PAPER 9

RECENT GEOMETRIC DESIGN RESEARCH: EXTRACTING ACTIONABLE PRACTICES FOR MUNICIPAL ROAD UPGRADES

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ABSTRACT

Municipal road upgrade projects are usually delivered under tight budget limits, short construction windows and a strong preference to retain the existing alignment. Under these conditions, geometric issues may be left unresolved on the assumption that meaningful improvement would require costly realignment. This paper reviews recent geometric design research to identify practical lessons for municipal road upgrades and to consider which consistency-related improvements may be justified within typical project constraints.

The review draws mainly on recent work on operating speed, geometric consistency, sight distance, three-dimensional alignment coordination, superelevation treatment and local curve refinement. Most of this evidence comes from rural and interurban highway studies. The paper therefore does not assume direct transfer to all municipal streets. Instead, it focuses on municipal corridors where highway-like geometric conditions still arise, such as urban arterials, peri-urban links, freight routes and other upgrade corridors with meaningful speed transitions, restricted sight distance or constrained horizontal and vertical alignment.

The review suggests that consistency-based assessment is useful in the municipal context not because it automatically leads to large geometric changes, but because it helps project teams ask the right scoping questions before budgets, briefs and tender scopes are fixed. In some cases, the appropriate response may be improved warning and delineation, revised speed management, visibility clearing or localised geometric refinement. In others, targeted widening treatment, superelevation or runoff adjustment, sight-distance correction, local profile modification or more detailed design review may be warranted. Only a smaller group of cases is likely to justify major reconstruction.

The paper argues for a case-by-case approach rather than a universal rule. Its contribution is a practical municipal scoping screen for municipalities and their consultants: how to interpret recent geometric design research, how to identify consistency-related problems early in project development, and how to match the response to the corridor, road function, risk, delivery route and available budget. The screen is intended to help distinguish issues that can be addressed through internal operations or maintenance, issues that should be included in the consultant's design scope, and issues that require separate capital intervention. In this way, the paper seeks to translate current research into realistic upgrade practice rather than idealised redesign.

Keywords: Geometric design consistency; municipal road upgrades; project scoping; operating speed; road function; delivery-route decision

1. INTRODUCTION

This paper developed from a broader review of recent geometric design research, where many current studies appeared to revisit fundamental design concerns such as operating speed, driver expectancy, sight distance, curve treatment, superelevation and alignment coordination. These concerns are familiar to experienced geometric designers, but in municipal projects they may remain embedded in individual judgement rather than being made explicit during early scoping.

The practical question is therefore how selected parts of that judgement can be made visible earlier in the project life cycle, especially for multidisciplinary teams and younger engineers. This is important because road problems should not always be viewed in isolation: a resurfacing, stormwater, widening or safety project may create an opportunity for a targeted geometric improvement if the issue is recognised before budgets, briefs and tender scopes are fixed. This paper responds by translating recent geometric design research into municipal scoping prompts that support better investment decisions and help identify where modest, localised improvements may be incorporated into works that are not initially framed as geometric upgrades.

1.1 Municipal road projects are scoped under constraint

Municipal road projects are rarely scoped in an unconstrained design environment. Rehabilitation, resurfacing, stormwater, widening and safety projects are usually developed within existing corridors, live traffic conditions, limited road reserve, service conflicts, land constraints, funding limits and delivery pressure. These conditions often make major geometric change difficult, even where the existing road does not fully support the current function of the corridor.

The pressure is not only technical. Municipal infrastructure delivery in South Africa operates within a context of uneven asset information, project delays, quality concerns and funding pressure. The 25-year review of local government noted that a proportion of municipalities had not assessed the condition of their road infrastructure and that a proportion of road projects exceeded completion dates (COGTA 2025). The Auditor-General's reporting on local government infrastructure has also highlighted recurring findings on project delays, poor construction quality and overspending (AGSA 2025). These are not geometric design findings in themselves, but they show why municipal scoping decisions need to be practical, timely and well targeted.

In this environment, the project brief often begins from the most visible defect: a failed pavement, flooding problem, edge break, narrow section, safety complaint or public transport need. That is understandable, but it creates a risk that the project is defined too narrowly before the road problem has been properly understood. A municipality does not need to complete full geometric design before tender, but it does need enough front-end review to know what kind of road problem it is procuring a solution for.

