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# Implementing wildlife-management strategies into road infrastructure in southern Ontario: a critical success factors approach

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# Implementing wildlife-management strategies into road infrastructure in southern Ontario: a critical success factors approach

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Wildlife-road conflict has profound negative impacts on both wildlife populations and society. Despite a long-held understanding of this problem, in most regions the wildlife-management strategies (WMS) available to mitigate this conflict are still relatively underutilized. This study examines the implementation of these strategies into road infrastructure, using Southern Ontario as a case study, in order to develop an understanding of what leads to successful WMS implementation. The project management concept of critical success factors was applied and interviews with project decision-makers and key stakeholders were conducted. Nine factors were identified and a comparison between a 'smooth' and 'rough' project is used to illustrate the cumulative effects that these factors, and their interrelationships, have on project implementation success. Practitioners can use these findings to evaluate WMS projects based on likelihood of success and allocate resources accordingly, ultimately leading to increased chances of implementation and overall benefit to conservation and society.

**Keywords:** wildlife-road conflict; project decision-making; wildlife-management strategies; critical success factors; road ecology

## 1. Introduction

Roads are essential to everyday life. They move people, transport goods, and facilitate the development of areas that would otherwise be inaccessible. Although beneficial for society, our ever-expanding road infrastructure is having a profound negative impact on wildlife; species displacement, habitat destruction and fragmentation, and individual animal deaths from wildlife-vehicle collisions are all contributing to the declining health of local wildlife populations (Coffin 2007; Fahrig and Rytwinski 2009; Spellerberg and Morrison 1998; Ontario Road Ecology Group 2010). These types of problems are categorized as issues within road ecology, a relatively new field that has emerged in the 1980s from the greater body of habitat loss and fragmentation research (Forman *et al.* 2003). However, the effects of road and wildlife interactions are not isolated to the ecological realm; in addition to affecting wildlife populations, these interactions can have serious impacts on society. Human safety is of concern as wildlife-vehicle collisions, particularly with large mammals, can lead to human injury or fatalities, depending on the severity of the collision (Pynn and Pynn 2004; Pelletier and Rey 2006; Beckmann *et al.* 2010). Societal costs are also incurred, including traffic delays, emergency services use, insurance premium increases, and, most directly, vehicle damage and medical costs (Huijser *et al.* 2008; Beckmann *et al.* 2010; Vanlarr *et al.* 2012). In monetary terms, a

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2003 estimate put the annual cost of wildlife-vehicle collisions with large animals in Canada at C$200 million when considering damage to vehicles and loss of wildlife alone (L-P Tardif and Associates 2003). When considering all other associated costs, Huijser *et al.* (2008) approximate that these collisions result in a total cost of US$8.39 billion annually in the United States.

The term *wildlife-road conflict* refers to all issues resulting from wildlife-road interactions such as wildlife-vehicle collisions, road-related human-wildlife conflict, non-vehicle related threats to wildlife, and socio-economic impacts. Various mitigation strategies exist to reduce the problems associated with wildlife-road conflict, varying in size and scope, and include road signage, wildlife detection systems, exclusion fencing, wildlife crossing structures, and others (Glista, DeVault, and DeWoody 2009; Beckmann *et al.* 2010). These strategies are increasingly being considered and incorporated into road projects in different regions globally. Within Canada, the Rocky Mountain region is renowned as a world-leader in road ecology research and large-scale mitigative strategies such as fencing and wildlife crossing structures (Clevenger 2012). Outside of this region, an understanding of wildlife-road conflict and available mitigation options is spreading much more slowly.

Over the years, the focus of road ecology research has moved from the identification of impacts of roads on wildlife populations to the development of potential technical solutions (i.e., specific wildlife-management strategies [WMS]), and subsequently to the monitoring and improvement of these strategies (Healy and Gunson 2014; Huijser *et al.* 2016). Tools have also been developed to help guide practitioners through the process of incorporating WMSs into road designs (Lee, Quinn, and Duke 2006; Olson *et al.* 2014; Paul *et al.* 2014; Polak, Rhodes, Jones, and Possingham 2014). The majority of these tools focus on the ecological and technical components, such as which species to target, the best WMSs to utilize, and the optimal geographic placement of these strategies.

Although undoubtedly very important components, these tools do not address a critical issue that requires additional consideration: in order for WMSs to be successfully implemented, first they must be given approval by the respective decision-making parties. Without this permission, the ecological and technological tools will not be applied; there will not be any opportunity to use them. Therefore, developing an understanding of how to shepherd WMS projects successfully through the decision-making process is essential to ensuring their success.

One of the root problems is that roads are typically publicly owned and therefore any decision-making concerning them takes place within the public domain. As such, governments and their various divisions are tasked with balancing a myriad of competing factors in addition to the technical elements of a problem; factors that include financial constraints, public opinion, political motivations, etc. Although it may be difficult to balance these factors, Barkenbus (1998) emphasizes the need to recognize the 'political realities' under which environmental policy decisions are made and to understand the various socio-economic and political factors that influence them if effective decision-making is to be achieved. We pose that the omission of this understanding in the current body of road ecology research may have contributed to the lack of widespread implementation of WMSs.

A case in point is the Transportation Research Board's National Cooperative Highway Research Program that has developed a tool specifically designed to aid the process of installing wildlife crossing structures across North America (Bissonette and Cramer 2008). This web-based interactive decision-guide takes practitioners through each step in the process from initial planning, through implementation, and finally to methods for adaptive management. It even includes a number of socio-economic and political considerations, such as the need to identify who has authority over the road and the appropriate project team composition (Bissonette and Cramer 2008). The guide is accompanied by an inventory of current crossing structures, a research database, and a search engine for publications on the topic. Overall, this is the most holistic tool available for aiding WMS implementation to date. Although designed with wildlife crossing structures in mind, the general components and processes it outlines could easily be applied to other WMSs. This being said, while the tool is identifying much of the kind of information practitioners should be looking for, it does not discuss the implications of that information. In other words, once the practitioners have the information they need, the tool does not inform them of how that information affects the potential success of the initiative.

Therefore, the purpose of this study was to fill in this missing component, i.e., the incomplete understanding of the various socio-economic and political factors that lead to the success or failure of WMS implementation. By examining various projects where WMSs have been incorporated into road infrastructure, we aimed to develop a comprehensive understanding of the different factors involved in the decision-making process and to garner insight into the influence of these factors. We hope that the results from this study will be informative and practically relevant to those looking to incorporate WMS in regions where they do not currently exist.

