



Integration of GPS, Drone Mapping, and Total Station Technologies with GIS and CAD Tools in Modern Land Surveying

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Abstract

Municipal planning in a newly formed administrative unit depends on a geospatial base that the unit lacks at the moment planning begins. Satellite positioning, drone mapping, and electronic total stations have each reached technical maturity, yet the distribution of survey tasks among them and the path their data follow into GIS and CAD environments receive less systematic attention than their accuracy. The review aims to classify integration schemes for the three technologies according to the tasks of municipal surveying and to trace the resulting data chain in practice-based records. Studies published from 2021 to 2026 were screened for accuracy values verified against independent checkpoints, and the reported figures were arranged into a task-by-technology matrix. The practical material comes from the 2019 survey of Tandur, Telangana, which covered 15.54 km² in a district formed in 2016, and whose records include 1,101 coded total station points along three streets, converted into AutoCAD street plans. Five integration schemes emerge from the analysis, ranging from total station traverses in local or GNSS-controlled frames to a full sequence in which satellite control, aerial capture, and terrestrial detailing converge within a single model. The matrix assigns network control to GNSS, area terrain capture to drones, and discrete features, frontages, and boundaries to the total station supported by ground RTK. The Tandur records show that feature codes and repeated station shots carry quality control from the field into the office, while the georeferencing of local coordinate frames determines whether CAD output can be imported into a GIS.

Keywords: GNSS, UAV Photogrammetry, Total Station, GIS, CAD, Municipal Surveying, Feature Coding, Georeferencing.

INTRODUCTION

Planning a road network, a stormwater system, or a sewer alignment starts from a measured description of the ground, and an administrative unit created by a recent reform has to produce that description from scratch, while zoning, utility design, and land allocation wait for the result. Three groups of instruments share this work. Global navigation satellite systems, abbreviated as GNSS and still called GPS in everyday professional language, deliver coordinates tied to a national or global reference frame. Unmanned aerial vehicles, referred to here as drones, capture imagery or laser returns over large areas in a few flights. The electronic total station measures angles and distances to individual targets and serves as the reference against which aerial products are checked (Dragomir et al., 2025; Tamimi & Toth, 2024).

Accuracy studies of each technology are plentiful. Drone georeferencing by ground control points and by post-processed kinematic positioning reaches centimeter-level agreement (Liu et al., 2022; Türk et al., 2022), ground-based real-time kinematic positioning, known as RTK, outperforms

drone-derived coordinates on the same checkpoints (Özdemir et al., 2025), and drone mapping has become feasible for cadastral work on building ensembles, although its legal acceptance still trails the technology (Kersten et al., 2025). Which instrument should take which task in a municipal survey, and by what route the outputs of all three reach the GIS layer and the CAD drawing used by planners, are questions that the same literature leaves open. Georeferencing alone illustrates the stakes, since the transformation of a local engineering frame into a geographic reference system remains a central obstacle to integrating data across design and GIS environments (Azari et al., 2025).

The review grows out of first-hand leadership of the 2019 land survey of Tandur, a town in the Vikarabad district of Telangana, India, performed by Telangana Engineering Services for the Tandur Town Planning Department. Direct responsibility for both the field campaign and the office processing allows the data chain to be traced from the coded field point to the finished street plan, with every decision documented within the project.

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The aim of the review is to systematize the choice of GNSS, drone, and total station combinations for municipal surveying tasks and to show how their data are integrated into GIS and CAD. The first objective is to classify integration schemes by the role each technology plays and by the stage at which the data streams converge. The second objective is to compile a task-by-technology matrix of accuracy values from the cited studies, verified against independent checkpoints or reference surveys. The third objective is to illustrate the chain with the Tandur records, from coded total station points to AutoCAD street plans. A classification of integration schemes organized by municipal survey tasks and linked to the data path into GIS and CAD was not found in the reviewed literature, and this gap defines the novelty of the work.

