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RESEARCH ARTICLE

PROPOSAL FOR AN OFFLINE DIGITAL LEVELING NOTEBOOK FOR AUTOMATIC CALCULATION OF THEORETICAL ELEVATIONS AND MONITORING DEVIATIONS IN ROAD AND SANITATION WORKS

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Abstract

Levelling control of road layers and drainage structures still relies largely on paper field books and manual computations, which are error-prone and slow. We present TOPO KYJ, a standalone client-side web application (single HTML file) that reads a Covadis Excel export, rebuilds the horizontal alignment (lines, arcs, clothoids) by numerical integration, the vertical profile (grades and parabolas) and the cross-section, and computes the theoretical elevation of each survey point from chainage and offset. Back-sight and fore-sight readings are converted into practical elevations through the height of instrument, and each discrepancy is automatically classified against 1 cm and 2 cm thresholds. The notebook is generated with a default step of 6.25 m and up to eight offsets per profile, then exported to Excel and PDF; a localization module (GPS, reverse geocoding, routing) complements the tool. The system does not extrapolate the work area: a PK outside the longitudinal profile range does not obtain any elevation rather than an estimated value. A comparative quantitative validation on-site was carried out; however, the tool provides a reproducible basis to make the production of leveling notebooks more reliable and faster.

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Introduction:-

The advent of the digital leveling log marks a transition in geodetic science, elevating topometry from a simple field measurement practice to a secure and continuous process of project data management. By automating the data acquisition process through the integration of electronic sensors and real-time calculation and/or compensation algorithms, this tool permanently eliminates the visual interpretation biases inherent in traditional optical methods (Subramanian, 2012). This complete elimination of manual transcription from the field data collection process ensures the absolute integrity of the database.This is a fundamental condition to reach and ensure the submillimeter levels of accuracy demanded in critical infrastructure monitoring projects (Metricop Surveying Research, 2026). Finally, beyond ensuring the reliability of the initial data capture, the revolutionary aspect of this system lies in its interoperable software architecture; by acting as a central hub capable of controlling heterogeneous sensors, the digital notebook standardizes the flow of raw observations and ensures seamless digital continuity to post-

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processing and computing platforms, without any break in the information chain (Montigny, B. (2014).Electronic Field Notebook (CTe): User Guide (Version 1.026). Topo Solution. topo-solution.com.

The reality is that, for various reasons, it is still common to encounter projects that use opto-mechanical devices without a built-in digital Notebook. The reasons vary: the purchase cost of these modern devices, their immediate availability on the market, or the scale of the project. It therefore remains important to find a solution that minimizes manual data transcription during fieldwork.One of the most common tasks on construction or inspection sites is elevation surveying. Measurements are taken frequently to meet project requirements or to study the movement of a structure over time. The results are processed and interpreted to inform decision-making.

Geometric leveling is the standard method for determining elevation differences between points: a back sight reading ($\mathbf{L_{AR}}$) at a point of known elevation provides the instrument's line of sight commonly referred to as the leveling line from which the forward sight readings ($\mathbf{L_{AV}}$) are subtracted to obtain the elevations of the surveyed points. On a road construction site, this principle is used to adjust and verify each layer of the pavement structure (subbase, subgrade, base courses, etc.) as well as ancillary structures (gutters, sidewalks, foundation slabs, and excavation bottoms). The elevations to be adhered to are the theoretical elevations derived from the project, which is generally designed using surveying and road design software such as Covadis, which exports the plan view, longitudinal profile, cross-section, and layer thicknesses.

