# Risk Assessment Mitigation Phase
# (RAMP-C)
# Risk Quantification Framework

# November 27, 2019

TABLE OF CONTENTS

# I. INTRODUCTION

This chapter provides a detailed overview of the multi-attribute value function (MAVF) applied to quantitatively assess risks throughout this report (referred to herein as the Risk Quantification Framework), including illustrating hypothetical examples of risk scores (using the ranges displayed in the examples). The Risk Quantification Framework is used to analyze risk by estimating current risk scores (the Pre-Mitigation Risk Scores) and forecasting future risk scores if new activities are started or current ones are ceased (the Post-Mitigation Risk Scores).

- Section II provides an overview of the quantitative analysis used to analyze each risk, according to the S-MAP settlement agreement (the SA Decision).[1]
- Section III describes the requirements of the MAVF per the SA Decision, and how the Company's Risk Quantification Framework was accordingly constructed.
- Section IV describes the steps to apply the Risk Quantification Framework in accordance with the SA Decision.
- Section V shows a hypothetical example of a risk score calculation using the Risk Quantification Framework.
- Section VI describes the decisions made in constructing the Risk Quantification Framework, including the scaling and weighing of attributes, demonstrating compliance with the SA Decision.
- Finally, Section VII demonstrates the Company's efforts towards development of probabilistic calculations and analysis, and discusses quantitative methodologies including statistical information and the use of computer software in development of this RAMP Report.

As the first to apply the quantitative analysis required by the SA Decision, the Company possesses a number of observations about the process that may aid the California Public Utilities Commission (Commission or CPUC) and other investor-owned utilities (IOU) in future applications of the framework. The Company offers these "lessons learned" in Chapter RAMP-G.

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[1] The SA Decision is Decision (D.) 18-12-014, including the settlement agreement adopted therein.

## II. OVERVIEW AND APPROACH

The quantitative analysis applied in this RAMP Report is derived from the SA Decision, and can be outlined as follows:

- Develop a MAVF, which the Company refers to as the Risk Quantification Framework;[2]
- Consider risks as defined and scoped in the Company's Enterprise Risk Register (ERR);[3]
- Compute a Safety Risk Score using the Safety Attribute of the MAVF for each risk included in the ERR;[4]
- For each identified risk that meets the SA Decision thresholds:[5]
  - Estimate the frequency of a risk event occurring in a given year and use that value for the Likelihood of Risk Event (LoRE);
  - Estimate the average (mean) consequences if the Risk Event were to occur;
  - Apply the average consequences to the Risk Quantification Framework to create a value known as the Consequence of Risk Event (CoRE); and
  - Multiply the values of LoRE and CoRE to determine a Risk Score for that risk. The result of this calculation constitutes a Pre-Mitigation Risk Score.

As required by the SA Decision, a resulting Pre-Mitigation Risk Score will be used: (1) to demonstrate a risk score for each risk along with a ranking, and (2) as an input into the calculations to determine the change in risk scores when a risk-reducing activity is started or ceased.

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2 *Id.* at Attachment A, A-5 – A-6 (Step 1A).

3 *Id.* at Attachment A, A-7 (Step 1B).

4 *Id.* at Attachment A, A-8 – A-9 (Step 2A).

5 *Id.* at Attachment A, A-11 – A-13 (Step 3).

## III. RISK QUANTIFICATION FRAMEWORK (OVERVIEW)

### A. Introduction

The Risk Quantification Framework (or MAVF) is a tool for combining all potential consequences of the occurrence of a risk event to create a measurement of value. This section presents the Risk Quantification Framework that will be used throughout this RAMP Report. Section IV of this chapter provides a thorough walkthrough of how this Risk Quantification Framework is applied, and Section V provides an example of its application. Section VI of this chapter describes the rationales for how the Company set the assumptions used in this Risk Quantification Framework.

This RAMP Report is the first filing that implements the SA Decision, and therefore there is still much to be learned and improved in the future.[6] The quantitative aspects shown in this chapter are not meant to reflect precision or a comprehensive view of risk, but rather serve as a starting point on which to build. Further, as explained below, the Risk Quantification Framework is the result of many discretionary assumptions. Should those assumptions change, different results would be expected.

### B. Risk Quantification Framework

According to the SA Decision, the Risk Quantification Framework requires a company to select certain "attributes," defined as "an observable aspect of a risky situation that has value or reflects a utility objective, such as safety or reliability."[7] The attributes "should cover the reasons that a utility would undertake risk mitigation activities" and must be reflected in "the way the level of an attribute is measured or expressed."[8] The determination of attributes is left to each utility's discretion. These attributes are a subset of the many criteria used to assess and manage risk. The selection of attributes for RAMP Report purposes is predicated on, among

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6 The Company offers "lessons learned" to aid the Commission and other IOUs in future applications of the framework in Chapter RAMP-G.

7 D.18-12-014 at Attachment A, A-2.

8 *Id.* at Attachment A, A-2 – A-3.

other factors, the level of data available, the strength of the data available, and the commonality of the attribute across risks.

The SA Decision also requires construction of a scale "that converts the range of natural units … to scaled units to specify the relative value of changes within the range, including capturing aversion to extreme outcomes or indifference over a range of outcomes."[9] Attributes also must be assigned weights reflecting each attribute's relative importance to other identified attributes:

> Weights are assigned based on the relative value of moving each Attribute from its least desirable to its most desirable level, considering the entire range of the Attribute.… Weights are assigned based on actual Attribute measurement ranges, not a fixed weight arbitrarily assigned to an Attribute. For example, the Attribute weights will reflect the relative importance of moving the safety outcomes from the least to the most desirable levels as compared with moving financial outcomes from the least to the most desirable levels in a risky situation.[10]

The following three tables show a Risk Quantification Framework utilized in this RAMP Report. Each table shows chosen attributes and assigned weights and scales. A narrative summary of the choices examined and made in assigning values to the variables shown below (*e.g.*, attributes, scales, weights) is described in Section VI below.

The Risk Quantification Framework is a prescribed methodology that is performed in accordance with the SA Decision, which may provide a data point to help inform risk-based decision making (amongst many other available data points). There are numerous ways to select attributes, scaling and weights. However, the SA Decision contains a prescribed methodology for selecting attributes, scaling and weights, which limits a utility's choices in certain ways. The choices elected in accordance with the SA Decision's prescribed methodology should not be viewed as a precise reflection of real-world circumstances and are made for RAMP purposes only.

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9 *Id.* at Attachment A, A-5.

10 *Id.* at Attachment A, A-6.

The SA Decision requires the Company to follow six principles to construct its MAVF.[11] The Company applied these six principles to arrive at the Risk Quantification Framework summarized in Table 1 below. The top-level attributes of Safety, Reliability, and Financial are consistent with the minimum attributes required by the SA Decision.[12] Given that "[a]ttributes are combined in a hierarchy,"[13] the top-level attributes are further broken down into sub-attributes.[14] Measurement of each sub-attribute is also required and is assigned based on the unique characteristics.[15] These sub-attributes are then rolled up to the top-level attribute. The combined measurement of each top-level attribute is represented in Table 1 below as the Measurement Unit. The scales contained in Table 1 also reflect the SA Decision's MAVF principles and were constructed to represent the relative value of changes in a range of the measured units.[16] Similarly, the Company completed a weighting process in accordance with the SA Decision[17] to develop the weights in Table 1 below (as further described in Section VI.C, *infra*).

[11] *Id.* at Attachment A, A-5 ("MAVF").

[12] *Id.* at Attachment A, A-8 ("Risk Assessment").

[13] *Id.* at Attachment A, A-5 ("MAVF Principle 1 – Attribute Hierarchy").

[14] *Id.* at Attachment A, A-5, ("MAVF Principle 1 – Attribute Hierarchy") and ("MAVF Principle 2 – Measured Observations") refer to lower-level attributes in the context of building a MAVF. The term "lower-level attribute" is referred to herein as "sub-attribute."