MATERIALS AND METHODS

The literature search covered journal articles and peer-reviewed conference papers published from 2021 to 2026. Queries ran through the Crossref metadata service and major publisher platforms, combining the terms GNSS, RTK, PPK, UAV photogrammetry, UAV LiDAR, total station, cadastral surveying, GIS integration, and georeferencing. A study was included in the final set when it reported positional accuracy against independent checkpoints or a reference survey, or when it addressed the transfer of survey data into GIS or building information environments. Ten studies met the criteria. Each integration scheme was described by the technologies that fix the frame, capture area data, and measure discrete features, and by the stage at which the streams merge, while accuracy values were entered into the matrix as reported, along with the conditions that limit them.

The Vikarabad district was formed on 11 October 2016, and Tandur, placed within the new district, needed a planning base for its expansion. In 2019, the Tandur Town Planning Department assigned the land survey to Telangana Engineering Services. The project ran from March to September 2019, covered 15.54 km², and engaged a team of eight specialists, with about 60% of the effort spent in the field and 40% in the office. The equipment comprised a total station and a drone, and the processing relied on ArcGIS and AutoCAD.

The corridor from the DSP office to the railway gate, Railway Station Road, and Shivaji Road provides the detailed records used here. The records contain 1,101 total station points, each with an identifier, an easting, a northing, and a height, and the feature code is embedded in the identifier. The point tables were compiled in 2025 from the 2019 field data, and the three AutoCAD street plans carry the date of August 2019. The identifiers were parsed into five feature classes: road edges and frontage corners, centerline points, utility features, public buildings and landmarks, and instrument stations with their orientation points. On Shivaji Road, chainage was computed by projecting each point onto the polyline connecting successive instrument stations, and repeated observations of the same station from consecutive

setups were compared to assess the internal consistency of the traverse.

The instrument model and the accuracy control procedure of the Tandur survey are not documented in the available records. For this reason, the Tandur data show how the chain is organized, and the accuracy of the technologies is compared against the literature.

RESULTS

The reviewed studies converge on a division of labor among the three technologies. GNSS fixes the coordinate frame. In a direct comparison of mapping techniques, ground-based RTK kept horizontal and vertical errors below 25 mm, whereas drone positions processed using post-processed kinematic positioning (PPK) produced errors above 60 mm in plan and up to 115 mm in height (Özdemir et al., 2025). Under obstruction, a low-cost receiver with a patch antenna lost precision, and a geodetic-grade antenna restored its performance (Janos & Kuras, 2021). Dense urban frontages call for terrestrial measurement wherever satellite visibility drops.

Drones cover area. Direct georeferencing of drone imagery reached root mean square errors, hereafter RMSE, of 0.041 m in plan and 0.087 m in height, while in control-based solutions, the error grew with distance from the nearest ground control point (Liu et al., 2022). Georeferencing using PPK and ground control points produced horizontal errors of 5.4 cm and 6.5 cm and vertical errors of 5.2 cm and 4.8 cm, placing both methods within a 10 cm accuracy class (Türk et al., 2022). Budget drones flown at 40 to 60 m gave terrain models with errors of 1.8 to 2.9 cm in plan and 2.8 to 6.8 cm in height, later used for building planning through GIS spatial analysis (Sestras et al., 2023), and a cadastral workflow checked at fifteen RTK GNSS checkpoints reported an absolute positional accuracy of 2.47 cm (Mirzapour et al., 2026).

The total station remains the reference instrument. Drone LiDAR, compared with total station data, yielded an RMSE of 0.07 m on an open road, checked at 350 points, and 0.21 m under forest canopy, checked at 50 points (Tamimi & Toth, 2024). Building contours extracted from drone photogrammetry and SLAM scanning differed from total station measurements by an RMSE of 0.109 m (Dragomir et al., 2025). Photogrammetric cadastral surveying, when tested against tachymetry, was judged technically and economically feasible for building ensembles, although the legal framework for it was still missing in some German federal states (Kersten et al., 2025).