Nowadays, design software offers the ability to extract the various data needed for a project in different formats. But it can also happen that the surveyor records this data on a paper notebook, manually interpolates the theoretical measurements between the project's key points, calculates successive reference plans, and then compares each measured value to the expected one when this data isn't available to them. This process is prone to transcription, interpolation, and arithmetic errors, and it takes up a lot of time both in the field and in the office. Existing solutions are either integrated into proprietary instruments and software, or designed for connected workstations; (Montigny, B. (2014). Electronic Field Notebook (CTe): User Manual (Version 1.026). Topo Solution. topo-solution.com)

The integration of the digital leveling book into the topographic measurement process happened at three distinct architectural levels: directly embedded in the device's firmware, transferred to mobile electronic devices and personal digital assistants (PDAs) communicating via serial connection or Bluetooth, and finally on processing computers. Originally, the pioneering work of Vaníček et al. (1989) formalized the integration of the digital notebook at the stage of desktop computer pre-processing to automate the correction of physical biases (atmospheric refraction, thermal expansion of invar rods, and Earth curvature) using standardized environmental metadata.Subsequently, the research by Awange & Grafarend (2005) and Uren & Price (2010) documented the evolution of this smart software directly into the device's control unit or field controller. By interacting directly with CCD sensors reading the barcode targets, the digital notebook transformed the geometric leveling process by integrating real-time quality control. This check involves instantly checking the parity of back and front sights ($\sum L_{AR} \approx \sum L_{AV}$), validating the tolerances for duplicate points, and continuously calculating the closure error of the path.As demonstrated by Bányai (2005) and Chong (2007) during inspections of structures, this technological breakthrough almost completely eliminates human errors in reading, manual transcription, and rounding that affected traditional paper Notebooks. Finally, Heunecke & Kuhlmann (2014) highlight the role of the digital platform of the modern Notebook, whose data structures allow for direct export without any metrological disruption to databases, thus ensuring rigorous geodetic traceability from the opto-electronic sensor to the final engineering model.

The gap we have identified is the lack of a lightweight tool that can be installed without infrastructure, used offline, or without a connection to the measuring device that directly links the Excel export of a road project to a calculated, tolerance-controlled, and archivable grade book, under field conditions where Internet connectivity is unreliable.The objective of this study (proposal) is to describe the design and operation of TOPO KYJ, a digital leveling Notebook, and to outline (i) its software architecture, (ii) the algorithms for calculating theoretical and practical elevations, and (iii) its built-in quality control rules. We hypothesize that an automated workflow from Covadis export to the verified Notebook reduces manual calculation errors and speeds up logbook production; this hypothesis requires experimental validation, which we outline at the end of this study.The difference with the other models offered is that this notebook gives you the option to export a project's data in Excel format so you can import it into TOPO KYJ and use it directly in the field.

Materials and Methods:-

Input data:-

The application optionally accepts the Excel workbook generated by Covadis. The sheets used are: « Project Plan Axis» (geometric elements, starting PK–Kilometer Point, starting X and Y coordinates, bearing, radius or clothoid parameter), « Project Longitudinal Profile» (slopes and parabolas, start PK, starting elevation, radius), « Typed Implementation Points» (exact project Z at characteristic PKs and named points of the cross-section profile), « Cross-Section Profile» (lane widths and superelevation), and « Layer Thickness by Section» (thickness of each layer per PK section). PKs are entered in kilometer format (for example 1+000.00); the analyzer tolerates spaces and the confusion between the letter « O» and the number '0» around the « +» sign. In the absence of a file, the notebook can be filled in manually.

Software architecture:-

TOPO KYJ is a unique HTML file written in JavaScript (temporarily and in the process of being converted to APK), run entirely on the client side in a browser. The reading of Excel workbooks relies on SheetJS (version 0.18.5), embedded in the file. PDF generation uses jsPDF (2.5.1) with its autotable extension and html2canvas (1.4.1); mapping uses Leaflet (1.9.4) with the OpenStreetMap base layer. In the analyzed version, these last three libraries are loaded from a content delivery network (CDN): calculations and data entry work without a connection, but offline PDF export assumes that these libraries are already cached or embedded.User accounts (roles 'Operator' and 'Chief Surveyor'), saved notebooks, and saved PDFs are stored in the browser's local storage; passwords are stored as SHA-256 hashes. An internal messaging module, which allows sending PDFs and the daily report, operates in local storage and can be connected to a Firebase database if one is set up.

