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Fauna-sensitive road design in practice: lessons from Australia

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Fauna-sensitive road design (FSRD) seeks to reduce the ecological impacts of transport infrastructure, yet its application in Australia remains inconsistent and context-dependent. This study examines how FSRD is shaped by policy and institutional settings in Queensland and Victoria, combining Institutional Grammar Tool (IGT) analysis of key guidance documents with interviews from 22 practitioners. Results revealed a strong reliance on non-binding language, with guidance framed as recommendations rather than enforceable requirements. Practitioners identified barriers including unclear legislation, poor data access, fragmented responsibilities, and limited influence during early project design. Suggested improvements focused on clearer specifications, stronger legislative mandates, improved interagency coordination, and national standardisation. The findings highlight that FSRD is as much a governance challenge as a technical one. This study provides a timely baseline for assessing reforms such as Queensland's 2024 Fauna Sensitive Transport Infrastructure Delivery (FSTID) Manual and underscores the need to further embed ecological priorities into infrastructure planning.

KEYWORDS: road ecology; fauna-sensitive road design; linear transport infrastructure; sustainable development; transport policy; environmental impact assessment; transport planning; environmental planning

1. Introduction

In Australia, growing public concern and rising government expectations have prompted greater attention to environmental management across sectors. Recent research highlights technological and governance advances natural resource management, water policy, and sustainability transitions (Jat *et al*. 2025; Komnos *et al*. 2025; Melnychuk *et al*. 2025). Yet, despite this momentum, the ecological impacts of linear transport infrastructure (LTI) – particularly roads and railways – remain underexamined in Australian planning discourse. This is surprising given the well-documented role of LTI in driving habitat fragmentation, road mortality, population isolation, and long-term biodiversity decline (Johnson, Matthews, *et al*. 2022; van der Ree, Smith, and Grilo 2015).

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Globally, road ecology has emerged as a field dedicated to understanding and mitigating these effects. Ecological impacts from LTI cannot be adequately addressed through traditional offset-based frameworks alone and must instead be considered throughout all phases of infrastructure planning, design, construction, and operation (Jaeger *et al*. 2011; van der Ree, Smith, and Grilo 2015). While a mitigation hierarchy prioritises avoidance, then minimisation, mitigation, and finally offsetting, avoidance is often deprioritised in favour of reactive or compensatory approaches (van der Grift *et al*. 2013).

FSRD offers a proactive approach to planning for biodiversity by embedding ecological knowledge into transport design. It includes a range of measures – such as fauna underpasses, canopy bridges, exclusion fencing, and habitat restoration – that aim to reduce wildlife mortality and maintain ecological connectivity. In jurisdictions such as the European Union, FSRD principles are supported by a strong legal and policy framework (e.g., the Birds and Habitats Directives) that require integration of biodiversity considerations throughout the entire infrastructure project lifecycle (Johnson, Matthews, *et al*. 2022; Papp *et al*. 2022; Trocmé 2005).

By contrast, Australia relies primarily on voluntary guidance – most notably in Queensland and Victoria – developed more than a decade ago (DTMR 2010; VicRoads 2012). A recent systematic review finds FSRD and road-ecology concepts are seldom engaged within Australian transport planning literature, constraining diffusion into mainstream practice (Johnson, Jones, *et al*. 2022). In the absence of a national framework with minimum standards, performance expectations, and clear links to monitoring and maintenance, implementation tends to be discretionary and approval-driven, with variable uptake and weak accountability for ecological outcomes.

In Queensland and Victoria, state-level manuals provide design specifications and ecological rationale. However, their use is non-binding and often contingent on project priorities, funding, and institutional will. While notable examples of wildlife crossings and fencing exist (Smith, van der Ree and Rosell, 2015; Taylor and Goldingay 2003; Young, King, and Allen 2023), few are monitored beyond installation (but see Jones *et al*. 2010; Van Der Ree 2006; van der Ree *et al*. 2009), and responsibility for maintenance and evaluation is frequently ambiguous (Soanes *et al*. 2024; Taylor and Goldingay 2010). Prior studies highlight legislative fragmentation, discretionary tools, and the absence of enforceable requirements as key barriers (Johnson, Jones, *et al*. 2022; Johnson, Matthews, *et al*. 2022).

This study builds on that earlier work by exploring how FSRD is interpreted and enacted by practitioners – those responsible for integrating ecological knowledge into transport systems. This study does not assess the ecological effectiveness of FSRD measures themselves, but rather the institutional and policy frameworks that govern their implementation. Using a mixed-methods approach that combines institutional document analysis with semi-structured interviews, the paper investigates how institutional arrangements, regulatory settings, and professional cultures influence FSRD implementation in Queensland and Victoria. In doing so, it argues that the success of FSRD is not merely a matter of technical guidance, but of governance: who decides what gets built, how priorities are set, and which forms of knowledge are seen as legitimate in the process of infrastructure development.

2. Methodology

2.1. Analytical framework: Institutional Grammar Tool

To investigate how FSRD is institutionally framed within government policy, this study applied the Institutional Grammar Tool (IGT), a linguistic coding framework

developed by Crawford and Ostrom (1995). The IGT allows for the disaggregation of institutional statements into five syntactic elements – Attribute, Deontic, aIm, Condition, and Or Else (ADICO) – which are used to classify statements as shared strategies, norms, or rules. These classifications provide insight into whether provisions are advisory, expected, or enforceable.

The IGT was selected for its demonstrated utility in public policy and environmental governance research (Clement, Moore, and Lockwood 2015; Siddiki *et al*. 2011), particularly in evaluating the structure, consistency, and regulatory strength of institutional arrangements. In this study, the IGT was applied to three key documents that guide FSRD implementation in Queensland and Victoria:

- *MRTS51 Environmental Management* (Queensland)
- *Fauna-Sensitive Road Design: Volume 2* (Queensland)
- *Fauna-Sensitive Road Design Guidelines* (Victoria)

Each document was reviewed manually to identify statements relevant to fauna mitigation and transport infrastructure planning. Statements were extracted into a tabular matrix and coded using the ADICO framework (Tables 1 and 2) to determine their institutional form (i.e. strategy, norm, or rule) and to assess internal consistency and clarity (Table 3). Particular attention was given to identifying whether institutional provisions were actionable and enforceable or merely advisory in nature (Table 4). The *Fauna Sensitive Transport Infrastructure Delivery Manual* (FSTIDM; DTMR 2024)

Table 1. Key documents for IGT analysis.