Five integration schemes follow from these roles. The first scheme combines GNSS control with total station detailing, so that coded features enter CAD with national coordinates that a GIS accepts without transformation, and it suits street corridors with dense frontage and small features. The second scheme is GNSS-georeferenced drone mapping, in which ground control points measured by RTK or onboard RTK and PPK positioning tie the imagery to the frame, and

the orthophoto and surface model pass into GIS as raster layers for open terrain and drainage catchments (Liu et al., 2022; Türk et al., 2022). The third scheme couples drone area capture with terrestrial infill and checking, in which the total station measures footing lines under eaves or ground under canopy and provides checkpoints for the aerial model (Dragomir et al., 2025; Tamimi & Toth, 2024). The fourth scheme is the full sequence, in which a GNSS network fixes the frame, drones capture the area, the total station records discrete features, and all streams merge into a single GIS model that also feeds the CAD drawings (Mirzapour et al.,

2026; Sestras et al., 2023). The fifth scheme runs total station traverses in a local frame and delivers the result to CAD at once, postponing the tie to the national frame until the GIS stage, which makes it fast to start and turns georeferencing into a separate task at a time when about 30% of integration tools make effective use of georeferencing information (Azari et al., 2025).

Table 1 arranges the reported values by the tasks of a municipal survey and assigns a lead technology and a supporting technology to each task.

Table 1. Task-by-technology matrix for municipal surveying based on accuracy values reported in the reviewed studies

Survey task	Lead and supporting technology	Reported accuracy	Main constraint	Sources
Control network and georeferencing	GNSS RTK, total station traverse	Below 25 mm in plan and height	Obstructed sky degrades low-cost receivers	Janos & Kuras, 2021; Özdemir et al., 2025
Terrain model for drainage and grading	Drone photogrammetry with GCP or PPK, RTK checkpoints	5.4 to 6.5 cm in plan, 4.8 to 5.2 cm in height	Error grows with distance from control	Liu et al., 2022; Türk et al., 2022
Road corridor topography	Drone LiDAR, total station checkpoints	0.07 m on an open road, 0.21 m under canopy	Canopy raises local errors to 0.5 to 0.6 m	Tamimi & Toth, 2024
Building footprints and frontage lines	Drone photogrammetry with SLAM, total station	0.109 m contour RMSE	Extracted contours need terrestrial verification	Dragomir et al., 2025
Parcels and boundaries	Total station or ground RTK, drone orthophoto	1.7 cm relative, 2.47 cm absolute, 1.8 to 2.9 cm in plan with budget drones	Legal acceptance of photogrammetric boundaries is incomplete	Kersten et al., 2025; Mirzapour et al., 2026; Sestras et al., 2023
Utilities, curbs and landmarks	Total station, ground RTK under open sky	Ground RTK below 25 mm, drone PPK above 60 mm in plan	Drone PPK without ground control exceeds small-object tolerance	Özdemir et al., 2025
Transfer into GIS and CAD	Transformation to the national frame, code library	About 30% of tools make effective use of georeferencing data	Local frames and inconsistent definitions	Azari et al., 2025

The matrix shows that accuracy depends on the quality of control and the site's openness as much as on the platform. Ground RTK stays below 25 mm; drone products tied to ground control or checkpoints range from 1.7 cm to about 10 cm; drone PPK without ground control exceeds 6 cm in plan; and corridor products degrade to decimeters where vegetation hides the ground. The lead technology of each task is the one whose error stays below the tolerance of the planning product that the task feeds.

The Tandur survey supplies a working example of the terrestrial branch, and Table 2 summarizes the coded records of the three streets and the parameters derived from them.

Table 2. Summary of the coded total station records of three Tandur streets from the 2019 survey

Parameter	DSP Office to Railway Gate	Railway Station Road	Shivaji Road	Total
Coded points	317	357	427	1,101
Road edges and frontage corners	228	204	253	685
Centerline points	71	67	77	215
Utility features	10	9	4	23
Public buildings and landmarks	8	11	12	31
Station and orientation records	0	66	81	147
Instrument setups	not recorded	10	12	22
Station traverse length, m	n/a	943	1,125	n/a
Plan extent, E × N, m	576 × 569	482 × 646	160 × 1,120	n/a
Centerline relative height range, m	96.7 to 101.1	95.7 to 102.6	99.5 to 102.8	n/a

Note. Shivaji Road extent and heights exclude one gross outlier, and the height range also excludes the twenty-two detail points observed from setup S12.