### *1.1. Critical success factors*

To frame the research process, we applied the concept of critical success factors (CSFs) as a lens for guiding the analysis. Originating in project management, CSFs are the key areas where "things must go right" (11) for a project, business, or initiative to be successful (Rockhart 1979). These factors vary depending on the project but can be organized into general categories: (1) project-related factors, e.g., type and size of the project; (2) human-related factors, e.g., the skills of the project manager and team members; (3) factors related to the organization and procedures of a project, e.g., communication and planning; and (4) factors related to the external environment, e.g., the economy and societal views (Belassi and Tukel 1996; Chan Scott and Chan 2004). Leidecker and Bruno (1984) underline the importance of identifying CSFs by maintaining that they provide "a means by which an organization can assess the threats and opportunities in its environment" (23). This information can be used to assess the likelihood of a project's success and subsequently: (1) avoid projects that are likely to be unsuccessful, (2) identify projects worth pursuing, and (3) identify problems surrounding current projects and enable actions to correct them (Sanvido *et al.* 1992). In doing so, effort and limited resources can be used in the most efficient manner.

After the CSFs have been identified, they can be used to evaluate different strategic alternatives (i.e., project options) for their potential effectiveness through what is referred to as 'CSF Fit' (Leidecker and Bruno 1984). Alternatives with a better fit will outperform the other options (De Vasconcellos E Sá and Hambrick 1989). The same process can be applied to alternatives being evaluated individually for their own merit: an alternative with a good fit is likely to be successful, while an alternative with a bad fit is likely to perform poorly (De Vasconcellos E Sá and Hambrick 1989).

Pursuing WMS projects that are most likely to succeed helps optimize the use of limited resources. To determine the likelihood of success, WMS practitioners need to be able to assess a project's CSF fit, which first requires the identification of the CSFs concerning WMS projects. As previously stated, much of the technical and ecological knowledge regarding WMS projects is already available and could potentially be used to identify a list of CSFs. However, this list would be incomplete because an understanding of the socio-economic, political, and various other human factors surrounding WMS projects is currently absent; any such CSF list would miss the critical human-related and external-environment factors mentioned previously. Consequently, to fill this gap we aimed to develop a comprehensive list of CSFs for WMS project implementation in southern Ontario.

## 2. Methods

We chose southern Ontario as the study region. As urban growth extends to accommodate population increases, the region's natural and agricultural lands are becoming more and more fragmented. Home to considerable biodiversity, southern Ontario is also home to the highest concentration of roads in Canada, and its road network only continues to grow. As such, negative interactions between wildlife and roads are increasing (L-P Tardif and Associates 2003). Additionally, new protections and required mitigation for endangered species in the Province of Ontario under the Endangered Species Act, 2007, create conditions for increased attention to wildlife-road conflict issues. WMSs are starting to receive more attention in the province and their timing and scattered implementation provided an excellent opportunity to examine the opportunities and challenges being faced. Furthermore, while WMS studies have been conducted in the Rocky Mountain region, as well as the United States and Europe, Ontario's situation remains relatively uninvestigated. Therefore southern Ontario presented a novel opportunity to investigate WMS implementation from the early stages.

For the purposes of this study, we extended the traditional boundaries of 'southern Ontario' slightly north to include the city of Sudbury, Ontario (Figure 1). This was done to enable exploration of more extensive WMSs targeted to larger wildlife not commonly seen within the more traditional boundaries of southern Ontario (i.e., moose), which pose a greater threat to human safety. Despite changes in the characteristics of wildlife in the area, Sudbury is still a rather large urban center, and therefore faces similar wildlife-road conflicts as more southern parts of the Province.

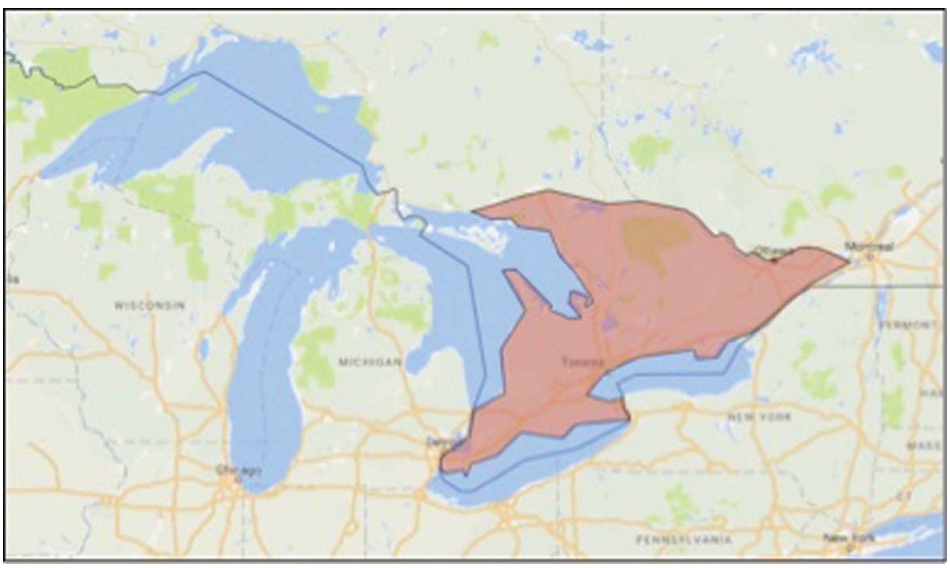


Figure 1. The study region in southern Ontario (shaded) with surrounding jurisdictions in Canada and the USA (https://www.google.ca/maps).

To collect data on WMS implementation opportunities and challenges, we identified as many WMS projects as possible. However, identifying projects to be examined proved difficult as much of the information was scattered and had to be located through small-town newspaper articles, road project plans, or award announcements. Additionally, we used web-based keyword searches, word-of-mouth, and chain-referral sampling to develop a list of WMS projects. This list did not contain any 'negative' cases (i.e., projects that failed), despite extensive searching. This lack of evidence of failed projects is likely due to the scattered state of road ecology knowledge and the fact that organizations and agencies do not tend to openly share information about failed endeavors. Consequently, we determined WMS project implementation challenges by extrapolating from the obstacles faced by projects that were ultimately able to overcome them.

We collected data through semi-structured interviews with decision-makers, project managers, and major stakeholders involved with WMS projects. We conducted these interviews in-person at either the interviewee's place of work or the project site, and recorded them for verbatim transcription. Questions were open-ended and focused on the experiences interviewees had with regards to project development, implementation, and execution. We conducted a total of 12 interviews, with 16 participants in total (i.e., several interviews involved two interviewees). The specific wildlife-road conflict issues and WMSs discussed varied across projects (Table 1).

