graph depicting annual frequency on the y-axis and N fatalities on the x-axis, where N is the cumulative number of potential fatalities for all scenarios represented by the corresponding cumulative frequency of events. Whereas the IR calculation gives insight into the probability of having a fatality, the SR calculation gives the likelihood of a number of potential fatalities. This is especially important for evaluating scenarios with a large potential impact for loss of life, such as train derailments of flammable materials.

1.1.1 Developing Quantitative Risk Criteria

After quantifying risk and presenting the calculations as IR and SR for a given operation or process, the results are evaluated for tolerability (or acceptability). Typically, stakeholders (e.g., government agencies, investors, communities) have a threshold risk level that is deemed acceptable—known as quantitative risk criteria. Currently, the U.S. Department of Transportation (DOT) Federal Railroad Administration (FRA) has not codified quantitative risk criteria for LNG hazardous materials transportation scenarios.[5] Additionally, QRA analyses are not common regulatory requirements in the U.S. and no broadly-accepted risk criteria are employed by domestic communities or industries. The Dutch government and their respective regulatory agencies have been international leaders in utilizing QRA techniques for determining acceptability of fixed facilities and transportation routes. The approach for evaluating the risk results presented here is consistent with the Dutch guidance.

There are several foreign and several domestic examples of quantitative risk criteria.[6,7,8] Within these, there is a wide disparity in risk criteria for public exposure, with acceptable IR fatality probabilities ranging from 10^{-4} yr^{-1} (or a fatality per 10,000 years) to 10^{-8} yr^{-1} (or a fatality per 100,000,000 years). Recommendations for QRA of LNG plants were issued in the National Fire Protection Association (NFPA) standard, NFPA 59A *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG).*[9,10] In addition to including QRA as a risk assessment

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5 Strang J, "Federal Railroad Administration Risk Reduction Programs," United States Army Corps of Engineers Workshop on Tolerable Risk, March 18-19, 2008, Alexandria, Virginia.

6 Appendix B: Survey of Worldwide Risk Criteria Applications, *Guidelines for Developing Quantitative Safety Risk Criteria*. Center for Chemical Process Safety, AIChE (2009).

7 Cornwell JB and MM Meyer, "Risk Acceptance Criteria or 'How Safe is Safe Enough?'" presented at II Risk Control Seminar in Puerto La Cruz, Venezuela, October 13, 1997.

8 Ham JM, M Struckl, AM Heikkila, E Krausmann, C DiMauro, M Christou, JP Nordvik, "Comparison of Risk Analysis Methods and Development of a Template for Risk Characterisation," Institute for the Protection and Security of the Citizen, European Commission, Directorate-General Joint Research Center (2006).

9 NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG),* 2016 edition, National Fire Protection Association.

10 It should be noted that an older version – the 2001 edition of NFPA 59A – is one of the primary references for the requirements found in 49 CFR § 193, which provides the regulatory requirement for fixed LNG facilities operating in the U.S., and many of the 49 CFR § 193 codes reference NFPA 59A requirements directly. The 2001 edition of NFPA59A does not include requirements or suggestions for QRA.