Automated Road Closure Gate Needs Assessment and I-90, Exit 67 Electric Actuator Project

Study SD2001-08
Executive Summary

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**Abstract**

Nearly all of South Dakota’s road closure gates were installed in the early 1980’s and few modifications have occurred to the gates since the original installations. This study examined possible changes to South Dakota road closure gates, including ways that automated features might be incorporated to make intended functionality more amenable. The ultimate goals of the project were to improve road closure gate operations and minimize the safety concerns for SDDOT maintenance personnel at road closure sites. The study required an overall assessment of road closure sites around the state to determine the performance issues surrounding existing gate configurations. The study then proceeded to relate what types of modifications might be warranted at each of the various sites, along with an assessment as to the extents that automation might be introduced.

Reviews of literature focusing on state-of-the-art road closure equipment, various methodologies to perform road closures, and the dictates that frame the performance of road closures resulted in the accumulation of a variety of material on the subject. The research efforts to perform detailed assessments of road closure sites on a statewide basis were performed through in-depth surveys of maintenance personnel at SDDOT Area Offices. Other information was gathered through on-site visits to road closure locations both in- and out of the state. To facilitate the analysis efforts of the automated aspects, an actual installation of electrically actuated drop-arm style gates was performed for testing and evaluation purposes. The “test installation” was meant to evaluate the reliability of the design, mechanical, and operational characteristics of this type gate in comparison to similar characteristics found in South Dakota’s existing swing-type gates.

The investigations of South Dakota’s existing road closure gate systems and their functional performance led to conclusions that the currently used gates do need to be replaced. However, the history collected on the existing gates frequency of use turned out to be a primary piece of evidence that indicated the gate replacement alternatives should not include very high costs, be greatly sophisticated, or include very extensive levels of automation. Study findings eventually led to conclusions that the implementation of basic, low cost equipment configurations at South Dakota road closure sites would be the best overall approach. Recommendations for alternative site treatments at the various road closure locations are based on criteria that strongly evidenced this strategy. However, research findings also indicated the SDDOT will need to ensure that applicable laws, policies, and procedural definitions for the performance of road closures in the state are closely adhered to during the implementation efforts.
PROBLEM DESCRIPTION

Road closure gates in the State of South Dakota are primarily used to close roads to vehicular traffic during hazardous travel conditions brought on by inclement weather (e.g., snow storms, ice storms, etc). Since the gates are currently swing-type, hinged to posts, deployment often requires highway personnel to physically move the free end of the gate out across the roadway during dangerous road and weather situations. Potential hazards include slippery surfaces, poor visibility, and drifting snow that create extremely unsafe situations for highway personnel when road closure gates need to be deployed. Nearly all of South Dakota’s road closure gates were installed in the early 1980’s and few modifications or changes to any of the gates have occurred since that time. This study examined possible changes to the road closure gate design including ways that automated features might be incorporated to make gate operations more amenable. The ultimate goals of the project focused on the discovery of practical ways to reduce the labor intensity, as well as minimize the safety issues during road closure gate operations. Another requirement of the study was an overall assessment of road closure sites around the state to eventually determine appropriate gate configurations, suitable levels of sophistication, and the extents of automation that might be warranted for each of the various sites.

TASK OVERVIEW

Tasks 1 and 2 were designed to review and summarize remote controlled road closure systems meeting FHWA standards that might then be employed at the SDDOT. Tasks 3 and 4 were designed for the installation, monitoring, and evaluation of drop-arm style gates and gate actuators on I-90, Exit 67 in South Dakota. Tasks 5 through 9 were designed to assess road closure sites, evaluate gate operations at those sites, and then formulate recommended strategies for improving gate operations on a statewide basis based on comparative analysis to the findings of previous tasks. The remaining project tasks were developed to allow SDDOT decision-makers to receive a formal presentation of the research findings, and also to have a documented report as reference.