Road edges and frontage corners form the largest class with six hundred eighty-five points, the centerline accounts for two hundred fifteen points, utility features such as transformers, a water tank, a mast and a traffic signal add twenty-three, and public buildings and landmarks add thirty-one. Railway Station Road was traversed with ten setups over 943 m, and Shivaji Road with twelve setups over 1,125 m, so the mean leg length stayed close to 100 m.

The spatial pattern of the records appears in Fig. 1, where points for each street are plotted by feature class within that street's local frame.

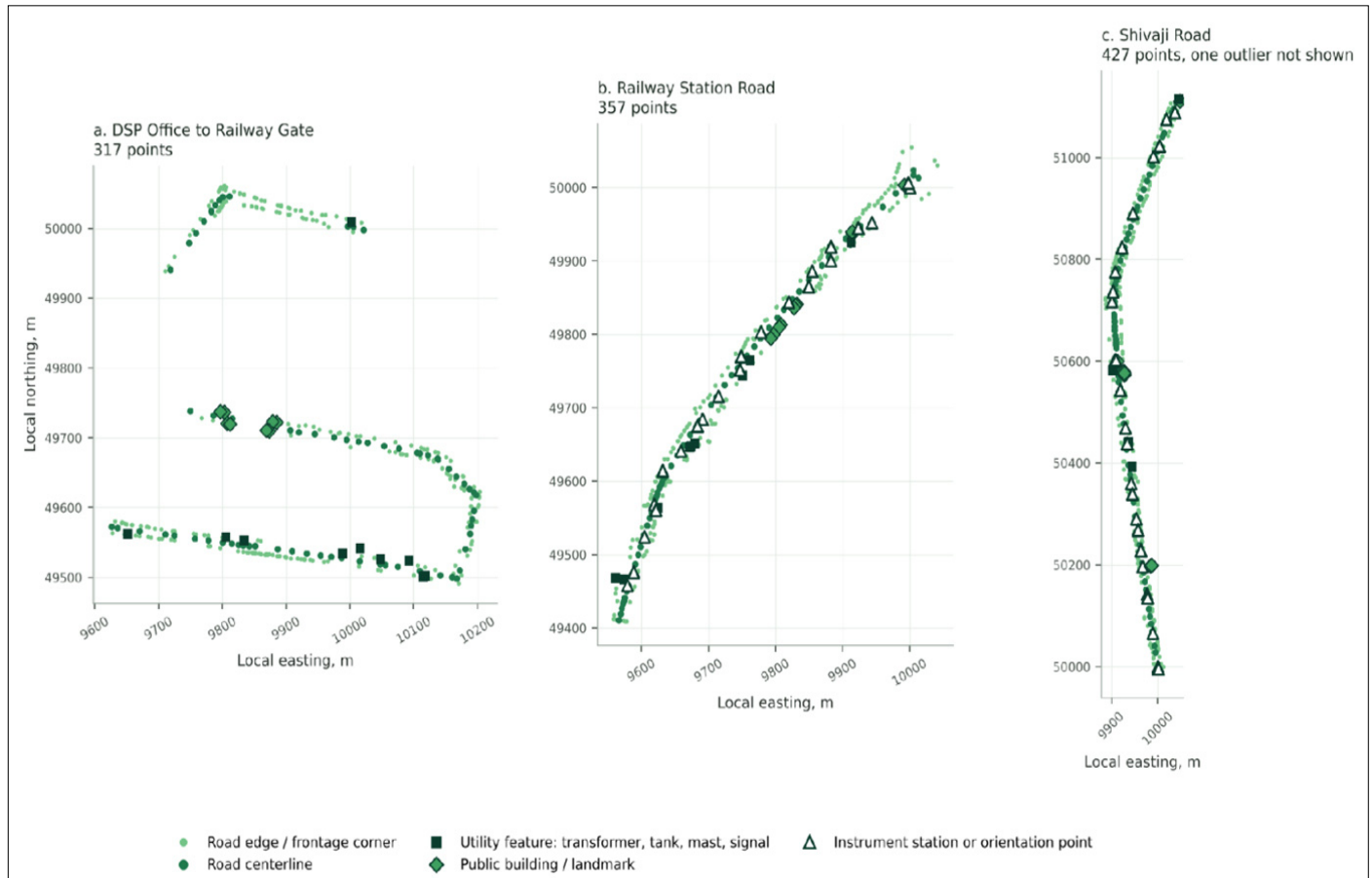


Fig. 1. Total station points of three Tandur streets by feature class, each street shown in its own local frame

