Resiliency of Utah's Road Network:

a Logit-based Approach

Max Barnes

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Gregory Macfarlane, Chair
Grant G. Schultz
Dan Ames

Department of Civil and Construction Engineering

Brigham Young University

ABSTRACT

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Max Barnes
Department of Civil and Construction Engineering, BYU
Master of Science

The abstract is a summary of the dissertation, thesis, or selected project with emphasis on the findings of the study. The abstract must not exceed 1 page in length. It should be printed in the same font and size as the rest of the work. The abstract precedes the acknowledgments page and the body of the work.

Keywords: resilience, logsum, logit, modechoice, destination choice, CUBE

ACKNOWLEDGMENTS

Students may use the acknowledgments page to express appreciation for the committee members, friends, or family who provided assistance in research, writing, or technical aspects of the dissertation, thesis, or selected project. Acknowledgments should be simple and in good taste.

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NOMENCLATURE

B	Barrier to extract information about a product from the product itself
$\overline{D}$	Macroscopic strain rate
D_0	First component of strain rate tensor
D_k^N	Normal direction of the k-th lamina, also an axis for the lamina reference frame
D_k^R	Rolling direction of the k-th lamina, also an axis for the lamina reference frame
D_k^T	Transverse direction of the k-th lamina, also an axis for the lamina reference frame
$\overline{d}$	Average grain size
Δg	Volume of discretized bins in Fundamental Zone
E	Young's modulus
$E_m(wxyz)$	Fourier coefficients representing Young's modulus in the $wxyz$ direction for the m-th bin of the Fundamental Zone
F	Estimated rate at which information is extracted from a product
F_m	Fourier coefficients of crystal volume fraction in the m-th bin of the Fundamental Zone
G	Shear modulus
g	Euler angles from Sample to Crystal reference frames
g_{wx}	Orientation matrix of Euler angles from Sample to Crystal reference frames
$\dot{\gamma}$	Shear rate
$\dot{\gamma}_0$	Reference shear rate
K	Estimated or actual information contained by a product
L	Distance between straight, parallel lines used to determine average grain size
λ	The contraction ratio for the strain tensor
M	Material class, (e.g., nickel, copper)
M_0	Selected alloy from material class
N	Number of laminae to be used in layer-by-layer creation of material
n	Inverse rate sensitivity parameter
n_c	Number of columns in the binned Fundamental Zone
n_h	Number of layers in the binned Fundamental Zone
n_r	Number of rows in the binned Fundamental Zone
ν	Poisson's ratio
P	Estimated power exerted to extract information contained by a product
$\phi_{1,i}$	Lamination orientation for the i-th layer
S	A measure of a product's ability to contain information
S_{11}	Material property constant obtained from literature for selected material class
S_{12}	Material property constant obtained from literature for selected material class
S_{44}	Material property constant obtained from literature for selected material class
$\overline{S}(wxyz)$	Sample compliance (average crystal compliance)
s	Slip systems. Comprised of slip plane normals, $\{111\}$, and slip directions $< 110 >$
σ'_{ij}	Deviatoric stress
σ_y	Yield strength
T	Estimated time to extract information K
t	Reference time frame for reverse engineering a product
τ	Reference time frame when all parameters are known

τ_0	Lattice friction stress
τ^*	Reference shear stress
Y_m	Fourier coefficients representing yield strength physics

Subscripts, superscripts, and other indicators

$[\,]^*$	indicates total measure or effective property
$[\,](t)$	indicates $[\,]$ is a function of time, in the t domain
$[\,](\tau)$	indicates $[\,]$ is a function of time, in the τ domain
$[\,]_0$	indicates $[\,]$ is evaluated at time t or τ equal to zero
$[\,]_p$	indicates $[\,]$ is in the part reference frame
$[\,]_c$	indicates $[\,]$ is in the crystal reference frame
$[\,]_l$	indicates $[\,]$ is in the lamina reference frame
$[\,]_t$	indicates $[\,]$ is the target value

CHAPTER 1. INTRODUCTION

This is an example of the introduction. It's pretty simple and shows off some of the basic commands.

1.1 Problem Statement

The Utah Department of Transportation (UDOT) is responsible for maintaining a transportation system to promote public welfare and economic activity throughout the state. UDOT is also responsible to maintain key components of the national highway transportation system. Given the importance of this system, UDOT has sought in the last several years to identify which facilities are most critical to the smooth operations of this system.

In 2017, AEM (2017) completed a risk and resilience analysis for the I-15 corridor on behalf of UDOT. This analysis quantified risk as the probability of threats (earthquakes, floods, fires, etc.) multiplied by the criticality of the asset to the overall system were such threats to materialize. The AEM analysis has two primary limitations. First, the methods are proprietary to AEM and UDOT cannot now apply the methods to study the criticality of other transportation corridors with regional and national significance (e.g. U.S. Route 6, Interstate 70). But more importantly, the current index treats each UDOT asset – each bridge, highway segment, etc. – as an independent unit when in fact UDOT operates a system of transportation facilities. The criticality of a single bridge to the overall system is not determined by the volume of traffic it supports directly, but by how inconvenient it would be for that traffic to find another path or destination were the bridge to fail. Resiliency must therefore be considered a function of network alternatives, or redundancy.

1.2 Objectives

The primary objective of this research is to develop a methodology and tool to evaluate the network redundancy of critical UDOT assets across the state. We base this tool on data collected for the Utah Statewide Travel Model (USTM), with certain improvements and additional model features to more accurately capture the economic costs associated with an impaired state highway network. In particular, we develop a method that explicitly considers the availability of alternative destinations, modes, and routes to individuals traveling on the impaired network. A secondary objective of this research is to apply the model to evaluate the criticality of specific highway links in Utah by comparison. This report presents the results of this evaluation applied on 41 individual highway links.