1.2 The risk of treating road problems in isolation

Roads do not operate as separate pavement, drainage, safety and geometric systems. A road section that appears to require resurfacing may also include a sight-distance issue, an unexpected speed transition, poor curve readability, inadequate tracking for buses or trucks, problematic crossfall, or weak coordination between horizontal and vertical alignment. If these issues are not recognised early, the project may improve the visible defect while leaving the underlying operating problem in place.

This is especially relevant where municipal roads perform higher-order functions. Some municipal corridors operate as urban arterials, peri-urban links, freight routes, industrial access roads, bus or taxi corridors, or constrained routes through hilly terrain and existing settlements. In such cases, road ownership alone is not the deciding factor. The important question is how the road is used, who uses it, and whether its existing geometry supports the present speed environment and road function.

Road safety data also supports the need to keep the road environment in view. The RTMC's July to September 2024 road safety report recorded 3 205 fatalities and noted that pedestrians made up 45.2% of fatalities in that period (RTMC 2024). The same report identified road and environmental factors such as sharp bends, poor visibility, poor road marking, poor lighting, blind rises and poor road surface among recorded contributory factors (RTMC 2024). These figures do not mean that every municipal rehabilitation project is a geometric project. They do, however, reinforce that road safety, visibility, speed environment and driver expectancy should not be separated too quickly from pavement, drainage or routine upgrade work.

The value of early scoping is therefore not to force wholesale redesign. It is to identify where a targeted geometric improvement could be incorporated into another road investment while the scope is still flexible. In some cases the appropriate response may be warning signs, delineation, vegetation clearing or speed management. In other cases it may be a consultant design-scope item such as sight-distance review, swept-path assessment, crossfall correction, local widening or three-dimensional alignment review. In more severe cases, the issue may need to be recorded as a separate capital intervention.

1.3 From tacit judgement to project-stage checks

Experienced geometric designers often recognise these issues through practice. They may identify a curve that does not read correctly, a tangent-to-curve transition that invites excessive approach speed, a crest or sag that limits visibility, a tight curve that is unsuitable for the road function, or a widening treatment that would affect vehicle path and driver comfort. This judgement is valuable, but it is not always formalised in municipal project briefs, preliminary design reviews or scoping checklists.

Recent geometric design research is useful because it makes some of these familiar concerns more explicit. Studies on three-dimensional alignment coordination emphasise that drivers experience the road as an integrated visual and operational environment, not as separate plan, profile and cross-section elements (de Santos-Berbel & Zimmermann 2025). Research on geometric design consistency similarly shows that operating speed, speed differentials, driver expectancy and alignment sequence can be used to assess whether a road section is likely to operate consistently.

For municipal practice, the issue is not whether this research should be imported directly as a new design standard. It should not. Many of the studies are based on international, rural or interurban highway contexts, and their model values, thresholds and crash relationships are context-specific. Their more useful contribution is that they help convert tacit professional judgement into project-stage questions: what should be checked, when should it be checked, and who should own the response?

This is particularly important for multidisciplinary teams. Municipal road projects may be led by pavement, stormwater, transport planning, traffic, road safety, project management or asset-management priorities. A simple scoping screen can help these teams recognise when specialist geometric input may be needed, without expecting every team member to carry decades of geometric design experience.

1.4 Aim and contribution of the paper

The aim of this paper is to translate selected recent geometric design research into a practical municipal scoping screen for road rehabilitation, resurfacing, stormwater, safety and upgrade projects. The proposed screen is intended to help project teams ask the right geometric questions before budgets, briefs and tender scopes are fixed. The contribution is not a new design standard, road safety audit procedure or compliance checklist. It is a front-end scoping aid that helps municipal teams distinguish between three broad response routes: issues that can be addressed through internal operations or maintenance, issues that should be included in the consultant's design scope, and issues that require a separate capital intervention.

The paper therefore uses recent research as a source of prompts rather than direct design prescriptions. Its central position is that municipal road projects should not be scoped only around the most visible defect where road function, operating speed, sight distance, curve treatment or three-dimensional alignment may also influence the appropriate response. In this sense, the paper transfers questions, not answers.

2. APPROACH AND TRANSFERABILITY

2.1 Targeted scoping review of recent geometric design research

This paper draws from a targeted scoping review of recent geometric design research. The review approach was appropriate because the purpose was not to calculate a pooled safety effect or test a single hypothesis, but to identify current research themes and translate them into practical questions for municipal project scoping.

The wider review searched recent literature on highway and roadway geometric design, including horizontal alignment, vertical alignment, geometric design, cross-section, superelevation, roadway design and highway design. Searches were undertaken in Scopus and Web of Science and limited to recent publications from 2020 onwards. The combined search produced 1 958 records before duplicate removal and screening. Following title screening, abstract screening and full-text relevance review, a wider set of 54 papers was retained for detailed consideration.

