Routeliner

Route events and chainage for QGIS. User manual

v0.5.4

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Purpose

Routeliner places table records on linear features when a record carries a station or a distance from the start of the alignment instead of coordinates. A linear feature is called a route, and in practice it is the centre line of a road, a railway track, a pipeline, a power line or a mine working. A table record is called an event: a point event is tied to one station, and a line event, or section, lies between two stations.

The plugin follows the survey practice of the CIS countries, so a station is read in five accepted notations. The ledger holds broken pickets and station equations, and one route may have several chainage systems. Every record is either placed on the map or sent to the error table with a code and an explanation of the reason.

The tools sit in the Processing Toolbox in the Routeliner group and are repeated in the Plugins - Routeliner menu. A tool has the same number in both places and in this manual.

Installation and requirements

The plugin is installed from the QGIS plugin repository or from a ZIP archive through Plugins - Manage and Install Plugins - Install from ZIP. It requires QGIS 3.40 or newer, QGIS 4 on Qt6 included. There are no external dependencies, because the computation runs on the NumPy that ships with QGIS.

The interface language follows the language of QGIS: with a Russian locale the labels and messages are Russian, and with any other locale they are English. Field names in the results are the same in both languages, so expressions, styles and projects work in any locale. The attribute table and forms show field aliases in the interface language, for example Measure, m instead of rl_m.

Menu, toolbar and log

The plugin adds the Plugins - Routeliner menu and the Routeliner toolbar. The menu holds all tools under their numbers and the items Manual (PDF), Work log and About. The toolbar has two buttons. The first opens the same list of tools, the second opens the About window.

The About window shows the version and links to the site, the source code, the bug tracker and the Support development section. Its buttons open the version history, the manual, the log and the log folder. The bottom of the window shows the last lines of the log, so an error can be read without looking for the file.

The work log is written to the file routeliner.log in the QGIS profile folder. It receives the plugin load with the plugin and QGIS versions, every tool run with its parameters and running time, the warnings of a tool and the recalculation of live layers. A failure is written together with its call stack. When the plugin loads, a file larger than 2 MB is renamed to routeliner.log.old, and the log starts anew.

In case of an error it is enough to attach the log to a message on the bug tracker. Log entries are written in Russian whatever the interface language.

Terms

Measure. The distance along the route axis from its start, in the units of the route coordinate system. All computations of the plugin go through the measure, and a station is converted to a measure and back.

Picket and chainage. A picket is a mark on the alignment every 100 m, and chainage is a distance in metres written as a picket number and a plus. The record ПК 15+35 means 1535 m of chainage, and the picket length is a tool parameter with a default of 100 m.

Ledger. A table of reference points in which every station is matched to a measure along the axis, and between neighbouring reference points the chainage changes linearly with the measure. The difference between chainage and measure on a section is called the misclosure, and it comes from the projection scale and from survey errors.

Station equation. A point of the alignment where the chainage jumps from the value “back” to the value “ahead”. When the value ahead is larger, the equation is a forward one, and some chainage

values never occur on the alignment. When the value ahead is smaller, the equation is a backward one, and some values occur twice.

Chainage section. A stretch of the route between neighbouring reference points or equations on which the chainage is monotonic. Sections are numbered from zero, and the section number is needed when a station falls into a backward equation and is ambiguous without it.

Chainage system. One set of ledger rows for a route. A route may have a design, an as-built and a former system, which differ by the value of the system field in the ledger. A route without ledger rows gets its chainage along the axis length from the given start station.

M values. The fourth coordinate of a line vertex next to X, Y and Z. M holds the chainage, odometer readings or a measure from another program. The plugin reads the chainage from the M of a route and writes the chainage or the measure into the M of a result. PostGIS, ArcGIS and the QGIS tools for M read such layers.

Offset. The distance from the axis along the normal. A positive offset lies to the left of the route direction by default, and a check box in the event tools reverses the sign.

Station notations

The notation is chosen in the Station notation parameter and applies to the whole table. A number without a plus is not accepted in the picket-and-plus mode, because 1535 can mean both a picket number and metres.

