## Appendix H

Risk Analysis of the Cost to Relieve Severe Congestion

Costs to add capacity were calculated using estimates of construction costs, induced travel, bridge widening construction, and elevated-tunnel construction costs (see Appendix B). But there is a fair amount of uncertainty in those numbers. To determine the likely range of costs, an uncertainty analysis of the cost was conducted using the Crystal Ball® software package. This software uses a *range* of numbers for each factor affecting the cost rather than just one, and produces a *range* of estimates rather than just one. To do this we assumed a range of uncertainty (typically about 10 percent standard deviation) for the many separate cost factors used in the calculations, then examined what the range of outcomes would be with many (10,000) 'trial' calculations. The result was a 'range' of answers rather than a single estimate, as shown in Figures H-1 and H-2.

Figure H-1: Distribution of Crystal Ball ® Simulation Results
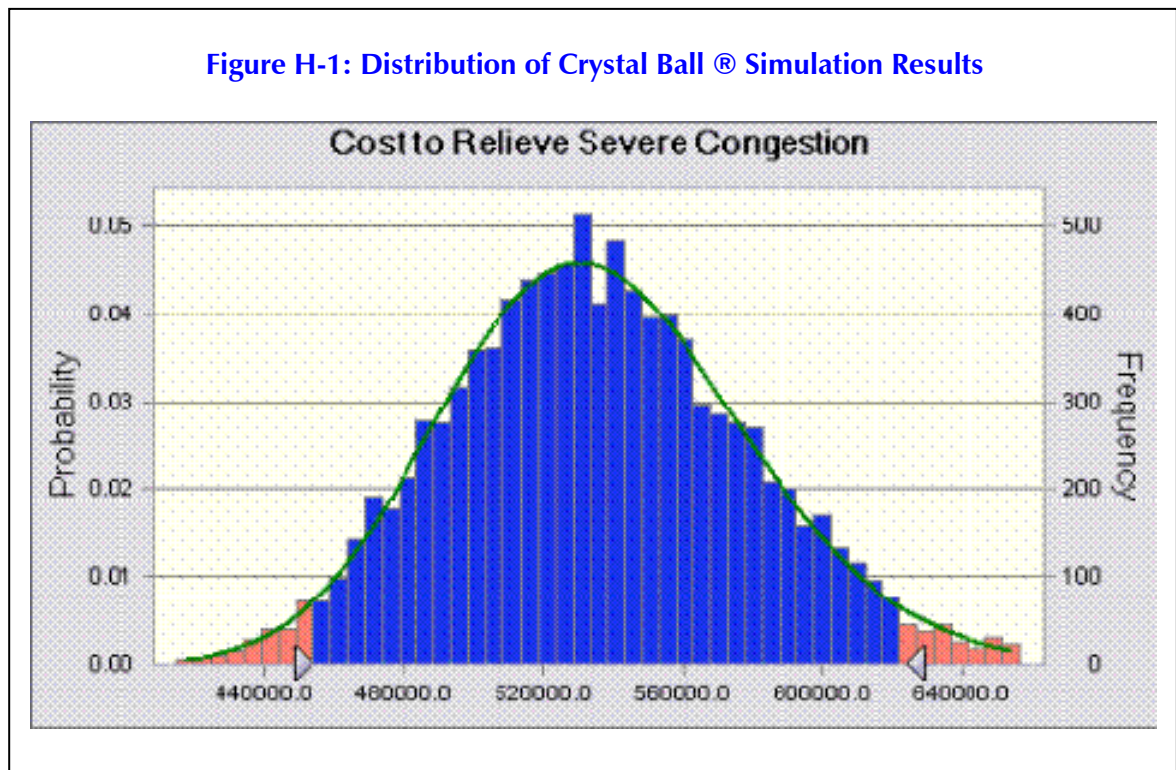
Base case: $533.5 Billion

Number of trials:	10,000
Mean of trials:	$535.7 Billion
Certainty level:	95.13%
Certainty range:	$454.6 to 623.0 Billion
80 Percent confidence estimate:	$572.1 Billion

Figure H-1 shows that there is a 95 percent certainty that the costs to relieve severe congestion will fall between $454.6 billion and $623.0 billion, in current dollars. Figure H-2 indicates that there is an 80% probability that the costs to relieve severe congestion are less than $573 billion, and a 90% probability that they are less than $593 billion.