Reconstruction of the axis in plan:-

The axis is reconstructed by numerical integration element by element, with a step of about 0.25 m (at least four sub-steps per element). The gradient, expressed in grades, is converted into radians (factor π/200). The curvature k is zero on a straight line, equal to −1/R on an arc, and varies linearly along a clothoid between the curvatures of neighboring elements. At each sub-step of length dl, the orientation θ and the position are updated using the midpoint method (formulas 1, 2, and 3):Casal, G., et al. (2017), Graf Plessen, M. M., & Bemporad, A. (2017), Pérez, J., et al. (2019), Milles, S., & Lagofun, J. (1999)

$$\theta_{(i+1)} = \theta_{(i)} + \frac{[K_{(i)}+K_{(i+1)}]}{2} * dl \qquad (1)$$

$$X_{(i+1)} = X_{(i)} + \sin\left[\frac{[\theta_{(i)}+\theta_{(i+1)}]}{2}\right] * dl \qquad (2)$$

$$Y_{(i+1)} = Y_{(i)} + \cos\left[\frac{[\theta_{(i)}+\theta_{(i+1)}]}{2}\right] * dl \qquad (3)$$

The position of a point at the requested chainage is obtained by linear interpolation along the polyline thus constructed. A point located at a signed d offset from the axis (negative to the left, positive to the right) has coordinates (formulas 4 and 5):

$$\mathbf{X = X_{axe} + d * \cos\theta} \quad \textbf{(4)}$$
$$\mathbf{Y = Y_{axe} - d * \sin\theta} \quad \textbf{(5)}$$

Longitudinal profile and cross-section of the axis:-

The longitudinal profile is a series of slopes, ramps, landings, and parabolas. For a PK located at a distance l from the beginning of a segment, with a starting elevation Z_0 and an initial slope g_0, the elevation of the axis is (formulas 6 and 7):

$$Z = Z_0 + g_0 * l \quad \textbf{(6)}$$

et

$$Z = Z_0 + g_0 * l + \frac{l}{2R} \quad \textbf{(7)}$$

Formula (6) is used on a slope; on a parabola of radius R, formula (7) is the one to use. And for the slope at the end of the parabola, formula (8) is used for a length L:

$$g_0 + \frac{L}{R} \quad \textbf{(8)}$$

A 2 mm joint tolerance between segments accounts for the rounded millimeter values in the Covadis listings. If the requested PK matches, within 2 mm, a line from the «Typed implantation points» sheet, the value read from the file is used as is; otherwise, the measurement is calculated from the longitudinal profile. Outside the covered range, or in an interval without a segment, the function returns no value: there is no extrapolation or copying of a nearby PK measurement.Casal, G., et al. (2017), Graf Plessen, M. M., & Bemporad, A. (2017), Pérez, J., et al. (2019), Milles, S., & Lagofun, J. (1999)

Cross profile, layers and auxiliary works:-

For a given side (left, CG, or right, CD), the typed points of the cross-sectional profile are sorted by increasing offset, and the dimension at the requested offset is linearly interpolated between the two points that bracket it. If the offset exceeds the area covered by these points, a constant camber read from the 'Cross-sectional Profile' sheet is applied. This value is determined using formula 9:

$$\mathbf{Z = Z_{axe} + d * (\frac{dévers}{100})} \quad \textbf{(9)}$$

Formula 10 is used to calculate the theoretical slope of a layer :

$$\mathbf{Z_{théorique} = Z_{travers} * d - E_{cumulée} - e_{manuelle}} \quad \textbf{(10)}$$

where $\mathbf{E_{cumulée}}$ is the sum of the thicknesses of the layers above the specified layer, as read for the section containing the PK, et $\mathbf{e_{manuelle}}$ is any offset that may have been entered. The surface layer does not result in any subtraction. The start PK and end PK of the log must belong to the same thickness section.Amann, J., Borrmann, A., et al. (2015), Lee, S. H., & Jeong, Y. S. (2006), Holgado-Barco, A., González-Aguilera, D., & Arias, P. (2015), Riveiro, B., et al. (2015).For the Sanitation module, the theoretical level is the project level increased by an offset δ specific to the element: 0 cm for a deck, −50 cm for a raft foundation, −58 cm for lean concrete, and −65 cm (these values are given as an indication; the values to be used must follow the project requirements) for a foundation bottom (structure "Gutter"). For a sidewalk, no offset is applied.