[15] *Id.* at Attachment A, A-5 ("MAVF Principle 2 – Measured Observations") and ("MAVF Principle 3 – Comparison").

[16] *Id.* at Attachment A, A-5 ("MAVF Principle 5 – Scaled Units").

[17] *Id.* at Ordering Paragraph 2 and at Attachment A, A-6 ("MAVF Principle 6 – Relative Importance").

**Table 1: Risk Quantification Framework Top-Level Attributes**

| Top-Level Attribute | Measurement Unit[18] | Scale | Weight |
|---|---|---|---|
| Safety | Safety Index | 0 – 30 | 60% |
| Reliability | Reliability Index | 0 – 1 | 20% |
| Financial | $ | $0 - $1B | 20% |

Table 2 below shows the sub-attributes contained in the Safety top-level attribute from Table 1 above. The measured unit for each of Safety's sub-attributes, when used together, create a single Safety Index value that is used in Table 1 above.[19] The components of the Safety Index are provided in Table 2 below.

**Table 2: Risk Quantification Framework Safety Index**

| Safety Sub-Attributes | Value |
|---|---|
| Fatality | 1 |
| Serious Injury | 0.25 |

Similar to Table 2 above, the following Table 3 shows the sub-attributes that are included in the Reliability top-level attribute from Table 1. Each sub-attribute is measured by its own unit. The Company's determination of Attributes, Scales and Weights are explained in Section VI, *infra*. When all of the four sub-attributes for reliability are summed together, it creates a single Reliability Index value that is used in Table 1 above.[20] These are shown in Table 3 below.

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18 "Measurement Unit" used herein is the measured attribute, also analogous to "Natural Unit" per the SA Decision Lexicon included in D.18-12-014 at Attachment A, A-3.

19 MAVF Principle 1 - Attributes are combined in a hierarchy. *See* D.18-12-014 at Attachment A, A-5.

20 *Id.*

**Table 3: Risk Quantification Framework Reliability Index**

| Reliability Sub-Attribute | Measurement Unit | Scale | Weight |
|---|---|---|---|
| Gas Core Meters | Number of Gas Core Meters Experiencing Outage | 0 – 75,000 meters | 25% |
| Gas Curtailment | Volume of Curtailments of Natural Gas exceeding 250 million cubic feet/day | 0 – 500 MMcf | 25% |
| Electric SAIDI | System Average Interruption Duration Index (SAIDI) minutes | 0 – 100 minutes | 25% |
| Electric SAIFI | System Average Interruption Frequency Index (SAIFI) outages | 0 – 1 outages | 25% |

Despite some of the prescriptive elements in the SA Decision, there remain a wide range of possible choices available to each utility in assigning attributes, weights, scales, and other variables. Because of this, the Company has chosen to provide a range of scoring, based upon two additional alternative Risk Quantification Framework methods. These alternative methods, and the rationales behind their presence, are described in greater detail in Section VI of this chapter. The two alternatives demonstrate a range of risk scores for each risk and consequently demonstrate a range of RSEs for each activity. The Risk Quantification Framework provides a direction on how to improve risk, but it is not a precise tool and should not be construed as such.

The structure of the alternatives is exactly the same as described above, with the only change being in the scale factor for the Safety Attribute. The "High Alternative" has a safety scale of 0 – 12, rather than 0 – 30; and the "Low Alternative" has a safety scale of 0 – 300, rather than 0 – 30. The SA Decision requires the Company to produce a single risk score and RSE using the adopted methodology. The Company refers herein to the result from its chosen Risk Quantification Framework methodology as the "Single Point" result. The Single Point represents a single score out of a range of possibilities, resulting from applying the SA Decision, using the Company's chosen set of assumptions. However, because of the uncertainty and subjective nature of the methodology with respect to the relative importance of each attribute, as further described in Section VI, *infra*, the Company is presenting a range of potential scales (and the resulting RSEs) in this RAMP Report. A Safety Index Scale that has a tighter range will tend to emphasize safety more than a Safety Index Scale that has a wider range. For example, a Safety Score of 2 will be 1/6 of the score when the Scales range from 0 – 12, but that score will only be 1/150 of the score when the Scales range from 0 – 300.

Summary tables for both alternatives are shown below in Tables 4 and 5.

**Table 4: High Alternative**

| Top-Level Attribute | Measurement Unit | Scale | Weighting |
|---|---|---|---|
| Safety | Safety Index | 0 – 12 | 60% |
| Reliability | Reliability Index | 0 – 1 | 20% |
| Financial | $ | $0 - $1B | 20% |

**Table 5: Low Alternative**

| Top-Level Attribute | Measurement Unit | Scale | Weighting |
|---|---|---|---|
| Safety | Safety Index | 0 – 300 | 60% |
| Reliability | Reliability Index | 0 – 1 | 20% |
| Financial | $ | $0 - $1B | 20% |

As a hypothetical example, suppose there was a risk that had a likelihood of exactly one event per year, and that the consequence of the event occurring lead to exactly one fatality every time. The LoRE for this risk would be 1, and the CoRE would be calculated using the Risk Quantification Framework.

The Single Point method would yield a CoRE of:

(1/30) * 60% + (0/1) * 20% + (0/$1B) * 20% = **0.02**

The High Alternative shown above would yield a CoRE of:

(1/12) * 60% + (0/1) * 20% + (0/$1B) * 20% = **0.05**

The Low Alternative shown above would yield a CoRE of:

(1/300) * 60% + (0/1) * 20% + (0/$1B) * 20% = **0.002**

The three different methods, each based on a LoRE of 1, can be summarized in the following table:

**Table 6: Example of Illustrative Risk Showing Single Point and Alternative Scorings**

| | LoRE | CoRE | Risk Score |
|---|---|---|---|
| **Single Point** | 1 | 0.024 | 2,400 |
| **High Alternative** | 1 | 0.05 | 5,000 |
| **Low Alternative** | 1 | 0.002 | 200 |

## IV. APPLICATION OF RISK QUANTIFICATION FRAMEWORK

Per the SA Decision, the Risk Quantification Framework must use specific methods of applying statistical information. The following statistical concepts are key to understanding the Risk Quantification Framework: (a) risks are evaluated at the “risk-level” as defined by the Company’s ERR, (b) each risk is evaluated for annual frequency using the risk quantification method (as required by the SA Decision), (c) each risk is evaluated by considering all possible consequences attributed to a risk event (rather than specific scenarios), and (d) averages, or expected values, are used for LoRE and CoRE.

In more detail, the Risk Quantification Framework methodology uses the following steps:

**Step 1: Estimate LoRE**. Estimate the frequency of a risk event occurring in a given year and set the LoRE to this value. If the frequency is estimated to be less than one per year, the frequency is put into decimal form. For example, if the estimate was a frequency of a risk event occurring 5 times a year, the LoRE would be set to 5. If the frequency of a risk events was estimated to be one event in 10 years, the LoRE would be set to 0.1. Depending on the risk, the frequency of Risk Events in the RAMP Report range from approximately 0.06 to 2000.

**Step 2: Estimate consequences of event for each attribute**. As discussed above, the Risk Quantification Framework has three attributes with several sub-attributes. This step uses the average consequence for each attribute and sub-attribute based on the wide variety of possible consequences. For example, suppose a Risk Event had a 10% chance of having a $2 million consequence and a 90% chance of having a $100,000 consequence. The value used for the financial consequence would be the weighted average of those chances, or (10% x $2 million) + (90% x $100,000) = $290,000. A similar exercise is done for all of the attributes in the Risk Quantification Framework.

**Step 3: Estimate CoRE**. Once the averages of consequences for each attribute are determined, use the Risk Quantification Framework to obtain a single consequence value known as the Consequence of Risk Event (CoRE). CoRE is a value that incorporates all attributes.