Notation	Examples	Chainage, m
Picket and plus	ПК 15+35, 15+35,5, пк15+35.5, ПК -1+50, ПК 15	1535, 1535.5, 1535.5, -50, 1500
Picket and plus, relative	+35 after ПК 15+10	1535
Kilometre and metres	км 1+535, 1+535.2	1535, 1535.2
Railway notation	км 12 ПК 3+45	11245
Metres as a number	1535, 1535,5, 1 535,5	1535, 1535.5, 1535.5
Kilometres as a decimal	1,535	1535

In the railway notation kilometres and pickets are numbered from one, with ten pickets per kilometre. A plus larger than the picket length is accepted, because that is how long pickets are written.

Tools

1.01 Demo example

The tool creates a GeoPackage with a data set on which the whole plugin is checked. Every record carries a reference answer computed analytically from the formulas of a line and a circle, without the plugin. With the check switched on, the example runs through tools 1.02, 1.03, 2.01, 2.02, 4.01, 4.02, 5.01 and 5.02 at once, and the result of the comparison goes to the log.

Calibration is checked in a round trip. Tool 1.03 moves the ledger chainage into the M of the routes. Then the same point events are placed by M without the ledger and compared with the reference.

Parameter	Meaning
Folder for the example	Folder for routeliner_demo.gpkg and events_points.csv
Number of random point events	60 by default, and half as many defects are created, at least 30
Random seed	The same seed gives the same example

Parameter	Meaning
Run through the plugin at once	Switches on the check against the reference

The content of the example is described in the section Demo example layers.

1.02 Route check

The tool assembles every route from all features of the layer with the same ID. It is the tool to start with on new data, because it shows the routes that the other tools will not be able to place events on.

Multi-lines are split into parts, and the parts are ordered by matching ends rather than by storage order. Ends closer than the joint tolerance are merged into one node.

The route direction is the one in which the larger share of the part length is digitised, and the reverse check box turns it round. Arcs (CircularString, CompoundCurve) are cut into chords with an angle of no more than 0.02°.

A gap larger than the tolerance and a branch of three or more ends at one point count as errors. A geographic coordinate system counts as an error too, because lengths in it come out in degrees. When gaps are allowed, the measure continues across a gap without counting its length.

Result field	Type	Content
route_id	text	Route ID
length	number	Length along the axis, m
parts	integer	Number of parts after assembly
gaps	integer	Number of gaps
gap_max	number	Largest gap, m

1.03 Calibrate routes

The tool assembles the routes and writes the chainage into the M of every vertex. The result serves as a route with ready chainage for other programs and for the plugin itself. The chainage source is chosen per route in this order: control points, ledger, M of the routes themselves, length along the axis.

A control point carries a known station, for example a marker post on the line or a survey point. The point is located on the nearest route within the search radius, and its measure becomes a reference point. Between the points the station runs linearly, and before the first and after the last point with a scale of 1.

At a station equation the line gets two vertices at one point. The first carries the station back, the second the station ahead.

Parameter	Meaning
Control points with stations	Optional point layer
Control points: station field	Station in the selected notation
Control points: route ID field	Restricts locating to one route
Search radius for control points, m	10 m by default
M values of the result	Chainage by default, or measure along the axis

Result field	Type	Content
route_id	text	Route ID
length	number	Length along the axis, m
st_from, st_to	number	Chainage of the start and the end, m
pk_from, pk_to	text	Stations of the start and the end in the selected notation
sections	integer	Number of chainage sections
equations	integer	Number of station equations
source	text	Chainage source: points, ledger, m or length

Common route and chainage parameters

These parameters belong to tools 1.02, 1.03, 2.01, 2.02, 3.01, 3.02, 4.01, 4.02 and 5.01.

Parameter	Meaning
Route layer (lines)	Line layer with the route axes
Route ID field	Field by which features are assembled into a route
Part joint tolerance, m	0.01 m by default
Allow gaps	A route with a gap does not go to the errors
3D length	The measure takes Z into account
Reverse route direction	The route start moves to the other end
Station notation	One of the notations of the section Station notations
Picket length, m	100 m by default
Route start station, m	Start chainage for routes without a ledger
Chainage ledger	Optional table of reference points and equations
Ledger: route ID field	Route ID in the ledger
Ledger: station field	Station of a reference point or station “back” of an equation
Ledger: distance field	Measure along the axis for a reference point
Ledger: station ahead field	Filled in the equation rows only
Ledger: chainage system field	Field with the system name
Chainage system	Value of the system field, rows of other systems are not read
Chainage from the M values of the route geometry	The route chainage is taken from the M of its vertices
Metres per M unit	1 by default, 1000 for M in kilometres

A ledger row with an empty station ahead is a reference point, and a row with a station ahead is an equation. The measure of an equation may be empty, in which case the equation position is computed from the neighbouring reference points. Before the first and after the last reference point the ledger is extended to the route ends with a scale of 1.

