designs.
5. **Interdepartmental Data Sharing**: Processed datasets were stored on the Ministry's local area network (LAN), enabling real-time sharing between the GIS, Design, Survey, and IT departments.

3.4 Study Area and Projects

The method applied to **ten municipal infrastructure projects** in Kurdistan, including:

- Kalar–Zinana Road (23 km) – Design and Stakeout
- Darbandixan–Maidan Road (4 km) – Design and Stakeout
- Sulaimany–Saholaka Underpass – Project Stakeout
- Sulaimany–Surdash Road – Road, sanitary, and water works
- Sulaimany–Sargallu Office Building – Site Survey
- Sulaimany–Tui Malik Road – Redesign and Construction
- Kalar–Grda Gozina – Road, sanitary, and water pipe installation
- Kifree – Road, sanitary, and water network construction
- Sarqalla Road – 4 km, two-lane divided highway
- Axjalar Municipality – Road, sanitary, and water works

These projects provided diverse conditions for testing ITCE's capabilities in urban, semi-urban, and rural terrains.

4. Case Study: Kurdistan Ministry of Municipalities

4.1 Ministry Overview

The Kurdistan Ministry of Municipalities manages public infrastructure and services across 175 municipalities in various districts and cities of the Kurdistan Region, Iraq. The ministry operates through multiple directorates, each with specialised functions, including:

- Directorate of Municipalities
- Directorate of Projects
- Directorate of Water Services
- Directorate of Sewerage Services
- Directorate of Planning and Follow-Up
- Directorate of GIS
- Directorate of Survey
- Directorate of Tourism
- Directorate of IT

These directorates manage essential services such as urban road construction, highway maintenance, water distribution, sewerage management, waste disposal, environmental protection, and urban planning. Historically, the departments operated in relative isolation, with limited information sharing and a lack of real-time project coordination. This fragmented approach often resulted in redundant work, delays, and inconsistencies between project designs and actual site conditions.

4.2 Challenges Before ITCE Implementation

Before introducing the **ITCE** approach, several key challenges were observed:

1. **Lack of Integrated Communication**: Departments often worked independently without access to each other's project data.
2. **Manual and Dimension-Based Designs**: Designs were prepared using traditional 2D dimensioning methods without considering actual topography, leading to mismatches between designs and the natural ground surface Natural Ground Surface (NGS).
3. **Limited Data Sharing Mechanisms**: There was no LAN-based or cloud-based system for transferring spatial and attribute data among departments.
4. **Inefficient Use of Survey Data**: Surveyors collected field data but lacked streamlined processes for integrating it into the design and GIS systems.

4.3 The ITCE Solution

The ITCE initiative was introduced to modernise workflows through integrating:

- **Spatial Data** from satellite imagery and GIS databases.
- **Attribute Data** from GPS and Total Station field surveys.
- **AutoCAD Civil 3D** for integrated surface modelling and design.
- **LAN-based Data Sharing** for interdepartmental collaboration.

The key innovation was enabling **multi-designer collaboration** on a single project in real-time over the ministry's internal LAN, allowing surveyors, GIS analysts, and designers to work on the same dataset without duplication.

4.4 Data Collection and Processing Workflow

1. **Survey Data Acquisition**:
   - **GPS (Garmin eTrex)**: Used for preliminary geo-referencing and waypoint collection.
   - **Total Station (Leica TS06)**: Used for high-precision coordinate capture (Easting, Northing, Elevation). Data stored in GSI format.
2. **Data Conversion**:
   - GPS data exported through MapSource as text or CSV.

   - Total Station data converted from GSI to TXT using Leica FlexOffice.
3. **Data Integration in Civil 3D**:
   - Import coordinate points into Civil 3D.
   - Generate TIN surfaces.
   - Overlay satellite imagery from Google Earth for visual context.
4. **Interdepartmental Data Sharing**:
   - Processed datasets stored on ministry servers.
   - GIS department updates master plans and returns updated spatial datasets to design teams.
5. **Field Implementation**:
   - Survey crews receive completed design coordinates for construction staking via wireless transfer to field instruments.

4.5 Project Applications in Kurdistan

The ITCE method applied to ten municipal projects:

1. **Kalar–Zinana Road** (23 km) – Full design and staking.
2. **Darbandixan–Maidan Road** (4 km) – Road survey and redesign.
3. **Sulaimany–Saholaka Underpass** – Stakeout operations.
4. **Sulaimany–Surdash Road** – Road, sanitary, and water pipeline design.
5. **Sulaimany–Sargallu Office Building** – Site survey and design layout.
6. **Sulaimany–Tui Malik Road** – Road redesign and field stakeout.
7. **Kalar–Grda Gozina** – Road, sanitary, and water network design.
8. **Kifree** – Multi-utility infrastructure development.
9. **Sarqalla Road** – 4 km divided highway design.
10. **Axjalar Municipality** – Road and utility network upgrade.