Setting Up the Notebook and Recording Readings data:-

The notebook is defined by the layer (or the work) to be adjusted, the side, the start and end PKs, the step between profiles (6.25 m by default), the number of offsets (1 to 8), and the carriageway width, automatically read from the imported file when available. The offset distances are entered on the first line of each column and then copied to all profiles; a value specific to a profile can be entered, which immediately recalculates the interpolation of the concerned line. Offsets must be entered in ascending order and must not exceed the carriageway width on the relevant side. The L_{AR} and L_{AV} readings are input in millimeters: only digits from 0 to 9 are accepted, with a maximum of four digits (0 to 9999 mm), and pasting more than four digits is refused.

Altimetric path and calculation of deviations:-

The process follows the principle: Reference → Waypoints (WP) → Closure. Waypoints are selected from the imported file or entered manually. For each station on the instrument and the selected reference waypoint, the elevation of the reference plane (H_i) is calculated using Equation 11:

$$\boldsymbol{H_i = Z_{référence} + L_{AR}} \quad \textbf{(11)}$$

To calculate the gradient of a point, expression (12) is used:

$$Z_{pratique} = H_i - L_{AV} \quad (12)$$

Equation (13) is used to determine the deviation:

$$e = Z_{théorique} - Z_{pratique} \quad (13)$$

An intermediate waypoint, with its own L_{AR} and L_{AV}, generates a new H_i that replaces the previous one for subsequent lines without altering the lines that have already been calculated. For the closing line, the deviation is defined by expression (14):Ghilani, C. D. (2010), Kavanagh, B. F., & Mastin, T. B. (2013).

$$e = Z_{pratique} - Z_{théorique}(bornedefermeture) \quad (14)$$

Compliance is automatically classified according to the absolute value of the deviation. For the work 'Caniveau' at the bottom of the excavation, the 2 cm tolerance is not applied to readings before currents, identified by the observation « PFD »; this exception never applies to the closing line.

Exports, Archiving, and Daily Reports:-

The notebook is exported in Excel format (.xlsx, with a sheet of $H_i$journal) via SheetJS and in PDF format via jsPDF, with a header including the project name, logo, address, date, and operator identity. A PDF saving procedure adapted for Android has been implemented, with automatic line breaks for long project titles. The PDFs are archived in the user's account, a daily activity report can be viewed and exported, and documents can be sent via internal messaging.

Module de localisation:-

The module uses the browser's high-accuracy geolocation API (maximum position age of 5 s, timeout of 20 s), following the display of a permission request and a GDPR consent banner. Accuracy is classified into three levels: good (less than 20 m), medium (from 20 to 100 m), and low (over 100 m); only one qualifier is displayed to the user. The administrative address (department, municipality, district, neighborhood) is obtained by reverse geocoding via Nominatim (OpenStreetMap), updated at most every 5 s and only if the operator has moved. A place search first queries an embedded administrative database of Benin (department, municipality, district, village, or neighborhood; up to five results), then Nominatim with restriction to Benin. The route is calculated by the OSRM routing service (Luxen & Vetter, 2011) from OpenStreetMap data (Haklay & Weber, 2008) and drawn on the Leaflet map.

Protocole de validation prévu:-

Quantitative validation consists of comparing, for a sample of PKs and offsets, the theoretical coordinates calculated by TOPO KYJ with those listed by Covadis, and then comparing the discrepancies of the logs produced with the tool and with the manual method on the same alignment.