**Step 4: Calculate Risk Score**. Lastly, multiply the LoRE and the CoRE to calculate the Risk Score. To ease readability, the Risk Score is multiplied by 100,000, then rounded to the nearest whole number, or decimal if less than 1.

These steps are also undertaken for the two alternative methods mentioned above in Section III of this chapter. The alternatives differ in Step 3 (because of a slight variation in how CoRE is calculated). Then Step 4 for each alternative uses the alternative CoRE values to multiple with LoRE.

The application of these process results in the Company's Single Point method and the two alternatives – low alternative, and high alternative.

## V. HYPOTHETICAL EXAMPLE OF RISK SCORE CALCULATION USING THE RISK QUANTIFICATION FRAMEWORK WITH ALTERNATIVES

The following example will follow steps 1 - 4 shown above. All values in this example are illustrative and not representative of a specific risk.

### A. Example: Risk XYZ Single Point Method

**Step 1: Estimate LoRE**. Internal and external data suggest that Risk XYZ will have an average of 12 Risk Events per year.

**Step 2: Estimate consequences of attributes**. Internal and external data suggest that if a Risk Event were to occur for Risk XYZ, the consequences would average as follows:

a. Fatalities: 0.02 (*i.e.* 1 fatality for every 50 risk events)
b. Serious Injuries: 0.1 (*i.e.* 1 serious injury for every 10 risk events)
c. Electric SAIDI: 0 minutes of SAIDI
d. Electric SAIFI: 0 outages of SAIFI
e. Gas Core Meters: 0 meters
f. Gas Curtailment: 0 curtailment
g. Financial: $1.5 million from damage to property

**Step 3: Estimate CoRE**. Using the Risk Quantification Framework, apply each of the estimates for each attribute/sub-attribute to generate top-level attribute information, then apply those values to the Risk Quantification Framework top-level attributes. The values from Step 2 are used below and shown in bold face type.

a. Safety Index: (Fatalities x 1) + (Serious Injuries x 0.25) = (**0.02** x 1) + (**0.1** x 0.25) = 0.045
b. Reliability Index: $\frac{Gas\ Core\ Meters\ Experiencing\ Outage}{75{,}000}\ x\ 25\% + \frac{Gas\ Curtailed\ exceeding\ 250MMcfd}{500MM}\ x\ 25\% + \frac{SAIDI}{100}\ x\ 25\% + \frac{SAIFI}{1}\ x\ 25\% = \frac{\mathbf{0}}{75{,}000}\ x\ 25\% + \frac{\mathbf{0}}{500MM}\ x\ 25\% + \frac{\mathbf{0}}{100}\ x\ 25\% + \frac{\mathbf{0}}{1}\ x\ 25\% = 0$
c. Financial: **$1.5 million**
d. CoRE = $\frac{Safety\ Index}{30}\ x\ 60\% + \frac{Reliability\ Index}{1}\ x\ 20\% + \frac{Financial}{\$1B}\ x\ 20\% = \frac{0.045}{30}\ x\ 60\% + \frac{0}{1}\ x\ 20\% + \frac{1.5M}{\$1B}\ x\ 20\%\ x = 0.0012$

**Step 4: Calculate Risk Score**. Multiply LoRE x CoRE x 100,000 and round to nearest whole number. From step 1, LoRE = 12, from step 3, CoRE = 0.0012. Risk Score = 12 x 0.0012 x 100,000 = 1,440. The Risk Score of Risk XYZ is 1,440.

As mentioned in Section III of this Chapter, the Company is providing ranges for each risk score. The risk scores will be calculated using the High Alternative and Low Alternative methods. The values for High Alternative and Low Alternative only differ in how CoRE is calculated.

**B. Example XYZ using Low Alternative**

**Step 1**: Same as above.

**Step 2**: Same as above.

**Step 3: Estimate CoRE**. Using the Low Alternative version of the Risk Quantification Framework, apply each of the estimates for each attribute/sub-attribute to generate top-level attribute information, then apply those values to the Risk Quantification Framework top-level attributes. The values from Step 2 are used below and shown in bold face type.

a. Safety Index: (Fatalities x 1) + (Serious Injuries x 0.25) = (**0.02** x 1) + (**0.1** x 0.25) = 0.045

b. Reliability Index: $\frac{Gas\ Core\ Meters\ Experiencing\ Outage}{75{,}000}\ x\ 25\% + \frac{Gas\ Curtailed\ exceeding\ 250MMcfd}{500MM}\ x\ 25\% + \frac{SAIDI}{100}\ x\ 25\% + \frac{SAIFI}{1}\ x\ 25\% = \frac{\mathbf{0}}{75{,}000}\ x\ 25\% + \frac{\mathbf{0}}{500MM}\ x\ 25\% + \frac{\mathbf{0}}{100}\ x\ 25\% + \frac{\mathbf{0}}{1}\ x\ 25\% = 0$

c. Financial: **$1.5 million**

d. CoRE = $\frac{Safety\ Index}{300}\ x\ 60\% + \frac{Reliability\ Index}{1}\ x\ 20\% + \frac{Financial}{\$1B}\ x\ 20\% = \frac{0.045}{300}\ x\ 60\% + \frac{0.0125}{1}\ x\ 20\% + \frac{1.5M}{\$1B}\ x\ 20\%\ x = 0.0039$

**Step 4: Calculate Risk Score**. Multiply LoRE x CoRE x 100,000 and round to nearest whole number. From step 1, LoRE = 12, from step 3, CoRE = 0.00039. Risk Score = 12 x 0.00039 x 100,000 = 468. The Low Alternative Risk Score of Risk XYZ is 468.

**C. Example XYZ using High Alternative**

**Step 1**: Same as above

**Step 2:** Same as above

**Step 3: Estimate CoRE**. Using the High Alternative version of the Risk Quantification Framework, apply each of the estimates for each attribute/sub-attribute to generate top-level attribute information, then apply those values to the Risk Quantification Framework top-level attributes. The values from Step 2 are used below and shown in bold face type.

a. Safety Index: (Fatalities x 1) + (Serious Injuries x 0.25) = (**0.02** x 1) + (**0.1** x 0.25) = 0.045

b. Reliability Index: $\frac{Gas\ Core\ Meters\ Experiencing\ Outage}{75{,}000}\ x\ 25\% + \frac{Gas\ Curtailed\ exceeding\ 250MMcfd}{500MM}\ x\ 25\% + \frac{SAIDI}{100}\ x\ 25\% + \frac{SAIFI}{1}\ x\ 25\% = \frac{\mathbf{0}}{75{,}000}\ x\ 25\% + \frac{\mathbf{0}}{500MM}\ x\ 25\% + \frac{\mathbf{0}}{100}\ x\ 25\% + \frac{\mathbf{0}}{1}\ x\ 25\% = 0$

c. Financial: **$1.5 million**

d. CoRE = $\frac{Safety\ Index}{12}\ x\ 60\% + \frac{Reliability\ Index}{1}\ x\ 20\% + \frac{Financial}{\$1B}\ x\ 20\% = \frac{0.045}{12}\ x\ 60\% + \frac{0}{1}\ x\ 20\% + \frac{1.5M}{\$1B}\ x\ 20\%\ x = 0.00255$

**Step 4: Calculate Risk Score**. Multiply LoRE x CoRE x 100,000 and round to nearest whole number. From step 1, LoRE = 12, from step 3, CoRE = 0.00255. Risk Score = 12 x 0.00255 x 100,000 = 3,060. The High Alternative Risk Score of Risk XYZ is 3,060.

**Table 7: Summary of Risk XYZ Risk Scores**

| | Low Alternative | Single Point | High Alternative |
|---|---|---|---|
| **Risk XYZ** | 468 | 1,440 | 3,060 |

## VI. MAVF CONSTRUCTION

Per the SA Decision, each utility is required to create a multi-attribute value function that will be used in the RAMP Report for risk scoring.[21] As stated above, the MAVF is a tool for combining all potential consequences of the occurrence of a risk event to create a measurement of value. The Company's MAVF construction followed the steps outlined in the SA Decision.[22] The process of creating the MAVF is complex and should be considered a non-perfect method to

21 *Id.* at Attachment A, A-5 – A-6 (Step 1A).