LITERATURE REVIEW

Literature reviews were performed with the intention of analyzing material thought to have the most direct relevance to South Dakota and the unique situations that are presented when road closures need to be performed in the state. There were some interesting findings that accrued during the literature reviews that bear careful consideration when weighed against the matters surrounding road closures in South Dakota. The essential items of interest were:

- Crash testing of road closure gates and their supporting structures have been minimal.
Intelligent Transportation Systems (ITS) initiatives are strongly suggesting more, and better integration of various transportation safety aspects including automated road closure gates, but the primary focus is in, and around urban areas.

Laws, regulations, and policies governing road closures tend to vary greatly from state-to-state, and also significantly impact road closure practices.

The means and mechanisms to perform road closures also vary widely across states.

**PLAN, MONITOR, & EVALUATE EQUIPMENT INSTALLATION AT I90, EXIT 67**

To facilitate the research efforts of this project, it was determined that an actual installation of electrically actuated drop-arm style gates would be warranted. The “test installation” would evaluate the reliability of the design, mechanical, and operational characteristics of this type gate in comparison to the similar characteristics of South Dakota’s existing swing-type gates. Because drop-arm style gates were included in the plans for SDDOT Project IM-P-90-2(71)66 (scheduled for Fall ‘02 construction on Interstate 90, Exit 67 near Rapid City), installation of linear actuators was proposed on the gates designed for both the eastbound mainline, as well as the off-ramp at that interchange. It was deemed more relevant to simply test the typical, basic components of a road closure system, which included drop-arm style gates, electric gate actuators, automated activation of advance warning lights, and remote operating devices. The estimated total cost for the final test plan was $34,393.

The final test plan did not imply that more sophisticated systems involving video aspects and Internet would be entirely excluded from consideration at the SDDOT. Instead, it was felt that the needs assessment portion of the research would be a better venue to identify the levels of automation that might be appropriate for individual road closure sites throughout the state.

Due to the unanticipated revisions to the project scope, delays in receiving project materials from suppliers, and coordinating efforts that burgeoned as deadlines became compressed, the actual installation of the road closure test system at Exit 67 did not begin until late November, 2002. Therefore, the primary purposes to test and observe the performance of system components could not be fully accomplished in the allotted time. It was originally anticipated that the evaluation performed on gate operations during winter conditions would greatly supplement the installation testing. Since no equipment evaluation occurred over the winter months, potential deficiencies noted during installation testing could not be verified against actual working conditions.

**DEVELOP INVENTORY OF EXISTING ROAD CLOSURE GATE SITES**

The SDDOT Office of Maintenance/Construction Management in the Division of Operations maintains a map of all road closure sites around the state. This “Road Closure
Gate Locations” map was obtained and reviewed in early phases of this project to assess road closure coverage on a statewide basis. Most of the road closure sites in South Dakota can be found on the Interstate system (I-29 and I-90) with coverage tending to vary greatly among SDDOT Areas. Seventy-one road closure sites were identified overall.

To facilitate the inventory collection process of existing equipment at road closure sites for this project, hardcopies of the “Road Closure Gate Locations” map were forwarded to each SDDOT Area Office. Along with copies of the map, a questionnaire requesting essential information for each road closure gate was enclosed. Nearly all SDDOT Area Offices returned inventory questionnaires complete with the desired information on road closure sites within their jurisdictions. The information received comprises a detailed inventory of the equipment at South Dakota road closure sites, as well as the specific locations and working conditions of that equipment. It was also discovered during the process of collecting inventory information that several gate locations had been abandoned, moved, or otherwise added as compared to the original map that was distributed.

