Software Requirements Specification for Bridge Corrosion: A Chloride Exposure Prediction Model

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Contents

Revision History

Date	Version	Notes
Jan 27, 2024	1.0	Initial release

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

Throughout this document SI (Système International d'Unités) is employed as the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

symbol	unit	SI
m	length	metre
kg	mass	kilogram
s	time	second

[Only include the units that your SRS actually uses. —TPLT]

[Derived units, like newtons, pascal, etc, should show their derivation (the units they are derived from) if their constituent units are in the table of units (that is, if the units they are derived from are used in the document). For instance, the derivation of pascals as $\mathrm{Pa} = \mathrm{N\,m^{-2}}$ is shown if newtons and m are both in the table. The derivations of newtons would not be shown if kg and s are not both in the table. —TPLT]

[The symbol for units named after people use capital letters, but the name of the unit itself uses lower case. For instance, pascals use the symbol Pa, watts use the symbol W, teslas use the symbol T, newtons use the symbol N, etc. The one exception to this is degree Celsius. Details on writing metric units can be found on the NIST web-page. —TPLT]

1.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The choice of symbols was made to be consistent with the heat transfer literature and with existing documentation for solar water heating systems. The symbols are listed in alphabetical order.

symbol	unit	description
a_{splash}	N/A	maximum deposition rate occur from splash
a_{spray}	N/A	maximum deposition rate occur from spray
a_{air}	N/A	maximum deposition rate occur from spray
b_{splash}	N/A	splash emission rate coefficient
b_{spray}	N/A	spray emission rate coefficient
C_s	$kg/m^3/vehicle$	chloride on the bridge substructure
$C_{s_{air}}$	$kg/m^3/vehicle$	chloride sprayed and splashed per unit air volume per vehicle
δ_{salt}	N/A	ratio of salt over water per unit area of road
d	m	distance between road edge and nearby bridge structure
h_{app}	m	daily water film thickness on the road
h_{film}	m	depth of the water film picked up in each rotation
h_{total}	m	water equivalent of snowfall
I	m/h	rainfall intensity
K	N/A	ratio of the tire width that is not a groove to the tire width
L	m	drainage length
M_{app}	kg/m^2	deicing salts quantity applied per day
M_{total}	kg/m^2	total amount of deicing salts quantity over winter
MR_{BW}	kg/s	MFR displaced by a single tire due to bow
MR_{CA}	kg/s	MFR displaced by a single tire due to capillary adhesion
MR_{SW}	kg/s	MFR displaced by a single tire due to side waves
MR_{TP}	kg/s	MFR displaced by a single tire due to tread pickup
MR_W	kg/s	general MFR displaced by a single tire due to capillary adhesion
N_{lane}	lane	number of lanes
ρ_{water}	kg/m^3	density of water
SD_{BW}	$kg/m^3/vehicle$	spray density by a single tire due to bow
SD_{CA}	$kg/m^3/vehicle$	spray density by a single tire due to capillary adhesion
SD_{SW}	$kg/m^3/vehicle$	spray density by a single tire due to side waves
SD_{TP}	$kg/m^3/vehicle$	spray density by a single tire due to tread pickup
SD_{total}	$kg/m^3/vehicle$	spray density kicked up by each passing truck
$SD_{total\ cl}$	$kg/m^3/vehicle$	mass of chloride ions per unit air volume
S	N/A	slope as a ratio
T	mm	profile depth
t_1	days	number of days with snowfall

t_2	days	number of days with snow melting
t_{snow}	days	number of days with snow
V	m/s	truck speed
V_{salt}	$tonnes/cm/km$	normalized salt application rate
V_{speed}	km/h	heavy vehicle speed
V'	$miles/h$	heavy vehicle speed
W_{lane}	m	lane width
WD	m	water depth/thickness
x	m	distance between road and object surface
Θ	N/A	ratio of chloride ions sprayed and splashed by trucks over those by light duty vehicles
$\theta_{chloride}$	N/A	molar mass ratio of chloride ions over deicing salts

[Use your problems actual symbols. The si package is a good idea to use for units. —TPLT]

1.3 Abbreviations and Acronyms

symbol	description
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
BS	Bridge Corrosion
TM	Theoretical Model
NaCl	Sodium Chloride, the main component of deicing salts
CA	Capillary Adhesion
TP	Tread Pickup
BW	Bow Waves
SW	Side Waves
MFR	Mass Flow Rate
ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
AADTT	Annual Average Daily Truck Traffic

[Add any other abbreviations or acronyms that you add —TPLT]

1.4 Mathematical Notation

symbol	description
$\mathbb{R}$	Real number
$\{\mathbb{R}\}$	a set of real number

[This section is optional, but should be included for projects that make use of notation to convey mathematical information. For instance, if typographic conventions (like bold face font) are used to distinguish matrices, this should be stated here. If symbols are used to show mathematical operations, these should be summarized here. In some cases the easiest way to summarize the notation is to point to a text or other source that explains the notation. —TPLT]

[This section was added to the template because some students use very domain specific notation. This notation will not be readily understandable to people outside of your domain. It should be explained. —TPLT]

[This SRS template is based on **???**. It will get you started. You should not modify the section headings, without first discussing the change with the course instructor. Modification means you are not following the template, which loses some of the advantage of a template, especially standardization. Although the bits shown below do not include type information, you may need to add this information for your problem. If you are unsure, please can ask the instructor. —TPLT]

[Feel free to change the appearance of the report by modifying the LaTeX commands. —TPLT]

[This template document assumes that a single program is being documented. If you are documenting a family of models, you should start with a commonality analysis. A separate template is provided for this. For program families you should look at **??**. Single family member programs are often programs based on a single physical model. General purpose tools are usually documented as a family. Families of physical models also come up. —TPLT]

[The SRS is not generally written, or read, sequentially. The SRS is a reference document. It is generally read in an ad hoc order, as the need arises. For writing an SRS, and for reading one for the first time, the suggested order of sections is:

- Goal Statement
- Instance Models
- Requirements
- Introduction
- Specific System Description

—TPLT]

[Guiding principles for the SRS document:

- Do not repeat the same information at the same abstraction level. If information is repeated, the repetition should be at a different abstraction level. For instance, there will be overlap between the scope section and the assumptions, but the scope section will not go into as much detail as the assumptions section.

—TPLT]

[The template description comments should be disabled before submitting this document for grading. —TPLT]

[You can borrow any wording from the text given in the template. It is part of the template, and not considered an instance of academic integrity. Of course, you need to cite the source of the template. —TPLT]

[When the documentation is done, it should be possible to trace back to the source of every piece of information. Some information will come from external sources, like terminology. Other information will be derived, like General Definitions. —TPLT]

[An SRS document should have the following qualities: unambiguous, consistent, complete, validatable, abstract and traceable. —TPLT]

[The overall goal of the SRS is that someone that meets the Characteristics of the Intended Reader (Section 2.3) can learn, understand and verify the captured domain knowledge. They should not have to trust the authors of the SRS on any statements. They should be able to independently verify/derive every statement made. —TPLT]

2 Introduction

In Ontario, most of the bridges in highway are made of reinforced concrete (RC) decks. However, the bridges may face the chloride-induced corrosion which damage its surface. There are many elements influencing this situation, one of the most important one is the deicing salts. The primary used is sodium chloride (rock salt),when they melt the snow and in contact with water, they could have a chemical reaction and release the chloride ions. Those chloride could penetrate the concrete and induce corrosion in the reinforcing steel, then damage the bridges' structure and capacity.