1.3 Scope

The purpose of the resiliency model is to provide a working model that can be used to evaluate the potential economic costs were a highway link – or a set of highway links – to be damaged or destroyed temporarily in Utah. This model is based in the theory of logit choice modeling and shortest path finding in a network. The specific choice utility equations in the model represent a plausible utility outcome, but the focus of this research has not been on developing robust utility equations or calibrated volume-delay functions. This model is therefore not designed to forecast traffic volumes or designed for any purpose other than providing a comparative estimate of the effects of link loss by man-made or natural causes.

1.4 Outline of Report

This report is organized as follows:

- Chapter 1. This introductory chapter.
- Chapter 2. A Literature Review, summarizing previous attempts to model network resiliency using the choices and accessibility of individuals on the impacted network.

- Chapter 3. This chapter presents a proposed model design and implementation of the model within the CUBE transportation planning software application. This chapter also describes model calibration efforts.

- Chapter 4. This chapter presents a method for identifying vulnerable and potentially critical highway links by considering the location-based elevated risk issues. This chapter summarizes a previous study conducted by BIO-WEST.

- Chapter 5. A Model Application, describing and comparing the results of the model developed in Chapter 3 to the highway links identified in Chapter 4.

- Chapter 6. A Conclusions chapter summarizing the findings and providing additional recommendations to UDOT.

CHAPTER 2. LITERATURE REVIEW

REFERENCES

[1] Aeyels, D., 1986. "Local and global stabilizability for nonlinear systems." In *Theory and Applications of Nonlinear Control Systems*, C. I. Byrnes and A. Lindquist, eds., Elsevier Science Publishers, pp. 93–105. 9

APPENDIX A. MAKING A FIGURE WITH WIDTH BASED ON PAGE SIZE

A.1 Width Based on Page Size Figure Example

Here's an example of a figure whose width depends on the width of the page. You can see it as Figure A.1. This also shows another citation [1].

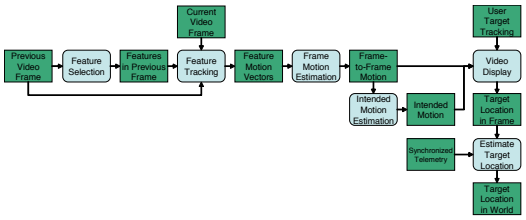

Figure A.1: This is an example of a figure whose width will be 45% of the width of the page. If you'd like to see a figure with a fixed width then you can see it as Figure **??** in Section **??** of Chapter 1.

APPENDIX B. FORMATTING GUIDELINES FOR THESIS

This appendix outlines the required formatting for theses and dissertations. While the LaTeX template takes care of most of these automatically, it is the student's responsibility to ensure that all formatting requirements are incorporated in the document.

B.1 Font

Times New Roman 12 pt. throughout text and 10 or 11 point for tables and figures.

B.2 Margins

- Preliminary Pages (Title page, Abstract page(s), Acknowledgment page, Table of Contents, List of Figures, List of Tables): 1 inch on all sides
- Body Pages, beginning with Introduction: 1 inch on all sides
- Chapter title pages, Appendix title page, Reference title page: 2 inches at top, 1 inch at bottom and sides

B.3 Printing

- Single-sided: Title page, Abstract page(s), Acknowledgment page
- Two-sided: Table of Contents, List of Figures, List of Tables, Body, Appendix, References

Note: Table of Contents, List of Figures, List of Tables, Chapter title pages, References and Appendix pages must begin on the front side of a page.

B.4 Page Numbering

- Page numbers are centered at the bottom of the page.

- Counting begins with the Title page; however, back pages are not counted until the Table of Contents.
- Page numbers do not appear on the page until the Table of Contents (v).
- Use Roman Numerals (v, vi, vii, ...) for the Table of Contents page and the pages thereafter until Chapter 1.
- Use Arabic numbers (1, 2, 3 ...) beginning with Chapter 1.
- Be sure numbers appear on all blank back pages once numbering begins.

B.5 Spacing

- Double-space text of body.
- Single-space abstract, captions, quotes, long chapter titles, headings, and subheadings.
- Table of Contents, List of Figures, List of Tables, and References can be single-spaced or double spaced.
- Double-space three times after chapter titles (48 pts).
- Double-space twice before subheadings (24 pts).
- Double-space once after subheadings (0 pts).
- Double-space once between two subheadings (0 pts).
- Double-space twice before and after figures (24 pts).
- Double-space twice before and after tables (24 pts).
- Double-space once before and after equations (0 pts).
- Do not leave a single line of text, a single-line equation, or a subheading alone on the top (widow) or bottom (orphan) of a page.
- Do not leave more than about 5 lines of white space remaining on a page unless its the end of a chapter.

B.6 Figures

- Figures are normally diagrams, graphs, maps, or charts.
- Center figures on the page.
- Center captions below the figure. If two lines are needed, the caption should be left justified at margin.
- A figure should be placed after the paragraph of reference. If it will not fit on the same page, continue the text and place the figure on the next page.

B.7 Tables

- Tables contain numerical or statistical information.
- Center tables on the page.
- Center captions above the table. If more than one line is needed, center the lines in an inverted pyramid:

Table 6.3 Comparison of roll rotation plots when node was displaced,
and an X-direction off-axis force was applied.

- If placed in the landscape position, the top of the table should be on the left side of the page, with the caption above the table. The page number is placed in the standard location.