Probably the most important finding of this project task was the number of times that road closures are actually performed. A primary question on the survey form asked Area Offices to approximate how many times per year (over the past 10 years) roads were actually closed at each existing site within their jurisdiction. The responses to this question were assimilated, average numbers of road closures were compiled, and results were then tabulated as follows:

<table>
<thead>
<tr>
<th>SDDOT Region</th>
<th>Average Number of Annual Road Closings/Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen (8 Sites)</td>
<td>Once Every 2 Years</td>
</tr>
<tr>
<td>Mitchell (21 Sites)</td>
<td>Once Every 2½ Years</td>
</tr>
<tr>
<td>Pierre (13 Sites)</td>
<td>Once Every 3 Years</td>
</tr>
<tr>
<td>Rapid City (24 Sites)</td>
<td>Once Every 2 Years</td>
</tr>
<tr>
<td>Statewide (66 Sites)</td>
<td>Once Every 2½ Years</td>
</tr>
</tbody>
</table>

The highest number of road closings at any one site (averaged over 10 years) was twice per year, and the least number of closings included several gates that had never been closed over a ten year period. Also, many reports indicated that not all road closures were for severe winter weather conditions, which would then tend to lower the average yearly closings for wintertime considerations.

**RECORD INFORMATION ON EXISTING ROAD CLOSURE GATE USAGE**

To facilitate the information gathering of the observations noted by SDDOT Area Office personnel on existing closure gate usage, a survey questionnaire was again employed. The questionnaire was included with the packet sent to SDDOT Area Offices as described above. It was anticipated that follow-up phone conversations and impromptu interviews
might need to be conducted with Area Office personnel upon receipt of the completed forms. This process would allow noteworthy observations to be further developed, or additional information to be requested afterwards.

All SDDOT Area Offices participated in the questionnaire process, phone interviews, or both. The observations and opinions of Area Office personnel entail a fairly comprehensive historical perspective concerning the use and maintenance of the existing SDDOT road closure equipment. Although a general consensus is that the present systems have performed adequately over the past several years, most feel that the time has come for key improvements to be instigated. Respondents to the study concurred overall on the primary shortcomings that need to be addressed, and these can be identified as follows:

- Ground anchors for cabling the gates in place across the roadway are not easily accessible when snow cover is present, are often damaged or removed by snowplows, and cannot be readily adjusted when cable lengths require adjustment.

- Gates are often difficult to swing out onto the roadway during severe winter weather conditions that may include heavy winds, icy conditions, or deep snow, and some injuries have occurred in the past during these operations.

- Battery-operated portable lights that need to be placed in gate bracket mountings during a road closure are often unreliable, particularly if the batteries are run down after long periods of storage or the brackets are filled with snow and ice.

- “Flip-up” advance warning signs are often difficult to open during severe winter weather conditions that include heavy winds and many of these signs are too high.

- Gates are often not highly visible, or lighting is felt to be insufficient enough to cause numerous reports of vehicles colliding with gates.

- Site monitoring is difficult, particularly for the more remote road closure sites, and many reports of vehicles driving around road closure gates were evidenced.

Although other problems were reported by study respondents, the above were considered the main items to be noted.

Many Area Offices have modified equipment, procedures, or operations at road closure sites over the years in efforts to overcome many of the deficiencies noted above. Most of these efforts have been performed on an ad hoc basis and have generally been considered as temporary modifications, at least until more permanent and reliable solutions could be found. The more notable “workarounds” include the following:
• Parking manned, or unmanned maintenance vehicles with mounted flashing lights either behind, or near the ends of road closure gates to increase visibility, help prevent vehicles driving around gates, and give the sense that the site is being monitored full-time.

• Piling snow around the gates to help prevent vehicle collisions with gates, stabilize the gates when cabling or cable anchors are deficient, or help prevent vehicles from driving around closed gates.

• Not replacing gates and/or advance warning signs at certain road closure sites when new construction requires their removal, and then simply taking portable barricades and signs to that site when a road closure needs to be performed.

• Taking portable barricades, signs, or maintenance vehicles with flashing lights to a site when a road closure needs to be performed because the existing road closure site has been abandoned, or existing equipment is not in good working order.

The workarounds reported may not be considered too drastic if there are indicators are that road closures at a particular location only happen very rarely and the countermeasures instilled tend to alleviate stresses for SDDOT maintenance personnel. However, if the workarounds leave ambiguity where conformance to appropriate laws or policies are concerned, then a more difficult set of problems may arise.