There is a tight connection between chloride exposure, weather conditions and traffic flow. Specifically, the amount of deicing salts applied on the road surface greatly depends on the amount of snowfall, and the amount of water and dissolved chloride ions that end up on nearby objects depends on the traffic patterns. This section outlines the document's purpose, delineates its scope of requirements, describes the intended audience's characteristics, and provides an overview of the document's organization.

[The introduction section is written to introduce the problem. It starts general and focuses on the problem domain. The general advice is to start with a paragraph or two that describes the problem, followed by a "roadmap" paragraph. A roadmap orients the reader by telling them what sub-sections to expect in the Introduction section. —TPLT]

2.1 Purpose of Document

This document details the requirements of the software Bridge Corrosion. The responsibilities of the user and software are laid out and the requirements that the software must satisfy are explicitly detailed. This document provides the software requirements specification (SRS) for a project to investigate how the climate and traffic could have impact on the corrosion-induced damage for the reinforced concrete, or to be more specific, how they influence the chloride exposure.

[This section summarizes the purpose of the SRS document. It does not focus on the problem itself. The problem is described in the "Problem Description" section (Section 4.1). The purpose is for the document in the context of the project itself, not in the context of this course. Although the "purpose" of the document is to get a grade, you should not mention this. Instead, "fake it" as if this is a real project. The purpose section will be similar between projects. The purpose of the document is the purpose of the SRS, including communication, planning for the design stage, etc. —TPLT]

2.2 Scope of Requirements

The entire document is written as the chloride is the main source of corrosion damage to the reinforced concrete, and chloride ions are transported from the road to the exterior surface of bridge substructures through vehicle spray and splash mechanisms. Another scope of the document is the factors that affect bridge corrosion is limit to chloride levels, climatic conditions, and traffic patterns.

[Modelling the real world requires simplification. The full complexity of the actual physics, chemistry, biology is too much for existing models, and for existing computational solution techniques. Rather than say what is in the scope, it is usually easier to say what is not. You can think of it as the scope is initially everything, and then it is constrained to create the actual scope. For instance, the problem can be restricted to 2 dimensions, or it can ignore the effect of temperature (or pressure) on the material properties, etc. —TPLT]

[The scope section is related to the assumptions section (Section 4.4.1). However, the scope and the assumptions are not at the same level of abstraction. The scope is at a high level. The focus is on the "big picture" assumptions. The assumptions section lists, and describes, all of the assumptions. —TPLT]

[The scope section is relevant for later determining typical values of inputs. The scope should make it clear what inputs are reasonable to expect. This is a distinction between scope and context (context is a later section). Scope affects the inputs while context affects how the software will be used. —TPLT]

2.3 Characteristics of Intended Reader

Readers of this documentation are expected to have a understanding of high school mathematics and chemistry, and the ability to comprehend basic results generated through computational fluid dynamics. The users of Bridge Corrosion may exhibit diverse levels of expertise, as further detailed in Section 3.2.

[This section summarizes the skills and knowledge of the readers of the SRS. It does NOT have the same purpose as the "User Characteristics" section (Section 3.2). The intended readers are the people that will read, review and maintain the SRS. They are the people that will conceivably design the software that is intended to meet the requirements. The user, on the other hand, is the person that uses the software that is built. They may never read this SRS document. Of course, the same person could be a "user" and an "intended reader." —TPLT]

[The intended reader characteristics should be written as unambiguously and as specifically as possible. Rather than say, the user should have an understanding of physics, say what kind of physics and at what level. For instance, is high school physics adequate, or should the reader have had a graduate course on advanced quantum mechanics? —TPLT]

2.4 Organization of Document

The organization of this document follows the template for an SRS for scientific computing software proposed by Smith et al. [1, 2, 3]. Starting with the reference material including units, symbols and abbreviations, this document next introduce the system that we are going to build from general to specific, including the problem, goal, assumptions, theoretical model and instance models. It also talks about the functional and nonfunctional requirements for this project, which could be referred to in process of development.

[This section provides a roadmap of the SRS document. It will help the reader orient themselves. It will provide direction that will help them select which sections they want to read, and in what order. This section will be similar between project. —TPLT]

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics and lists the system constraints. [This text can likely be borrowed verbatim. —TPLT]

[The purpose of this section is to provide general information about the system so the specific requirements in the next section will be easier to understand. The general system description section is designed to be changeable independent of changes to the functional requirements documented in the specific system description. The general system description provides a context for a family of related models. The general description can stay the same, while specific details are changed between family members. —TPLT]

3.1 System Context

[Your system context will include a figure that shows the abstract view of the software. Often in a scientific context, the program can be viewed abstractly following the design pattern of Inputs → Calculations → Outputs. The system context will therefore often follow this pattern. The user provides inputs, the system does the calculations, and then provides the outputs to the user. The figure should not show all of the inputs, just an abstract view of the main categories of inputs (like material properties, geometry, etc.). Likewise, the outputs should be presented from an abstract point of view. In some cases the diagram will show other external entities, besides the user. For instance, when the software product is a library, the user will be another software program, not an actual end user. If there are system constraints that the software must work with external libraries, these libraries can also be shown on the System Context diagram. They should only be named with a specific library name if this is required by the system constraint. —TPLT] Figure 1 shows the system context of the software. The user should input a coordinates to the software, and the software will return the predicted chloride exposure over time to the user. The user and the software also assume the following responsibilities.

[For each of the entities in the system context diagram its responsibilities should be listed. Whenever possible the system should check for data quality, but for some cases the

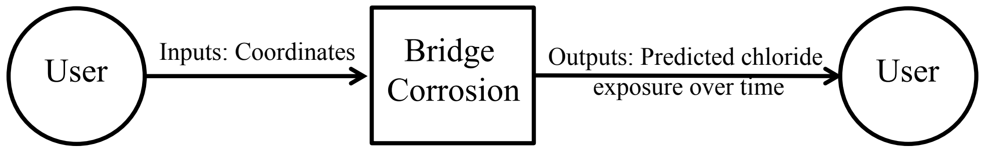


Figure 1: System Context

user will need to assume that responsibility. The list of responsibilities should be about the inputs and outputs only, and they should be abstract. Details should not be presented here. However, the information should not be so abstract as to just say "inputs" and "outputs". A summarizing phrase can be used to characterize the inputs. For instance, saying "material properties" provides some information, but it stays away from the detail of listing every required properties. —TPLT]

- User Responsibilities:
  - Provide valid coordinates to the software.
- Bridge Corrosion Responsibilities:
  - Build a database storing the chloride exposure data for every 25 km over time.
  - Search and return the chloride exposure trend at given input coordinate.
  - Provide visualization of the output.

[Identify in what context the software will typically be used. Is it for exploration? education? engineering work? scientific work?. Identify whether it will be used for mission-critical or safety-critical applications. —TPLT] [This additional context information is needed to determine how much effort should be devoted to the rationale section. If the application is safety-critical, the bar is higher. This is currently less structured, but analogous to, the idea to the Automotive Safety Integrity Levels (ASILs) that McSCert uses in their automotive hazard analyses. —TPLT]

[The —SS]

3.2 User Characteristics

[This section summarizes the knowledge/skills expected of the user. Measuring usability, which is often a required non-function requirement, requires knowledge of a typical user. As mentioned above, the user is a different role from the "intended reader," as given in Section 2.3. As in Section 2.3, the user characteristics should be specific an unambiguous.