For the present paper, the wider review was narrowed to papers with relevance to municipal road rehabilitation, resurfacing, stormwater, widening, safety and upgrade projects. Sixteen papers were identified as a municipal focused candidate set. Thirteen of these were actively charted after excluding papers that were inaccessible or less relevant to the municipal scoping focus. The active charting set was then grouped according to the role each paper played in developing the proposed municipal scoping screen.

2.2 Charting and synthesis

The selected papers were charted according to their role in developing the proposed municipal scoping screen, rather than treated as equal sources of design guidance. Two papers formed the conceptual spine: one on three-dimensional alignment coordination and driver perception, and one on geometric design consistency and corridor-to-element screening. The remaining papers were grouped as support modules that helped populate specific prompts on sight distance, road function, curve widening, operating speed, curve prioritisation, constrained geometry, superelevation and future local evidence needs. Table 1 summarises how the reviewed papers were

TABLE 1: *Role of reviewed papers in developing municipal scoping prompts*

Role in synthesis	Reviewed papers	Main issue	Scoping contribution
Conceptual spine	de Santos-Berbel & Zimmermann (2025); Sharma et al. (2026)	3D alignment, driver perception and geometric consistency.	Review the corridor as drivers experience it, then assess individual elements.
Sight distance and road-function support	Megat-Johari et al. (2025); Rinaldi et al. (2021)	Sight distance, vertical profile and visibility risk.	Trigger sight-distance/profile review where road function, constrained profiles or night-time visibility warrant it.
Curve widening and design-vehicle support	Günay (2023); Ciampa & Olita (2022)	Curve widening, swept path, tight curves and constrained geometry.	Check retained-curve/design-vehicle fit; consider swept-path review, widening or local refinement.
Operating-speed and horizontal-curve consistency support	Tottadi & Mehar (2024); Godumala & Ravi Shankar (2024); Atif et al. (2026)	Operating speed, speed reduction and vehicle mix.	Ask whether retained geometry creates unexpected speed changes, especially on higher-speed or mixed-traffic corridors.
Prioritisation and applied consistency support	Chakraborty & Gates (2024); Igene & Ogirigbo (2021)	Curve safety, sequence and global/local consistency.	Prioritise higher-risk curve sequences and move from corridor screen to local issue and delivery route.
Background and future local-evidence support	García-Ramírez et al. (2025); Trakakis et al. (2025)	Parameter review and superelevation/runoff.	Supports local evidence and review of assumptions; does not form the core screen.

translated into municipal scoping triggers, with emphasis on what project teams should ask before a rehabilitation or upgrade scope is fixed, rather than on transferring models, equations or numerical thresholds.

2.3 Transferability position

A central limitation is that the reviewed technical papers are not South African municipal case studies. Many are based on rural, interurban or international highway contexts. Their findings are therefore not adopted as direct design criteria for South African municipal roads. The paper does not transfer model values, crash factors, thresholds, equations, vehicle parameters or proposed design-rule changes into local practice.

Instead, the review transfers the underlying questions raised by the literature. These include whether drivers can read the road consistently, whether the operating speed environment matches the retained geometry, whether sight distance is adequate, whether curve treatment supports the road function, whether heavy vehicles or buses require additional consideration, and whether horizontal and vertical alignment work together from the driver's perspective. These questions are relevant to municipal roads where similar geometric mechanisms arise, particularly on urban arterials, peri-urban links, freight or industrial routes, bus and taxi corridors, constrained corridors, steep routes and existing roads carrying a higher-order function.

The application of each question must still be filtered through local road function, user mix, speed environment, available road reserve, land and service constraints, safety history, funding route and the likely delivery mechanism. In this sense, the proposed screen is not a compliance tool or substitute for professional judgement. It is a scoping aid that helps decide whether an issue should be handled through internal operations or maintenance, included in the consultant's design scope, or recorded as a separate capital intervention. The paper transfers questions, not answers.

2.4 Use of AI-assisted tools

AI-assisted tools were used to support literature organisation, spreadsheet structuring, preliminary extraction, consistency checking, drafting support, and the generation of draft table/figure visuals. The tools were not used as a substitute for author judgement. The selection of the final paper set, interpretation of the literature, transferability decisions, synthesis of implications, figure content and final conclusions remained under the control of the author. AI-assisted outputs were reviewed, corrected and integrated only where they supported the paper's argument.