Policy document	Study area	Condition	Purpose of policy
Specifications MRTS51 Environmental Management	Queensland (DTMR)	Statutory	Outlines the environmental management requirements for construction contracts under the Queensland Department of Transport and Main Roads. Includes measures to protect significant vegetation and native fauna.
Fauna Sensitive Road Design Volume 2 Chapters 3-7	Queensland (DTMR)	Non-statutory	Offers guidelines for best practices to mitigate the impact of road infrastructure on wildlife.
Fauna Sensitive Road Design Guidelines	Victoria (VicRoads)	Non-statutory	Presents a framework for implementing FSRD in road projects.

Table 2. Subcomponents of the IGT syntax including the modifications applied in this study.

Subcomponent	Description
Attribute	Individual/organisation to which it applies
Deontic	What is permitted, obliged, or forbidden (e.g. must, may, shall, shall not, will, etc.)
aIm	The goal or action to which the deontic refers to
Condition	When, where, how, or why the aim applies
Or else	Punitive action if a rule is not adhered to (e.g. fine)
oBject	Inanimate or animate part of a statement that receives the action (e.g. plan or policy)

Table 3. Description of institutional statements.

Type of statement	Description	Subcomponents
Shared strategies	Statements for mutual understanding to guide behaviour, effective with stable actor preferences and their active pursuit and optimisation.	AIC/ABIC
Norms	Statements that rely on collective perceptions of appropriate behaviour in each context. They work best when individuals act in alignment with their beliefs, values, and identity.	ADIC/ABDIC
Rules	Statements and actions contradicting these standards become ineffective or may face sanctions from authorised actors.	ADICO/ABDICO

Source. Clement, Moore, and Lockwood (2015).

released by the Queensland Department of Transport and Main Roads in June 2024 was not included in this analysis, as it was published after this study had concluded.

This analysis provided a structural overview of how FSRD is conceptualised in formal guidance documents and informed the subsequent comparison with on-ground practitioner experience.

2.2. Participant recruitment and inclusion criteria

To complement the institutional analysis and understand how FSRD is interpreted and applied in practice, the study incorporated semi-structured interviews with professionals working in academia, public service, and the private sector (e.g., consulting). Participants were recruited using purposive and snowball sampling methods, beginning with professional contacts and followed by referrals.

Eligibility criteria required that participants had direct experience with LTI projects involving ecological or biodiversity components, particularly where FSRD measures were considered or implemented. Participants were drawn from three sectors – government agencies, consulting firms, and academia – with representation from both Queensland and Victoria.

A total of 22 participants, out of 28 contacted, were interviewed between June 2022 and January 2024. While small in number, this sample represents a substantial

Table 4. Illustrative IGT application of the IGT on policy statements present in the DTMR FSRD guidelines (2012).

	Statement	Subcomponent	Attribute	aIm	Deontic
1	"For existing roads, the principles can be adopted during repair and/or maintenance."	ADIC	Project Manager (implied)	Adopt	'can'
2	"Connectivity between habitats at a regional scale (at the minimum) should be considered, with particular regard for transport infrastructure, distribution of habitats and other potential barriers such as built-up areas."	ADIC	Project Manager (implied)	Consider	'should'
3	At a regional scale, fauna mitigation structures are required to maintain necessary contact within and between populations of animals (permeability concept).	ADIC	DTMR	Maintain	'must' (implied)

proportion of the specialised FSRD practitioner community in Australia. The study reached thematic saturation, meaning no new insights emerged in the final interviews, and the resulting data represented a range of perspectives and experiences.

2.3. Semi-structured interview procedure

Interviews were conducted online or *via* telephone and followed a semi-structured format designed to elicit detailed reflections on institutional processes, project decision-making, and implementation challenges. Interviews typically lasted between 45 and 75 min.

An interview guide was used to ensure consistency while allowing flexibility for participants to elaborate on issues of relevance to their expertise (see Supplementary A). All interviews were audio recorded with participant consent, transcribed verbatim, and de-identified. Ethical clearance was granted by Griffith University's Human Research Ethics Committee (GU Ref. No.: 2022/006). Participants were informed of their rights and offered the opportunity to review their transcripts.

2.4. Thematic coding and analytical integration

Interview transcripts were analysed using reflexive thematic analysis (Braun *et al.* 2023), supported by NVivo 14 software. Coding began with a deductive framework based on the study's research questions and previous literature, then evolved inductively as patterns emerged from the data. Thematic categories were refined iteratively and reviewed across cases to ensure consistency and conceptual depth.

Major coding categories included:

- Professional background and experience with FSRD
- Institutional documents and tools shaping practice
- Barriers to implementation (e.g., regulatory gaps, knowledge constraints)
- Facilitators (e.g., leadership, inter-agency collaboration)
- Monitoring, maintenance, and evaluation practices
- Perceived opportunities for reform

To strengthen analytical validity, coded interview data were triangulated with findings from the IGT analysis. This comparative approach allowed for the identification of alignments and mismatches between formal policy structures and lived practitioner experiences. It also revealed areas where institutional design lacked clarity or failed to translate into practice.

3. Results

3.1. IGT analysis

Application of the IGT to three publicly available documents, relevant to FSRD guidance, revealed notable variation in institutional expression and directive strength between state jurisdictions (Table 5). The *Queensland TMR Specifications MRTS51 Environmental Management* included 79 policy statements, of which 85.9% were shared norms and 14.1% were rules. No shared strategies were identified. These

Table 5. Analysis of IGT components in FSRD and related documents in Australian Road Transport Departments.