For instance, "The end user of ProgName should have an understanding of undergraduate Level 1 Calculus and Physics." —TPLT] The end user of Bridge Corrosion should have the basic understanding of geographic coordinates. Additionally, users may benefit from some knowledge of bridge construction or civil engineering principles to better understand the context and implications of the predicted chloride exposure.

3.3 System Constraints

[System constraints differ from other type of requirements because they limit the developers' options in the system design and they identify how the eventual system must fit into the world. This is the only place in the SRS where design decisions can be specified. That is, the quality requirement for abstraction is relaxed here. However, system constraints should only be included if they are truly required. —TPLT] The software must be able to provide output for coordinates inside Ontario.

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finally the instance models. [Add any project specific details that are relevant for the section overview. —TPLT]

4.1 Problem Description

This project is intended to investigate how climate, traffic might impact corrosion-induced damage for reinforced concrete bridges by influencing the chloride exposure.

[What problem does your program solve? The description here should be in the problem space, not the solution space. —TPLT]

4.1.1 Terminology and Definitions

[This section is expressed in words, not with equations. It provide the meaning of the different words and phrases used in the domain of the problem. The terminology is used to introduce concepts from the world outside of the mathematical model The terminology provides a real world connection to give the mathematical model meaning. —TPLT]

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making it easier to correctly understand the requirements:

- Mass flow rate: The amount of water displaced by a single tire.
- Spray density: The water concentration(mass of water per unit air volume) in the environment.

- Airborne deposition: The process of particles moving from the atmosphere to the earth's surface.

- Deposition rate: The rate at which a substance is deposited onto a surface over a specific period of time.

4.1.2 Physical System Description

[The purpose of this section is to clearly and unambiguously state the physical system that is to be modelled. Effective problem solving requires a logical and organized approach. The statements on the physical system to be studied should cover enough information to solve the problem. The physical description involves element identification, where elements are defined as independent and separable items of the physical system. Some example elements include acceleration due to gravity, the mass of an object, and the size and shape of an object. Each element should be identified and labelled, with their interesting properties specified clearly. The physical description can also include interactions of the elements, such as the following: i) the interactions between the elements and their physical environment; ii) the interactions between elements; and, iii) the initial or boundary conditions. —TPLT]

The key physical system of Bridge Corrosion, as shown in Figure 2, simulate the situation that a vehicle spray and splash the water, it includes the following elements:

PS1: Capillary adhesion: The absorption of water (present on the road surface) by the tires through surface tension.

PS2: Tread pickup: Water within the grooves of a tire being sprayed and splashed behind the tire by turbulent flow in the grooves.

PS3: Bow wave: Water sent towards the front of the tire because of the physical displacement of water from the road surface due to the vehicle tires.

PS4: Side wave: Water sent in the direction perpendicular to the traffic because of the physical displacement of water from the road surface due to the vehicle tires.

[A figure here makes sense for most SRS documents —TPLT]

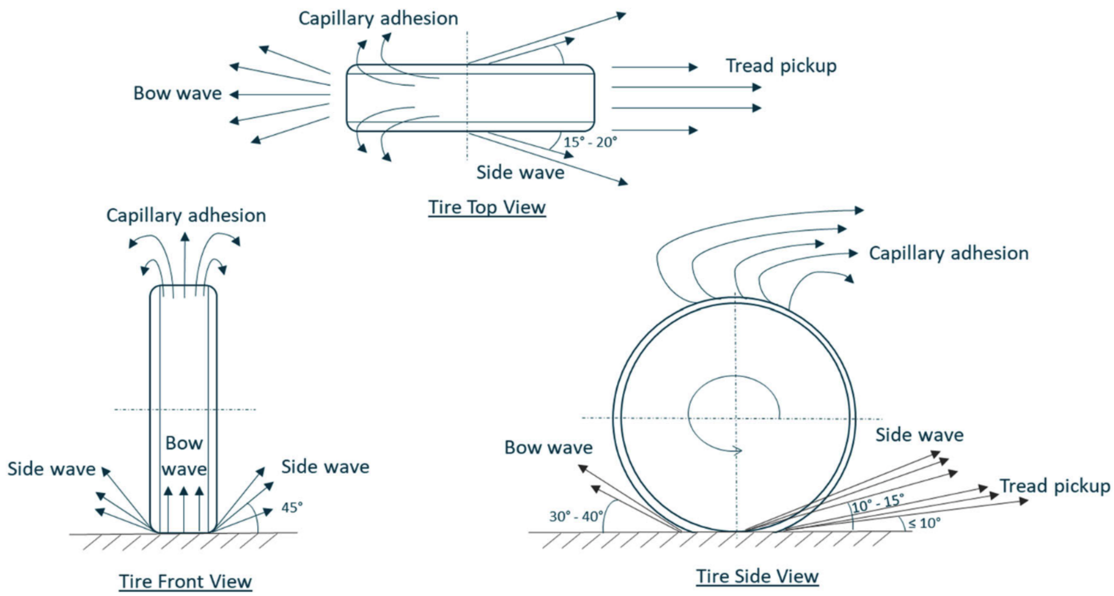


Figure 2: Mechanisms of vehicle spray and splash

4.1.3 Goal Statements

[The goal statements refine the "Problem Description" (Section 4.1). A goal is a functional objective the system under consideration should achieve. Goals provide criteria for sufficient completeness of a requirements specification and for requirements pertinence. Goals will be refined in Section "Instanced Models" (Section 4.4.6). Large and complex goals should be decomposed into smaller sub-goals. The goals are written abstractly, with a minimal amount of technical language. They should be understandable by non-domain experts. —TPLT]
Given the salt application data, climate data and traffic data across different regions and time period , the goal statements are:

GS1: Predict the chloride exposure for bridges in Ontario over time.

GS2: Allow user to input coordinate and return the prediction for the nearest bridge.

[One sentence description of the goal. There may be more than one. Each Goal should have a meaningful label. —TPLT]