3. WHAT RECENT GEOMETRIC DESIGN RESEARCH HELPS MUNICIPAL TEAMS ASK

The reviewed papers do not provide a ready-made design manual. Their value is that they make familiar geometric design concerns more explicit and provide a technical basis for asking better questions during scoping. For municipal practice, the important output is not the direct adoption of models or thresholds, but the translation of recurring geometric issues into practical prompts that can be considered before a rehabilitation, resurfacing, stormwater, widening or safety project is fixed in scope.

3.1 Three-dimensional alignment and driver perception

The first major prompt is that the road should be considered as a three-dimensional operating environment, not only as separate horizontal, vertical and cross-sectional elements. De Santos-Berbel et al. (2025) highlight that alignment coordination can affect how drivers perceive the road ahead, including whether curves are visible, whether the path reads clearly and whether sight distance is affected by the interaction between plan and profile. This is especially important on existing roads, where the designer's freedom to correct alignment may be limited.

For municipal projects, the practical question is whether the existing road 'reads' safely from the driver's perspective. A pavement rehabilitation or stormwater project may retain the existing centreline and profile, but that does not mean the alignment should be accepted without a basic visual and consistency screen. Where horizontal and vertical curvature overlap, where a curve begins near a crest or sag, or where a constrained corridor limits visibility, the project team should ask whether a more detailed geometric review is required before the scope is locked.

This does not mean that every project must include a full three-dimensional redesign. It means that significant municipal road investments should include a quick screen for hidden alignment, sight-distance and driver-perception issues. If the screen identifies no material concern, the project can proceed within its original scope. If it identifies a concern, the municipality can decide whether the response is operational, a consultant design-scope item, or a separate capital intervention.

3.2 Geometric consistency and corridor-to-element screening

The second major prompt is that geometric consistency should be considered at corridor level before isolated elements are reviewed. The geometric design consistency review shows that consistency can be assessed through several lenses, including operating speed, speed differentials, driver

workload, alignment indices and driver perception (Sharma et al. 2026). The common principle is that drivers should not encounter unexpected changes in the road environment that require sudden or uncomfortable adjustment.

For practical use, this supports a two-stage approach. The first stage is a corridor-level screen: does the road function, speed environment and sequence of elements appear consistent? The second stage is an element-level screen: which curve, transition, sight-distance restriction, crossfall issue or constrained section requires closer review? This matters because budgets seldom allow every element of a road to be corrected. A practical screen should therefore help teams identify where the risk is concentrated.

This approach also avoids treating geometric design as a late compliance check. Instead of asking only whether individual elements meet minimum criteria, the project team asks whether the road as a whole is understandable and proportionate to its function. This is particularly relevant on municipal arterials, peri-urban links, industrial routes and former rural-style roads that now operate under different traffic and land-use conditions.

3.3 Road function, sight distance and vertical profile

Sight distance is a recurring issue in the reviewed literature, but its municipal relevance depends strongly on road function. Stopping-sight-distance and vertical-curve studies revisit assumptions about what drivers can see, how they react, and how vertical profile affects available visibility (Megat-Johari et al. 2025; Rinaldi et al. 2021). Some of these studies move towards parameter review or risk-based calibration, which is beyond the scope of this paper. However, they reinforce a practical scoping question: is visibility part of the real road problem?

For municipal projects, this question becomes important where the road carries buses, taxis, freight, emergency vehicles or industrial traffic; where the corridor includes underpasses, bridge approaches, crests, sags or constrained vertical profiles; or where night-time visibility and lighting are concerns. A resurfacing project on a low-speed local street and a resurfacing project on a freight route approaching an underpass do not activate the same geometric questions.

The proposed screen should therefore begin with road function. If the road is a freight route, public transport route, peri-urban link or constrained corridor, sight distance and vertical profile may need to be checked before the project is treated as routine rehabilitation. The response may still be modest, such as vegetation clearing, signage, lighting, delineation or speed management. In other cases, it may require a formal sight-distance check, local profile adjustment, or a larger capital intervention.

3.4 Operating speed and horizontal-curve consistency

Several reviewed papers reinforce that drivers respond to the geometry they experience, not only to design speed or posted speed. Studies on operating speed and horizontal alignment show that curve radius, approach conditions, gradient, vehicle class and tangent-to-curve transitions can influence how drivers adjust speed through a road section (Tottadi & Mehar 2024; Godumala & Ravi Shankar 2024; Atif et al. 2026). These papers are not transferred as local speed-prediction models, but they support the operating-speed lens.