Our data analysis was guided by a qualitative content analysis approach, with concurrent data collection and analysis. We analyzed the data using both an informal data immersion process and formal data reduction in the form of coding (Forman and Damschroder 2008). We applied both deductive codes, developed a priori, and inductive codes – those that emerged from the data itself – to identify themes within the data. We continued with data collection and analysis until it appeared that theoretical data saturation had been achieved (Glaser and Strauss 1967; Charmaz 2006). This occurred after the ninth interview. We then conducted three additional interviews to confirm that saturation had indeed been reached. To validate the analysis results, interview participants were contacted and provided a summary of the analysis and results. We encouraged participants to review the analysis and results to ensure that their experiences were accurately reflected. Any recommendations were then incorporated into the final version of the analysis and results.

The University of Waterloo Office of Research Ethics has reviewed this research project and full ethics clearance has been granted (ORE# 19752).

## 3. Results and analyses

Analysis of the interview data led us to identify nine factors that are critical to successfully incorporating WMSs into road infrastructure in southern Ontario (Table 2). In the subsequent sections, we present analyses and results with supporting interview quotes for each of these factors.

### *3.1. Factors relating to the project*

#### *3.1.1. Project category*

A key distinction between the various projects examined is the timing and way in which the WMSs were incorporated. There are two different categories of projects: (1) wildlife-specific retrofits to existing road infrastructure, and (2) mitigation measures that are incorporated during larger road infrastructure projects, whether it be regularly scheduled

Table 1. List of investigated projects, with main wildlife-road conflict issues and the corresponding wildlife-management strategies or activities employed.

| Project | Main wildlife-road conflict issue | Wildlife-management strategy |
|---|---|---|
| 1 | Road mortality of amphibians and reptiles along road that bisects wetland habitat | Installation of wet & dry culverts into existing road, exclusion fencing |
| 2 | Prevention of deer-vehicle collisions on new road | Deer exclusion fencing, underpass, road alignment considerations |
| 3 | Wildlife-vehicle collisions with large mammals, wildlife habitat connectivity, and species-at-risk (multiple projects) | Various wildlife crossing structures with exclusion fencing |
| 4 | Increasing efficiency and guidance regarding how and where to implement wildlife management strategies | WMS Implementation Strategy for jurisdiction |
| 5 | Prevention of deer-vehicle collisions on new road, and species-at-risk presence | Various wildlife crossing structures, exclusion fencing, road alignment considerations, stream crossing enhancements |
| 6 | Road mortality of amphibians and reptiles along road that bisects a wetland | Installation of wet and dry culverts, and elevated road design |
| 7 | Ensuring ecological connectivity between natural areas is maintained | Underpasses, amphibian crossing, exclusion fencing, road alignment considerations |
| 8 | Reducing wildlife-vehicle collisions with turtles | Collaboration with other expert groups for research, turtle exclusion fencing projects |
| 9 | Known species-at-risk mortality along road dissecting a migration path, anticipated future deer-vehicle collision hotspot location, species-at-risk presence | Seasonal road closures, underpass, exclusion fencing, culvert, retaining wall |
| 10 | Turtle mortality from wildlife-vehicle collisions, general road mortality (multiple projects) | Artificial turtle-nesting site, culverts, exclusion fencing |
| 11 | General wildlife-road mortality, particularly turtles, on road adjacent to nature sanctuary | Exclusion fencing for small wildlife, tied into existing stream crossing |
| 12 | General wildlife-road mortality, particularly turtles | Exclusion fencing for small wildlife |

road improvements or an entirely new road. Of these, the latter are the most common in southern Ontario. For multiple reasons, wildlife-specific retrofits are more challenging than mitigation measures incorporated during larger road projects. First, many challenges for larger road projects are exacerbated when dealing with wildlife-specific retrofits. The primary example of this is funding. Funding for retrofits must be acquired from external sources, often charitable, in order to do the work because the costs cannot simply be rolled into the overall budget approved for the original infrastructure improvement or construction. Sourcing this extra funding can be difficult and can draw heightened attention to the WMS spending with the potential for increased criticism. Another challenge for retrofits is the need to plan the mitigation within the constraints of the pre-existing infrastructure. This means that there is no 'clean-slate' to work with and the roadway and mitigation measures cannot be planned simultaneously for optimal

Table 2. Critical success factors for wildlife-management strategies as identified in this study. For explanation of critical success factors (see Section 3).

| Critical success factor category | Critical success factor for wildlife-management strategies |
|---|---|
| Project | Project category (Section 3.1.1) |
| | Species-at-risk (Section 3.1.2) |
| Human | Main proponent (Section 3.2.1) |
| Organization and planning | Environmental assessment process (Section 3.3.1) |
| | Data availability (Section 3.3.2) |
| | Knowledge availability (Section 3.3.3) |
| External | Public support (Section 3.4.1) |
| | Funding (Section 3.4.2) |
| | Bureaucratic process (Section 3.4.3) |

effectiveness. Hence it is easier to 'piggy-back' WMSs onto new and larger projects than it is to undertake a completely separate wildlife-specific retrofit:

> … the road is being ripped up anyway, so you have a chance to put stuff in the ground and it doesn't cost as much. But if you're going in just specifically to do that, then to get all that equipment and get everything mobilized like just to do conservation, it's crazy … (I-9)

Overall, wildlife-specific retrofits to existing road infrastructure face more challenges than endeavors that are integrated parts of larger infrastructure projects and are therefore less likely to be successfully implemented.

#### 3.1.2. *Species-at-risk*

The presence of a species-at-risk (SAR) at the site of a planned road infrastructure project increases the likelihood of implementing a WMS. The presence of SARs affects this process in two ways. First, if it is demonstrated that a SAR is affected by the road infrastructure, mitigation is legally required under provincial and/or federal acts. Because of this legal requirement, often the decision is made for the project planners – instead of by them – to incorporate WMSs because they do not have any other option:

> There's an EA going on for [place]. And we're getting a crossing installed there as well because there's Jefferson salamanders [a SAR] on both sides of it. (I-9)

Second, if projects are being required to mitigate for a SAR, often the scope of the project will be expanded to benefit other species as well. The reason for this is that if mitigation measures are required anyways, limited extra work and resources can be added to achieve further benefits such as improved driver safety, additional conservation benefits, or heightened project recognition.

### 3.2. ***Human-related factors***

#### 3.2.1. *Main proponent*

Another key distinction amongst the projects is the advocating party. There are three different groups of advocating parties: (1) provincial government agencies, (2) municipal government agencies, and (3) expert groups (here this term describes proponents that have established themselves as a proficient source of local ecological knowledge [e.g., Conservation Authority, volunteer committees]). This factor is neither a barrier nor a facilitator to WMS implementation, but it is a mediating factor: the identity of the advocating party impacts how and to what degree the other critical factors influence implementation. In other words, what may not be a challenge for one type of advocating party may pose a significant barrier to another. For example, expert groups advocating for WMSs revealed that it was often challenging to complete the necessary components of their projects because they were working with quite limited resources (i.e., funding and staff). In contrast, although funding for environmental endeavors is limited in general, provincial and municipal government agencies are likely to have a more consistent, formalized source of resources that can be allocated to the projects.