4.2 Solution Characteristics Specification

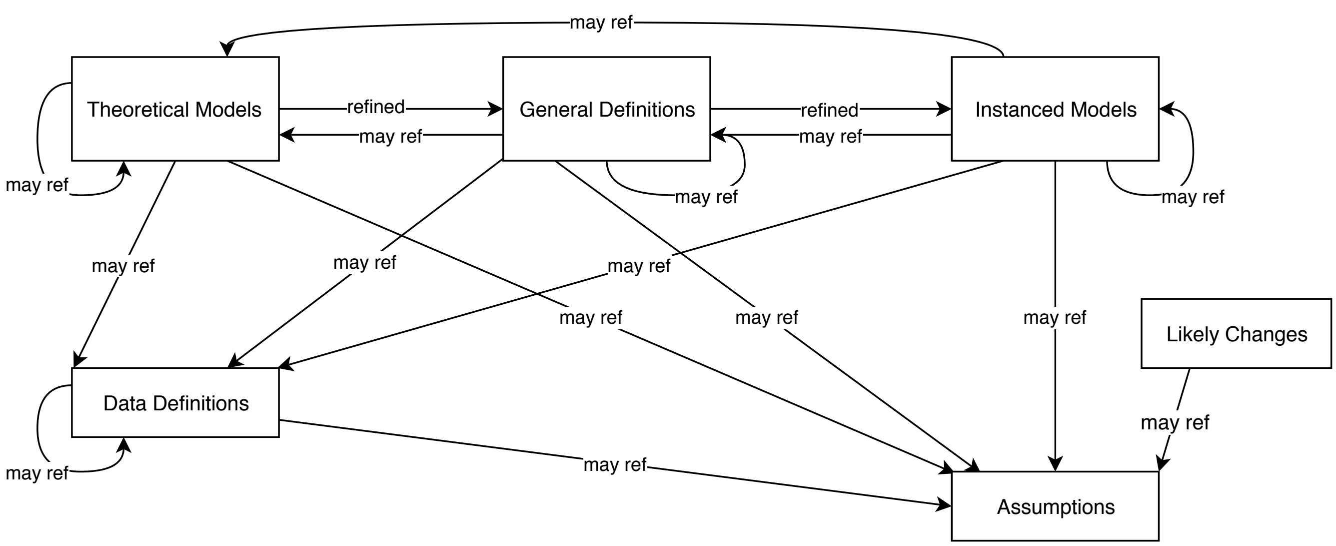
[This section specifies the information in the solution domain of the system to be developed. This section is intended to express what is required in such a way that analysts and stakeholders get a clear picture, and the latter will accept it. The purpose of this section is to reduce the problem into one expressed in mathematical terms. Mathematical expertise is used to extract the essentials from the underlying physical description of the problem, and to collect and substantiate all physical data pertinent to the problem. —TPLT]

[This section presents the solution characteristics by successively refining models. It starts with the abstract/general Theoretical Models (TMs) and refines them to the concrete/specific Instance Models (IMs). If necessary there are intermediate refinements to General Definitions (GDs). All of these refinements can potentially use Assumptions (A) and Data Definitions (DD). TMs are refined to create new models, that are called GMs or IMs. DDs are not refined; they are just used. GDs and IMs are derived, or refined, from other models. DDs are not derived; they are just given. TMs are also just given, but they are refined, not used. If a potential DD includes a derivation, then that means it is refining other models, which would make it a GD or an IM. —TPLT]

[The above makes a distinction between "refined" and "used." A model is refined to another model if it is changed by the refinement. When we change a general 3D equation to a 2D equation, we are making a refinement, by applying the assumption that the third dimension does not matter. If we use a definition, like the definition of density, we aren't refining, or changing that definition, we are just using it. —TPLT]

[The same information can be a TM in one problem and a DD in another. It is about how the information is used. In one problem the definition of acceleration can be a TM, in another it would be a DD. —TPLT]

[There is repetition between the information given in the different chunks (TM, GDs etc) with other information in the document. For instance, the meaning of the symbols, the units etc are repeated. This is so that the chunks can stand on their own when being read by a reviewer/user. It also facilitates reuse of the models in a different context. —TPLT]
[The relationships between the parts of the document are show in the following figure. In this diagram "may ref" has the same role as "uses" above. The figure adds "Likely Changes," which are able to reference (use) Assumptions. —TPLT]



The instance models that govern this project are presented in Subsection 4.4.6. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

4.2.1 Types

[This section is optional. Defining types can make the document easier to understand. —TPLT]

Input:

- longitude = $\mathbb{R}$
- latitude = $\mathbb{R}$

Output:

- predictedChlorideExposure = $\{\mathbb{R}\}$

4.3 Scope Decisions

[This section is optional. —TPLT]

4.4 Modelling Decisions

[This section is optional. —TPLT]

4.4.1 Assumptions

[The assumptions are a refinement of the scope. The scope is general, where the assumptions are specific. All assumptions should be listed, even those that domain experts know so well that they are rarely (if ever) written down. —TPLT] [The document should not take for granted that the reader knows which assumptions have been made. In the case of unusual assumptions, it is recommended that the documentation either include, or point to, an explanation and justification for the assumption. —TPLT] [If it helps with the organization and understandability, the assumptions can be presented as sub sections. The following subsections are options: background theory assumptions, helper theory assumptions, generic theory assumptions, problem specific assumptions, and rationale assumptions —TPLT]

This section simplifies the original problem and helps in developing the theoretical model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the theoretical model [TM], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1: All the deicing salts are applied on days with snowfall. (RefBy: TM3, GD3, DD1, DD2)

A2: The lane width for all the roads are the same. (RefBy: DD1, LC1)

A3: The main component of deicing salt is NaCl. (RefBy: DD3, DD6)

A4: Same class of the road over which the bridge spans has the same AADT. (RefBy: GD3, LC2)

[Short description of each assumption. Each assumption should have a meaningful label. Use cross-references to identify the appropriate traceability to TM, GD, DD etc., using commands like dref, ddref etc. Each assumption should be atomic - that is, there should not be an explicit (or implicit) "and" in the text of an assumption. —TPLT]

4.4.2 Theoretical Models

[Theoretical models are sets of abstract mathematical equations or axioms for solving the problem described in Section "Physical System Description" (Section 4.1.2). Examples of theoretical models are physical laws, constitutive equations, relevant conversion factors, etc. —TPLT]

[Optionally the theory section could be divided into subsections to provide more structure and improve understandability and reusability. Potential subsections include the following: Context theories, background theories, helper theories, generic theories, problem specific theories, final theories and rationale theories. —TPLT]

This section focuses on the general equations and laws the project is based on. [Modify the examples below for your problem, and add additional models as appropriate. —TPLT]

Number	TM1
Label	**Water film thickness**
SI Units	m
Equation	$WD = 6 \times 10^{-4} \cdot T^{0.09}(L \cdot I)^{0.6} \cdot S^{-0.33}$
Description	The above equation compute the water film thickness based on the rainfall intensity and pavement surface properties. • WD is the water depth (m) • T is the texture (mm) • L is the drainage length (m) • I is the rainfall intensity (m/h) • S is the slope (ratio)
Source	[5]
Ref. By	TM2

Number	TM2
Label	**Max flow rate general**
SI Units	kg/s
Equation	$MR_W = V \cdot b \cdot WD \cdot \rho_{water}$
Description	The above equation is the general equation for mass flow rate, which is the maximum amount of water available for splash and spray. • V is the truck speed (m/s) • b is the tire width (m) • WD is the water depth/thickness (m) • ρ_{water} is the density of water (kg/m^3)
Source	[5]
Ref. By	GD1
Use	TM1

Number	TM3
Label	**Chloride sprayed and splashed**
SI Units	kg/m^3/vehicle
Equation	$C_{s_{air}} = (SD_{total\ cl} \times \frac{1}{\Theta} \times \frac{ADT-N}{N_{lane}} + SD_{total\ cl} \times \frac{N}{N_{lane}}) \times t_{snow}$
Description	The above equation computes the mass of chloride ions per unit air volume sprayed and splashed by all the vehicles passing near the bridge pier every winter, accounting for all the days with snow in a typical winter season. • $SD_{total\ cl}$ is the mass of chloride ions per unit air volume $(kg/m^3/vehicle)$ • Θ is the ratio of chloride ions sprayed and splashed by trucks to light-duty vehicles • ADT is the average daily traffic • N is the average number of heavy-duty vehicles per day • N_{lane} is the number of lanes • t_{snow} is the number of days with snow
Notes	The first part in the parentheses calculate the chloride exposure by light-duty vehicle, and the second part is for heavy-duty vehicles. The calculation focues on the road lane that is closest to the bridge component, so N_{lane} is included in the denominator.
Source	[4]
Ref. By	GD3
Use	A1, DD6