The municipal prompt is straightforward: where an existing alignment is being retained, does the likely operating-speed environment remain compatible with the sequence of tangents, curves and grades? This is particularly important where long tangents feed into sharper curves, where curves are sight-restricted, where road function includes freight or mixed traffic, or where a corridor has higher operating speeds than its surrounding municipal context might suggest.

The reviewed operating-speed papers also support the need to consider vehicle mix. A curve may be experienced differently by light vehicles, buses, trucks, taxis or motorcycles. On mixed-traffic municipal routes, the project team should not assume that a curve is acceptable simply because the existing road has been in use for many years. If the route function has changed, or if heavier vehicles now use the corridor, the same retained geometry may create a different operational problem.

3.5 Curve widening, design vehicle and constrained geometry

The reviewed research also points to the need to prioritise horizontal-curve issues rather than treating all curves equally. Work on horizontal-curve safety and applied consistency screening supports the idea that curve sequence, approach conditions, speed environment and local geometry can help identify which locations deserve closer attention (Chakraborty & Gates 2024; Igene & Ogirigbo 2021). In municipal practice, this matters because project budgets may allow only selected improvements.

Curve widening and design-vehicle papers add a practical detail to this discussion. Günay (2023) shows that curve widening is not simply a matter of adding pavement width; the way widening is introduced can affect edge definition, vehicle path and curve readability. Ciampa & Olita (2022) similarly reinforce that severe or hairpin-like curves should not be treated as ordinary retained geometry where road function or design vehicle demands more careful review.

For municipal scoping, the prompt is whether the retained curve is suitable for the road function and expected users. A tight curve on a residential access street may require a different response from a tight curve on a bus, freight, refuse, emergency or industrial route. Where widening, resurfacing or drainage works are already planned, it may be possible to include targeted curve refinement, swept-path review, shoulder treatment, delineation or local widening without turning the whole project into a major realignment.

3.6 Superelevation, runoff and future local evidence

Superelevation, runoff and crossfall appear in the reviewed papers mainly as specialised design-method issues rather than as the core of the municipal checklist. Papers dealing with superelevation runoff and local parameter review show that some design assumptions may need to be revisited when terrain, vehicle fleet, operating conditions or local context differ from the assumptions embedded in guidance (García-Ramírez et al. 2025; Trakakis et al. 2025). These papers are used cautiously in this paper.

Their practical value is that they remind municipal teams that resurfacing, widening and drainage works may affect crossfall, superelevation and runoff. A project that changes the surface, edge, shoulder, drainage path or curve widening detail may also change how water drains, how vehicles track and how drivers experience the curve. The screen should therefore ask whether these issues require design input where curve-related works are involved.

The same papers also support a future-research point. South African municipal, provincial and national road environments have their own vehicle mixes, operating conditions, design histories and upgrade constraints. International studies can help identify useful questions, but local evidence is needed to refine the answers. This reinforces the position that the present paper is an interim practice translation: it transfers questions into municipal scoping practice while highlighting the need for more South African geometric design research.

4. PROPOSED MUNICIPAL GEOMETRIC SCOPING SCREEN

The synthesis above points to a practical need for an early-stage scoping screen. The screen is not intended to replace detailed geometric design, a road safety audit or professional judgement. It is intended to help municipal project teams identify whether a road project that is initially framed as rehabilitation, resurfacing, stormwater, widening, safety or pavement work

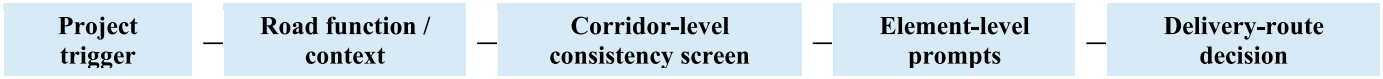


FIGURE 1: *Proposed municipal geometric scoping-screen logic*

may also contain a geometric consistency issue that should be considered before the scope is fixed.

The screen should also be distinguished from a road safety audit. The proposed screen is applied before the project brief, budget and delivery route are fixed. Its purpose is to identify whether geometric input, further design assessment or later safety review should be included in the project scope. A road safety audit, where required, remains a separate formal process that reviews the safety implications of a design or existing road at defined stages. The screen should therefore not be used to bypass formal safety review; it should help identify when such review or specialist input may be needed.

The screen follows five steps: project trigger, road function and context, corridor-level consistency, element-level prompts and delivery-route decision. The sequence is important. It avoids starting with isolated technical checks before the project team has first considered the function of the road and whether the corridor as a whole presents a consistency, visibility or driver-expectancy concern.