Chainage from M goes to a route without ledger rows, because the ledger takes precedence. A route without M keeps the chainage by length. Between vertices the station runs linearly, and a vertex without M is skipped. Two vertices at one point with different M are read as a station equation, including at the joint of two features.

Tools 1.03, 2.01, 2.02 and 4.01 write M into the result geometry when the parameter M values of the result asks for it. By default no M is written, and the choices are the measure along the axis and the chainage, both in metres. At an equation a section gets two vertices at one point, with the station back and the station ahead.

2.01 Point events

The tool places table records on the routes by station, with an offset from the axis. Any QGIS layer serves as the table, CSV, Excel, DBF and a table without geometry included. The record «+35» takes the picket number from the previous record of the same route.

Parameter	Meaning
Event table	Layer or table with the records
Events: route ID field	Route ID of the record
Events: station field	Station in the chosen notation
Events: offset from the axis field, m	Optional offset
Positive offset to the right of the route direction	Reverses the offset sign
Events: section number field	Section number for a station in a backward equation
M values of the result	No M, measure along the axis or chainage

The result repeats all fields of the source record and adds the fields of the plugin.

Result field	Type	Content
rl_m	number	Measure along the axis, m
rl_pk	text	Station in the chosen notation, two decimals
rl_x, rl_y	number	Point coordinates in the route coordinate system
rl_azimuth	number	Axis azimuth at the point, degrees clockwise from north

2.02 Sections (line events)

The tool cuts route sections between the start and end stations with a parallel offset. A section recorded against the route direction is turned over, and a section across a route gap comes out as a multi-line when gaps are allowed. The parameters are those of tool 2.01, with two stations instead of one.

Result field	Type	Content
rl_m_from, rl_m_to	number	Start and end measures, m
rl_length	number	Section length along the axis, m
rl_pk_from, rl_pk_to	text	Start and end stations in the chosen notation
rl_swapped	integer	1 when the start and the end were swapped

3.01 Live layer of point events

The tool takes the parameters of tool 2.01 and creates two in-memory layers in the Routeliner group, an event layer and an error layer. These layers are recalculated by themselves 0.4 s after the last edit of the route layer, the event table or the ledger. Recalculation also follows unsaved edits and a CSV or Excel file changed on disk.

The binding of the layers is written to the project, and when the project opens the in-memory layers are filled again, because QGIS saves them empty. Removing the event layer from the project stops the recalculation, and the fields of the layer are those of the result of tool 2.01.

3.02 Live layer of sections

The tool does for sections what tool 3.01 does for point events. Its parameters and fields are those of tool 2.02.

4.01 Picket stakeout

The tool places points of whole pickets along every route with the stakeout step. With a ledger, broken pickets and equations are taken into account, so pickets skipped by a forward equation are not placed, and pickets repeated by a backward equation are placed twice with different section numbers.

Result field	Type	Content
route_id	text	Route ID
pk	text	Station in the chosen notation
station	number	Chainage, m
m	number	Measure along the axis, m
section	integer	Chainage section number, from zero
azimuth	number	Axis azimuth, degrees, for label rotation
km	integer	1 for a picket that is a whole kilometre

4.02 Locate points on routes

The tool solves the inverse task: for every point it finds the nearest route and computes the measure, the station and the offset from the axis on it. A point beyond the search radius goes to the error table. When the points have a route ID field, a point is located on the given route only. Points in another coordinate system are transformed to the route coordinate system.

Result field	Type	Content
rl_route	text	Route ID
rl_m	number	Measure along the axis, m
rl_pk	text	Station in the chosen notation
rl_offset	number	Offset from the axis, m, positive to the left of the route direction
rl_side	text	Side relative to the route direction: left, right or axis

The values of rl_side are written as codes, so that they do not depend on the interface language.