Résultats:-

Application obtenue:-

The obtained application has three work modules, accessible after logging in and entering the site identity (Table 1). The Development and Sanitation modules share the same five-step structure: optional import of the Covadis file, logbook settings, markers and routing, automatic calculation of H_i, and generation and export of the Notebook.

Table 1. TOPO KYJ Modules

Modules	Main features	Network connection required
Landscaping	Leveling of pavement layers, theoretical gradients by interpolation, profile log, and offset	No
Sanitation	Leveling of gutters, sidewalks, foundation slabs, concrete subbase, and excavation bottoms with predefined offsets	No
Location	GPS location, administrative address, area search, map, and directions	Yes

The other features (saved PDF files, daily reports, internal messaging) are cross-functional.



Photo 2: Verifying the app's authenticity

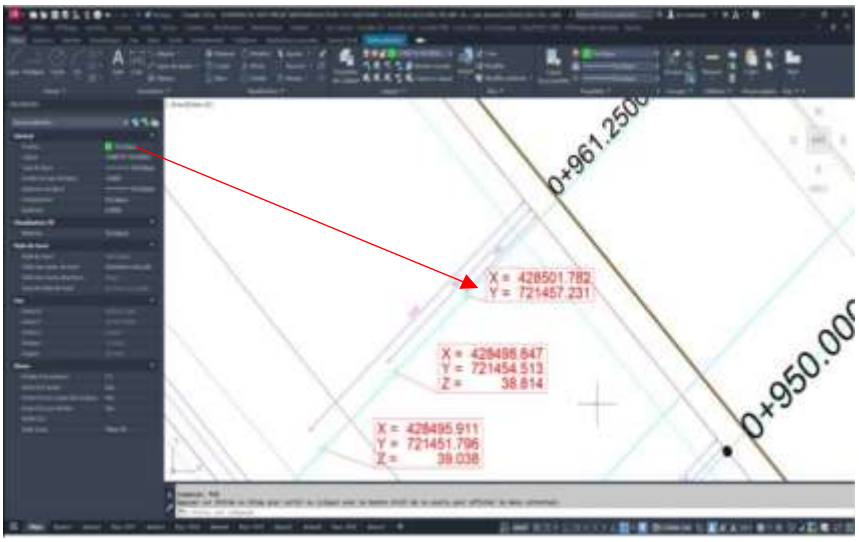

Photo 3: Interpolation at PK 0+961.250 Covadis

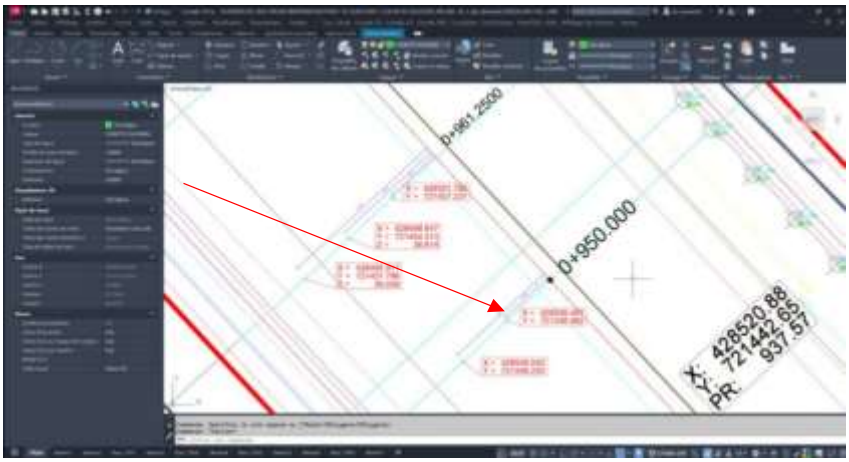

Photo 4: Interpolation at PK 0+950.000 Covadis

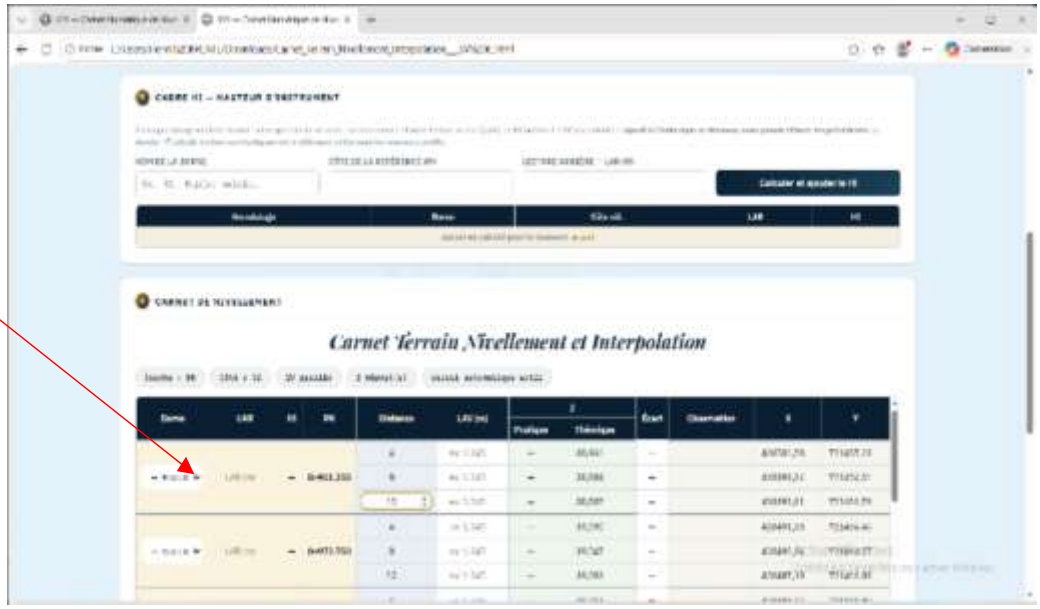

Photo 5: Interpolation at PK 0+961.250 TOPO KYJ

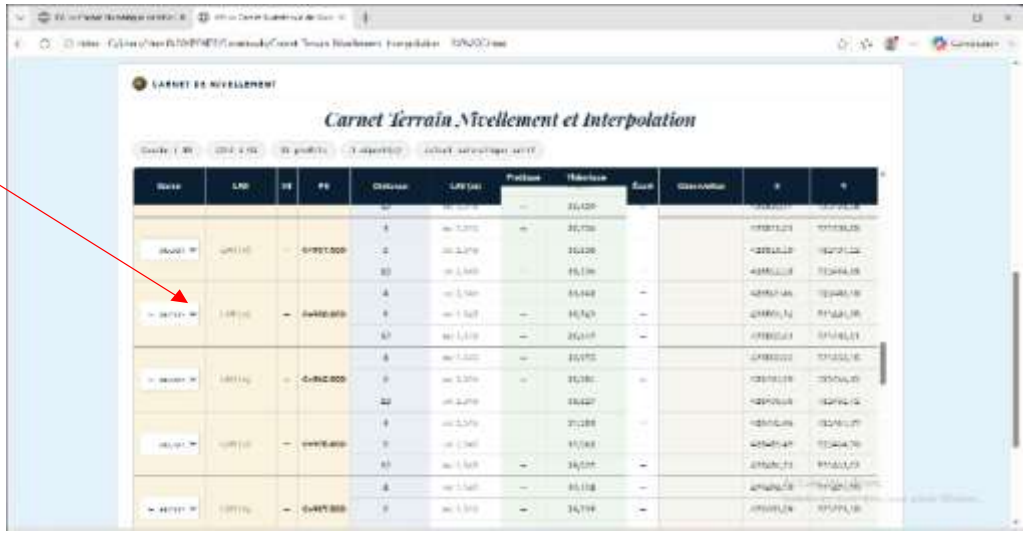

Photo 6 : Interpolation at PK 0+950.000 TOPO KYJ

Generated Notebook:-

For each profile, the Notebook displays the PK, the offset distances, the theoretical X and Y coordinates, the theoretical elevation, the entered L_{AR} or L_{AV}, the practical elevation, the deviation, and an observation. The X and Y coordinates are still calculated even when the theoretical elevation is unavailable. When there is no axis elevation or layer thickness for an exact PK, the theoretical elevation cell displays the symbol □ and no value is taken from another PK.