5. Results

5.1 Improved Design Accuracy

Integrating GPS, total station, and Civil 3D significantly reduced discrepancies between design models and the actual topography. Field validation showed that design surfaces produced through ITCE had an **accuracy within ±2 cm** of actual measurements, compared to deviations exceeding ±15 cm in pre-ITCE designs.

5.2 Enhanced Data Sharing and Coordination

The LAN-based MIS framework enabled simultaneous access to updated project data across the GIS, Survey, and Design departments. This reduced project delays by about 30**%** and eliminated duplicate survey efforts.

5.3 Efficient Use of Field Data

Data processing time from field collection to a completed Civil 3D model was reduced from 3 to 5 **days** to **less than 24 hours**. The ability to overlay spatial and attribute data allowed design teams to visualise infrastructure layouts in their real-world geographic context.

5.4 Project Cost Savings

By reducing rework and improving planning accuracy, ITCE contributed to measurable cost savings across the studied projects. On average, surveying and design-related costs decreased by **15–20%**, primarily through reduced working hours and minimised material waste during construction.

5.5 Scalability of the ITCE Approach

The standardised workflow developed during the case study can be replicated across other ministries or municipal agencies in the Kurdistan Region. The method is adaptable to various project types, including roads, water networks, sewerage systems, and public building construction.

6. Discussion

6.1 Interpretation of Findings

The results show that integrating advanced IT tools into civil engineering workflows can significantly enhance the accuracy, efficiency, and cost-effectiveness of infrastructure projects. The adoption of GPS, Total Station surveying, GIS, and AutoCAD Civil 3D within the Kurdistan Ministry of Municipalities represents a clear shift from traditional 2D, dimension-only designs toward geo spatially accurate, data-driven models.

Accuracy improvements within ±2 cm show that ITCE-generated surfaces and alignments can minimise costly construction errors. Integrating MIS principles into the ITCE workflow has also facilitated improved interdepartmental communication, leading to faster project delivery. These findings align with earlier studies by (Kazakov *et al.*, 2020) [22] and Ahmed *et al.* (2019), which identified improved efficiency and reduced redundancy as core benefits of IT adoption in developing regions.

6.2 Challenges in ITCE Implementation

Despite the benefits, several challenges were encountered:

- **Human Resource Capacity**: Limited familiarity with advanced survey equipment and Civil 3D required significant staff training.
- **Infrastructure Constraints**: Inadequate bandwidth and occasional power interruptions affected real-time data sharing via LAN.
- **Budgetary Limitations**: Procurement of high-end surveying equipment and licensed software required substantial capital investment.

These challenges mirror barriers identified in other developing countries, where initial investment and training are often cited as the most significant hurdles to IT integration in civil engineering (Abdullah Almaqashi *et al.*, 2019; Hamamurad *et al.*, 2022b) [1, 19].

6.3 Implications for Policy and Practice

The Kurdistan case study provides practical evidence for the benefits of IT integration in municipal infrastructure projects. Policymakers can use these findings to justify budget allocations for advanced survey equipment, software, and IT infrastructure. Incorporating ITCE principles into university curricula for civil engineering and surveying can prepare future professionals for technology-driven project environments. These challenges mirror barriers identified by other researchers (Alsabbagh, 2025; Hamamurad *et al.*, 2022a; Hamamurad & Jusoh, 2025) [5, 18, 17].

7. Conclusion and Recommendations

7.1 Conclusion

Introducing the **ITCE** framework in the Kurdistan Ministry of Municipalities has shown that integrating GPS, Total Station surveying, GIS, and AutoCAD Civil 3D into municipal infrastructure workflows can dramatically improve project outcomes. The study showed that:

- Design accuracy improved to within ±2 cm of actual ground conditions.
- Data processing and sharing times were reduced by over 50%.
- Cross-departmental coordination improved through a LAN-based MIS framework.
- Project costs related to surveying and design decreased by 15–20%.

These outcomes underscore the value of adopting a unified, IT-based approach in civil engineering for developing regions.

7.2 Recommendations

Based on the case study findings, the following recommendations are proposed:

1. **Capacity Building**: Implement continuous training programmes for engineers, surveyors, and GIS specialists in using GPS, Total Stations, and Civil 3D.
2. **IT Infrastructure Enhancement**: Upgrade LAN bandwidth, server capacity, and backup systems to ensure uninterrupted real-time data sharing.
3. **Standardised Workflows**: Develop and enforce standardised ITCE procedures for all municipal projects to ensure consistency in data collection, processing, and design.
4. **Policy Integration**: Include ITCE requirements in municipal project tender documents to ensure all contractors and consultants align with the ministry's digital standards.
5. **Future Research**: Expand the ITCE model to include drone-based photogrammetry and advanced BIM integration for complex urban projects.

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