IGT component	Queensland TMR specifications MRTS51 Environmental Management	Queensland FSRD manual vol. 2	Victoria FSRD guidelines
Shared Strategies	0	64 (25.1%)	58 (22.4%)
Shared Norms	68 (85.9%)	191 (74.9%)	201 (77.6%)
Rules	11 (14.1%)	0	0
Total statements	79	255	259
Attributes (all)	The Contractor – **61** (8 implied) The Principal – **9** The SQEP – **5** The Administrator – **4**	DTMR – **247** Fauna spotter/catcher – **8**	The project team (VicRoads) – **233** The Consultant – **18** Environmental/Biodiversity Officer – **13** VicRoads – **12** Environmental Officer (regional) – **8** The Contractor – **4**
aIms (top 5)	Comply – **8** (4 implied) Responsible – **7** (2 implied) Advise – **7** (3 implied) Monitor – **6** (1 implied) Engage – **4**	Consider – **65** (32 implied) Identify – **21** (14 implied) Minimise/Reduce – **14** (1 implied) Educate/Encourage/Facilitate/Suggest – **13** (3 implied) Build/Construct/Install – **13** (9 implied)	Consider/Consult – **82** (52 implied) Build/Install – **35** (23 implied) Design/Develop/Establish – **33** (18 implied) Implement/Include/Provide – **26** (11 implied) Inspect/Monitor/Record/Measure – **18** (3 implied)
Deontics (all)	Shall – **45** Will – **26** (18 implied) Must – **5** (3 implied) May – **3**	Should – **99** (73 implied) Must – **64** (29 implied) May – **23** (5 implied) Can – **3** Will – **1**	Should – **128** (25 implied) Must – **47** (32 implied) Will – **17** (1 implied) May – **12** (4 implied) Can – **0**

Note. Values in bold indicate the total number of policy statements encountered in relation to the identified IGT component.

provisions were almost exclusively applicable during construction, with limited relevance to longer-term FSRD implementation. Attributions were mostly to third-party contractors ($n = 61$), while just four directives were attributed to the Department itself (as "The Administrator"). Deontics leaned toward obligation, with "shall" and "will" statements dominating and a clear emphasis on compliance, responsibility, and monitoring.

In contrast, the *Queensland Fauna Sensitive Road Design (FSRD) Manual Vol. 2* yielded 255 policy statements, including 64 shared strategies and 191 shared norms. No rules were recorded. Most statements were attributed to the Department of Transport and Main Roads (DTMR) ($n = 247$), but the directive force was comparatively weak: 99 statements used "should" and only 64 used "must". Goals frequently referenced discretionary language such as "consider", "identify", or "minimise".

Similarly, Victoria's *FSRD Guidelines* contained 259 policy statements, with 58 shared strategies and 201 shared norms, again with no rules. The majority of statements were attributed to "The Project Team" ($n = 233$), with deontics again favouring non-mandatory language ("should", $n = 128$; "must", $n = 47$). These patterns collectively highlight a consistent preference for voluntary guidance over enforceable obligations across jurisdictions, limiting the extent to which FSRD can be treated as a regulated practice.

3.2. *Interview analysis*

Twenty-two professionals participated in semi-structured interviews. Participants represented a cross-section of sectors (state and local government, private consulting, academia), disciplines (engineering, ecology, project management), and regions (Queensland $n = 15$; Victoria $n = 7$), as detailed in Table 6 and Supplementary B. The sample included highly experienced practitioners – 11 with more than 15 years of industry experience and 6 with equivalent FSRD-specific experience – alongside early-career professionals. This ensured both breadth and depth of insight into contemporary FSRD practice.

3.2.1. *Barriers to FSRD implementation*

Participants consistently pointed to institutional constraints and regulatory ambiguity as primary barriers to effective FSRD delivery. The most frequently cited impediments were "inadequate legislation, policy, or guideline" ($n = 20$ participants, 106 references), "institutionalised procedures and attitudes" ($n = 18$, 69), and "limited knowledge"

Table 6. Categories and numbers of interview participants.

Region	Sector	Profession	Specialisation
Queensland (15)	State Government (5) Private Industry (7) Local Government (3)	Project Management (9) Consulting (4) Academia (2)	Road ecology (3) Engineer (6) Ecology (2) Botany (2) Environment – general (2)
Victoria (7)	State Government (3) Private Industry (3) Local Government (1)	Project Management (4) Consulting (3) Academia (2)	Road Ecology (4) Engineer (2) Environment – general (1)

($n = 19$, 68), with respondents emphasising the absence of binding mandates, overlapping responsibilities, and enforcement gaps. Operational challenges were also prominent, including "design conflicts" ($n = 13$), "beyond project or position scope" limitations ($n = 13$), and persistent "miscommunication and coordination" issues ($n = 15$, 44). Budgetary and administrative concerns (e.g. "limited budget", "project mismanagement") reinforced the perception that ecological objectives are frequently deprioritised in project planning.

3.2.2. *Facilitators of FSRD practice*

Several factors were cited as enabling FSRD implementation. These included public perception ("public image", $n = 13$), growing "practitioner awareness" ($n = 10$), and the "perceived risk of infringement" ($n = 11$), particularly in high-profile projects or those involving community scrutiny. However, references to strategic levers such as "international commitments" or "corridor mapping" were rare, indicating that larger-scale planning tools and global policy frameworks remain weakly integrated in practice.

3.2.3. *Recommendations for improvement*

Recommendations centred on structural and procedural reforms. The most cited was the need for "clearer guidance and specifications" ($n = 15$), such as standardised templates and minimum design criteria. Calls for better "communication and coordination" ($n = 13$) and improved "planning and design" processes ($n = 9$) were common, while several participants stressed the importance of "monitoring" ($n = 9$), "information availability" ($n = 9$), and "accessibility" ($n = 9$). Financial incentives and regulatory enforcement were mentioned less often but flagged as potentially valuable tools to encourage uptake.

3.2.4. *Practice context and measures applied*

Respondents reported implementing a range of FSRD measures, with frequent references to "underpasses and culverts" ($n = 11$), "exclusion fences" ($n = 11$), "canopy bridges" ($n = 10$), and retrofitted structures (e.g. drainage culverts) ($n = 12$). Larger interventions, such as "land bridges" ($n = 8$), were cited less frequently, likely reflecting their cost and non-compulsory status. In terms of project phase, most participants reported FSRD considerations during "planning" ($n = 9$) and "design" ($n = 5$), with far fewer indicating involvement during "construction" ($n = 3$) or "operation" ($n = 2$), revealing limited lifecycle integration.

3.2.5. *Institutional guidance and document use*

Use of formal guidance documents varied widely. While "regional FSRD plans" were the most commonly referenced ($n = 14$), reliance on "infrastructure standards" ($n = 9$) and "internal procedures" ($n = 7$) was also noted. Notably, only 4 participants cited peer-reviewed literature, and 3 were unsure which documents guided their practice. This suggests a strong preference for context-specific, practitioner-oriented resources

over academic or generalised sources – highlighting a key gap in knowledge exchange and the operationalisation of research.