4.1 Step 1: Identify the project trigger

The screen is not intended for every minor maintenance activity. It is most useful where a project creates a material opportunity to affect the road environment and one or more activation flags are present. Typical project triggers include rehabilitation, resurfacing, pavement strengthening, stormwater improvements, culvert or bridge works, widening, shoulder works, public transport improvements, freight-route improvements and localised safety interventions.

The purpose of this step is to ask a simple question: is the municipality about to spend money on a road while assuming that the retained geometry is acceptable? The trigger is not project value alone; it is the combination of project opportunity and geometric risk indicator. A routine pothole repair would not normally activate the screen. A resurfacing, stormwater, culvert, widening or safety project on a bus route, freight route, peri-urban link, constrained curve or visually confusing corridor probably should.

4.2 Step 2: Identify road function and context

The next step is to identify how the road functions and who uses it. This is necessary because the same geometric feature can create different levels of concern depending on the road environment. A tight curve on a low-speed residential street does not raise the same scoping questions as a similar curve on a bus route, industrial road, freight corridor or peri-urban link.

The road-function screen should consider whether the road operates as a freight or industrial route, bus or taxi route, urban arterial, distributor, peri-urban link, rural-style municipal road, residential access road, pedestrian-heavy corridor, constrained underpass or bridge approach, or stormwater/flood-prone route. These contexts help determine which element-level prompts are relevant. For example, freight and bus routes may activate swept-path, curve widening, sight-distance and vertical-profile prompts, while residential and pedestrian-heavy environments may place greater emphasis on speed management, visibility and vulnerable road users.

4.3 Step 3: Undertake a corridor-level consistency screen

Before checking isolated elements, the project team should first consider whether the road corridor reads consistently to drivers. The corridor-level screen should ask whether there are sudden changes in speed environment, unexpected curve sequences, hidden alignment changes, poor visual guidance, constrained sight distance or locations where horizontal and vertical alignment may combine to create driver-perception issues.

This step reflects the principle that geometric risk is not always located in one obvious element. A curve may be problematic because of the tangent that precedes it, the vertical profile that masks it, the road function it now serves, the speed environment created by the wider corridor, or the way drivers perceive the road in three dimensions. The corridor-level screen therefore helps the project team decide where more detailed checks should be focused.

4.4 Step 4: Apply element-level prompts where relevant

Where the corridor screen identifies potential concern, the project team should apply relevant element-level prompts. These prompts should be selected based on road function, project type and observed risk, not applied mechanically to every road.

The purpose of these prompts is not to generate a full design checklist. Their purpose is to prevent relevant geometric questions from being missed at the point where the project scope is still flexible. Some prompts will lead to no further action. Others may lead to a note in the design brief, a small operational intervention, a defined consultant task, or a decision to defer a larger issue to a separate project. Low-cost measures should be used where

TABLE 2: *Activation flags for applying the scoping screen*

Activation flag	Examples	Reason for applying the screen
Road function	Arterial, distributor, freight, bus/taxi, industrial or peri-urban route.	Higher speed, heavier vehicles or a stronger movement function can make retained geometry more significant.
Geometry	Sharp curve, crest, sag, underpass, bridge approach, steep grade or constrained cross-section.	May create sight-distance, operating-speed or driver-expectancy concerns.
Safety / operations history	Run-off-road or pedestrian crashes, guardrail damage, repeated complaints or edge failures.	May indicate that the visible defect is not the whole problem.
User mix	Buses, taxis, trucks, refuse or emergency vehicles, pedestrians or cyclists.	May trigger swept-path, visibility, speed-management or crossing-safety prompts.
Project opportunity	Resurfacing, widening, stormwater, culvert/bridge, shoulder or localised safety works.	Allows targeted improvement before the scope is fixed.
Visual concern	Poor curve readability, hidden alignment change, poor delineation, or vegetation/wall/barrier obstruction.	May indicate that the road does not read clearly to drivers or pedestrians.