Figure H-2: Cumulative Distribution of Crystal Ball ® Simulation Results
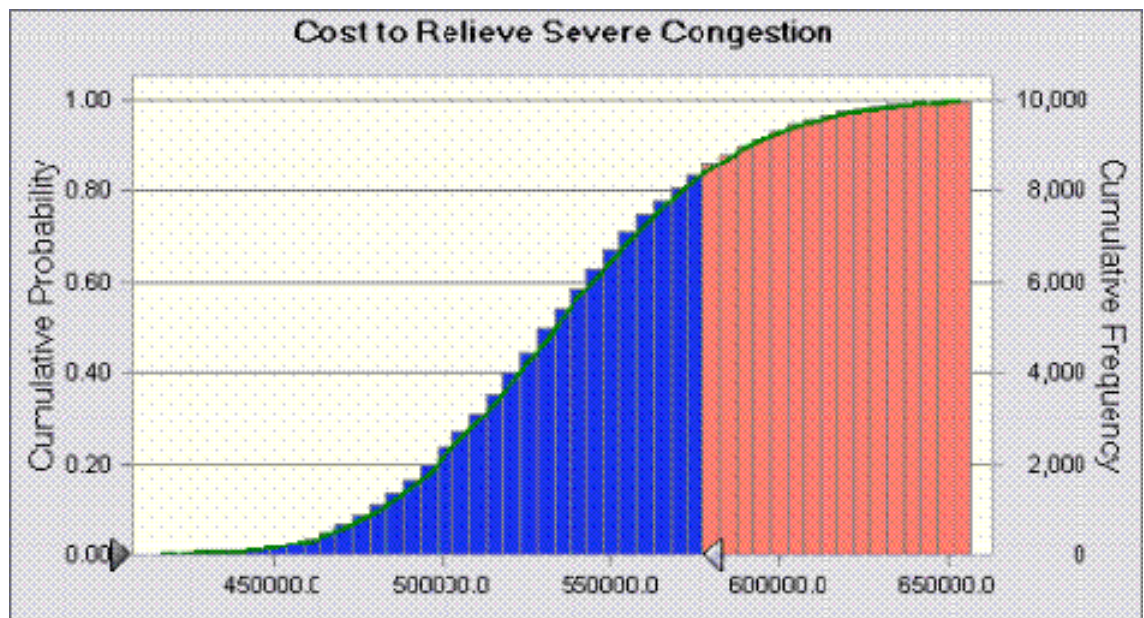
Percentiles	Forecast values	Percentiles	Forecast values
0%	396,444.7	60%	544,664.8
10%	481,092.8	70%	556,927.3
20%	498,999.4	80%	572,123.3
30%	512,119.5	90%	592,724.6
40%	523,297.8	100%	706,893.2
50%	533,482.6		

Finally, we conducted a sensitivity analysis of the impact of the various factors that were varied in Crystal Ball® on the final cost distribution (Figure H-3). These results show that the higher construction costs for the interstates and freeways, and differences in state construction costs are

the key factors influencing overall cost. They account for about 60 percent of the uncertainty in the final cost. Although major bridge widening needs and elevated sections are individually expensive, they are a relatively small part of total costs.

We did not test the effects of inflation on rising costs and declining 'purchasing power' of construction dollars. Forecasts of inflation are problematical at best and most economists treat forecasts in current-dollar terms.

Figure H-3: Sensitivity Analysis of Crystal Ball® Simulation Input Factors

Factor	Value
Costs / LM High, Int. Fwy	33.7%
State Cost Indices	25.2%
Induced Travel - 3000K+	15.0%
Bridge 3000K+	8.1%
Cost/LM Norm, Int-Fwy	6.7%
Elevated Hwy-Tunnel	5.5%
Cost/LM Norm, MA-COLL-LS	1.3%
Cost/LM Norm, CPA	0.9%
Induced Travel 1000K-3000K	0.7%
Costs/LM High, MA-COLL-LS	0.7%
Costs/LM High, CPA	0.6%
97-05 Cost Increase	0.3%
Bridge 1000K-3000K	0.1%
Bridge <500K	0.1%
Induced Travel 500K-1000K	0.1%
Bridge 500K-1000K	0.0%
Induced Travel < 500K	0.0%