5.01 Profile table

The tool collects the points of a longitudinal profile along every route and samples raster values at them. Points are placed at the route start and end, at station equations, at whole pickets, at axis vertices and with a constant step. Points closer than 1 cm along the measure are merged into one.

A raster may be terrain, a design surface, the roof or floor of a seam, the groundwater level or any other surface. The value is interpolated bilinearly between cell centres, and the raster may be in any coordinate system.

Points from an event layer, such as crossings, manholes or boreholes, are put on the profile by projection onto the axis. A point gets onto the profile only when it lies closer to the axis than the corridor parameter allows.

Parameter	Meaning
Routes separated by commas	Empty - all routes of the layer
Rasters	One or several rasters, one field for each
Raster band number	1 by default
Points at whole pickets every, m	100 m by default, 0 - no pickets
Points with a constant step, m	0 by default - no step
Axis vertices	Only with a turn above 1° or a grade break above 1 ‰, all vertices or no vertices
Events for the profile	Optional point layer and label field
Events: corridor from the axis, m	10 m by default

The other parameters are those of the section Common route and chainage parameters.

Result field	Type	Content
route_id	text	Route ID
n	integer	Point number in the order of the measure
kind	text	Point kind, start, end, equation, event, picket, vertex or step
m	number	Measure along the axis, m
station	number	Chainage, m, chainage back for an equation
station_ahead	number	Chainage ahead, filled for an equation only
pk	text	Station in the chosen notation, both stations with an equals sign for an equation
section	integer	Chainage section number
x, y	number	Point coordinates on the axis
z_axis	number	Axis elevation from the route Z, empty without Z or with zero Z
turn	number	Turn angle of the alignment at a vertex, degrees, positive to the left
label	text	Event label
z_name	number	Raster value, the field name is built from the raster layer name

5.02 Profile drawing

The tool builds the drawing of the longitudinal profile of one route from the 5.01 table. Surface lines and the elevation scale are drawn above the grid, and the grid rows and the straightened plan go below them. The scale ticks are at least 5 mm apart, and the labels at least 10 mm.

The drawing is placed in the same coordinate system as the table, in paper millimetres. One map unit equals one millimetre, so in a QGIS print layout the profile prints at full size with the map scale 1:1000. If the lower left corner is not given, the drawing is placed below the routes with a margin of 100 units.

The grid is set by a table of rows, and by default it holds the Pipeline template. Rows can be removed, added and reordered. A row without data is not put into the grid, so the drawing has no empty rows.

Row table column	Meaning
Title	Text in the title column on the left
Type	value, text, grade, distance, station or plan
Source	A QGIS expression for value and grade, a field of the section layer for text
Decimals	Number of decimals in the labels
Height, mm	Row height, 0 - the row only draws a line above the grid
Line (1/0)	1 - the values of a value row are drawn as a line above the grid

Row type	What is drawn
value	A number at every point from an expression over the profile table fields
text	Section labels from a field of the section layer, with separators at the boundaries
grade	Grade in per mille and length of the sections of constant grade
distance	Distances along the measure between neighbouring labelled points
station	Point stations, an equation in two lines
plan	Straightened plan with the axis, turn angles and points with offsets

Expressions may use the profile table fields and the placeholders {ground}, {design}, {pipe}, {d} and {base}. The first three are replaced by the fields chosen in the parameters, and the last two by the pipe diameter and the bedding thickness. If a placeholder is not set, the row is skipped with a log message.

Pipeline template row	Type	Source
Design ground level, m	value	{design}
Existing ground level, m	value	{ground}
Pipe top level, m	value	{pipe}
Trench bottom level, m	value	{pipe} - {d} - {base}
Ground to pipe, m	value	{ground} - {pipe}
Trench depth, m	value	{ground} - ({pipe} - {d} - {base})
Pipe type and coating	text	field pipe of the section layer
Bedding	text	field base of the section layer
Grade, ‰ / length, m	grade	{pipe}
Distance, m	distance	
Station	station	
Straightened plan	plan	

Grade sections are found by vertical simplification of the line, and the simplification tolerance is a parameter with a default of 0.02 m. A short section is crossed by a diagonal from corner to corner. On a section longer than four row heights such a diagonal almost merges with the row border, so a grade sign four row heights wide is drawn at the section centre. Sections for text rows come from the result of 2.02 or from any table with start and end measure fields.