4. Discussion

This study offers one of the first detailed evaluations of FSRD implementation in Australia, combining institutional analysis with practitioner perspectives. While FSRD principles are increasingly referenced in LTI projects, their application remains inconsistent and often falls short of achieving meaningful ecological outcomes.

This is especially problematic given the well-established ecological consequences of roads. LTI fragment landscapes, disrupt ecological processes, and cause direct harm to wildlife through habitat loss, reduced connectivity, and collisions (Fahrig and Rytwinski 2009; Laurance, Goosem, and Laurance 2009; Laurance 2015). Australian studies have reported declines in birds (Johnson, Evans, and Jones 2017; Pell and Jones 2015), amphibians (Hoskin and Goosem 2010), and mammals (Goosem 2001; Van Der Ree 2006). Although use of mitigation tools such as underpasses, land bridges, and exclusion fencing is well documented (Jones and Bond 2010; Jones and Pickvance 2013; McGregor, Wilson, and Jones 2015; McGregor, Matthews, and Jones 2017; Soanes *et al*. 2024; Taylor and Goldingay 2003; van der Ree *et al*. 2009), their deployment remains patchy and insufficiently supported by policy.

Through the application of the IGT to policies in Queensland and Victoria, and 22 semi-structured interviews with transport ecology professionals, this study identifies key systemic limitations. Chief among these are four key themes:

1. Environmental legislation lacks the clarity or authority to support meaningful FSRD implementation;
2. Existing FSRD guidelines remain voluntary and are poorly enforced;
3. Decision-making is hindered by gaps in ecological knowledge, implementation guidance, and organisational capacity; and,
4. Monitoring, data access, and knowledge sharing are insufficient, preventing adaptive management or long-term learning.

These findings reinforce earlier reviews of European and Australian transport sectors (Johnson, Matthews, *et al*. 2022, Johnson, Jones, *et al*. 2022), which noted limited engagement with FSRD in both academic and practical planning. Although the rationale for ecological integration is strong, its operationalisation remains undermined by discretionary frameworks and uneven institutional support. The discussion that follows contextualises these findings and outlines implications for policy, planning, and infrastructure delivery.

4.1. Legislation is ineffective

The analysis highlights a foundational weakness in the legislative environment underpinning FSRD in Australia – despite growing awareness of road impacts, there is no clear, enforceable legal mandate for integrating FSRD into project delivery. Instead, implementation relies heavily on individual interpretation and discretion. Interview participants overwhelmingly identified the lack of legislative clarity, consistency, and enforcement as the most significant impediment to practice – mirroring findings from

Johnson, Matthews, *et al*. (2022; Johnson, Jones, *et al*. 2022), which identified institutional ambiguity and weak legal frameworks as core structural barriers to FSRD uptake.

At the Commonwealth level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) was described as vague and difficult to apply to routine infrastructure projects. Its threshold concept of "significant impact" was widely criticised, with one consultant noting:

> It's defined in the EPBC, but it's wishy-washy. It just uses general terms. You cannot have a reduction in numbers. For available species, it's an impact on a population, and for endangered species, it is an impact on an individual.

Another observed that protection was limited to species formally listed under the Act:

> If cassowaries aren't there, or unlikely to ever be there, then it would not be a trigger. But if there's cassowary activity, I might have to manage it. If there are wallabies in the area that aren't listed, the Commonwealth doesn't care.

Such feedback illustrates that the legislative focus is on individual threatened species, rather than ecological function or connectivity. This narrow scope fails to support broader FSRD measures unless a high-profile species is present – undermining proactive or landscape-scale planning approaches encouraged in the global literature (e.g. Laurance, Goosem, and Laurance 2009; van der Ree, Smith, and Grilo 2015).

State-level legislation introduces further complications. In Queensland, the *Nature Conservation Act 1992* (NCA) was described as overly vegetation-centric given the primary vehicle for threatened species conservation is through the preservation of suitable habitat that is managed under the *Vegetation Management Act 1999* (VMA). As one consultant explained: "Fauna moves, and so the NCA kind of just ignores them. If you protect the [vegetation] community, you protect the fauna." As another explained, this logic becomes problematic as when only vegetation is protected: "There is nothing about the functions they serve or the interactions within them." Victoria's *Fauna and Flora Guarantee Act 1988* (FFGA) was similarly critiqued. Participants described a fragmented system of landholder-specific management plans that lacked integration and often produced unintended consequences. A government officer reflected on kangaroo management: "Each parcel has its own plan … but they're pushing the kangaroos next door, which has its own plan [to push kangaroos next door]. It's hideous."

Even when legal protections exist, implementation is hampered by unclear jurisdictional responsibilities. For instance, Queensland's Department of Environment and Science (DES), as it was known as prior to 2023, can nominate roadside corridors as Nature Refuges, but their protection hinges on agreement from the Department of Transport and Main Roads (DTMR) – an arrangement that has proven unreliable. One consultant described the interdepartmental stalemate:

> They [the DES] don't want to start overriding other state departments' legislation as it is too complicated. One department [DES] has legislation to protect the fragment, but the other department [DTMR] has to agree to it or else they lose the administrative ability to override it.

Notably, this same interagency agreement, which was intended to support such an arrangement, was allowed to lapse in 2010. As one participant bluntly concluded: "This is how bad it is!".

Finally, several participants described legal complications related to land tenure. Private land adjacent to transport corridors often prevents the implementation of FSRD structures or obstructs maintenance.

> You can have a road where wildlife is crossing, but if it's private land on either side, people generally don't want wildlife bridges in their front yards.

In some cases, even vegetation maintenance becomes difficult: "I can't control what our neighbours do … trees grow right up against the fence, and because it's not our land, we can't do anything about it."

Together, these findings illustrate that while laws nominally protect biodiversity, they rarely extend to practical, enforceable mandates for FSRD. The result is a fragmented system in which ecological mitigation depends more on individual interpretation than consistent legal standards – leaving significant gaps between intention and implementation.