22 *Id.*

interpret the utility risk.  Because the Company is in the process of determining effective quantitative risk methods, the value functions presented in this RAMP Report are the beginning steps into a complex and multi-layered methodology.

It is important to note that the construction of the MAVF discussed herein was a single effort undertaken for both SoCalGas and SDG&E.  The attributes, scales, and weighting of attributes in the MAVF were determined collectively for both Companies given the Companies' shared assets (*e.g.*, natural gas distribution system, IT infrastructure), and shared risk management framework.

There were several considerations when developing the Companies' first Risk Quantification Framework, as described below.

### A. Determination of Attributes

An attribute, as defined by the SA Decision, is "an observable aspect of a risky situation that has value or reflects a utility objective, such as safety or reliability.  Changes in the levels of attributes are used to determine the consequences of a Risk Event."[23]  Following MAVF Principle 1, the Company considered a large number of attributes for the Risk Quantification Framework.  The method of attribute inclusion was: (a) create a list of potential attributes - where the list was generated by combining efforts with the CPUC workshops, consulting internal subject matter experts (SMEs), and researching external entities, and (b) determine the ability to include such attributes by considering availability of data, consistency of data, commonality of the attribute across risks, and complications arising from their inclusion, among others.  The attributes included in this RAMP Report are not meant to represent all dimensions of risk management that occur at the Company but are useful for the purposes of this filing, namely to create estimated risk quantification that can assist in decision-making.

An example of a potential attribute that was not selected due to the unavailability of consistent data is company trust.  It is possible to measure company trust through public surveys or polling, but the purpose of the attribute for the RAMP Report is to determine pre- and post-activity measurements and it will require consistency of individuals for each survey or polling,

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23 *Id.* at Attachment A, A-2.

and a measurement after each activity, which can be in the hundreds. The Company has, for now, concluded that measuring company trust for each change in risk-reducing activities would be an exercise that requires large amounts of guesswork and subjectivity. Perhaps in the future, the concept of company trust will be more easily measurable, or some appropriate proxy will be devised so that this attribute could be included.

Environmental attributes were also not selected. While the Company is very focused on environmental impacts and thoughtfully consider how to reduce those impacts, for the purposes of quantification, the Company was unable to determine how to express an environmental attribute that would meet the standards of the SA Decision. There are several dimensions of impacts related to the environment, including impacts to water, soil, air, species, and cultural. Within those dimensions there are numerous sub-dimensions. For example, pollution of air can take many forms that include greenhouse gas (GHG) emissions, but also near-ground pollution such as exhaust from vehicles and generators that have more of a local impact to air quality.

In addition to the various challenges described earlier as to the scope and impacts of the environmental attributes, it was also difficult to define relative weights between each of these environmental impacts. One option was to focus on a narrower view of environmental impacts, such as only considering GHG for use in the attribute. But it was understood that this narrow approach would lead to undesirable outcomes by overestimating certain projects and giving an incorrect impression that the Company was not interested in reducing the other non-represented impacts.

Future versions of the Risk Quantification Framework may be designed with the goal of expanding and refining the number of attributes and sub-attributes in line with other key parameters used in day-to-day decision making.

**B. Scales of Attributes**

The SA Decision directs the utility to construct a scale that converts the range of natural units to scaled units.[24] While the notion of applying scales for attributes appears to be straightforward, there are many aspects to consider, especially when applying the next step of

[24] *Id.* at Attachment A, A-5 – A-6 (Step 1A).

assigning weights to each scale. The SA Decision states that the top of the scale approximates the maximum expected results for a risk. However, the SA Decision method also requires expected values to be used and expected values have very different "maximum expected results" depending on each scenario used. For example, a plane crash might lead to a few hundred deaths, but the annual expected value of fatalities for a particular airline in a given year is something far less. The Company exercised its discretion[25] to make a reasoned decision in choosing the top end of the scales for the attributes because not all risk scenarios involving a particular risk yield the same maximum expected results. As discussed in the Weights of Attributes section below, scales and weights are strongly connected.

## C. Weights of Attributes

### 1. Quantitative Notes on Weights

The weight applied to each attribute is an important step in determining risk scores. Different weights applied to several risks can lead to different rankings of those risks. Below is a simplified, illustrative example of sample risks that show how weights can alter results:

**Table 8: Illustrative Example of Weighting**

| | Safety Score | Financial Score | Risk Score Method 1: Safety: 90% Weight Financial: 10% Weight | Risk Score Method 2: Safety: 50% Weight Financial: 50% Weight |
|---|---|---|---|---|
| **Risk A** | 0.5 | 0.2 | 4700 | 3500 |
| **Risk B** | 0.2 | 0.6 | 2400 | 4000 |

In Table 8, above, Risk A has a Risk Score near twice as large as Risk B (4700 vs 2400) using Method 1 (90% Safety and 10% Financial) but has a lower risk score using Method 2. This is because Risk A has more Safety risk relative to Risk B, and a weighting that favors Safety would therefore favor Risk A. This example illustrates that choosing weights can have significant impact on the scoring that follows. The Company is aware that its choice of weights is not perfect for all situations, and therefore scores should be thought of as estimates, rather than precise values.

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25 The discretion built into the MAVF may be a good topic of consideration for future S-MAP proceedings.

There is a very strong relationship between scales and weights. The two characteristics work hand-in-hand to create the value framework. The following example highlights this point.

Suppose there are two Multi-attribute Value Functions that only have attributes for Safety and Financial. Their illustrative characteristics are shown below:

**Table 9: Illustrative Example of Scale & Weight**

| | MAVF #1 | MAVF #2 |
|---|---|---|
| **Safety Scale** | 0 – 100 (measured in fatalities) | 0 - 10 (measured in fatalities) |
| **Safety Weight** | 80% | 50% |
| **Financial Scale** | 0 - $1 billion (measured in $) | 0 - $1 billion (measured in $) |
| **Financial Weight** | 20% | 50% |

Now suppose there is a risk that has been assessed as having an expected value of impacts as $100M financial loss for property damage, and 2 fatalities. The Consequence of Risk Event for each MAVF would be:

MAVF #1: CoRE = (2 / 100) * 80% + ($100 million / $1000 million) * 20% = 0.036

MAVF #2: CoRE = (2 / 10) * 50% + ($100 million / $1000 million) * 50% = 0.15

Note that the portion of the CoRE that comes from the Safety is:

MAVF #1: CoRE = (2 / 100) * 80% = 0.016

MAVF #2: CoRE = (2 / 10) * 50% = 0.1

Although MAVF #1 has a higher weighting for Safety (80% versus 50%), it gives a lower score for safety, due to the scale being different. Therefore, it is not enough to solely focus on the weight of each attribute to determine the importance of the attribute in the risk score.

### 2. Methodology for Determining Weights

The SA Decision requires that the Safety Attribute of the MAVF have a minimum weight of 40%.[26] Other than that safety minimum weight requirement, the SA Decision provides discretion for the Company to select the applicable weights through its own internal processes.

The main method to determine weights for the Company's Risk Quantification Framework was to consider alignment with the Company's ERM ERR process. During the creation of the ERR, a qualitative scoring method that contained several risk dimensions was used.