The coordinates of each street are based on an assumed origin near an easting of 10,000 m, a northing of 50,000 m, and a height of 100 m, so the three frames overlap in their numbers and cannot be combined into a single plan without transformation. The street records analyzed here correspond to the fifth scheme, in which the tie to the national frame belongs to the GIS stage. The same class of road edge appears as RD-CORNR, RD-CRNR, and S@RD-CRNR on different streets, and a transformer appears as TRNSFRM and TRNSFRAM. A statue on the Shivaji Road axis carries a centerline code and sits about 2.5 m above the neighboring centerline points, so Table 2 and Fig. 1 count it as a landmark, and one corner point lies 322 m beyond the end of the corridor, at 5 to 7 m above its surroundings. Such defects are harmless in a drawing read label by label, whereas an automatic GIS import splits one class into several.

The repeated station shots provide an internal check of the traverse. On Railway Station Road, 22 repeated observations agreed with the original station coordinates, with a median of 6.7 mm and a maximum of 11.5 mm in plan, and all vertical differences remained within 8.7 mm. On Shivaji Road, twenty-six repeated observations gave a median of 10.8 mm and a maximum of 23.6 mm in plan, and twenty-three of them agreed within 10 mm in height. One difference reached 0.65 m at the last setup, S12, while the plan coordinates of the same stations matched within centimeters. A vertical shift of this size with stable plan coordinates points to an error in the instrument or target height entered at that setup, and the twenty-two detail points observed from S12 inherit the shift.

The consequences for terrain interpretation can be traced in Fig. 2, which shows the height profile along the Shivaji Road centerline with chainage measured along the station traverse.

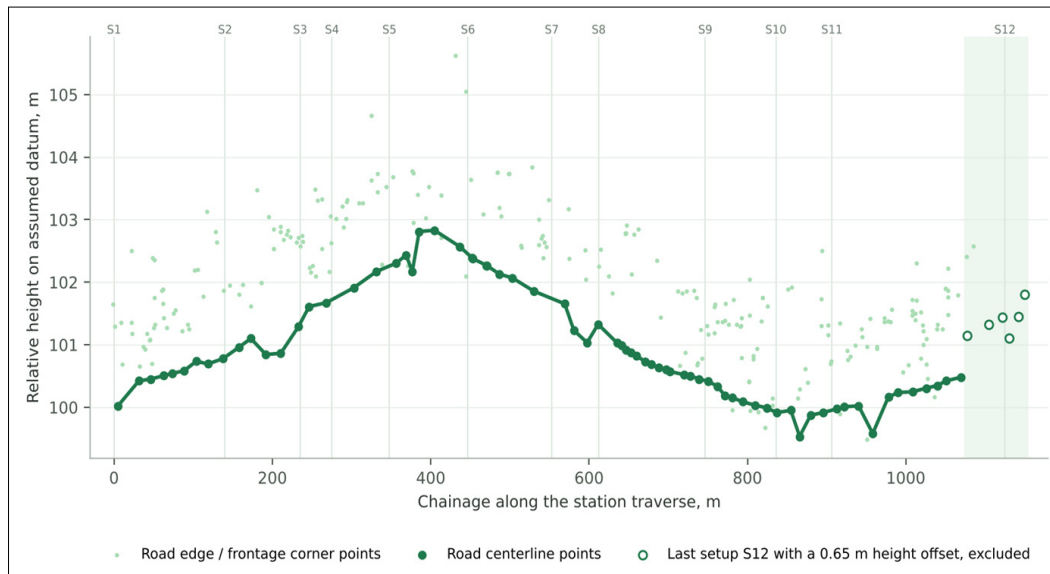


Fig. 2. Relative height profile along the Shivaji Road centerline with instrument stations S1 to S12

The centerline rises from 100.02 m at the southern end to 102.83 m at a chainage of about 405 m, falls to 99.53 m near 866 m, and returns to 100.48 m at about 1,070 m. The average grade is 0.70% on the ascending section and 0.71% on the descending one, which leaves little natural fall for stormwater, and the low point between 860 and 960 m marks the place where runoff from both directions collects. Edge and frontage points lie a median of 1.20 m above the nearest centerline point, and 96% of them are higher than the road axis, so plinths and plot entrances drain toward the carriageway.