4.2. Existing guidelines are voluntary

Despite the existence of formal FSRD guidance – such as Queensland's *Fauna Sensitive Road Design Manual Vol. 2* (DTMR 2010) and Victoria's *Fauna Sensitive Road Design Guidelines* (VicRoads 2012) – their practical application remains inconsistent and largely discretionary. This is reflected in the IGT analysis, which identified an overwhelming dominance of non-binding language. In both jurisdictions, over 74% of statements were framed as shared norms rather than enforceable rules, with permissive terms such as "should", "may", and "can" dominating the guidelines.

The findings confirm earlier observations made in Johnson, Jones, *et al*. (2022), which highlighted that while FSRD is increasingly present in planning documents, its uptake is rarely underpinned by binding legislative or policy commitments. As a result, implementation is frequently left to the discretion of the decision-maker, project-specific approval conditions, or the presence of internal champions rather than structured, systemic requirements.

This sentiment was echoed across interviews. One consultant recounted:

> It seemed to be more like pushing a big rock up a hill. It was funny because it was their bloody document [I was trying to convince them of]. They [the transport department] were like, 'Nah, what we do is build roads. It is too costly, so we're not going to do it.'

Another government officer added: "I think I knew [the guideline] existed, but I've never had to work with it at all, and I have been in [the department] for four years. That's how voluntary it is!".

While Queensland's *Environmental Process Manual* (DTMR 2013) and *Technical Specifications* (MRTS51; DTMR 2019) make reference to the FSRD Guideline and appear to elevate its status, the Guideline itself is framed as a "reference document"

rather than a standard that must be followed. This internal contradiction weakens its authority and further blurs the lines between recommendation and requirement.

Participants noted that while this flexibility can, in theory, support site-responsive design, it also places a significant burden on practitioners – especially those with limited ecological expertise. The lack of minimum specifications for key design elements (e.g. fencing alignment, structure dimensions, or monitoring requirements) was repeatedly identified as a source of uncertainty and inconsistency. In some cases, effective implementation occurred only where there was clear in-house ecological expertise or motivated staff members who could advocate for FSRD integration. One government officer noted: "You get outcomes when there's someone in the room that knows what they're doing, but that's not always the case." Such insights reaffirm findings from Johnson, Matthews, *et al*. (2022), which emphasised the value of internal champions and practitioner-driven action in environments where formal mandates are weak. However, this dependence on individual effort is inherently unstable – producing pockets of excellence but no guarantee of consistent outcomes across projects or jurisdictions.

Ultimately, while guidelines like those developed in Queensland and Victoria provide important conceptual frameworks for FSRD, their normative language and non-binding status significantly constrain their influence. Without enforceable standards or institutional structures that require adherence, these documents serve more as aspirational tools than operational directives – resulting in variable application and missed opportunities for consistent biodiversity outcomes in infrastructure projects.

4.3. Limits to informed decision-making

A central challenge identified in this study is the limited availability, accessibility, and application of ecological evidence to support FSRD. Despite a growing body of road ecology literature, practitioners consistently described a fragmented and difficult-to-navigate information landscape. As one consultant observed: "It's pretty all over the shop. Some of it is hard to find. And if you're a practitioner, you've just got no chance of ever finding it all. You just chance upon it." This reflects broader concerns raised by Johnson, Matthews, *et al*. (2022), who noted poor knowledge integration and weak diffusion of ecological insights into transport planning frameworks. Participants reported relying heavily on informal networks, precedent, or organisational memory rather than structured, public evidence bases, not dissimilar to the manner in which knowledge of transport planning has proliferated (see Bray, Taylor, and Scrafton 2011). This informal reliance perpetuates inconsistency and limits the scalability of effective design responses.

Concerns were also raised about the quality and applicability of available research. Several interviewees pointed to a persistent gap between emerging tools and empirical validation. This was most notable with respect to virtual fencing, which continues to attract interest despite no scientific support of its use (see Candy, Bunker, and Englefield 2024; Coulson *et al*. 2020, 2022; Stannard *et al*. 2021).

These knowledge gaps have tangible implications for FSRD implementation. Practitioners described being asked to specify fauna mitigation measures without access to adequate technical guidance. One consultant recalled: "The engineer was asking me how tall [glider poles] needed to be, what they needed to be made of, and how many. He didn't know what a glider pole was, how to build one, or where to put them." Importantly, participants stressed that general ecological expertise is often

insufficient for FSRD application – several noted that many ecological consultants engaged in transport projects may not have the specialised background needed to meaningfully inform designs. One government officer explained: "You can't just pluck any ecologist and ask them to provide some FSRD advice. They really have to understand fauna, animal movements, and have the background and expertise." Another government officer also added: "There are also challenges with getting academics to advise on this as they might have the knowledge, but they don't understand the practice." As one experienced road ecologist observed: "There are very few people in the country with that skillset and the ability to advise on this stuff." Together, these reflections highlight the scarcity of qualified road ecology professionals and underscore the need to invest in discipline-specific training, mentorship, and institutional memory to bridge the gap between ecological research and infrastructure delivery.

Practitioners also emphasised that access to relevant data is inconsistent, with internal monitoring reports often siloed or withheld. This restricts opportunities for learning and replication. As one consultant remarked: "You have to know someone who knows someone who knows someone. You end up going around in circles." Similarly, in the absence of well-documented Australian case studies, practitioners frequently turn to international examples that are poorly suited to local ecological and regulatory contexts. One government officer explained: "You can't just plonk it down. You need to understand where that crossing structure fits in the landscape … but also where everything else needs to go, such as lighting, drainage, utilities, etc." These challenges point to the need for a growing, context-sensitive evidence base that reflects Australia's unique landscapes, fauna, and planning frameworks.

Finally, participants described FSRD as frequently underrepresented in early planning – despite nominal references to it in that phase in the FSRD guidelines (DTMR 2010; VicRoads 2012). Consultants and academics reported being engaged too late to meaningfully shape designs, often after clearing or construction had already occurred. As one consultant described: "They've already built the road … it's too long, or fencing can't be done because they've already cleared 17,000 trees and can't clear another 4,000 to put in a fence." This marginalisation of ecological input was described as both procedural and cultural. One government officer stated:

> With one or maybe two people in the entire organisation, I don't feel like that's happening yet … [it's] kind of like the engineers do the roads, the capital projects people build the roads, and environment is just there to make sure no one gets sued.

Collectively, these findings reveal significant structural and procedural deficiencies that hinder the effective use of ecological evidence in infrastructure planning. The absence of detailed, context-specific guidance, limited access to road ecology expertise, and the failure to embed ecological considerations early in project workflows all constrain the practical implementation of FSRD. Addressing these challenges will require improved technical guidance, targeted capacity building, and more deliberate knowledge governance to support interdisciplinary planning and delivery.