Number	TM4
Label	**Total airborne deposition at a certain distance**
SI Units	kg/m^3
Equation	$D(x) = a_{spray} \times e^{b_{spray}\ x} + a_{splash} \times e^{b_{splash}\ x}$
Description	The above equation describes the total airborne deposition at a certain distance from the road. • a_{spray} is the maximum deposition rates that occur from spray. • a_{splash} is the maximum deposition rates that occur from splash. • b_{spray} is the spray emission rate coefficient. • b_{splash} is the splash emission rate coefficient. • x is the distance between the road and the object. (m) • e is the base of natural logarithm.
Source	[12]
Ref. By	IM1

["Ref. By" is used repeatedly with the different types of information. This stands for Referenced By. It means that the models, definitions and assumptions listed reference the current model, definition or assumption. This information is given for traceability. Ref. By provides a pointer in the opposite direction to what we commonly do. You still need to have a reference in the other direction pointing to the current model, definition or assumption. As an example, if TM1 is referenced by GD2, that means that GD2 will explicitly include a reference to TM1. —TPLT]

4.4.3 General Definitions

[General Definitions (GDs) are a refinement of one or more TMs, and/or of other GDs. The GDs are less abstract than the TMs. Generally the reduction in abstraction is possible through invoking (using/referencing) Assumptions. For instance, the TM could be Newton's Law of Cooling stated abstracting. The GD could take the general law and apply it to get a 1D equation. —TPLT]

This section collects the laws and equations that will be used in building the instance models.

[Some projects may not have any content for this section, but the section heading should be kept. —TPLT] [Modify the examples below for your problem, and add additional definitions as appropriate. —TPLT]

Number	GD1
Label	**Mass flow rate**
SI Units	kg/s
Equation	$$\begin{cases} MR_{CA} = V_{speed} \times b \times K \times h_{film} \times \rho_{water} & \text{for } CA \\ MR_{TP} = V_{speed} \times b \times (1-K) \times h_{app} \times \rho_{water} & \text{for } TP \\ MR_{BW} = MR_{SW} = 0.5 \times V_{speed} \times b \times (h_{app} & \\ -K \times h_{film} - (1-K) \times h_{app}) \times \rho_{water} & \text{for } BW\ and\ SW \end{cases}$$
Description	The above equations compute the contribution to the amount of water displaced by a single tire(also called mass flow rate) of each splash and spray mechanism, using the following equations in the order presented until the total amount of available water is exhausted. $MR_{CA}, MR_{TP}, MR_{BW}, MR_{SW}$ stands for capillary adhesion, tread pickup, bow waves and side waves correspondingly. • V_{speed} is the heavy vehicle speed (km/h) • b is the tire width (m) • K is the ratio of the tire width that is not a groove to the tire width • h_{film} is the depth of the water film picked up in each rotation (m) • h_{app} is the thickness of melted water per day with snow melting (m) • ρ_{water} is the density of water (kg/m^3) The tread pickup will be activated only if there is water remaining after the capillarity adhesion, and the bow and side waves will be activated only if there is water remaining after the capillary adhesion and tread pickup
Source	[4]
Ref. By	GD2
Use	DD2

Detailed derivation of mass flow rate

The maximum mass flow rate associated with capillary adhesion (MR_{CA}) is estimated as the number of tire rotations per second multiplied by the volume of water dispersed on each tire rotation multiplied by the density of water, or

$$MR_{CA} = \left[\frac{V_{speed}}{2\pi R}\right] \cdot [2\pi R \times b \times K \times h_{film}] \times \rho_{water} = [V_{speed} \times b \times K \times h_{film}] \times \rho_{water}$$

After capillary action, the tire is able to displace a volume of water within its tread. The maximum flow rate for this mechanism (MR_{TP}) will occur when all the water contained in the tread volume is flung out of the tread during each tire rotation. Thus, it can be computed as the number of tire rotations per second multiplied by the capacity of tire's tread on each rotation multiplied by the density of water:

$$MR_{TP} = V_{speed} \times b \times (1 - K) \times h_{app} \times \rho_{water}$$

Any remaining water for which there is no capacity either underneath the tire contact area or within the tire tread must be displaced to the front of the tire or to the side, causing the bow wave and side wave, respectively. So, the total mass flow rate that can be attributed to bow and side wave mechanisms can be written as:

$$MR_{BW} + MR_{SW} = \rho_{water} \times b \times V_{speed} \times (h_{app} - K \times h_{film} - (1 - K) \times h_{app})$$

So, MR_{BW} and MR_{SW} can be estimated separately as:

$$MR_{BW} = \alpha \times \rho_{water} \times b \times V_{speed} \times (h_{app} - K \times h_{film} - (1 - K) \times h_{app})$$

$$MR_{SW} = \beta \times \rho_{water} \times b \times V_{speed} \times (h_{app} - K \times h_{film} - (1 - K) \times h_{app})$$

where α and β are calibration factors that satisfy $\alpha + \beta = 1$. Until other evidence is available, it will be assumed that $\alpha = \beta = 0.5$.

[This may be necessary when the necessary information does not fit in the description field. —TPLT] [Derivations are important for justifying a given GD. You want it to be clear where the equation came from. —TPLT]

Number	GD2
Label	**Spray density**
SI Units	kg/m^3/vehicle
Equation	$\begin{cases} SD_{CA} = (-2.69 \times 10^{-5} \times V' + 2.43 \times 10^{-3}) \times MR_{CA} & \text{for } CA \\ SD_{TP} = (1.16 \times 10^{-5} \times V' - 5.25 \times 10^{-5}) \times MR_{TP} & \text{for } TP \\ SD_{BW} = (2.67 \times 10^{-5} \times V' - 4.71 \times 10^{-4}) \times MR_{BW} & \text{for } BW \\ SD_{SW} = (1.65 \times 10^{-5} \times V' - 3.99 \times 10^{-4}) \times MR_{SW} & \text{for } SW \end{cases}$
Description	Spray density is derived by conducting regression analysis to develop relationship between spray density, mass flow rate and vehicle speed, to compute the concentration of water kicked up to the environment. The detailed process could be found in section 6.6.1 in [4] . • V' is the heavy vehicle speed $(miles/h)$ • $MR_{CA}, MR_{TP}, MR_{BW}, MR_{SW}$ is the mass flow rate for capillary adhesion, tread pickup, bow waves and side waves correspondingly (kg/s)
Source	[4]
Ref. By	DD4
Use	GD1

Number	GD3
Label	**Chloride sprayed and splashed**
SI Units	kg/m^3/vehicle
Equation	$C_{s_{air}} = (SD_{total\ cl} \times \frac{1}{\Theta} \times (AADT\ per\ lane - AADTT\ per\ lane) + SD_{total\ cl} \times AADTT\ per\ lane) \times t_2$
Description	The cumulative mass of chloride ions per unit air volume sprayed and splashed by all vehicles every winter, can be calculated by first finding the mass of chloride ions per unit air volume sprayed and splashed by all the vehicles per day, and times with the number of says with snow melting. • $SD_{total\ cl}$ is the mass of chloride ions per unit air volume $(kg/m^3/vehicle)$ • Θ is the ratio of chloride ions sprayed and splashed by trucks to light-duty vehicles • $AADT\ per\ lane$ is the annual average daily traffic per lane • $AADTT\ per\ lane$ is the annual average daily truck traffic per lane • t_2 is the number of days with snow melting
Notes	This equation simplified TM3 by using AADT and AADTT that are generated from existing database for calculation for light traffic and heavy-duty traffic.
Sources	[7, 8]
Ref. By	IM1
Use	A1, A4, DD6, TM3