Using the ERR as a starting point, initial weights were identified and considered for use in the RAMP Report. Although the ERR is more of a qualitative than quantitative view of risk, it can lend itself to numerical comparisons. For example, in the ERR, an attribute of Health, Safety, and Environmental (HSE) are weighted 40%, and Reliability is weighted as 20%. Therefore, an HSE score of 4 would give twice the value to the Risk Score as a Reliability score of 4. Below is sample from the qualitative scoring method that is currently part of the Company's ERR:

**Table 10: Qualitative Scoring**

| | **Impact Score 4** | **Impact Score 3** | **Weight** |
|---|---|---|---|
| **Health, Safety and Environmental** | Permanent/Serious Injuries or Illnesses: Few serious injuries or illnesses to the public or employees.<br>Significant and short-term impacts to environment | Minor Injuries or Illnesses: Minor injuries or illnesses to many public members or employees.<br>Moderate and short-term impacts to environment | 40% |
| **Operations and Reliability** | > 10,000 customers affected; impacts single critical location or customer; disruption of service greater than 1 day | > 1,000 customers affected; impacts single critical location or customer; disruption of service for 1 day | 20% |

[26] D.18-12-014 at Ordering Paragraph 2.

By observing the relationship between the types of impacts that would create an HSE score of 4 versus a Reliability score of 4, for example, it is possible to adjust the Risk Quantification Framework to find similar relationships.

Additional information considered in the creation of Risk Quantification Framework weights was to utilize an industry-leading reliability study that comments on financial equivalences with reliability.[27] The study considers the amount of financial loss to customers due to loss of electric power. As mentioned in more detail below, because every electric outage is unique, the study is used as a guide rather than as a source of precise equivalences. While there is not an equivalent reliability study available specific to financial loss to customers due to loss of natural gas, the findings in the study can be extrapolated to generally apply to all utility customers.

The use of the ERR and the reliability study led to a rough approximation of how weights might look across all three attributes. Draft versions of the scales and weights were created and run through a series of real-world events to check the results for reasonableness. Adjustments were made after the reasonableness test runs and results were internally discussed.

During the internal testing and discussions, it became clear that no set of scales and weights would lead to expected results for all situations for all individuals. Different subject matter experts had their own experience of how to value different scenarios. More refinements were made, and a set of scales and weights that may reflect a compromise on how different subject matter experts and external sources view this relationship is being utilized in this RAMP Report.

To summarize how weights used in the Risk Quantification Framework were attained, the solution was a reconciliation of different values and data points and considers the following items: a) current ERR framework, b) electric reliability study, c) historical comparison of gas and electric reliability impacts to society, d) scenario testing, e) input from ERM staff and leadership, f) research into other utilities and industries, g) input from personnel of varying levels

27 Ernest Orlando Lawrence Berkeley National Laboratory, *Estimated Value of Service Reliability for Electric Utility Customers in the United States* (June 2009), *available at* https://emp.lbl.gov/sites/default/files/lbnl-2132e.pdf.

at the Company through the senior vice president level, and h) using rounded numbers for readability.

### 3. Observations when Determining Weights

This section discusses several issues the Company encountered when determining the final scales and weights to utilize for the Risk Quantification Framework.

The Risk Quantification Framework utilizes three attributes – safety, reliability and financial. In an ideal world, the relationship between each of the three pairwise combinations (*i.e.*, reliability vs. safety, safety vs. financial, and financial vs. reliability) would be consistent. In mathematics, the transitive property is commonly stated as "If a=b and b=c, then a=c." But for multi-attribute value functions the transitive property is less clear. As noted above, for electric reliability, the Lawrence Berkeley study was used as a starting point to compare reliability to financial. Using that data, a blackout occurring across SDG&E's service territory for eight hours would have a financial impact to SDG&E's customers of over $1 billion. As stated previously, while there is not a gas customer-specific equivalent study, the results generally can be extrapolated to SoCalGas customers. This hypothetical created one pairwise combination of the attributes (reliability vs. financial). Separately, a hypothetical question was posed to determine another pairwise combination (reliability vs. safety): "Which risk event would you least like to happen, a systemwide blackout for eight hours that harms no one or a safety incident at a substation that results in an employee fatality?" The Company prioritized the elimination of the safety incident. With the two pair-wise comparisons developed, the transitive property was applied to derive the third pair-wise comparison. When doing so, the third pair-wise comparison (safety vs. financial) did not follow the first two pair-wise comparisons and thus led to unhelpful values for the third pair-wise comparison.

Another issue is that the Company is not accustomed to quantifying the value (financially or otherwise) of preventing safety incidents. Safety is not simply a priority at the Company; it is our culture and is the Company's core value.

Another concept observed during the creation of the Risk Quantification Framework relates to comparing the value of preventing an incident versus the value of remediating the impact if the incident were to happen. For example, if an employee becomes injured on the job, it might take some amount of financial effort and Human Resource involvement to make sure the employee is taken care of and that the employee's group has a trained person to temporarily fill the role. The value of trying to prevent the event is not equal to the value of the expected remediation costs

To address uncertainty and discretion, the Company constructed a Risk Quantification Framework that demonstrates the variability in outcomes based upon the reasoned inputs used by the Company. The Company uses in this RAMP Report three versions of the Risk Quantification Framework, which together will create a "Single Point" number as well as a range around that number. The information at the beginning of this chapter discussed the Single Point version, which satisfies the SA Decision. The additional range of outputs will be reflected in the Risk Score of each risk and in the RSE values that are created for each risk-reducing activity. The range created by presenting options of the Safety Scale provides different views on how interested parties might view a risk based on differing views of safety. The ranges are illustrated in Tables 11, 12, and 13 below:

**Table 11: Single Point**

| Top-Level Attribute | Natural Unit | Scale | Weighting |
|---|---|---|---|
| **Safety** | Safety Index | 0 – 30 | 60% |
| **Reliability** | Reliability Index | 0 – 1 | 20% |
| **Financial** | $ | $0 - $1B | 20% |

**Table 12: High Alternative**

| Top-Level Attribute | Natural Unit | Scale | Weighting |
|---|---|---|---|
| **Safety** | Safety Index | 0 – 12 | 60% |
| **Reliability** | Reliability Index | 0 – 1 | 20% |
| **Financial** | $ | $0 - $1B | 20% |

**Table 13: Low Alternative**

| Top-Level Attribute | Natural Unit | Scale | Weighting |
|---|---|---|---|
| **Safety** | Safety Index | 0 – 300 | 60% |
| **Reliability** | Reliability Index | 0 – 1 | 20% |
| **Financial** | $ | $0 - $1B | 20% |

### D. Implementation of Attributes

The SA Decision contemplates expression of attributes in "natural units."[28] The natural unit of an attribute is defined as follows:

> [T]he way the level of an attribute is measured or expressed. For example, the natural unit of a financial attribute may be dollars. Natural units are chosen for convenience and ease of communication and are distinct from scaled units.[29]

The top-level attributes of Safety and Reliability comprise sub-attributes that are used to create Safety and Reliability indices, respectively. The Safety Index has two sub-attributes, while the Reliability Index has four sub-attributes. The measurement units chosen to represent the natural units for the sub-attributes are shown in Table 14 below. The sub-attributes within safety and reliability are used to create an index for the top-level attribute.

**Table 14: Attributes**

| Attribute | Sub-Attribute | Measurement Unit |
|---|---|---|
| **Safety** | Fatality | Number of Fatalities |
| **Safety** | Serious Injury | Number of Serious Injuries |
| **Reliability** | Gas Core Meters | Number of Gas Core Meters Experiencing Outage |
| **Reliability** | Gas Curtailment | Volume of Curtailments of Natural Gas exceeding 250 million cubic feet/day |

[28] D.18-12-014 at Attachment A, A-3.

[29] *Id.*

| | | |
|---|---|---|
| **Reliability** | Electric SAIDI | System Average Interruption Duration Index (SAIDI) |
| **Reliability** | Electric SAIFI | System Average Interruption Frequency Index (SAIFI) |

### E. Safety Attribute

The Safety Attribute consists of a Safety Index, which is calculated by assessing its two sub-attributes. The sub-attributes are included because the data is readily available. The relative value between Fatalities and Serious Injuries is derived from information provided through the Occupational Health & Safety Administration (OSHA) and the Federal Aviation Administration (FAA).[30] Fatalities each receive a score of 1, and Serious Injuries receive a score of 0.25 each. A Serious Injury is usually defined as an event that requires overnight hospitalization or a permanent disfigurement of an individual.[31] The sum of these two sub-attributes create the Safety Index, which is then used as a top-level attribute in the Risk Quantification Framework.