4.4. FSRD is data-deficient

The lack of comprehensive and accessible data emerged as a critical barrier to the effective implementation of FSRD in LTI projects. Practitioners described difficulty in

establishing SMART (Specific, Measurable, Achievable, Realistic, Timeframe) objectives due to poor baseline information and limited performance data. This finding aligns with Johnson, Jones, *et al*. (2022), which highlighted the fragmented and under-resourced nature of evidence integration in Australian transport planning – much like long-standing critiques of urban transport policies (Bray, Taylor, and Scrafton 2011).

Although formal repositories, such as Queensland Government's WildNet, are commonly used, these platforms were frequently described as incomplete or outdated. As one Queensland government officer explained:

> While you might have the Nature Conservation Act 1992, and the planned protection of wildlife under that, the database that supports this [WildNet], is really data deficient. All our road works need to comply with the legislation, but it can sometimes be quite difficult to make decisions based on very limited information.

A lack of data-sharing between sectors compounds this issue. Several participants reported that large volumes of development-related ecological data – particularly from resource extraction and infrastructure assessments – are never incorporated into shared databases. One consultant noted how survey efforts in a single region could have expanded recorded observations from 66 to over 3,000 records but lamented: "None of it goes anywhere. It just sits in reports or on people's hard drives."

Monitoring, which could help to address these gaps, is often superficial or absent. Despite detailed guidance in Queensland and Victorian FSRD manuals, few participants could point to meaningful post-construction evaluations. One road ecologist stated: "Most monitoring of road projects is a waste of time in the sense that we put a camera in and confirm, yet again, that koalas use underpasses." Another road ecologist warned against drawing conclusions from anecdotal or incidental observations: "Don't just clap your hands and pat yourself on the back when you've got your wombat running through the tunnel. You need to understand whether that was a one-off or a single individual." This concern was reinforced by examples of inadequate monitoring, including a land bridge designed for EPBC-listed species (cassowary) that was never evaluated, despite some monitoring of driver behaviour and camera trapping for structure use, and a kangaroo sighting through a 60-centimetre pipe being incorrectly interpreted as evidence of use as a crossing structure.

Participants also questioned the scientific basis for costly or novel mitigation measures – such as skylights, culverts, and virtual fencing – when local evidence of effectiveness was lacking. One government officer remarked: "I would love to see some research on those, as they're bloody expensive to put in. If we're building it and they're not being used, it's just ridiculous." Several noted that structures are often installed to meet perceived approval expectations rather than being grounded in site-specific ecological evidence. Another government officer explained:

> The regulators have to be informed that it hasn't been successful, and you have to validate why. So, if you have evidence to point to these structures not working … that's very powerful information.

Most concerning were comments revealing a strategic avoidance of monitoring to prevent scrutiny or additional regulatory obligation. One consultant observed: "If you solve the problem, nobody wants to monitor because they say that the problem has

gone away." A government officer echoed this sentiment: "If there's no data, there's no problem. That way, we don't know the information and therefore don't have to respond to requests." Others acknowledged internal withholding of data, with one government officer stating: "If it's in-house, it's in-house and we know it's here. We know what's working and what's not working, but it's our data."

Taken together, these findings highlight a serious deficit in baseline data, ecological transparency, and monitoring accountability. Without robust and shared evidence, FSRD implementation risks becoming performative – reinforcing precedent without proving effectiveness or facilitating learning. Addressing these deficiencies will require not only better data governance, but also cultural and institutional shifts that prioritise open knowledge exchange and measurable outcomes.

5. The evolution of FSRD – where to next?

This study highlights the evolving nature of FSRD in Australia, particularly in Queensland and Victoria. Early guidance – such as DTMR's FSRD Manuals (2000, 2010) and VicRoads' Guidelines (2012) – played a formative role in mainstreaming road ecology, but their normative language and voluntary status have limited consistent application. As previously documented (Johnson, Jones, *et al*. 2022), these documents lacked enforceable standards, creating barriers for practitioners seeking to advocate best practice. One participant summarised this challenge: "without clear requirements, it's difficult to set expectations and make the case for best-practice FSRD."

The recent release of Queensland's *Fauna Sensitive Transport Infrastructure Delivery* (FSTID) Manual (DTMR 2024) marks a significant shift toward firmer governance. With prescriptive language, clearer responsibilities, and structured monitoring, the manual aims to embed FSRD across the infrastructure lifecycle. While its potential is promising, its effectiveness remains untested – this study offers a critical pre-implementation baseline. The FSTID Manual also emphasises interagency and cross-sector collaboration, a welcome development in a field that thrives on integrated expertise (Johnson, Matthews, *et al*. 2022). Still, several participants argued for a unified national approach.

> We're dealing with pretty much the same species across the board with similar requirements … A combined document would set the benchmark and leave a lasting legacy.

To support uptake, reforms should elevate ecological input during early planning, enhance knowledge-sharing, and enable adaptive management through centralised design and monitoring databases.

> The more we're connected across different authorities, the better we are because we can share and learn.

Finally, national legislation – such as the *EPBC Act* – could incorporate FSRD-specific triggers and use mapped bioregional corridors to guide infrastructure design.

> If government stepped in with the necessary protections, fines, and penalties like those in Europe, it would take the burden off individuals.

In short, FSRD must move from being a best-practice aspiration to a governance norm – supported by strong policy, clear roles, and applied accountability.

6. Concluding remarks

This study provides one of the first detailed examinations of how FSRD is implemented in Australia, using institutional analysis and practitioner perspectives to reveal systemic weaknesses in the governance frameworks that underpin delivery. Across Queensland and Victoria, FSRD guidelines are dominated by non-binding language, environmental legislation provides limited and inconsistent triggers, and decision-making is constrained by knowledge gaps, poor data governance, and fragmented institutional responsibilities. While practitioners demonstrate a strong commitment to integrating ecological considerations, outcomes often rely on the presence of individual champions rather than enforceable requirements. These findings echo earlier reviews at both the international and Australian level (Johnson, Jones, *et al*. 2022; Johnson, Matthews, *et al*. 2022), underscoring that meaningful biodiversity outcomes will remain inconsistent unless ecological objectives are embedded into binding policy, supported by clear roles, and backed by adequate technical guidance and resourcing.