Règles de contrôle appliqués:-
Compliance is automatically classified based on the absolute value of the deviation (Table 2). The values shown here are for reference only, as standards vary depending on the specifications of each project.

Table 2. Automatic Classification of Deviations

Absolute value of the difference	Color	Observation	
≤ 1 cm		Green	☐
> 1 cm et ≤ 2 cm		Orange	☑ ☐
> 2 cm		Red	☐
Drain channel, excavation base (L_{AR}common)		Special mention	PFD

Exports and Localization Module:-
Excel and PDF exports include the project header and, for Excel, a timestamped log of successive H_i values. The location module displays the latitude, longitude, and a three-level accuracy indicator, the four administrative fields, the map, and the route to the selected location.

Discussion:-

Interpretation:-
The architecture adopted answers the question posed in the introduction: it is possible to link a Covadis export to a leveling book that has been calculated and verified within a single file, without installing a calculation server. Three design choices account for the expected reliability of the results. First, reconstructing the axis and longitudinal profile using the same geometric formulas as the design software supplemented by incorporating the exact values of classified points when they exist limits the discrepancy between the calculated elevation and the project elevation. Second, the refusal to extrapolate prevents a plausible but incorrect elevation from being used to adjust a layer. Finally, data entry checks (readings of no more than four digits, offsets that increase and are bounded by the roadway width, and uniform section thicknesses) prevent the most common data entry errors from occurring in the first place.

Perspective:-
The calculation of the reference plane and then of the elevation by difference of readings is the classical principle of geometric leveling (Ghilani & Wolf, 2012): TOPO KYJ does not change the method but automates its arithmetic and tolerance control. Compared to the paper notebook, it eliminates manual interpolation of theoretical elevations and step-by-step comparison. The use of OpenStreetMap data for localization is part of collaborative geographic information practices (Haklay & Weber, 2008), with the caveat that the completeness of administrative division is not guaranteed in Benin; the embedded local database serves to compensate for this lack.

Limites:-
The main limitation is the lack, at this stage, of quantitative validation across multiple construction sites of varying scales, on straight sections of road and at interchanges, to evaluate performance in terms of accuracy and time savings. Other limitations relate to the design. The route is verified by comparing the closure to a tolerance, but the closure error is not distributed through compensation. The workbook analyzer assumes the structure and sheet names of the Covadis export, so a variation in format may prevent the import. Authentication and storage are handled locally within the browser, without an authentication server, which does not meet high security requirements or support data sharing across devices without additional configuration. Finally, PDF export and the map feature rely on libraries loaded from a CDN, and the accuracy of the location module depends on the device's receiver, with potential degradation in built-up areas.

Perspectives:-
Three suggestions emerge: carry out the validation described in section 2.10 on several projects; include all the libraries in the file and package the tool as an Android application (APK) using a WebView container loading the HTML file, with JavaScript, local storage, and geolocation enabled; finally, add route compensation and secure synchronization of notebooks between devices.

Conclusion:-

This study aims to propose an application (software) designed to give field teams the ability to eliminate manual calculations and data transfers during site measurements. Files exported from design software (like Covadis) are

imported and used for interactive and smart use directly on-site. This helps save time and avoid errors related to calculations.

TOPO KYJ brings together in a single file the import of project data, the calculation of theoretical elevations, the calculation of reference plans and discrepancies with tolerances, the editing of the notebook, and its archiving. It provides a practical answer to the need for a lightweight construction leveling tool that can be used offline. Its scientific and operational value continues to be improved through comparative validation on multiple construction sites.

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