Point labels are thinned when the points are closer on paper than the given gap, 3 mm by default. The label stays at the point with the higher priority. The priority falls from the route start and end to an equation, an event, a picket, a vertex and a step point.

The straightened plan is built from points with the fields rl_m and rl_offset, that is from the result of 4.02. The plan is schematic, so offsets are compressed until the farthest point fits into the row.

Parameter	Meaning
Profile table	Result of 5.01
Route	Empty - the first route of the table
Ground level field {ground}	Usually the field of the terrain raster
Design level field {design}	Optional field
Pipe or axis level field {pipe}	Empty - z_axis
Pipe outer diameter {d}, m	0.16 m by default
Bedding thickness {base}, m	0.3 m by default
Horizontal and vertical scale	1:500 and 1:100 by default
Datum, m	Empty - 1 m below the lowest level rounded down to a metre
Smallest gap between labels, mm	3 mm by default

The result consists of two layers. The line layer holds the fields kind (line kind), row (row), color (colour) and width (width, mm). The label layer holds the fields text, kind, rot (rotation, degrees), size (height, mm), halign and valign. The style of both layers is set on loading and takes colour, width, rotation and alignment from these fields.

Error table

Tools 1.02, 2.01, 2.02, 3.01, 3.02 and 4.02 produce an error table without geometry. It repeats the fields of the source record and adds three fields.

Field	Content
rl_route	Route ID of the record
rl_error	Reason code, the same in both languages
rl_message	Explanation in the interface language

rl_error code	Reason
route_not_found	No route with this ID, or the route is not assembled
route_gap	The route falls apart with a gap larger than the tolerance
route_branching	Three or more part ends meet at one point
geographic_crs	The routes are in a geographic coordinate system
station_parse_failed	The station record does not match the chosen notation
station_out_of_range	The station is outside the route chainage
station_in_gap	The station falls into a forward equation
station_ambiguous	The station occurs twice in a backward equation, no section number given
measure_out_of_range	The measure is outside the route, or the point is beyond the search radius
ledger_invalid	The ledger is inconsistent, for example the chainage does not grow on a section
from_ge_to	Zero-length section

Demo example layers

Tool 1.01 writes five layers in the EPSG:32640 coordinate system to the file routeliner_demo.gpkg. The fields with the exp_ prefix hold the reference answer and are needed for the check only.

The terrain raster routeliner_demo_dem.tif with a 5 m cell is written next to it. The terrain is an inclined plane z = 151.5 + 0.01 (x - 455000) + 0.02 (y - 6428000), and bilinear interpolation on a plane is exact. Along R1 the ground lies 1.5 m above the axis, so on the profile the R1 axis looks like a pipe. That is why profile levels are checked against the formula and not against the raster itself.

routes. Four routes. R1 is a 2000 m straight line with Z values from 150 to 170 m. R2 is a 500 m straight line, an arc of 300 m radius turning 90° to the left and another 500 m straight line, with the arc stored as a CompoundCurve. R3 is a polyline of four 400 m legs stored as three features with parts in arbitrary order and one part reversed. R4 consists of two parts with a 15 m gap and has to end up in the errors.

Field	Content
route_id	Route ID, R1-R4
name	Route description

ledger. The as-built ledger of route R3. The misclosure over the first 400 m is 0.40 m, a backward equation of 25 m stands at the measure of 700 m, and a forward equation of 40 m at the measure of 1300 m.

Field	Content
route_id	Route ID
system	Name of the chainage system, «исполнительная» (as-built)
station	Station of a reference point or station “back” of an equation
measure	Measure along the axis, m
station_ahead	Station “ahead”, filled for an equation only
note	Row explanation

events_points. Point events, random and predefined. The same set is written next to the GeoPackage to the file events_points.csv with a semicolon as the separator.