> A lot of these [funding] programs are asking non-professional, not-for-profit volunteer organizations to do this kind of work, and treating them as if we're X-, treating us like we're XYZ Corporation with all the equivalent resources of staff and that. (I-1)

### 3.3. *Factors relating to organization and planning*

#### 3.3.1. *Environmental assessment process*

The environmental assessment (EA) process is a major factor related to project development. It is often during the EA process that the need for WMSs is first identified, either through the investigative process itself or the required consultation with stakeholders:

> When they start though it's like … okay got to fix that road. Only got this much money, right. Got to meet engineering standards. Well the EA process also makes us look at the environmental factors and all the other legislation that goes around that. (I-4)

The EA process can also virtually guarantee that WMSs will be incorporated into a road infrastructure project. This guarantee arises when legal commitments are made within the EA approval, which projects are required to meet. These commitments can emerge as conditions for approval placed by the approving authority or can be included voluntarily by the proponent of the project, perhaps in response to stakeholder concerns. Either way, once the commitments are made it is very hard to back-out of them without penalty. Therefore, WMSs are likely to be successfully incorporated despite potential implementation challenges (i.e., financial constraints, stakeholder resistance) that may arise:

> … if you have a commitment or a condition that says you shall do that – if you want your highway you have to do this too, put it in as a commitment or a condition and then that gives you a little bit more oomph when you're trying to fight this. (I-5)

#### 3.3.2. *Data availability*

Data availability plays a large part in the decision-making process and manifests itself in three different ways: (1) as previously identified WMS need, (2) availability of pre-existing data, and (3) available resources to collect data.

Previously identified WMS need means a road infrastructure project is being planned for an area that has already been identified as an area for future WMSs. This is beneficial because all parties are in agreement when a new road infrastructure project starts and all measures can be planned from the beginning. None of the projects examined for this research fit this scenario, but many of the interviewees expressed a desire for this type of situation. The interviewees also believed that regional-level identification of WMS needs would be more efficient than having individual projects investigate need for WMSs on their own:

> So if we have basically a map of all the areas where mitigation would be warranted, and how we could prioritize it so that we can, you know, try to tackle it in an efficient and cost effective manner, then, you know, we could also actually put the signs up everywhere and say okay those are markers for future mitigation. (I-4)

Availability of pre-existing data differs from previously identified WMS need in that it is not necessarily agreed upon or known that WMSs need to be incorporated. Rather it is that some form of monitoring has been conducted producing data that may indicate the need for WMSs, if properly analyzed and used as an argument. Clearly, most decision-makers, particularly in government, prefer 'hard data' to anecdotal evidence as a means of justifying their decisions to protect them against potential criticism:

> … once we presented the numbers to the region, there was very little opposition … the data spoke for itself. We were surprised and everyone was surprised how many animals we found … So I think that [the data] was the big factor in this going through the way it did. I think without the data it would have been a much harder sell. (I-6)

Finally, if the need for WMSs has not been identified previously and pre-existing data is not available, then it is important that the advocating party has the resources available to collect data to help convince decision-makers:

> It's really hard when you're volunteers. I mean, your resource base is pretty thin, right? I mean, if you were doing it as a government agency, or some big organizations like Green Peace, or NCC, you've got staff and everything. (I-1)

Time is of particular importance in this context. It can take a considerable amount of time, sometimes years, to collect sufficient data to show need for a WMS. If data collection is not commenced early enough, the project planning process will likely have progressed too far for mitigation measures to be included. Many interviewees therefore emphasized the need for advance notice of future road infrastructure projects to allow proper planning. This is particularly true of expert groups given that they usually do not have jurisdiction over the infrastructure project and are often notified later in the planning process. Staffing levels are also of particular importance to expert groups because they tend to have less staff or are volunteer-based, limiting their ability to collect data themselves.

#### *3.3.3. Knowledge availability*

Knowledge availability refers to the sources of information available to those attempting to incorporate WMSs. The information being sought is the general 'know-how' to incorporate the strategies, which is different from the previously described issue of data availability that may confirm the need for the implementation of a WMS. This factor is composed of three themes that emerged from the data: (1) lack of a central body of knowledge, (2) learning experience, and (3) and knowledge sharing and collaboration.

Many interviewees expressed a desire for a central knowledge repository they could consult to answer questions, stating they were unsure what to do next after deciding they wanted to incorporate WMSs. According to them, even if the information exists, it is usually scattered across various government, academic, and practice-related sources (e.g., EAs), making it laborious and time-consuming to find, thus slowing down progress on WMS design and implementation:

> … there's just such a need to have a central repository for all this stuff (I-9)

Given the lack of a central body of knowledge, many agencies that are looking to incorporate WMSs are left to sort out the process on their own. Interviewees often described their projects as a learning experience, with ups and downs. Associated with these learning experiences is the notion that any subsequent projects are easier and proceed much more smoothly, with those involved feeling more prepared and capable:

> This whole thing is just one rolling learning experience from the scientific side, but also from the community relations, public relations side and all that type of thing. (I-1)
>
> So I'm really glad that the first project has been positive so far. If it hadn't been positive we might never be able to do this again. (I-6)

A way to manage the lack of a central knowledge repository is through knowledge sharing and collaboration with more experienced staff and agencies. Collaboration also can aid project implementation by creating a sense of 'togetherness' and increasing project resiliency; when challenges arise, those involved are more likely to persevere to find a solution if they feel supported and appreciated for their contributions:

> The planners do talk to each other about you know "I know you've done this, I need this … what have you done, how did it work?" Definitely a lot of information sharing. (I-2)

Although positive collaboration is beneficial to anyone advocating for WMSs, it is especially important for municipal governments and expert groups. Many municipal governments are resource-limited, particularly in terms of the specialized staff who could provide the needed expertise internally; therefore they often have to collaborate with other partners to obtain the required expertise. Expert groups generally advocate for mitigation measures to be placed on a road within someone else's jurisdiction and therefore require their permission, which is extremely difficult without positive collaboration.