4.4.4 Data Definitions

[The Data Definitions are definitions of symbols and equations that are given for the problem. They are not derived; they are simply used by other models. For instance, if a problem depends on density, there may be a data definition for the equation defining density. The DDs are given information that you can use in your other modules. —TPLT]

[All Data Definitions should be used (referenced) by at least one other model. —TPLT]

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given. [Modify the examples below for your problem, and add additional definitions as appropriate. —TPLT]

Number	DD1
Label	**Deicing salts quantity**
Symbol	M_{app}
SI Units	kg/m^2
Equation	$$\begin{cases} M_{app} = M_{total}/t_1 \\ M_{app} = \frac{V_{salt} \times h_{total}}{t_1 \times W_{lane}} \end{cases}$$
Description	The equation determine the quantity of deicing salts applied per day with snowfall, with A1. In some case there is absence of the data of M_{total}, the second equation is used. • M_{total} is the total amount of deicing salts applied on the road during the winter season (kg/m^2) • t_1 is the number of days with snowfall. • V_{salt} is the normalized salt application rate(tonnes/cm/km) • W_{lane} is the lane width according to A2(m).
Sources	[4, 7]
Ref. By	DD5
Use	A1, A2

Number	DD2
Label	**Daily water film thickness**
Symbol	h_{app}
SI Units	m
Equation	$h_{app} = h_{total}/t_{snow}$
Description	The equaition above calculates the thickness of melted water per day with snow melting. • h_{total} is the total water equivalent of the total snowfall during a winter season (m) • t_{snow} is the number of days with snow melting
Sources	[4, 9]
Ref. By	GD1, DD5
Use	A1

Number	DD3
Label	**Ratio of chloride in deicing salts**
SI Units	none
Equation	$\theta_{chloride} = \frac{\text{mass of } Cl^-}{\text{mass of } NaCl}$
Description	This equation computes the molar mass ratio of chloride to deicing salts, where we assume the main component of deicing salts is NaCl. • Cl^- is the chloride ions whose exposure we want to investigate • $NaCl$ is the most commonly used salt
Source	Mass Ratio Calculation
Ref. By	DD6
Use	A3

Number	DD4
Label	**Total spray density**
SI Units	kg/m^3/vehicle
Equation	$SD_{total} = SD_{CA} + SD_{TP} + SD_{BW} + SD_{SW}$
Description	The spray density (i.e. mass of water per unit air volume kicked up by each passing truck), is the sum of the four mechanism. • SD_{CA} is the spray density due to capillary adhesion • SD_{TP} is the spray density due to tread pickup • SD_{BW} is the spray density due to bow waves • SD_{SW} is the spray density due to side waves
Source	[4]
Ref. By	DD6
Use	GD2

Number	DD5
Label	**Ratio of salt over water**
SI Units	none
Equation	$\delta_{salt} = \frac{M_{app}}{h_{app} \times \rho_{water}}$
Description	This equation computes the ratio of the mass of salt applied per unit area of road to the mass of water per unit area of road. • M_{app} is the quantity of deicing salts applied per day (kg/m^2) • h_{app} is the thickness of melted water per day (m) • ρ_{water} is the density of water (kg/m^3)
Source	[4]
Ref. By	DD6
Use	DD1, DD2

Number	DD6
Label	**Mass of chloride ions**
SI Units	kg/m^3/vehicle
Equation	$SD_{total\ cl} = SD_{total} \times \delta_{salt} \times \theta_{chloride}$
Description	This equation computes the mass of chloride ions per unit air volume kicked up by each truck. • SD_{total} is the mass of water per unit air volume ($kg/m^3/vehicle$) • δ_{salt} is the salt-to-water mass ratio per unit area of road • $\theta_{chloride}$ is the molar mass ratio of chloride to deicing salts
Source	[4, 7]
Ref. By	TM3, GD3
Use	A3, DD3, DD4, DD5

4.4.5 Data Types

[This section is optional. In many scientific computing programs it isn't necessary, since the inputs and outpus are straightforward types, like reals, integers, and sequences of reals and integers. However, for some problems it is very helpful to capture the type information. —TPLT]

[The data types are not derived; they are simply stated and used by other models. —TPLT]

[All data types must be used by at least one of the models. —TPLT]

[For the mathematical notation for expressing types, the recommendation is to use the notation of ?. —TPLT]

This section collects and defines all the data types needed to document the models. [Modify the examples below for your problem, and add additional definitions as appropriate. —TPLT]

Type Name	Name for Type
Type Def	mathematical definition of the type
Description	description here
Sources	Citation here, if the type is borrowed from another source

4.4.6 Instance Models

[The motivation for this section is to reduce the problem defined in "Physical System Description" (Section 4.1.2) to one expressed in mathematical terms. The IMs are built by refining the TMs and/or GDs. This section should remain abstract. The SRS should specify the requirements without considering the implementation. —TPLT]

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.4.4 to replace the abstract symbols in the models identified in Sections 4.4.2 and 4.4.3.

The goal GS1 is solved by IM1. The goal GS2 is solved by IM2.

[reference your instance models —TPLT]. [other details, with cross-references where appropriate. —TPLT] [Modify the examples below for your problem, and add additional models as appropriate. —TPLT]

Number	IM1
Label	**Chloride on the surface**
Input	$C_{s_{air}}, e, d$
Output	C_s
Equation	$C_s = 0.015 \times C_{s_{air}} \times e^{-0.05d} + 0.985 \times C_{s_{air}} \times e^{-0.5d}$
Description	The above equation computes the chloride ions deposition on bridge substructure, taking into account the distance between the edge of the road near the bridge substructure and the bridge substructure. • $C_{s_{air}}$ is the cumulative mass of chloride ions per unit air volume sprayed and splashed by all the vehicles passing near the bridge pier(kg/m^3) • d is the distance between the road edge and nearby bridge structure(m) • e is the base of natural logarithm.
Notes	The first part of the equation calculate the chloride ions sprayed by vehicles, and the second part is those splashed by vehicles. The proportions of chloride ions sprayed (0.015) and splashed (0.985) were adapted from the studies by [11, 12], which measured the deposition of deicing salts along a highway in Sweden to define the relation between the mass of deicing salts per unit area (collected from the sites) and distance from roadside, and used nonlinear fitting techniques to determine the proportions of sprayed and splashed chloride ions.
Sources	[7, 10, 11, 12]
Ref. By	IM2, LC3
Use	TM4, GD3

Detailed derivation of chloride on the surface

According to [12], the spray emission rate coefficient and splash emission rate coefficient could be taken as -0.05 and -0.5, and the distance between road edge and nearby bridge structure is d, so we have

$$C_s = a_{spray} \times e^{-0.05d} + a_{splash} \times e^{-0.5d}$$

According to [11, 12] which measured the deposition of deicing salts along a highway in

Sweden to define the relation between the mass of deicing salts per unit area and distance from roadside, and used nonlinear fitting techniques to determine the proportions of sprayed and splashed chloride ions:

$$a_{spray} = a_{air} \times 0.015$$

$$a_{splash} = a_{air} \times 0.985$$

Combining the above equation in the scenario of chloride, we have:

$$C_s = 0.015 \times C_{s_{air}} \times e^{-0.05d} + 0.985 \times C_{s_{air}} \times e^{-0.5d}$$

Number	IM2
Label	**Search data for specific coordiinate**
Input	$(longitude, latitude)$
Output	$\{C_{s_1}, C_{s_2}..., C_{s_n}\}$
Description	This instance model get the longitude and latitude as input, and return a series of the amount of chloride exposure as output. This is the model that the end user of this software will encounter. • $\{C_{s_1}, C_{s_2}..., C_{s_n}\}$ is a list of chloride exposure data ($\{kg/m^3\}$) • $(longitude, latitude)$ is the coordinate of a location (°, °)

Derivation of ...