TABLE 3: *Municipal geometric scoping prompts*

Prompt area	Early scoping question	Typical evidence to check	Likely delivery route
Sight distance and vertical profile	Is visibility part of the road problem at crests, sags, underpasses, bridge approaches or constrained profiles?	Survey/long section; field review; photographs; obstructions; night-time or lighting concern; crashes/complaints.	Operations for clearing, signs or lighting; design scope for sight-distance/profile assessment; capital for major correction.
Road function and user mix	Does the road carry buses, taxis, freight, refuse/emergency vehicles, pedestrians or mixed traffic that alters the concern?	Classification; land use; routes; vehicle mix; complaints; operating history.	Internal screen; design scope for design vehicle, tracking, sight distance or speed review.
Tangent-to-curve transition	Does retained geometry demand an unexpected speed reduction or create a driver-expectancy issue?	Curve sequence, radius and tangent length; speed observation; drive-through; crash/complaint history.	Operations for warning, delineation or speed management; design scope for speed/geometry review or local refinement.
Horizontal-curve risk and prioritisation	Are there curves or curve sequences that need closer review before the scope is fixed?	Sharp, reverse or compound curves; long tangents; edge/guardrail damage; run-off-road history; sight restrictions.	Mixed / needs triage: operations for low-cost safety; design scope for geometry/sight-distance review; capital for major correction.
Curve widening and swept path	Is the retained curve suitable for the road function and design vehicle?	Swept path; lane/shoulder width; radius; kerb/edge condition; bus or truck tracking; edge failure.	Design scope for widening or tracking review; capital where land, services, structures or major widening are affected.
Three-dimensional alignment coordination	Does the road read correctly where horizontal and vertical alignment interact?	Plan/profile overlay; 3D model; drive-through; photos/video; field inspection; sight-distance review.	Design scope; capital where substantial alignment or profile correction is required.
Superelevation, runoff and crossfall	Could resurfacing, widening, shoulder or drainage changes affect crossfall, runoff, ponding, comfort or curve safety?	Crossfall survey; drainage path; superelevation transition; edge levels; resurfacing thickness; ponding complaints.	Design scope, often linked to pavement or drainage works.
Low-cost safety treatment	Can warning, delineation, markings, vegetation clearing or speed management reasonably address the issue?	Field inspection; signage and markings; vegetation; visibility; crash/complaint history.	Internal operations / maintenance unless the underlying issue requires design input.

they address the identified risk or provide an interim treatment; they should not be used to normalise a known geometric deficiency where the operating risk remains unacceptable.

4.5 Step 5: Decide the delivery route

The final step is to classify each flagged issue according to the likely response route. This is the main practical output of the screen.

As an illustrative example, consider a resurfacing project on a peri-urban municipal distributor that also serves buses, taxis and occasional freight traffic. The visible project driver may be pavement condition, but the road-function screen identifies a higher-order movement role. A corridor-level review then notes a long tangent leading into a sharper curve near a crest, with poor delineation and vegetation partly restricting visibility. The element-level prompts would activate checks for tangent-to-curve speed transition, sight distance, curve readability and design-vehicle tracking. The delivery-route decision may then separate the response into operations or maintenance items such as vegetation clearing, chevrons and road markings; consultant-scope items such as sight-distance and swept-path review; and any major profile correction or realignment as a deferred capital-planning item if it cannot reasonably be accommodated in the resurfacing project.

The delivery-route decision is important because it helps prevent two opposite risks. The first risk is scope creep, where every identified issue is added to the current project without regard to budget, mandate or procurement route. The second risk is missed opportunity, where a modest and logical improvement is ignored because it falls outside the initiating department's immediate project driver.

Where a flagged item falls outside the initiating department's scope, the screen can support a deliberate coordination decision. For example, a stormwater or bridge project may reveal that the preceding curve requires a modest safety or geometric improvement. If identified early, the municipality could decide whether the roads maintenance or road safety unit should co-fund the item, whether it should be included in the consultant's design brief,

TABLE 4: *Delivery-route decision matrix*

Finding from scoping screen	Likely response route	Required output / examples
Can be addressed through routine operational measures.	Internal operations / maintenance	Maintenance instruction or minor works note: signs, chevrons, markings, delineation, vegetation clearing, lighting review or minor speed-management measures.
Requires technical assessment or design input but can be incorporated into the current project.	Consultant design-scope item	Design brief or drawing mark-up: sight-distance/swept-path checks, curve widening detail, crossfall/superelevation review, local profile refinement or 3D alignment review.
Is significant and cannot reasonably be resolved within the current project scope.	Separate capital intervention	Capital register or future-project note: major realignment, land, retaining structures, service relocation, bridge/culvert widening, profile correction or reconstruction.
Cuts across departments or funding sources.	Mixed / needs triage	Documented coordination decision, e.g. a stormwater project reveals a curve-safety issue, a bridge/culvert upgrade reveals a sight-distance/approach issue, or pavement works identify local widening.

whether it can be packaged into the same contract, or whether it should be recorded as a future capital intervention. Where procurement rules allow, a defined small work package may also create an opportunity for emerging contractor participation. The intention is not to encourage uncontrolled scope expansion, but to support informed and documented decisions before procurement and construction limit the available options.