SUMMARIZE EXISTING ROAD CLOSURE POLICIES

SDCL 31–4–14.3 is a law enacted within recent years that is not referenced in SDDOT Policy OM-1996-01. Basically, the law states that it is a civil misdemeanor for a motorist to drive around any barriers, warning devices, or flagmen when travel has become restricted on a highway, or the highway has become closed pursuant to subdivision SDCL 31–4–14.2(1), (4), or (5). Penalties are encompassed in declarations that violators will be liable for all rescue and recovery costs, but not to exceed ten thousand dollars. Again, it should be noted that SDCL 31–4–14.2(5) is not worded like SDDOT Policy OM-1996-01, item (5).

As stated early on in this report, laws and policies governing travel restrictions on highways vary greatly among states. South Dakota laws that deal with road closures during adverse weather conditions appear to be somewhat loosely structured as compared to similar laws of other states. For most states, prevailing law will clearly dictate how a state DOT will address the needs at road closure sites. As a relative example, the Jackson, MN pilot project involving the use of video cameras to monitor, record, and provide evidence of any vehicles driving around a closed gate during winter conditions could
represent an action the Minnesota DOT is considering due to the prevailing laws of that state.

**DEVELOP OPTIMUM GATE CONFIGURATIONS AT ROAD CLOSURE SITES**

The primary assumption throughout most of the task descriptions for this project envisioned optimum gate configurations at the SDDOT that would generally include some degree of automation to alleviate many of the perceived problems at road closure sites. Therefore, during the task efforts where information about existing gate equipment and gate usage was being collected, the research also sought to survey power and telecommunications companies in South Dakota to determine availability of those utilities at each of the various road closure sites. All of the material from SDDOT Area & Region Offices, utility companies, and other sources was combined into a spreadsheet for subsequent analysis. It was felt the assimilated data would essentially provide the decision-making factors that could be used to weigh, score, and categorize road closure sites so that optimum site configurations could then be conceived.

The research efforts to perform detailed assessments of existing road closure sites on a statewide basis entailed three primary points of focus: 1) siting suitability, 2) prevailing conditions of the road closure equipment, and 3) feasibility to instill improvements. It was felt that focusing the information gathering and subsequent analysis on these three areas would lead to the most appropriate recommendations for gate configurations at all South Dakota road closure sites. Thereby, the critical information to be collected and analyzed was defined to include the following:

- Type of existing gate(s),
- Condition of existing gate(s),
- Availability of facilities in near proximity (including motels, restaurants, etc),
- Power/telecommunications accessibility,
- Frequency of use history,
- Aptness of gate locations, and
- Road closure performance needs.

Ensuing recommendations needed to identify site-specific road closure gate configurations suitably adapted to each location, and also assure that prevailing conditions would allow for the desired improvements.

Finally, it became apparent during the course of the study that some road closure sites might evidence the need to be abandoned, or else relocated. Such recommendations would
need to be justified through comprehensive reviews of the following supplemental information:

- Any history of ongoing problems,
- Prevailing road closure policies, and
- The impacts of changing conditions at certain sites over extended timeframes.

In analyzing the criteria to ultimately develop optimum gate configurations for road closure sites in South Dakota, the next logical course was to eliminate site configurations deemed unfeasible to implement. The initial focus centered on configurations that included automated aspects. Two conditions were quickly identified as the critical decision factors to use during the process of elimination. The decision factors were namely the average frequency of use for the existing South Dakota road closure sites, and the estimated costs to introduce automated aspects to a road closure site.

Based on reviews of the items above, the analysis efforts began with road closure site configurations that included 6 primary alternatives. At the same time, it was also assumed that various subsets could be developed from the 6 main configurations by either adding, or removing certain equipment components. To facilitate accuracy when comparing alternatives, the configurations are based on a road closure for one lane of traffic only. The 6 primary configurations are described as follows, along with estimated costs and a brief opinion about the implementation feasibility for each:

1) **Basic, drop-arm style gate.** This configuration would be very similar to the WYDOT gate system that includes a gate arm, light pole, base, raising-lowering mechanism, LED lights, and switch kit to interface lights with advance warning signs. **Estimated cost: $15,000.** (Please note that this cost estimate does not include installation of power to the light pole also used for the gate mounting.)