### *3.4. External factors*

#### *3.4.1. Public support*

The impact of public support varies considerably depending on who is advocating for the project. WMS projects advocated for at the provincial level are rarely affected by public support or opposition, because these measures are almost always part of larger infrastructure projects and the WMSs usually go unnoticed by the public. And even if the public notices the plans for WMSs, the effect of their support or opposition is less significant because of the increased political distance between the general public and provincial government. There are so many levels of governmental organizations involved in the decision-making that public opposition seldom penetrates the provincial decision-making process effectively. The exact opposite is true for WMSs at the municipal government level. Any public support or opposition can be easily focused and delivered directly to local politicians, creating political pressure:

> … they went to council, a group in [town]. I mean, they went in with a bunch of frogs nailed to a-, dead frogs on a board, pinned on a board, and took it to council, said, this is what we collected on our street this week. Do something. (I-1)

Public recognition is another element related to public support that influences the success of WMS implementation. Although not a main factor in decision-making, public recognition can sometimes act as an important factor swaying decision-makers who are uncertain about the project. Various forms of public recognition exist including awards, media coverage, and acknowledgement as leaders:

> Being green is very cool these days, so. And then the more that it's talked about, the more credit you give them and the more they're going to do it again. (I-8)

### *3.4.2. Funding*

Lack of funding is commonly believed to be a major barrier to the widespread implementation of WMSs. But the results of the current study suggest that funding is a complex element in the decision-making process and its influence differs depending on the circumstances surrounding the project. In general, funding has considerably less impact on the decision-making process than is often assumed. For WMSs that are part of larger road infrastructure projects, WMS funding is usually just considered part of the overall infrastructure cost, the same way guardrails or sound walls would be. Because the majority of projects in Ontario attempting to incorporate WMSs are of this type, in most cases funding is not the main barrier to WMS implementation:

> Down here, and there's going to be a lot of wildlife crossings on this corridor, they get tied in with the expansion budgets … So if your contract is-, if you're putting out a contract that is a hundred million dollars, now your culvert might be one million dollars, that's only one per cent of the contract. So it's just sort of included in that package, right? (I-3)

However, funding can become a significant barrier to implementation during wildlife-specific retrofits. First, these projects must acquire their funding separately from any original road infrastructure project. Second, they can cost more, for example, because equipment has to be brought in specifically for the retrofit that would otherwise already be there for the original project. Third, considerable time can be spent navigating the approval process, which can exacerbate the funding problems if grants are relied on that require deliverables with specific deadlines. Lastly, funding is more likely to be a primary concern for wildlife-specific retrofits because related challenges can use up funds that should be going to the actual WMSs themselves:

> So we ended up spending over 30 percent of our budget on … approvals and the EA and stuff. On a regular construction project it's like maybe 15 percent. It was just one thing after another. At points I thought, we're never going to build anything because there won't be any money left to build anything. We'll just have, you know, the tower of paper and stuff … we don't have any money left to do anything. (I-1)

### *3.4.3. Bureaucratic process*

Lastly, depending on the situation, the bureaucratic process – here defined as the combination of processes, departmental structuring, and responsibilities associated with governmental administration – can work either in support of or as a barrier to WMS implementation. The bureaucratic process is of benefit if it triggers the discussion of WMSs, such as through an EA. However, the bureaucratic process can hinder WMS implementation if it is inefficient, unclear, or redundant, which can be caused by an over-reliance on the process in the absence of an understanding of road ecology and WMS implementation:

> … the [governmental ministry] asked us, we had to do a study to have this evaluated because they have some stupid reporting format checklist thing. We had to hire a consultant to come down and decide that this was suitable SAR habitat, SAR turtle, snake habitat, right? So the guy gets here, I meet him, and he goes, geez, he says, I don't know why I'm here. I said, well what do you mean? He says, well, anyone would know this is a typical Great Lakes coastal wetland dominated by cattails, da, da, da, thus, and probably has species-at-risk in it. (I-1)

## *3.5. Interrelationships and process*

The CSF literature clearly indicates that the factors that impact a project's success are diverse and not always obvious. Only focusing on a few aspects of a project can result in an incomplete understanding of the system and decrease the project's likelihood of success. The relationships among the individual CSFs are just as important as the factors themselves; only with an understanding of these relationships can cumulative effects of CSFs be determined. With this in mind, a process diagram of the critical factors for WMS implementation was developed to illustrate these relationships (Figure 2).

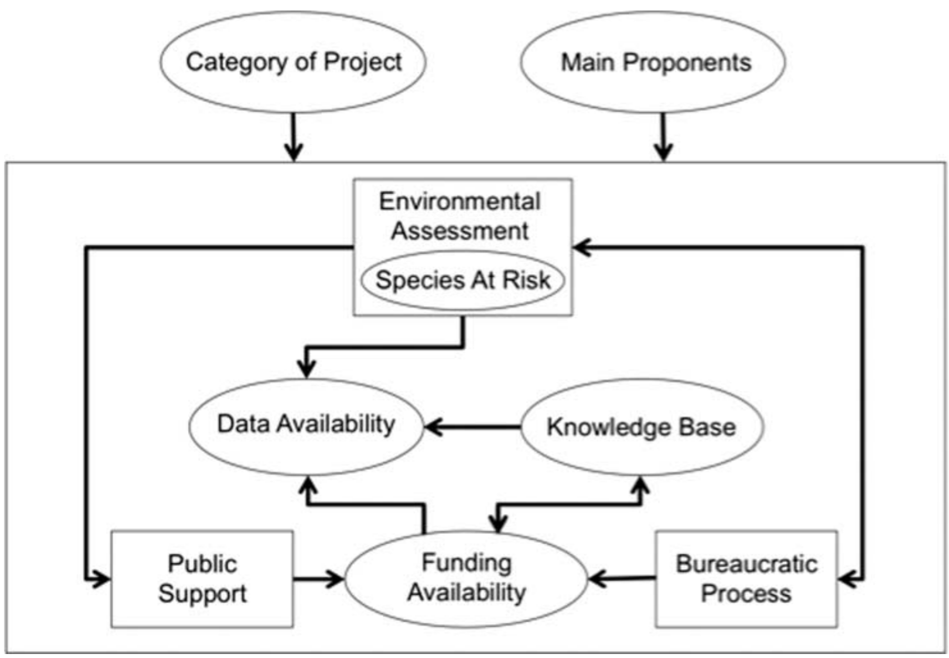


Figure 2. Process diagram depicting the relationships between the critical success factors identified in the current study, which are involved in the implementation of wildlife-management strategies.

Both *Category of Project* and *Main Proponent* are exogenous factors that influence the other factors and their interactions while not being influenced themselves by them. The SAR factor is represented within the EA process because they are inherently linked: the presence of SARs will trigger the EA process, while any EA process increases the likelihood of identification of SARs. However, both these factors impact all other endogenous factors individually.

*Public Support* is impacted because the EA process requires public consultation, providing a formal avenue for public participation in the decision-making process. The EA process and SARs influence the *Bureaucratic Process*, because of their regulatory components. Inversely, the bureaucratic process influences the EA process and SAR identification because it is often an adherence to the bureaucratic process that triggers the completion of an EA. The EA process and SAR also influence the *Data Availability* factor, because data is often collected through the EA process and to establish the presence of SARs.