Field	Content
eid	Event number
route_id	Route ID
pk	Station in the picket-and-plus notation
offset	Offset from the axis, m
section	Section number for a station in a backward equation
exp_m	Reference measure, m
exp_x, exp_y	Reference coordinates
exp_error	Expected error code, empty for a valid record
note	Record explanation

events_lines. Six sections, among them a section across the arc with a 10 m offset, a section across both equations of route R3 and a zero-length section.

Field	Content
eid	Section number
route_id	Route ID
pk_from, pk_to	Start and end stations
offset	Offset from the axis, m
exp_m_from, exp_m_to	Reference start and end measures, m
exp_error	Expected error code
note	Record explanation

defects. Points near routes R1-R3 with offsets from 1 to 15 m to both sides.

Field	Content
did	Point number
exp_route	Reference route ID
exp_m	Reference measure, m
exp_station	Reference chainage, m
exp_offset	Reference offset, m, positive to the left

Accuracy

Measures, lengths, offsets, coordinates and levels in the result fields are rounded to 0.001 m, and angles to 0.01°. This rounding is finer than the computation error described below.

Accuracy is checked on the demo example. A run with seed 42 and 3000 random events in QGIS 4.0.3 matched all 3002 point events with the reference, with a largest deviation of 2.2 mm. All 1500 defects of the same run were located on their own route with a deviation of the measure and the offset below 1 cm.

In the same run the profile table along routes R1-R3 gave 573 points. The terrain levels at all points matched the plane formula with a deviation of at most 0.5 mm, which comes from rounding the values to a millimetre. The axis levels of R1 matched at all 194 points, and both equations of R3 got into the table.

Calibration in the same run wrote both ledger equations into the M of route R3. All 2976 point events without a section number, placed by M without the ledger, matched the reference within 1 cm.

The deviation appears on arcs with an offset, because an arc is cut into chords, and the normal to a chord differs from the normal to the arc by no more than 0.01°. Chainage from a ledger does not depend on the cutting, because it is computed through the measure.

Relation to the standard QGIS tools

QGIS has tools that work with one line and one distance. Routeliner uses the same geometry and adds the event table, the chainage and the ledger to it.

QGIS tool	What it does	What Routeliner adds
Interpolate point on line	A point at a given distance from the start of one line	Station instead of distance, a table of records, offset, ledger
Line substring	Part of one line between two distances	Sections from a table, offset, route assembly from parts
Points along geometry	Points with a constant step	Picket stakeout with equations

QGIS tool	What it does	What Routeliner adds
Set M value	One M value for all vertices	Chainage in M from a ledger or control points, with equations
Linear Referencing symbol layer (since 3.40)	Distance labels along a line at rendering	Pickets as layer features with fields
Elevation profile (since 3.26)	Profile of surfaces along a line in a separate panel	Profile grid with ledger stations, grades and a straightened plan as layers for a print layout
Network analysis, shortest path	A path over a road graph between points	Builds no networks, a path from network analysis can serve as a route

Network analysis and Routeliner solve different tasks, because network analysis searches for a path over a road graph, and Routeliner places data on an axis that already exists. The result of the Shortest path tool fits as a route layer once it has an ID field.

Limitations

A live layer is recalculated as a whole and in the main QGIS thread, so on tables of hundreds of thousands of records the interface stops for the time of the computation.

The parallel offset of a section is built with sharp corners cut, so loops are possible when the offset exceeds the radius of a curve on the section.

When gaps are allowed, the order of the route parts is set from the first part in storage order to the nearest end. For parts lying far from each other, the order is worth checking with tool 1.02.

Chainage sections from M are numbered by breaks of scale and by equations, not by the ledger reference points. A section number from an events table set by the ledger can therefore shift after calibration. The number for chainage from M is best taken from the picket stakeout 4.01 of the same route.

The profile drawing is built for one route per run and with one datum. That is why the profile of a long alignment with a large height difference comes out tall.

Unlike the live layers 3.01 and 3.02, the profile drawing is not recalculated by itself after data edits. After an edit tools 5.01 and 5.02 have to be run again.

Developed with the support of Inform++ LLC (www.informpp.ru).

Plugin page on the site - www.informpp.ru/главная-страница/qgis-routeliner

Source code - github.com/Valery35/routeliner

Routeliner v0.5.4

Routeliner grows on tasks of real enterprises. If your production lacks a function, write to us - www.informpp.ru/главная-страница/предприятиям