   *Feasibility statement: Costs are not excessive (although the estimate is only for equipment, and does not include installation or construction costs). This configuration seems to represent a significant improvement over the existing swing-type gates from an operational standpoint for SDDOT maintenance personnel.*

2) **Drop-arm style gate with limited automated aspects.** This configuration takes the basic equipment components from 1, above, and adds the automated aspects identical to the test equipment installed at the I90, Exit 67 pilot project initiated for this research study. **Estimated cost: $34,000.** (This estimate of costs includes $15,000 for the drop-arm gate configuration of 1, above, then adds $19,000 which is based on the original estimate to install the I90, Exit 67 test equipment utilizing existing SDDOT drop-arm gates and signage, and thereby represents the costs to incorporate both types of equipment. Again, the estimate is based on automating 1
gate only, and does not include the costs associated with automating ramp, and other gates like at Exit 67.)

**Feasibility statement:** This configuration represents an even greater improvement over the existing swing-type gates from an operational standpoint for SDDOT maintenance personnel. However, the costs increase quite dramatically as compared to 1, above.

3) **Drop-arm style gate with a full range of automated aspects** – This configuration takes the basic equipment components of 1, above, and adds the full range of automation for a road closure site, and like the one originally specified and proposed for the Exit 67 test site. **Estimated cost:** $107,000. (This estimate of costs includes $15,000 for the drop-arm gate configuration of 1, above, then adds $92,000 which is based on the original proposal to install the full range of automated aspects at the I90, Exit 67 test site whereby existing SDDOT drop-arm gates and signage would be utilized. The estimate is again based on automating 1 gate only, but does include a video camera, web host server, corresponding software, and appropriate radio communications equipment.)

**Feasibility statement:** This configuration represents the ultimate in improvements over the existing swing-type gates from an operational standpoint for SDDOT maintenance personnel. However, the costs are extremely high when compared to any of the other configuration estimates.

4) **Portable barriers and message signs** – This configuration represents an alternative that could be incorporated on an as-, and where needed basis at the SDDOT. Plastic, sectionalized, and interlocking barriers that meet NCHRP Report 350 recommendations can be filled with sand-, or water-ballast and would include reflective safety markings and battery operated warning lights. **Estimated cost:** $2,500. (Estimate includes 3 interlocking barrier sections and metal flip-up signs that are portable, but does not include any portable, digital message board type of advance warning devices.)

**Feasibility statement:** This configuration represents the minimum requirement for performing a road closure, but also has to be perceived as a feasible alternative for certain situations, or else an alternative to supplement other configurations.

5) **Road closure signage with warning lights, but no barriers** – At the present time this configuration could only be considered at the juncture of 2 major highway routes falling on a stretch of road where 2 permanent road closure sites lie at either end. **Estimated cost:** Minimal. (Fully dependent on the type of signs and warning lights to meet minimum requirements for such functionality.)

**Feasibility statement:** This alternative could only be used to supplement existing, permanent road closure sites unless applicable South Dakota codified laws and SDDOT policies were interpreted and/or modified in ways to make this more feasible as a “stand-alone” road closure option.
6) Standard, SDDOT swing-type gate – This configuration represents what the SDDOT has been using since the early 1980’s. However, most existing sites would require significant maintenance and/or modifications to be brought up to acceptable working standards. Estimated cost: Variable. (Dependent on costs associated with the maintenance and/or modifications needed at each individual site.) Feasibility statement: Essentially a “do nothing” alternative carrying no great risk.

PREPARE CONCEPTUAL PLANS FOR ROAD CLOSURE SITES

Since this project emphasized the possible incorporation of automated aspects to road closure sites in South Dakota, most of the research efforts were geared toward the ultimate formulation of plans that included technology components. As research progressed however, findings tended to scale back significantly the emphasis to implement configurations with automated features, and also to minimize the number of possible configurations that might be afforded. Also, based on the recommendations of the final report there was a realization that final decisions might clearly necessitate the formulation of wholly new road closure configurations integrating components from 2 or more alternatives. Therefore, in lieu of furnishing any detailed plans under this task effort, specific road closure equipment was detailed along with suggested ways the equipment might be integrated to afford optimum site configurations.