The *Knowledge Base* factor also influences *Data Availability*. For example, if pre-existing knowledge exists about the possible existence of a SAR, additional data collection becomes easier. The *Knowledge Base* factor also influences *Funding Availability* by providing an understanding of various funding sources and how to qualify for them. In some cases, having this knowledge can help overcome lack of access to conventional funding as an obstacle to WMS implementation. Conversely, *Funding Availability* affects the *Knowledge Base*: when external consultation is required, funds are required to hire that expertise. A lack of funding can therefore limit the available knowledge. *Funding Availability* also influences *Data Availability*, by enabling or limiting the resources to acquire data. *Funding Availability* is affected by both the *Bureaucratic Process* and *Public Support*. The bureaucratic process can lead to various government opportunities for funding, or it can drain project funds by tying them up in regulatory requirements. Finally, *Public Support* affects funds by providing alternatives to public funding sources, such as private funding, or by triggering government financial support that might otherwise not exist.

### ***3.6. Cumulative effects***

Ultimately, each of the projects discussed in the interviews were successful in that they managed to achieve the implementation of some form of WMSs into road infrastructure. However, when considering the cumulative effects of the CSFs, it is evident that some projects were more successful than others. In examining how 'smoothly' the WMS implementation process went for each project and how well the end results matched the original goals, the cumulative effects become clear. This is illustrated through the comparison of a 'smooth' and 'rough' project (Table 3).

#### *3.6.1. Smooth project*

Project 6 was a 'smooth' project (Table 3). This project aimed to reduce amphibian and reptile road mortality along a section of a regional road that dissects a wetland by installing wet and dry culverts and heightening the road surface slightly to create a barrier to small fauna. The project was part of a larger road improvement for the widening of the road and the main proponent was a staff member of a Conservation Authority (CA, a regional, semi-governmental resource management organization) that owned land adjacent to the road.

Table 3. Comparison of critical success factors for a 'smooth' and 'rough' project.

| | Project | |
|---|---|---|
| Critical success factor | 'Smooth' (project 6) | 'Rough' (project 1) |
| Project category (Section 3.1.1) | Part of road improvement | Wildlife-specific retrofit |
| Species-at-risk (Section 3.1.2) | Yes | Yes |
| Main proponent (Section 3.2.1) | Expert group (conservation authority) | Expert group (environmental committee) |
| Environmental assessment (Section 3.3.1) | Yes, included early in process | Yes, required to conduct |
| Data availability (Section 3.3.2) | | |
| Previously identified need | No | No |
| Pre-existing data | No | No |
| Available resources to collect data | Yes | Time: yes; staffing and funds: no |
| Knowledge availability (Section 3.3.3) | | |
| Central knowledge base | No | No |
| Learning experience | Minimal | Yes, extensive |
| Knowledge sharing and collaboration | Yes, between organizations and departments | Minimal |
| Public support (Section 3.4.1) | Yes | No, extreme public backlash |
| Funding (Section 3.4.2) | Part of overall project budget | Had to arrange funding separately |
| Bureaucratic process (Section 3.4.3) | Helpful | Hindered |

The idea for the implementation of WMSs came about when the regional government (a form of municipal government) approached the CA very early in the planning process for their input and expertise. The relationship between the CA and the regional government was described as a very healthy, reciprocal one where both parties work together well: the regional government recognized the CA's ecological expertise and the CA recognized the government's planning and project implementation experience. In this case, the regional government approached the CA for help proactively in developing their preliminary plans to accommodate road ecology practices.

No need for WMSs was previously determined and no pre-existing data existed. However, by including the CA early in the process, the CA was able to allocate staff and had sufficient time to conduct roadside studies over the course of two summers before the formal project planning process began. These small studies confirmed the need for WMSs and this quantitative data was instrumental in convincing initially opposed parties of the need for WMSs. Another beneficial aspect was that the regional road is a popular biking route. Therefore the issue of high wildlife mortality due to wildlife-vehicle collisions was very visible to the public. In addition to the public support, the CA was able to bring to the regional government's attention that a different region recently received an award for similar environmental endeavors: the potential for similar recognition caught the attention of regional representatives.

With regards to the WMS plans themselves, the CA was not advocating for extreme measures. Instead, they recommended relatively simple additions to the infrastructure project such as modifying existing culverts to accommodate wildlife and installing wildlife-specific culverts that also happen to benefit the hydrology of the area. The costs for these WMSs were very low in comparison to the overall project costs and were simply rolled into the overall infrastructure project budget. The positive relationship between the CA and the regional government also helped resolve issues: all parties worked together to develop solutions to funding constraints, such as foregoing an additional culvert and instead widening a pre-existing culvert that needed upgrades anyway. Overall, the installed WMSs very closely matched the original goals.

### *3.6.2. Rough project*

Project 1 was a 'rough' project (Table 3). This project also aimed to reduce amphibian and reptile road mortality along a section of regional road that dissects a wetland. Similarly, they planned to install various culverts while restricting access to the road with exclusion fencing, however no other work on the road was being done so the project was a wildlife-specific retrofit. The main proponent was a committee that was created for the sole purpose of reducing wildlife-road conflict in that particular area. The group was made up of various experts from environmental organizations adjacent to the area of concern, and had a paid project coordinator.

Because the project was a retrofit, funding had to be raised independently. Finding potential funding sources was a difficult process, but ultimately was achieved with the backing from various government and non-government grant programs. However a large portion of the funds raised had to be used for a complicated approval process. This included seemingly unnecessary components such as requirements for multiple environmental studies to demonstrate minimal environmental effects of the project, despite the purpose of the project being to improve the ecological functioning of the area. The disconnect between different organizations and even across different branches of the same government agencies were barriers. For example, a provincial ministry gave funds to the committee to construct the wildlife culverts; however, the local branch of that same ministry required the committee to spend some of these funds to complete more environmental studies, which reduced funds available for the actual WMS implementation.

Although collaboration between environmental groups interested in the project was strong, initially very limited information was available to help guide the process. The study participant from this project expressed that they were 'trail-blazing' the way for this type of WMS implementation in Ontario and consequently spent much time gathering the expertise they needed. Despite the involvement of environmental professionals, the group struggled to obtain the necessary local support, both from municipal government and the public. This proved problematic for two reasons: first, because the group did not have jurisdiction over the road, they required cooperation from the road authority, in this case the municipal government who functioned as a "reluctant partner at best", making it difficult to submit EAs and to receive approvals. Second, there was vehement opposition from the public. This was exacerbated by misunderstandings and the spread of inaccurate information concerning the project, particularly in local media. The extent of the opposition was so great that a counter-organization was established to fight the project.