The forthcoming trial of Queensland's updated FSTID Manual offers an important opportunity to test stronger governance settings, but its success will depend on sustained institutional commitment and transparent performance evaluation. This study provides a pre-implementation benchmark against which that progress can be assessed. The implications extend nationally, given the alignment of planning frameworks, the influence of Queensland's guidelines on other jurisdictions, and the largely shared ecological contexts across state borders. Advancing FSRD from an aspirational best-practice layer to an established governance norm will require national alignment of policy frameworks, the integration of FSRD triggers into environmental legislation, investment in knowledge-sharing infrastructure, and the institutionalisation of monitoring and adaptive management. Achieving this shift is not only an environmental necessity but a governance imperative, ensuring that biodiversity protection is embedded into the core business of infrastructure planning and delivery rather than left to discretionary interpretation.

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Author contributions

Conceived the study: CJ, DJ, and TM. Performed the data collection: CJ. Analysed the data: CJ. Contributed materials/critique/analysis tools: CJ, DJ, TM, and MB. Wrote, formatted and edited the paper: CJ.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Chat GPT in order to improve the readability and language of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Supplementary material

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References

Braun, V., V. Clarke, N. Hayfield, L. Davey, and E. Jenkinson. 2023. "Doing Reflexive Thematic Analysis." In *Supporting Research in Counselling and Psychotherapy: Qualitative, Quantitative, and Mixed Methods Research*, 19–38. Cham: Springer International Publishing.

Bray, D. J., M. A. P. Taylor, and D. Scrafton. 2011. "Transport Policy in Australia – Evolution, Learning and Policy Transfer." *Transport Policy* 18 (3): 522–532. doi:10.1016/j.tranpol.2010.10.005.

Candy, S. G., J. A. Bunker, and B. Englefield. 2024. "A Trial of a Virtual Fence to Mitigate Roadkill on an Unsealed Rural Road in Tasmania, Australia." *Animals: An Open Access Journal from MDPI* 14 (11): 1641. doi:10.3390/ani14111641.

Clement, S., S. A. Moore, and M. Lockwood. 2015. "Authority, Responsibility and Process in Australian Biodiversity Policy." *Environmental and Planning Law Journal* 32 (2): 93–114.

Coulson, G., and H. Bender. 2020. "Roadkill Mitigation is Paved with Good Intentions: A Critique of Fox *et al.* (2019)." *Australian Mammalogy* 42 (1): 122–130. doi:10.1071/AM19009.

Coulson, G., and H. Bender. 2022. "Wombat Roadkill Was Not Reduced by a Virtual Fence. Comment on Stannard *et al.* Can Virtual Fences Reduce Wombat Road Mortalities? Ecological Engineering 2021, 172, 106414." *Animals* 12 (10): 1323. doi:10.3390/ani12101323.

Crawford, S. E. S., and E. Ostrom. 1995. "A Grammar of Institutions." *American Political Science Review* 89 (3): 582–600. doi:10.2307/2082975.

DTMR. 2010. *Fauna Sensitive Road Design* Volume 2. Department of Transport and Main Roads, Design and Environment Division, Queensland State Government. Brisbane.

DTMR. 2013. Technical Manual – Environmental Processes Manual. Department of Transport and Main Roads. Queensland State Government. Brisbane

DTMR. 2019. Transport and Main Roads Specifications MRTS51 Environmental Management. Queensland State Government. Brisbane

DTMR. 2024. Fauna Sensitive Transport Infrastructure Delivery manual. Queensland State Government. Brisbane.

Fahrig, L., and T. Rytwinski. 2009. "Effects of Roads on Animal Abundance: An Empirical Review and Synthesis." *Ecology and Society* 14 (1): 21–20. doi:10.5751/ES-02815-140121.

Goosem, M. 2001. "Effects of Tropical Rainforest Roads on Small Mammals: Inhibition of Crossing Movements." *Wildlife Research* 28 (4): 351–364. doi:10.1071/WR99093.

Hoskin, C. J., and M. W. Goosem. 2010. "Road Impacts on Abundance, Call Traits, and Body Size of Rainforest Frogs in Northeast Australia." *Ecology and Society* 15 (3): 15. doi:10.5751/ES-03272-150315.

Jaeger, J., T. Soukup, L. Madriñán, C. Schwick, and F. Kienast. 2011. *Landscape Fragmentation in Europe*. Luxembourg: Publications Office of the European Union.

Jat, Hanuman Sahay, Shivani Khokhar, Kailash Prajapat, Madhu Choudhary, Manish Kakraliya, Manoj Kumar Gora, Mahesh Kumar Gathala, *et al.* 2025. "A Decade of Conservation

Agriculture in Intensive Cereal Systems: Transitioning to Soil Resilience and Stable Yield Trends in a Climate Crisis." *Journal of Environmental Management* 373: 123448. doi:10.1016/j.jenvman.2024.123448.

Johnson, C. D., T. Matthews, M. Burke, and D. Jones. 2022. "Planning for Fauna Sensitive Road Design: A Review." *Frontiers in Environmental Science* 10: 959918. doi:10.3389/fenvs.2022.959918.

Johnson, C. D., D. Evans, and D. Jones. 2017. "Birds and Roads: Reduced Transit for Smaller Species over Roads within an Urban Environment." *Frontiers in Ecology and Evolution* 5 (10): 36. doi:10.3389/fevo.2017.00036.

Johnson, C., D. Jones, T. Matthews, and M. Burke. 2022. "Advancing Avian Road Ecology Research through Systematic Review." *Transportation Research Part D: Transport and Environment* 109: 103375. doi:10.1016/j.trd.2022.103375.

Jones, D., and A. Bond. 2010. "Road Barrier Effect on Small Birds Removed by Vegetated Overpass in South East Queensland." *Ecological Management and Restoration* 11 (1): 65–67. doi:10.1111/j.1442-8903.2010.00516.x.

Jones, D., and J. Pickvance. 2013. "Forest Birds Use Vegetated Fauna Overpass to Cross Multi-Lane Road." *Oecologia Australis* 17 (1): 147–156. doi:10.4257/oeco.2013.1701.12.