**Table 15: Safety Attributes**

| Safety Sub-Attribute | Value |
|---|---|
| Fatality | 1 |
| Serious Injury | 0.25 |

In the RAMP Report, safety impacts are agnostic to (a) cause or reason for the event that results in safety impact, (b) characteristics of those affected, (c) level of fault for the utilities or others, (d) mitigating or aggravating circumstances related to the person's situation, and (e) other such concerns.

30 *See* United States Department of Labor, *Severe Injury Reports*, *available at* https://www.osha.gov/severeinjury/; *see also* United States Department of Labor, *Reports of Fatalities and Catastrophes – Archive*, *available at* https://www.osha.gov/fatalities/reports/archive; *see also* Federal Aviation Administration, *Data & Research*, *available at* https://www.faa.gov/data_research.

31 8 CCR § 330(h).

## F. Reliability Attribute

The Reliability Attribute comprises a Reliability Index that consists of four equally weighted sub-attributes. The sub-attributes with their Natural Units (Measurement Units) are shown in Table 16 below. The Reliability Index shown below is structured similarly to the overall Risk Quantification Framework and also contains attributes, scales, and weights.

**Table 16: Reliability Attributes**

| Reliability Sub-Attribute | Measurement Unit | Scale | Weight |
|---|---|---|---|
| Gas Core Meters | Number of Gas Core Meters Experiencing Outage | 0 – 75,000 meters | 25% |
| Gas Curtailment | Volume of Curtailments of Natural Gas exceeding 250 million cubic feet/day | 0 – 500 MMcf | 25% |
| Electric SAIDI | System Average Interruption Duration Index (SAIDI) minutes | 0 – 100 minutes | 25% |
| Electric SAIFI | System Average Interruption Frequency Index (SAIFI) outages | 0 – 1 outages | 25% |

The SA Decision requires a utility to identify relative weights between sub-attributes like gas and electric reliability, but relating the gas to electric reliability is difficult, with little industry consensus on how to do so. The rationale for the scales/weights used for the Reliability attributes was therefore based on a combination of external information and internal subject matter expert judgment. "Worst case" scenarios that have occurred involving gas and electric outages were used to consider the impact from gas and electric reliability. In 1994, the Northridge earthquake affected tens of thousands of core gas customers, and the Pacific Southwest blackout of 2011 affected all of SDG&E's customers for several hours. It was reasoned that the respective impacts of these events could be used as a baseline to create the sub-attribute scales with the Northridge gas event approximately equaling 200 minutes of a system wide SDG&E blackout.

In addition, with respect to gas Reliability sub-attributes, residential and select commercial gas customers are designated as "core" customers and have top priority to receive gas service during outages.[32] The prioritization means that core customers will not normally get curtailed during gas supply shortages. Core customers can also be affected by local pipeline events such as dig-ins or equipment issues. The gas reliability sub-attribute Gas Core Meters is used to value the importance of maintaining natural gas service to core customers.

The gas Reliability sub-attribute of Gas Curtailment is a new measurement, one that the Company believes can be useful in describing the impact to customers and society. For various reasons – such as when there is a disturbance with a major gas transmission pipeline and a coincident high demand for natural gas – there are situations when natural gas service needs to be curtailed to non-core customers. The order in which curtailments are undertaken is systematic, with a goal to prevent severe disruptions to the community. However, when large curtailments are necessary, the impact to the greater community can eventually be felt. The Company strives to prevent all curtailments, especially those that require curtailing over 250MMcfd. Curtailments at that higher level can impact critical infrastructure such as electric generation, major industries, and hospitals. The use of this sub-attribute helps to value the importance of keeping curtailments limited in size and duration.

Valuing electric reliability is a complex endeavor but requires a simplified view for the purposes of the RAMP Report. To the customer, electric reliability is a composite of at least the following items: a) having electricity when the customer wants it, b) having a high quality of electricity without flicker or dimming, c) having power restored quickly if an outage occurs, and d) having access to information about when power will be restored.

The Institute of Electrical and Electronics Engineers (IEEE) has been viewed as a leader on topics related to Electric Reliability. IEEE publishes a document, known as IEEE 366-2012, that is considered the industry "best practice" for how to measure electric reliability. The IEEE 1366-2012 has 12 distinct measurements that utilities can use to express reliability, and some of those measurements have sub-measurements providing essentially infinite combinations of

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32 *See* SoCalGas Rule 1 at Sheet 3 ("Core Service: Service to end-use Priority 1 or Priority 2A as set forth in Rule No. 23").

measurements. For example, one measurement indicates the number of customers who experience a certain number of outages in a year. That measurement can be used to evaluate customers who experience one outage, or three outages, or seven outages, and so on. The large number of possibilities of measurements is indicative of how complex the subject can be.

SDG&E has used eight different measurements in the past few years to internally measure its reliability (SAIDI, SAIFI, Worst Circuit SAIDI, Worst Circuit SAIFI, MAIFI, CAIDI, SAIDET, and ERT). For the Risk Quantification Framework, SAIDI and SAIFI were the sole indices used due to their widespread industry usage and their relative ease to use from a forecasting perspective. Future versions of the Risk Quantification Framework may include additional methods of valuing electric and gas reliability.

The electric reliability sub-attribute of Electric SAIDI measures the average duration of service loss for each utility's electric meters over the span of a year. SAIDI is a widely used index in the electric utility industry and is frequently used to compare utilities' performance. This index does not distinguish between the type of customer or the time of day of an electric outage.

The electric reliability sub-attribute of Electric SAIFI measures the average number of outages that each utility's electric meters experiences over the span of a year. This index does not distinguish between the type of customer or the time of day of an electric outage. A SAIFI value of 0.8, for example, means that on average 80% of customers served by the utility experienced an outage during a calendar year. But because SAIFI measures averages, using SAIFI alone is not enough to ascertain how many different customers experienced outages. If a utility had 100,000 meters, a SAIFI value of 0.8 could mean that 80,000 meters experienced one outage during one calendar year or it could mean that 40,000 meters experienced two outages during one calendar year.

There is significant complexity when trying to determine appropriate scales and weights to SAIDI and SAIFI in the Risk Quantification Framework. Different outages have different impacts depending on who is affected and when the outage occurred. For example, given a choice between three short outages or one long outage, a small retail store may prefer the shorter outages. Shorter outages may only temporarily affect their sales and not significantly affect their infrastructure. A large factory however may prefer one long outage, because some machinery may be negatively affected by outages and subjecting the equipment to multiple outages can be detrimental to the business' operations. Similarly, a three-hour electric outage at a residence will be dramatically different while cooking a Thanksgiving feast versus one while everyone at the residence is at school or work.

Although gas and electric sub-attributes give information to help understand levels of reliability risk, in the end, they are merely numbers that tell a story. Particularly with reliability, limited data exists to determine the equivalency of gas reliability relative to other attributes resulting in the need to leverage electric reliability data at this time. Accordingly, there is no single combination of reliability attributes that will give the perfect answer on how to measure risk. The values shown throughout the RAMP Report should be thought of as an approximation of risk rather than a precise value.

### G. Financial Attribute

The Financial attribute has no sub-attributes or index and is measured in dollars. Like the other attributes, the Financial attribute is used to estimate aspects of the impact from risk events. However, different types of costs are measured in the attribute. The types of costs measured include: societal damage (including physical damages, lost wages, relocation costs, etc.) and utility repair costs (labor, materials). As required by D.16-08-018, the Financial attribute does not include any direct impacts related to shareholder financial interests, such as fines to shareholders, stock price changes, changes in credit ratings, or unrecoverable legal fees.