Despite these challenges, retrofit WMSs were eventually incorporated upon getting approval from the municipal government. However the resources and time spent to reach this stage were excessive and the project was only able to install three of the original twelve planned culverts. Fortunately, after these first culverts were installed, public opposition subsided and support from the municipal government increased after seeing the extensive recognition the project received. The project has since received further funding and approval to add more culverts to the road, and the project team is now widely acknowledged for its leadership in WMS implementation in Ontario.

## 4. Discussion

The comparison of the smooth and rough projects upholds the notion of 'CSF fit'. There is no one particular CSF to blame for making the rough project difficult, but there is no denying that the project had a poor CSF fit overall. On the other hand, the smooth project represents a project where *the few key areas all went right* (Rockhart 1979), and right from the start led to a very successful project.

This in itself alone might suggest that applying a CSF framework to the problem of WMS implementation may be appropriate. However, it is also apparent when examining the pattern of WMS research in retrospect: it appears as though there has been a natural progression towards approaching wildlife-road conflict work using CSF methods by identifying contributing factors to the problem (Litvaitis and Tash 2008), developing processes to guide mitigation planning (Gunter, Rousseau, and Bednarczuk 2006; Carruthers and Gunson 2015), and creating tools to navigate the various stages and considerations that must be made (Bissonette and Cramer 2008).

Further evidence is found in the similarities between the CSFs identified by the current study and those identified for the construction project industry. Given that this is the first time CSFs have been applied to WMS implementation, there is no research available to directly compare and contrast findings with. However, Sanvido *et al.*'s (1992) determination that successful construction projects have cohesive teams, contracts that enable teamwork and shared responsibility, experienced team members, and timely provision of information, very closely resembles the experiences of participants in this study. In particular the emphasis on collaboration, learning experience, and knowledge sharing is common to both construction and WMS projects. Ultimately, this finding might not be surprising considering that WMSs usually are, at their most basic level, construction projects. Chan Scott and Chan (2004) emphasize that construction projects are surrounded by uncertainties in technology, process, and budget, making both the industry and individual projects dynamic. As demonstrated by this study, this is certainly the case with WMS decisions as well and, therefore, it is reasonable that both construction and WMS projects face similar challenges and opportunities.

### *4.1 Application and recommendations*

Proponents of WMS projects can use the insights gained from this study to help determine whether a project is likely to be successfully implemented. By referencing the nine CSFs that we have identified and comparing them to the circumstances surrounding their own projects, practitioners can evaluate a project's CSF fit. This screening of projects can lead to more efficient allocation of resources to the projects that are more likely to succeed and ultimately optimize overall wildlife-road conflict reduction efforts.

Based on the results from this study, we formulated three recommendations to be considered by governmental and non-governmental bodies involved in mitigating wildlife-road conflicts:

(1) Focus efforts and resources for implementing WMSs into road infrastructure on road improvements or new development projects. By facing fewer obstacles than wildlife-specific retrofits, these projects have a greater likelihood of success. This recommendation echoes the notion expressed by Huijser *et al.* (2008) in their wildlife-vehicle collisions Best Practices Manual in which they suggest taking an 'opportunistic approach' to implementing WMSs in roads that are already scheduled for other maintenance.
(2) Proactively create an inventory of locations that are to be fitted with WMSs if and when road improvement or development projects arise. Doing so will ensure that opportunities for implementation of individual WMSs are not missed, and will increase the overall efficiency of WMS implementation at a regional level by eliminating the need to justify individual WMSs.
(3) Develop a cohesive knowledge base for compiling and sharing research, learned experiences, information, and data relevant to wildlife-road conflict. This knowledge base should be organized such that the information is centralized, accessible, easily navigable, and clearly presented.

In heeding these recommendations, addressing wildlife-road conflict will become a more successful and efficient process. This will result in swifter and more significant reductions in the ecological, societal, and economic impacts caused by these conflicts. Considering the economic costs of wildlife-road conflicts alone, the investments of time and money required for making these recommendations a reality certainly would be worthwhile.

## 5. Conclusions

Wildlife-road conflict is a significant contributor to overall habitat fragmentation worldwide. Therefore, environmental managers and planners have long been interested in ways to minimize these conflicts. However, despite ample knowledge of the impact that wildlife-road conflict has on ecological connectivity, and an increasingly sophisticated understanding of mitigation options, the decision-making process for implementing WMSs has largely gone uninvestigated. At the same time, WMSs have remained relatively underutilized in the Province of Ontario as well as in many other jurisdictions. This suggests that the conventional approaches for addressing this issue may be insufficient. As such, our study approached this problem from a new angle: by combining traditional wildlife-road conflict research with the project management concept of CSFs. In doing so, we developed a thorough understanding of the individual factors involved in implementing WMSs, including the socio-economic and political elements that had largely gone uninvestigated in previous research. This investigation culminated in the identification of nine CSFs: project category, main proponent, environmental assessment, species-at-risk, data availability, knowledge availability, public support, funding, and bureaucratic process. Not only did we identify these factors for the first time, but their interrelationships as well, providing a more complete understanding of the overall effects these factors have on WMS project implementation. We hope that this increased understanding will allow more targeted allocation of resources to WMSs with the highest likelihood of successful implementation. Individual WMS project success, as well as implementation of the study recommendations, will help increase confidence and advancement of WMSs: a key step in reducing wildlife-road conflict as a strategy to address overall habitat fragmentation.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

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## References

Barkenbus, J. 1998. *Expertise and the Policy Cycle*. Knoxville, TN: University of Tennessee, Energy, Environment and Resources Center. https://www.gdrc.org/decision/policy-cycle.pdf

Beckmann, J. P., A. P. Clevenger, M. P. Huijser, and J. A. Hilty. 2010. *Safe Passages: Highways, Wildlife, and Habitat Connectivity*. Washington, DC: Island Press.

Belassi, W., and O. I. Tukel. 1996. "A New Famework for Determining Critical Success/Failure Factors in Projects." *International Journal of Project Management* 14 (3): 141–151.

Bissonette, J. A., and P. C. Cramer. 2008. *NCHRP Report 615: Evaluation of the Use and Effectiveness of Wildlife Crossings*. Washington, DC: Transportation Research Board. doi:10.17226/14166

Carruthers, B., and K. E. Gunson. 2015. *Development of a Provincial Wildlife Mitigation Strategy for Large and Small Animals on Highways in Ontario*. Raleigh, NC: 2015 International Conference on Ecology and Transportation. https://eco-kare.com/wp-content/uploads/2016/11/Carruthers_Gunson_2015_icoet_technical_paper_25-Sep-15_FINAL.pdf

Chan, A. P. C., D. Scott, and A. P. L. Chan. 2004. "Factors Affecting the Success of a Construction Project." *Journal of Construction Engineering and Management* 130 (1): 153–155.