[The derivation shows how the IM is derived from the TMs/GDs. In cases where the derivation cannot be described under the Description field, it will be necessary to include this subsection. —TPLT]

4.4.7 Input Data Constraints

Table 1 shows the data constraints on the input output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The column for software constraints restricts the range of inputs to reasonable values. The software constraints will be helpful in the design stage for picking suitable algorithms. The constraints are conservative, to give the user of the model the flexibility to experiment with unusual situations. The column of typical values is intended to provide a feel for a common scenario. The uncertainty column provides an estimate of the confidence with which the physical quantities can be measured. This information would be part of the input if one were performing an uncertainty quantification exercise. In the Bridge Corrosion project, I would talk about not only the input variables mentioned in instance models, but

also include those in other models that the software need to process.
The specification parameters in Table 1 are listed in Table 6.

Table 1: Input Variables

Var	Physical Constraints	Software Constraints	Typical Value	Uncertainty
b	$0.2 \leq b \leq 0.71$	$b_{min} \leq b \leq b_{max}$	0.56m	10%
d	$d > 0$	$d > 0$	3m	10%
h_{film}	$h_{film} > 0$	$h_{film} > 0$	0.0001m	10%
K	$0 \leq K \leq 1$	$b_{min} \leq K \leq b_{max}$	0.75	10%
t_2	$0 \leq t_2 \leq 365$	$t_{snow} \leq t_2 \leq 365$	70days	10%
t_{snow}	$0 \leq t_{snow} \leq 365$	$0 \leq t_{snow} \leq 365$	65days	10%
V'	$37 \leq V' \leq 65$	$V'_{min} \leq V' \leq V'_{max}$	65miles/h	10%
V_{speed}	$60 \leq V_{speed} \leq 105$	$V_{speed_{min}} \leq V_{speed} \leq V_{speed_{max}}$	105km/h	10%
Θ	$0 \leq \theta < 1$	$0 \leq \theta < 1$	0.61	10%

4.4.8 Properties of a Correct Solution

A correct solution must exhibit the chloride exposure values that does not exceed the solubility limits of chloride ions.

[fill in the details —TPLT]. [These properties are in addition to the stated requirements. There is no need to repeat the requirements here. These additional properties may not exist for every problem. Examples include conservation laws (like conservation of energy or mass) and known constraints on outputs, which are usually summarized in tabular form. A sample table is shown in Table 2 —TPLT]

Table 2: Output Variables

Var	Physical Constraints
C_s	$C_s < 357kg/m^3$ (by Water Quality Guidelines)

[This section is not for test cases or techniques for verification and validation. Those topics will be addressed in the Verification and Validation plan. —TPLT]

5 Requirements

[The requirements refine the goal statement. They will make heavy use of references to the instance models. —TPLT]

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

5.1 Functional Requirements

R1: The user input need to be a coordinate within Ontario (By IM2). [Requirements for the inputs that are supplied by the user. This information has to be explicit. —TPLT]

R2: The output need to be a series of data showing the trend of chloride exposure over time at the input location (By IM2). [It isn't always required, but often echoing the inputs as part of the output is a good idea. —TPLT]

R3: During the calculation, the software should be capable of handling situations where units do not match. [Calculation related requirements. —TPLT]

R4: The output from the previous year should be verifiable against real-world data. [Verification related requirements. —TPLT]

R5: The output should be in two decimal points, showing the mass of chloride ions per unit air volume (By IM1). [Output related requirements. —TPLT]

[Every IM should map to at least one requirement, but not every requirement has to map to a corresponding IM. —TPLT]

5.2 Nonfunctional Requirements

[List your nonfunctional requirements. You may consider using a fit criterion to make them verifiable. —TPLT] [The goal is for the nonfunctional requirements to be unambiguous, abstract and verifiable. This isn't easy to show succinctly, so a good strategy may be to give a "high level" view of the requirement, but allow for the details to be covered in the Verification and Validation document. —TPLT] [An absolute requirement on a quality of the system is rarely needed. For instance, an accuracy of 0.0101 % is likely fine, even if the requirement is for 0.01 % accuracy. Therefore, the emphasis will often be more on describing now well the quality is achieved, through experimentation, and possibly theory, rather than meeting some bar that was defined a priori. —TPLT] [You do not need an entry for correctness in your NFRs. The purpose of the SRS is to record the requirements that need to be satisfied for correctness. Any statement of correctness would just be redundant. Rather than discuss correctness, you can characterize how far away from the correct (true) solution you are allowed to be. This is discussed under accuracy. —TPLT]

NFR1: **Reliability**: The predictions generated by the software should be accurate and reliable, reflecting real-world conditions and factors influencing chloride exposure. [Characterize the accuracy by giving the context/use for the software. Maybe something like, "The accuracy of the computed solutions should meet the level needed for <engineering or scientific application>. The level of accuracy achieved by ProgName shall be described following the procedure given in Section X of the Verification and Validation Plan." A link to the VnV plan would be a nice extra. —TPLT]

NFR2: **Usability**: The software interface should be intuitive and user-friendly, allowing users in the section 3.2 to easily input coordinates and look at the predicted chloride exposure over time.

[Characterize the usability by giving the context/use for the software. You should likely reference the user characteristics section. The level of usability achieved by the software shall be described following the procedure given in Section X of the Verification and Validation Plan. A link to the VnV plan would be a nice extra. —TPLT]

NFR3: **Maintainability**: The code for this software should be designed and structured in a way that it could be easily comprehended and modified by other potential developers.

[The effort required to make any of the likely changes listed for ProgName should be less than FRACTION of the original development time. FRACTION is then a symbolic constant that can be defined at the end of the report. —TPLT]

NFR4: **Portability**: This software should be able to run on recent versions of Google Chrome, Firefox, MS Edge and Safari. The operating system include Windows 7+ and Mac OS X 10.7+. [This NFR is easier to write than the others. The systems that ProgName should run on should be listed here. When possible the specific versions of the potential operating environments should be given. To make the NFR verifiable a statement could be made that the tests from a given section of the VnV plan can be successfully run on all of the possible operating environments. —TPLT]

NFR5: **Scalability**: The software should be scalable to accommodate potential future expansions or updates, ensuring its continued usefulness as new data or techniques become available.