Jones, D. M., M. Bakker, O. Bichet, R. Coutts, and T. Wearing. 2010. Restoring Connectivity over Compton Road: Assessing recreated habitat on the land-bridge - A Report for Brisbane City Council. Environmental Futures Centre, Griffith University.

Komnos, D., R. Smit, L. Ntziachristos, and G. Fontaras. 2025. "A Comparative Analysis of Car Fleet Efficiency Evolution in Europe and Australia Insights on Policy Influence." *Journal of Environmental Management* 373: 123313. doi:10.1016/j.jenvman.2024.123313.

Laurance, W. F. 2015. "Bad Roads, Good Roads." In *Handbook of Road Ecology*, edited by Rodney van der Ree, Daniel J. Smith, and Clara Grilo, 10. Chichester, UK: Wiley.

Laurance, W. F., M. Goosem, and S. G. Laurance. 2009. "Impacts of Roads and Linear Clearings on Tropical Forests." *Trends in Ecology and Evolution* 24 (12): 659–669. doi:10.1016/j.tree.2009.06.009.

McGregor, M., S. Wilson, and D. Jones. 2015. "Vegetated Overpass Enhances Habitat Connectivity for Forest Dwelling Herpetofauna." *Global Ecology and Conservation* 4: 221–231. doi:10.1016/j.gecco.2015.07.002.

McGregor, M., K. Matthews, and D. Jones. 2017. "Vegetated Fauna Overpass Disguises Road Presence and Facilitates Permeability for Forest Microbats in Brisbane, Australia." *Frontiers in Ecology and Evolution* 5: 153. doi:10.3389/fevo.2017.00153.

Melnychuk, M. C., S. Lees, P. Veiga, J. Rasal, N. Baker, L. Koerner, D. Hively, *et al.* 2025. "Comparing Voluntary and Government-Mandated Management Measures for Meeting Sustainable Fishing Targets." *Journal of Environmental Management* 374: 124090. doi:10.1016/j.jenvman.2025.124090.

Papp, C.-R., I. Dostál, V. Hlaváč, G. M. Berchi, and D. Romportl. 2022. "Rapid Linear Transport Infrastructure Development in the Carpathians: A Major Threat to the Integrity of Ecological Connectivity for Large Carnivores." *Nature Conservation* 47: 35–63. doi:10.3897/natureconservation.47.71807.

Pell, S., and D. Jones. 2015. "Are Wildlife Overpasses of Conservation Value for Birds? A Study in Australian Sub-Tropical Forest, with Wider Implications." *Biological Conservation* 184: 300–309. doi:10.1016/j.biocon.2015.02.005.

Siddiki, S., C. M. Weible, X. Basurto, and J. Calanni. 2011. "Dissecting Policy Designs: An Application of the Institutional Grammar Tool." *Policy Studies Journal* 39 (1): 79–103. doi:10.1111/j.1541-0072.2010.00397.x.

Smith, D., R. van der Ree, and C. Rosell. 2015. *Wildlife Crossing Structures: An Effective Strategy to Restore or Maintain Wildlife Connectivity across Roads. Handbook of Road Ecology*, edited by R. van der Ree, D. Smith, and C. Grilo, 172–183. 2nd ed. Chichester, UK: John Wiley and Sons Ltd.

Soanes, K., T. Rytwinski, L. Fahrig, M. P. Huijser, J. A. G. Jaeger, F. Z. Teixeira, R. van der Ree, and E. A. van der Grift. 2024. "Do Wildlife Crossing Structures Mitigate the Barrier Effect of Roads on Animal Movement? A Global Assessment." *Journal of Applied Ecology* 61 (3): 417–430. doi:10.1111/1365-2664.14582.

Stannard, H., M. B. Wynan, R. J. Wynan, B. A. Dixon, S. Mayadunnage, and J. M. Old. 2021. "Can Virtual Fences Reduce Wombat Road Mortalities?" *Ecological Engineering* 172: 106414. doi:10.1016/j.ecoleng.2021.106414.

Taylor, B. D., and R. L. Goldingay. 2003. "Cutting the Carnage: Wildlife Usage of Road Culverts in North-Eastern New South Wales." *Wildlife Research* 30 (5): 529–537. doi:10.1071/WR01062.

Taylor, B. D., and R. L. Goldingay. 2010. "Roads and Wildlife: Impacts, Mitigation and Implications for Wildlife Management in Australia." *Wildlife Research* 37 (4): 320–331. doi:10.1071/WR09171.

Trocmé, M. 2005. "The Swiss Defragmentation Program - Reconnecting Wildlife Corridors between the Alps and Jura: An Overview." Paper presented at the ICOET Conference 2005, San Diego, CA, August 29–September 2.

van der Grift, E. A., R. van der Ree, L. Fahrig, S. Findlay, J. Houlahan, J. A. Jaeger, N. Klar, L. F. Madriñan, and L. Olson. 2013. "Evaluating the Effectiveness of Road Mitigation Measures." *Biodiversity and Conservation* 22 (2): 425–448. doi:10.1007/s10531-012-0421-0.

Van Der Ree, R. 2006. "Road Upgrade in Victoria a Filter to the Movement of the Endangered Squirrel Glider (*Petaurus Norfolcensis*): Results of a Pilot Study." *Ecological Management and Restoration* 7 (3): 226–228. doi:10.1111/j.1442-8903.2006.312_3.x.

van der Ree, R., D. Heinze, M. McCarthy, and I. Mansergh. 2009. "Wildlife Tunnel Enhances Population Viability." *Ecology and Society* 14 (2): 7. http://www.ecologyandsociety.org/vol14/iss2/art7/. doi:10.5751/ES-02957-140207.

van der Ree, R., D. Smith, and C. Grilo. 2015. "The Ecological Effects of Linear Infrastructure and Traffic: Challenges and Opportunities of Rapid Global Growth." *Handbook of Road Ecology*. Editors R. van der Ree, D. Smith, and C. Grilo, 1–9. 2nd ed. West Sussex: John Wiley and Sons Ltd.

VicRoads. 2012. *Fauna Sensitive Road Design Guidelines*. VicRoads, Victoria Government. Melbourne.

Young, G., R. King, and B. Allen. 2023. "Where Do Wildlife Cross the Road? Experimental Evaluation Reveals Fauna Preferences for Multiple Types of Crossing Structures." *Global Ecology and Conservation* 46: E 02570. doi:10.1016/j.gecco.2023.e02570.