The quantitative approach used by the Company considered historical events as a guide for possible future impacts. But precision for the financial attribute is difficult to achieve. Risk events are rarely reported with a single summation of all financial impacts. Depending on the risk event, differing approaches were used to estimate the financial impacts. For pipeline risks, Pipeline and Hazardous Materials Safety Administration (PHMSA) data was used in combination with internal data, but the financial values provided by PHMSA do not necessarily include all financial impacts to society. For electrical outages, estimates were made for the amount of labor and cost of repair.

Financial estimates are gathered from various sources including internal estimates based on claims data or work orders, third party sources, news reporting, among others. Because these data sources rarely include all financial impacts from a risk event, estimates are used.

## VII. PROBABILISTIC INFORMATION

This section will discuss quantitative methodologies, including statistical information as well as how computer software was used for this RAMP Report.

The SA Decision requires utilization of specific quantification methods for the RAMP Report. Among those methods are the creation of LoRE and CoRE values for each current risk. These two values are then multiplied together to obtain a risk score. Additionally, LoRE and CoRE are used to calculate Risk Spend Efficiencies (RSEs) by estimating new LoRE and CoRE when risk-reducing activities are introduced or ceased.

### A. Expected Values

As mentioned above, LoRE and CoRE utilize expected values. The term "Expected Value" is a statistical term meaning the weighted average. For example, suppose there was a casino game that paid $10 to the player 25% of the time and paid $1 to the player the other 75% of the time. The expected value of this game would $3.25 because $10 * 25% + $1 * 75% = $3.25. The term "Expected Value" is not meant to imply that the Company expects a certain outcome. Note that in the example above, the expected value of $3.25 can never occur, because only the values of $10 and $1 can be paid out.

### B. Likelihood of Risk Event (LoRE)

In the context of the SA Decision, the "Likelihood" is not a true likelihood in the usual statistical or probabilistic sense. In standard mathematics, a likelihood is the probability of an event occurring given a set of conditions (*e.g.*, the chance that a red jellybean is drawn from a jar of jellybeans). These standard probabilities can take a value between 0 and 1, where 0 indicates the event will never occur and 1 indicates the event will always occur. In traditional terms, the probability of flipping a coin and obtaining "tails" is 0.5. For purposes of the RAMP Report, however, likelihood is used in the sense of frequency, and that frequency is always in the context of the annual frequency of an event.

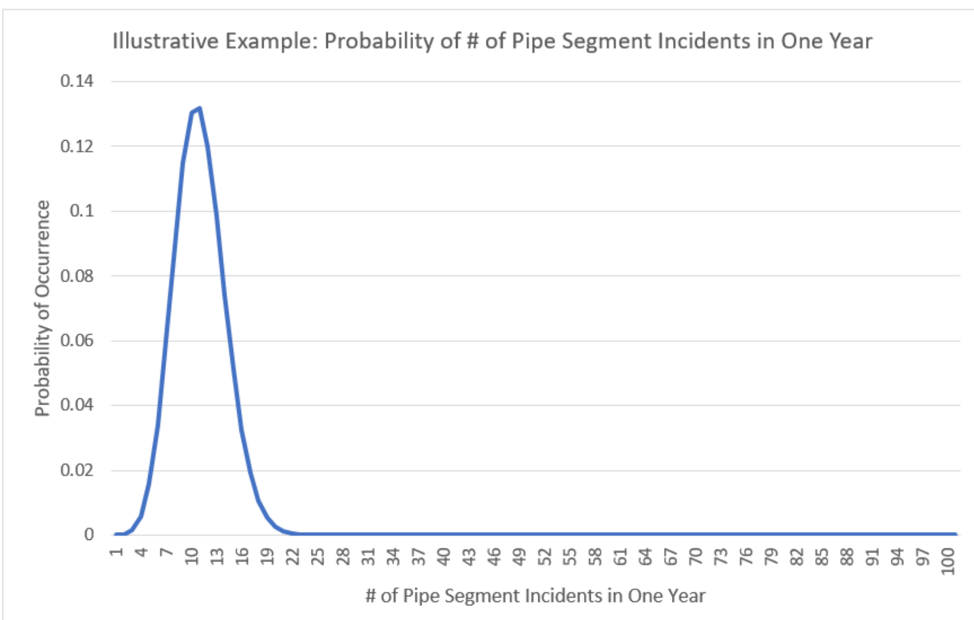
The following is an illustrative example to highlight how likelihoods are used in the RAMP Report:

### i. Example: Illustrative Gas Risk

The RAMP Report views risks at the "risk-level" over the span of a year. Suppose that the Company has an item in its ERR known as Illustrative Gas Risk. For the RAMP Report, it is necessary to determine the likelihood of that risk occurring each year. In this illustrative example, assume the following:

- The utility uses data to estimate the incident rate.
- The illustrative gas system is composed of 100 pipe segments.
- Each pipe segment has a likelihood of an event of 1/10 over a given year.
- If the pipe segment had an event, the event would cause some amount of safety, reliability, and financial impact to society and to the utility.

From a purely probabilistic point of view, the likelihood that at least one pipe segment will have an incident in a given year is quite high (>0.999 or over 99.9%). The graph below shows the probability of the number of incidents, given the assumptions above:



For the RAMP Report, the important concept is not the *likelihood that a pipe segment will have an incident*, but rather, the number of pipe segments that are estimated to have an incident in a year. The likelihood value that is provided is the "Expected Value" of the frequency. In the example above, the expected value of pipe segments that will have an incident in a given year is determined by multiplying the number of pipe segments in the system by the likelihood of a single pipe segment incident occurring: 100 x 1/10 = 10.

In this example, the LoRE for this system would be 10, which behaves like an estimated frequency of the number of incidents predicted in a year.

Depending on the risk, LoREs were compiled using a combination of internal data, external data, and/or SME input. In the individual risk chapters throughout the RAMP Report, the methods used to estimate LoRE are indicated in Sections IV and VI.

**C. Consequence of Risk Event (CoRE)**

The CoRE is determined by estimating each of the data points required by the Risk Quantification Framework as discussed below. Like LoRE, the data points that inform CoRE are also expected values. For example, the number of serious injuries used in the calculations are the expected values of serious injuries if the risk event were to occur. Applying this to one of the RAMP risks, an illustrative example can be found in the SoCalGas Customer and Public Safety Risk Chapter (Chapter SCG-4) where actual safety consequences range from one serious injury to several fatalities. The calculations used in the Risk Quantification Framework for that risk use the expected value of that range. In the case of Customer and Public Safety, the expected value of the safety impact when a risk event occurs is 0.37.

The expected values of each of the seven attributes and sub-attributes are used as inputs into the Risk Quantification Framework to produce a CoRE for each risk. This process was undertaken many times for each risk; once to establish the current Risk Score, and once for each activity where the estimations of CoRE are performed as if the risk-reducing activity has been put in place in order to calculate RSEs.

Depending on the risk, the data used to compute CoREs was a combination of internal data, external data, and/or SME input. In the individual risk chapters throughout the RAMP Report, the methods used to estimate CoRE are indicated in Sections IV and VI.

## D. Modeling

Computer software was used for many quantitative aspects of the RAMP Report. The primary software applications used by the Company was Microsoft Excel, Visual Basic, and @Risk. Additional work was also done with Microsoft Access, R, and Python. Various business units at the Company have unique ways of storing and accessing data that involve other software.

Monte Carlo simulations were performed on each risk. Monte Carlo analysis is a technique used to understand the impact of uncertainty related to a particular risk. Although the Settlement Agreement does not specify that Monte Carlo simulations are necessary, the modeling assisted in several ways that bolstered the analysis and occasionally informed critical elements. Throughout the individual risk chapters, analytical methods are discussed including the extent of modeling.

One of the benefits of modeling is that it can be used to demonstrate a range of outcomes that might be observed, given a set of inputs. When trying to identify ranges of outcomes, or the certainty thereof, performing Monte Carlo modeling can be easier to implement than precise statistical equations.