5.3 Rationale

The assumptions made in this document are based on practical considerations to simplify and quantify the data required in the model. In A1, the deicing salts need to be applied on the roads in time to ensure safe driving conditions during winter weather. In A2, it simplifies the model by assuming a standardized lane width across all roads. While lane widths can vary depending on road type and location, assuming a uniform lane width streamlines the analysis and allows for consistent calculations. Additionally, a lane width of 3 meters is commonly used in many road design standards and provides a reasonable approximation for modeling purposes. Similarly, NaCl is one of the most widely used deicing salts due to its effectiveness and affordability, so A3 simplifies the model while still capturing the essence of typical deicing salt compositions. Lastly, AADT is an important parameter for assessing traffic volume on roads and is typically used to classify roads into different categories based on their traffic intensity, A4 simplifies the analysis by providing a standardized measure of traffic volume. By incorporating these assumptions, the model can effectively simulate real-world scenarios and provide valuable insights into the factors influencing bridge corrosion. The constraints in Table 1 are defined considering real-world scenarios. For example, the speed constraints adhere to established speed limits, ensuring a realistic representation of vehicle speeds. Similarly, the constraints associated with the variable about days are confined within the bounds of the annual calendar, reflecting a practical consideration of time duration within a given year.

[Provide a rationale for the decisions made in the documentation. Rationale should be provided for scope decisions, modelling decisions, assumptions and typical values. —TPLT]

6 Likely Changes

LC1: The lane width in some area might not be fixed, and the lane width standards might change in the future, so A2 is likely to be changed.

LC2: A4 might be changed with the population density, urbanization, or transportation preferences in different area, which all may influence traffic volume and distribution.

LC3: The proportions(0.015 and 0.985) in IM1 might change with the site characteristics of a bridge, such as the roadside environment (forested or urban), traffic characteristics (direction and volume), wind direction, and road surface condition.

[Give the likely changes, with a reference to the related assumption (aref), as appropriate. —TPLT]

7 Unlikely Changes

ULC1: The deicing salt need to be applied on days with snowfall to effectively mitigate the formation of ice and ensure safe road conditions, so A1 is unlikely to change.

ULC2: A3 is also unlikely to change, as the main component of deicing salt remain consistent.

[Give the unlikely changes. The design can assume that the changes listed will not occur. —TPLT]

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" may have to be modified as well. Table 3 shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions. Table 4 shows the dependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table 5 shows the dependencies of instance models, requirements, and data constraints on each other.

[You will have to modify these tables for your problem. —TPLT]

[The traceability matrix is not generally symmetric. If GD1 uses A1, that means that GD1's derivation or presentation requires invocation of A1. A1 does not use GD1. A1 is "used by" GD1. —TPLT]

[The traceability matrix is challenging to maintain manually. Please do your best. In the future tools (like Drasil) will make this much easier. —TPLT]

	A1	A2	A3	A4
TM1				
TM2				
TM3	X			
TM4				
GD1				
GD2				
GD3	X			X
DD1	X	X		
DD2	X			
DD3			X	
DD4				
DD5				
DD6			X	
IM1				
IM2				
LC1		X		
LC2				X
LC3				
ULC1	X			
ULC2			X	

Table 3: Traceability Matrix Showing the Connections Between Assumptions and Other Items

	TM1	TM2	TM3	TM4	GD1	GD2	GD3	DD1	DD2	DD3	DD4	DD5	DD6	IM1	IM2
TM1		X													
TM2					X										
TM3							X								
TM4														X	
GD1						X									
GD2											X				
GD3														X	
DD1												X			
DD2					X							X			
DD3													X		
DD4													X		
DD5													X		
DD6			X				X								
IM1															X
IM2															

Table 4: Traceability Matrix Showing the Connections Between Items of Different Sections

	IM1	IM2	R1	R2	R3	R4	R5	NFR1	NFR2	NFR3	NFR4	NFR5
IM1							X					
IM2			X	X					X		X	
R1		X			X					X		
R2						X	X	X				
R3			X									X
R4				X				X				
R5				X								
NFR1		X				X						
NFR2		X		X								
NFR3												X
NFR4												
NFR5										X		

Table 5: Traceability Matrix Showing the Connections Between Requirements and Instance Models

9 Values of Auxiliary Constants

[Show the values of the symbolic parameters introduced in the report. —TPLT]

[The definition of the requirements will likely call for SYMBOLIC_CONSTANTS. Their values are defined in this section for easy maintenance. —TPLT]

[The value of FRACTION, for the Maintainability NFR would be given here. —TPLT]

Table 6: Auxiliary Constant

Symbol	**Description**	**Value**	**Unit**
V'_{min}	minimum speed of heavy vehicle	37	miles/h
V'_{max}	maximum speed of heavy vehicle	65	miles/h
$V_{speed_{min}}$	minimum speed of heavy vehicle	60	km/h
$V_{speed_{max}}$	maximum speed of heavy vehicle	105	km/h
b_{min}	minimum tire width	0.2	m
b_{max}	maximum tire width	0.71	m
b_{spray}	spray emission rate coefficient	-0.05	N/A
b_{splash}	splash emission rate coefficient	-0.5	N/A
W_{lane}	lane width	3	m
V_{salt}	salt application rate	0.06	tonnes/cm/km
Θ	ratio of chloride ions sprayed and		
	splashed by trucks over light-duty vehicles	6	N/A

Reference

[1] Smith, W. Spencer and Koothoor, Nirmitha. ”A Document-Driven Method for Certifying Scientific Computing Software for Use in Nuclear Safety Analysis.” Nuclear Engineering and Technology, vol. 48, no. 2, April, 2016. http://www.sciencedirect.com/-science/article/pii/S1738573315002582. pp. 404–418.

[2] Smith, W. Spencer and Lai, Lei. ”A new requirements template for scientific computing.” Proceedings of the First International Workshop on Situational Requirements Engineering Processes - Methods, Techniques and Tools to Support Situation-Specific Requirements Engineering Processes, SREP’05. Edited by PJ Agerfalk, N. Kraiem, and J. Ralyte, Paris, France: 2005. pp. 107–121. In conjunction with 13th IEEE International Requirements Engineering Conference

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[The following is not part of the template, just some things to consider when filing in the template. —TPLT]
[Grammar, flow and LaTeXadvice:

- For Mac users `*.DS_Store` should be in `.gitignore`
- LaTeX and formatting rules
  - Variables are italic, everything else not, includes subscripts (link to document)
    * Conventions
    * Watch out for implied multiplication
  - Use BibTeX
  - Use cross-referencing
- Grammar and writing rules
  - Acronyms expanded on first usage (not just in table of acronyms)
  - "In order to" should be "to"

—TPLT]
[Advice on using the template:

- Difference between physical and software constraints
- Properties of a correct solution means *additional* properties, not a restating of the requirements (may be "not applicable" for your problem). If you have a table of output constraints, then these are properties of a correct solution.
- Assumptions have to be invoked somewhere
- "Referenced by" implies that there is an explicit reference
- Think of traceability matrix, list of assumption invocations and list of reference by fields as automatically generatable
- If you say the format of the output (plot, table etc), then your requirement could be more abstract

—TPLT]

Appendix — Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Lifelong Learning. Please answer the following questions:

1. Which of the courses you have taken, or are currently taking, will help your team to be successful with your capstone project.

2. What knowledge and skills will the team collectively need to acquire to successfully complete this capstone project? Examples of possible knowledge to acquire include domain specific knowledge from the domain of your application, or software engineering knowledge, mechatronics knowledge or computer science knowledge. Skills may be related to technology, or writing, or presentation, or team management, etc. You should look to identify at least one item for each team member.

3. For each of the knowledge areas and skills identified in the previous question, what are at least two approaches to acquiring the knowledge or mastering the skill? Of the identified approaches, which will each team member pursue, and why did they make this choice?