The proposed screen therefore converts the literature synthesis into a practical municipal workflow. It begins with the project trigger, filters the issue through road function and context, checks the corridor before isolated elements, applies targeted prompts only where relevant, and ends with a delivery-route decision. This keeps the tool proportional to municipal practice while retaining the key lesson from recent geometric design research: road geometry, driver perception, operating speed and safety should not be treated as isolated concerns.

5. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Using the screen judiciously

The proposed screen should be used as an early scoping aid, not as a substitute for detailed geometric design, a road safety audit or professional judgement. Its value is in helping municipal teams ask the right questions before a project brief, budget or tender scope is fixed. In many cases the screen may confirm that no further geometric action is required. In other cases it may identify a small operational intervention, a consultant design-scope item or a more substantial issue that should be recorded for a future capital project.

The screen is therefore intended to support proportionate decision-making. It should not be used to expand every rehabilitation, resurfacing or stormwater project into a geometric redesign. Equally, it should help avoid the opposite problem, where a project proceeds as routine roadworks while a visible geometric, safety or operating-speed concern is left unaddressed. The practical purpose is to define the road problem more completely before deciding what type of intervention is appropriate.

The screen also has value where municipal responsibilities are divided between departments or funding streams. A stormwater or bridge project may, for example, reveal that a preceding curve requires modest delineation, widening, visibility improvement or speed-management treatment. If identified early, the municipality can decide whether the issue should be funded by the initiating project, co-funded by a roads maintenance or road safety unit, packaged into the same contract, or recorded as a separate intervention. Where procurement rules allow, defined small work packages may also create opportunities for emerging contractor participation. The intention is not to encourage uncontrolled scope expansion, but to support deliberate and documented decisions before procurement and construction limit the available options.

5.2 Main conclusions

Municipal road projects are often initiated in response to visible defects such as pavement failure, drainage problems, localised safety concerns, widening needs or public transport pressure. These are valid project drivers, but they do not always represent the whole road problem. The reviewed research reinforces that road geometry, driver perception, operating speed, sight distance, curve treatment, vehicle tracking and alignment coordination can influence how an existing road operates, even where major realignment is not feasible.

The main conclusion of this paper is that municipalities do not need full geometric redesign before every tender, but they do need enough front-end review to know what kind of problem they are procuring a solution for. A conceptual geometric scoping screen can help project teams identify whether a flagged issue is likely to be an internal operations or maintenance matter, a consultant design-scope item, a separate capital intervention, or a mixed issue requiring departmental coordination.

The review also shows that recent international geometric design research should not be transferred directly into South African municipal practice as design thresholds, models or standards. Its more appropriate value is to help formulate practical questions. In this sense, the paper transfers questions, not answers. The proposed screen uses these questions to make selected parts of experienced geometric-design judgement more visible, repeatable and available earlier in municipal project scoping.

A further conclusion is that South African road authorities, consultants and universities should contribute more actively to local geometric design research. The absence of South African municipal studies in the focused review is a limitation, but it is also a professional opportunity. More local work is needed on operating speed, design consistency, mixed traffic, sight distance, existing-alignment upgrades and constrained municipal corridors.

5.3 Recommendations

It is recommended that municipalities pilot the proposed scoping screen on selected rehabilitation, resurfacing, stormwater, widening and safety projects before tender scope is finalised. The screen should be applied particularly where municipal roads operate as arterials, peri-urban links, freight or industrial routes, bus or taxi corridors, constrained underpass or bridge approaches, steep routes, or roads with meaningful speed transitions.

The screen should be used to record a simple delivery-route decision for each flagged issue. The decision should indicate whether the issue can be addressed through internal operations or maintenance, should be included in the consultant's design scope, requires a separate capital intervention, or needs cross-departmental triage. This record can help distinguish justified scope additions from uncontrolled scope creep.

Municipalities and consultants should also use the screen to support multidisciplinary scoping discussions. Pavement, stormwater, structures, road safety, traffic, transport planning and asset-management teams may each see different parts of the road problem. A shared scoping screen can help these teams identify where specialist geometric input is required before briefs and budgets are fixed.

Finally, the proposed screen should be refined through practice. It should be tested on real municipal corridors, compared with project outcomes and updated as South African evidence develops. Future research should examine operating-speed behaviour, geometric consistency, curve safety, sight-distance constraints, heavy-vehicle movement and retrofit opportunities on South African municipal and provincial road networks.

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