The survey output served as the base for planning road alignments, stormwater drainage, domestic sewers, and other utility networks in the proposed development areas, in a regional context shaped by the state drinking water program Mission Bhagiratha, and the Tandur Town Planning Department and the Greater Hyderabad Municipal Corporation later used the project data in their planning work.

DISCUSSION

The values in Table 1 vary by an order of magnitude across tasks, and the drone LiDAR that reaches 0.07 m on an open road degrades to 0.21 m under a canopy (Tamimi & Toth, 2024). The accuracy and fitness of a survey for municipal planning are thus defined by the allocation of instruments to tasks and by the path their data take to GIS and CAD; the place where the frame is fixed determines how much work remains at the GIS stage.

The Tandur records show why the stage at which streams converge matters as much as the instruments. The point tables preserve the field records as observed, and in them, the repeated station shots make the 0.65 m height shift at S12 visible, while the parsed codes expose variants that would split classes in a GIS table. Defects of this kind are routine at the field stage, and the office stage exists to catch

them. They are caught late or missed when the field crew and office processors belong to different teams, because the field context leaves with the crew. In the Tandur project, direct involvement in both stages meant that a coded point could be followed from the instrument to the AutoCAD plan by the same people who had chosen its code on site. A chain run by one team from the coded field point to the CAD plan and GIS layer keeps that context at hand during office checks, reducing losses at the junction between field and office work.

A new district magnifies these effects. Tandur entered the Vikarabad district in 2016 without a geospatial base of its own, and the survey of 2019 became the starting point for road, drainage, and utility planning. An assumed origin lets the traverse begin on the first day, and the price appears later, when the local frames of three streets have to be transformed before they can be overlaid with each other or with any national dataset, a step that reviews of design and GIS integration rank among the fundamental obstacles of the field (Azari et al., 2025). A few RTK observations on traverse stations made before the first detail shot close this gap at the field stage, and drone imagery tied to the same frame adds the area context that street corridors lack (Liu et al., 2022; Mirzapour et al., 2026).

Practical rules for comparable surveys follow from these observations. Firstly, GNSS should fix the frame before the first traverse, with control placed at open sites and carried into the streets by the total station (Janos & Kuras, 2021). Secondly, a single code library with a fixed spelling for every feature class should be shared with all crews before fieldwork. Thirdly, repeated station shots should be compared at the end of each field day, and a vertical difference beyond a few centimeters should trigger a review of the heights entered at that setup. Finally, CAD drawings should leave the office in the national frame, ready for GIS.

The conclusions rest on accuracy values reported by ten studies conducted under different conditions and on survey records from one town. The instrument model and the accuracy control procedure of the Tandur survey are not documented in the available records, which confines the Tandur material to the organization of the data chain and leaves the comparison of instrument accuracy to the literature.

CONCLUSION

Five schemes for integrating GNSS, drone mapping, and total station surveying with GIS and CAD were identified, and they differ above all in the stage at which the coordinate frame is fixed. The task-by-technology matrix assigns network control to GNSS, area capture to drones, and discrete features, frontages, and boundaries to the total station supported by ground RTK.

The Tandur survey of 2019 illustrates the terrestrial branch of the chain at 1,101 coded points along three streets, which were converted into AutoCAD street plans. Embedded feature codes and repeated station shots carry quality control from the field into the office, and in the Tandur records, they reveal a 0.65 m height shift at one setup and code variants that would split feature classes in a GIS. The step that ties local street frames to the national system decides whether CAD output can serve as the GIS base of a district that starts without one. Further work can address the tie of local survey frames to permanent reference stations, including the Indian regional navigation system NavIC, and the automatic validation of field codes at the moment of download.

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