RECOMMENDATIONS

The reviews, analysis, and conclusions arising from the task definitions for this research study resulted in the following recommendations:

1) The SDDOT needs to ensure that ambiguities or discrepancies between departmental policies and SDCL relating to road closures on the state highway system are addressed through proper legal counsel. Reviews would need to compare and contrast SDDOT policies with SDCL to note any perceived irregularities. The project researcher would be made available to SDDOT legal counsel for further clarification of the reviews performed during this research project as needed. SDDOT Operations Support could then determine the impacts of finalized SDDOT policies to road closure equipment appropriateness, site layouts, signage types, and other considerations. This needs to be accomplished by November 1, 2003. If this action is not fulfilled, certain ambiguities will remain concerning the setup and operations of road closure sites.

2) The SDDOT Region Engineers need to meet with the project researcher to determine a final, standardized procedure for selecting road closure sites based on the “Criteria Spreadsheet to Configure SDDOT Road Closure Sites” furnished in the project Final Report by December 15, 2003. This could be
accomplished as an agenda item at regularly scheduled meetings. The successful completion of Recommendation 1, above, may well produce results that will impact this process. If this action is not accomplished, the selection of road closure sites will continue to be performed on an ad hoc basis where important criteria have the possibility of being ignored, and equipment procurements could become very non-homogeneous.

3) **The SDDOT needs to begin replacing the existing swing-type gates with new drop-arm gates under a phased implementation plan that considers replacement necessities resulting from construction activities or total replacement needs based on deteriorated conditions of existing gates.** The age, operational issues, and safety concerns associated with the existing swing-type gates all point to the need to replace this equipment with drop-arm gates that have the desired operational upgrades and safety features. The replacement process should be a phased effort that minimizes impacts to budgets, and it also should not be perceived as a statewide construction effort with immediate intentions to get all existing gates replaced at once. Instead, existing gates can be phased out during highway construction projects that dictate their removal, or as the existing gates reach states of disrepair that do indeed require their replacement. If the existing gates are not replaced, SDDOT maintenance personnel will continue to struggle with operational problems and safety will also continue to be an issue.

Based on the outcomes of Recommendations 1 & 2 above, there may well be sites where gates are felt to be unnecessary (i.e., Lack of nearby facilities, highly infrequent need to close the roadway, etc.) In these cases, portable barriers and signs, or else simply warning signs with proper notification to the public may be deemed adequate. In other cases, sites like those previously cited near state borders or at critical points around urban areas may need to include powered gate installations at the site. Considerations would include future ITS integration, under-equipped personnel manning the site more regularly (such as a SD Highway Patrol Officer), or other planned actions where future integration would require retrofitting of non-powered gate arms to be burdensome. Other than special attention to the equipment configurations at low-, and high priority sites, a basic drop-arm gate configuration is recommended for all other sites in South Dakota. Not recognizing the low-, and high priority sites at this time would most likely result in additional future expenditures.

4) **Each SDDOT Region should consider procurement of one road closure site configuration that is comprised of portable equipment.** The equipment configuration would consist of one set of portable barricades, signs, and warning lights that are all readily transportable to any road closure location of choice. Prior to any procurement, the use of portable equipment should be discussed with maintenance personnel at each Region. At the same time, compliance of the equipment with NCHRP Report 350 should be ensured. Maintenance personnel at each Region would
be expected to test and verify the workability of this equipment in “standalone” configurations, and as supplemental equipment to pre-existing sites.

SDDOT personnel designated to respond to these recommendations should feel free to contact the SDDOT Office of Research for any clarifications or assistance regarding the above. Since this study was performed “in house”, implementation of the recommendations contained herein can be presumed as inter-office continuation of the project efforts.