Devising ranges is an important part of risk analysis. Consider two risks, both with an expected value of a $10 million loss, but with very different ranges. Suppose Risk A rarely occurs, but when it does, it can require $1 billion of reparations; but, assuming it is a 1/100-year event, its expected value is $10 million ($1 billion x 1/100). Risk B has risk events that occur several times a year and the annual financial impact varies only slightly from $8 million to $12 million, with an expected value of $10 million. Certain stakeholders may be interested in knowing that the risks are not similar in their range of outcomes. Creating ranges of outcomes, whether through Monte Carlo modeling or via pure statistical approaches, can illuminate differences in risks.

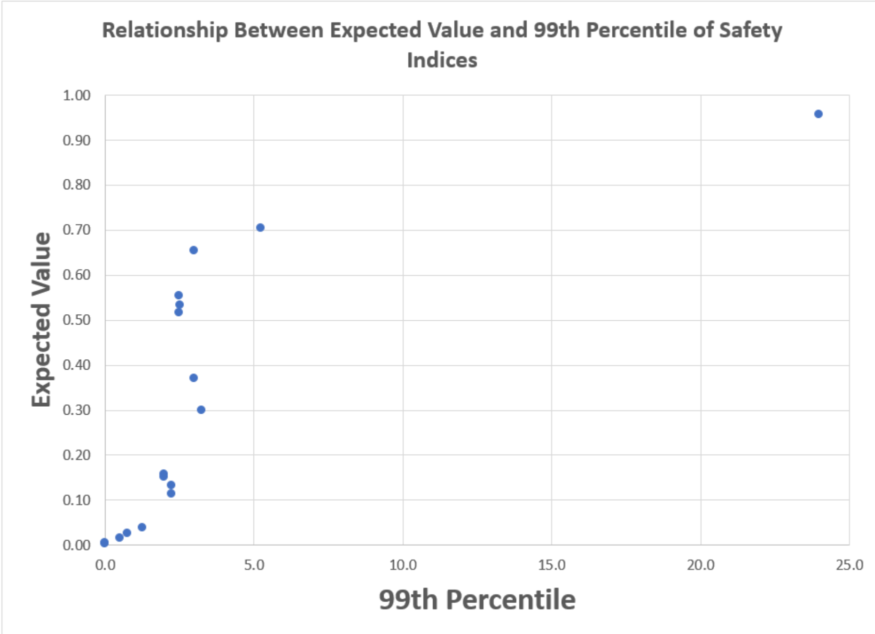
The Company found that using a Monte Carlo analysis to show where differences arise between these various types of risks (*i.e.*, one with a more consistent loss compared to a rarer but more significant loss) can be informative. To obtain a 99$^{th}$ Percentile, each risk was modeled 10,000 times, then ranked in order of consequence from lowest to highest. The 99$^{th}$ Percentile is the 100th worst consequence out of the 10,000 runs. This analysis was conducted by ERM to determine how large of an impact risks might have, even though less frequent. The result of this analysis is shown in Table 17 below.

**Table 17: Risks Sorted by Expected Value of Safety Index**

| Utility | Risk Name | Expected Value Safety Index | 99th Percentile of Safety Index |
|---|---|---|---|
| SDG&E | Wildfire | 0.96 | 24.0 |
| SDG&E | Contractor Safety | 0.65 | 3.0 |
| SDG&E | Electric Infrastructure Integrity | 0.53 | 2.5 |
| SDG&E | Employee Safety | 0.30 | 3.3 |
| SDG&E | Customer and Public Safety | 0.16 | 2.0 |
| SDG&E | Medium Pressure Gas Pipeline Incident | 0.11 | 2.3 |
| SDG&E | Third Party Dig-in on a Medium Pressure Pipeline | 0.03 | 0.8 |
| SDG&E | High Pressure Gas Pipeline Incident | 0.02 | 0.5 |
| SDG&E | Third Party Dig-in on a High Pressure Pipeline | 0.00 | 0.0 |

| Utility | Risk Name | Expected Value Safety Index | 99th Percentile of Safety Index |
|---|---|---|---|
| SCG | Medium Pressure Gas Pipeline Incident | 0.70 | 5.3 |
| SCG | Employee Safety | 0.55 | 2.5 |
| SCG | Contractor Safety | 0.52 | 2.5 |
| SCG | Customer and Public Safety | 0.37 | 3.0 |
| SCG | High Pressure Gas Pipeline Incident | 0.15 | 2.0 |
| SCG | Third Party Dig-in on a Medium Pressure Pipeline | 0.13 | 2.3 |
| SCG | Third Party Dig-in on a High Pressure Pipeline | 0.04 | 1.3 |
| SCG | Storage Well Integrity | 0.01 | 0.0 |

In some cases, in the RAMP analysis, the 99th percentile gives a different risk ranking than the Expected Value. The following is a graph showing the relationship between the Expected Value and the 99th Percentile for each risk's Safety Index. Note that the relationship between the two variables is not very strong, which supports the case that Expected Values are sufficient in themselves to understand the consequences from infrequent risks.




Because this alternative analysis provides useful information on rarer but more significant risk events, the individual risk chapters in this RAMP Report include this alternative analysis in addition to the standard modeling.

## E. Key Considerations

### 1. Secondary Impacts

The Company uses the term "Secondary Impacts" to distinguish between the impacts that are directly caused by a Risk Event, and those impacts that are "downstream" of the initial Risk Event. Because each risk has its own definition of a Risk Event, it is difficult to generalize the difference between the direct impacts and secondary impacts. Table 18 below provides examples, using the Companies' different RAMP risks:

**Table 18: Illustrative Examples of Secondary Impacts**

| | Direct Impact | Secondary Impact |
|---|---|---|
| **Electric Infrastructure Integrity** | Person hurt due to touching fallen electrical wire | Driver of vehicle not stopping at traffic light that is not operating properly during electrical outage |
| **Medium Pressure Gas Incident** | Person hurt due to gas explosion | Customer experiencing gas outage decides to cook using a charcoal barbecue, and is accidentally injured |

| | | |
|---|---|---|
| **Cyber Security** | Intruder uses remote attack to overload transformer which subsequently explodes and harms individuals | Intruder uses remote attack to steal financial information from utility customer, which leads to financial harm to customer |

Secondary Impacts are generally not used in risk scoring in this RAMP Report because they are difficult to estimate and track and are not always controllable by the Company. Data sources used for risk assessments do not consistently track secondary impacts, if tracked at all. Secondary impacts will rarely be a large driver of risk scores, even if the data was well collected. One illustrative example mentioned earlier-- large electrical outages that span entire cities--could have secondary impacts, but the history of such events fail to provide sufficient data to measure that risk. SDG&E experienced a systemwide blackout in 2011 due to electrical problems outside of its service territory. The blackout caused outages in all of San Diego and Imperial counties, as well as parts of Orange County and western Arizona. The outage in SDG&E's service territory lasted nearly 12 hours, with the average customer without power for over eight hours. During that time, safety-related incidents were reported. It is clear that undesirable outcomes can occur in large electric or gas outages, but the available data is not conducive to determining expected values of impact. Perhaps in future years, there will be more opportunities to refine how to use secondary impact information as part of risk assessments.

## VIII. CONCLUSION

The purpose of this chapter was to describe the quantitative approaches used throughout this RAMP Report and to provide a detailed overview of the Company's Risk Quantification Framework. The framework is intended to be "customizable."[33] The SA Decision recognizes that there are both advantages and disadvantages to the currently adopted approach.[34] The Company offers further discussion on this topic in Chapter RAMP-E. The Company also offers "lessons learned" to aid the Commission and other IOUs in future application of the framework in Chapter RAMP-G, from the perspective of one of the first utilities to apply the new Risk Quantification Framework adopted by the SA Decision.

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33 D.18-12-014 at 27.

34 *See* D.18-12-014 at 28-30.