Charmaz, K. 2006. *Constructing Grounded Theory: Practical Guide Through Qualitative Analysis*. London: Sage.

Clevenger, A. P. 2012. "15 Years of Banff Research: What We've Learned and Why It's Important to Transportation Managers Beyond the Park Boundary." In *Proceedings of the 2011 International Conference on Ecology and Transportation (ICOET 2011)*, Seattle, WA, p. 433–447.

Coffin, A. W. 2007. "From Roadkill to Road Ecology: A Review of the Ecological Effects of Roads." *Journal of Transport Geography* 15: 396–406. doi: 10.1016/j.jtrangeo.2006.11.006

De Vasconcellos E Sá, J. A. S., and D. C. Hambrick. 1989. "Key Success Factors: Test of a General Theory in the Mature Industrial-Product Sector." *Strategic Management Journal* 10 (4): 367–382. doi:10.1002/smj.4250100406

Fahrig, L., and T. Rytwinski. 2009. "Effects of Roads on Animal Abundance: An Empirical Review and Synthesis." *Ecology and Society* 14 (1): 21.

Forman, J., and L. Damschroder. 2008. "Qualitative Content Analysis." In *Empirical Methods for Bioethics: A Primer (Advances in Bioethics, Volume 11)*, edited by Liva Jacoby and Laura A. Siminoff, 39–62. Albany, NY: Emerald Group Publishing Limited.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, and L. Fahrig, *et al.* 2003. *Road Ecology: Science and Solutions*. Washington, DC: Island Press.

Glaser, B. G., and A. L. Strauss. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago: Aldine.

Glista, D. J., T. L. DeVault, and J. A. DeWoody. 2009. “A Review of Mitigation Measures for Reducing Wildlife Mortality on Roadways.” *Landscape and Urban Planning* 91: 1–7. doi:10.1016/j.landurbplan.2008.11.00.

Gunter, C., G. Rousseau, and E. Bednarczuk. 2006. *Environmental Standards and Practices User Guide, Section 5: Wildlife Habitats and Movements (Terrestrial Ecosystems)*. St. Catharines: Ministry of Transportation, Provincial and Environmental Planning Office. http://www.ontla.on.ca/library/repository/mon/20000/277703.pdf

Healy, A., and K. E. Gunson. 2014. *Reducing Wildlife Collisions: What is Working in Northeastern Ontario*. Montreal: 2014 Conference of the Transportation Association of Canada. http://conf.tac-atc.ca/english/annualconference/tac2014/s-29/healy.pdf

Huijser, M. P., E. R. Fairbank, W. Camel-Means, J. Graham, V. Watson, P. Basting, and D. Becker. 2016. “Effectiveness of Short Sections of Wildlife Fencing and Crossing Structures Along Highways in Reducing Wildlife-Vehicle Collisions and Providing Safe Crossing Opportunities for Large Mammals.” *Biological Conservation* 197: 61–68. doi: 10.1016/j.biocon.2016.02.002

Huijser, M. P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A. P. Clevenger, D. Smith, and R. Ament. 2008. *Wildlife-Vehicle Reduction Study: Report to Congress.* (Report No. FHWA-HRT-08-034). Washington, DC: U.S. Department of Transportation, Federal Highway Administration. https://www.fhwa.dot.gov/publications/research/safety/08034/08034.pdf

Lee, T., M. S. Quinn, and D. Duke. 2006. “Citizen, Science, Highways, and Wildlife: Using a Web-Based GIS to Engage Citizens in Collecting Wildlife Information.” *Ecology and Society* 11 (1): 11.

Leidecker, J. K., and A. V. Bruno. 1984. “Identifying and Using Critical Success Factors.” *Long Range Planning* 17 (1): 23–32.

Litvaitis, J. A., and J. P. Tash. 2008. “An Approach Toward Understanding Wildlife-Vehicle Collisions.” *Environmental Management* 42: 688–697. doi:10.1007/s00267-008-9108-4

L-P Tardif & Associates. 2003. *Final Report: Collisions Involving Motor Vehicles and Large Animals in Canada*. Nepean: Transport Canada Road Safety Directorate. http://www.wildlifecollisions.ca/docs/d6acdb93dfabc8c6.pdf

Olson, D. D., J. A. Bissonette, P. C. Cramer, A. D. Green, S. T. Davis, P. J. Jackson, and D. C. Coster, 2014. “Monitoring Wildlife-Vehicle Collisions in the Information Age: How Smartphones Can Improve Data Collection.” *PloS One* 9 (6): e98613. doi: 10.1371/journal.pone.0098613

Ontario Road Ecology Group. 2010. “A Guide to Road Ecology in Ontario.” Prepared for the Environment Canada Habitat Stewardship Program for Species at Risk. ISBN: 978-1-89541-50-6. https://www.rom.on.ca/sites/default/files/imce/oreg_final.pdf

Paul, K., M. S. Quinn, M. P. Huijser, J. Graham, and L. Broberg. 2014. “An Evaluation of a Citizen Science Data Collection Program for Recording Wildlife Observations Along a Highway.” *Journal of Environmental Management* 139: 180–187. doi:10.1016/j.jenvman.2014.02.018

Pelletier, A., and A. Rey. 2006. “Injuries from Motor-Vehicle Collisions with Moose – Maine 2000-2004.” *MMWR: Morbidity & Mortality Weekly Report* 55 (47): 1272–1274.

Polak, T., J. R. Rhodes, D. Jones, and H. P. Possingham. 2014. “Optimal Planning for Mitigation the Impacts of Roads on Wildlife.” *Journal of Applied Ecology* 51 (3): 726–734. doi:10.1111/1365-2664.12243

Pynn, T. P., and B. R. Pynn. 2004. “Moose and Other Large Animal Wildlife Vehicle Collisions: Implications for Prevention and Emergency Care.” *Journal of Emergency Nursing* 30 (6): 542–547. doi:10.1016/j.jen.2004.07.084

Rockhart, J. F. 1979. (March). “Chief Executives Define Their Own Data Needs.” *Harvard Business Review*. https://hbr.org/1979/03/chief-executives-define-their-own-data-needs

Sanvido, V., F. Grobler, K. Parfitt, M. Guvenis, and M. Coyle. 1992. “Critical Success Factors for Construction Projects.” *Journal of Construction Engineering Management* 118: 94–111.

Spellerberg, I. F., and T. Morrison. 1998. *The Ecological Effects of New Roads: A Literature Review*. Wellington: Department of Conservation.

Vanlarr, W. G. M., K. E. Gunson, S. W. Brown, and R. D. Robertson. 2012. *Wildlife-Vehicle Collisions in Canada: A Review of the Literature and a Compendium of Existing Data Sources*. Ottawa: Traffic Injury Research Foundation.