APPLYING PROBABILISTIC NETWORK-LEVEL RISK ANALYSIS TO THE TRAVEL DEMAND MODEL

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ABSTRACT

Travel Demand Model (TDM) results are dependent upon the inputs (e.g., socio-economic and demographic characteristics used in the 'trip generation' step of the standard four-step model) and the selected parameters (e.g., α and β values in the standard link performance function used in the 'trip assignment' step). Given the uncertainty involved in determining appropriate inputs and parameters, there is a risk of programming less critical construction projects based on TDM results that are not truly representative of the community. To account for this uncertainty, a probabilistic framework, along with sensitivity analysis, is recommended. By randomly sampling inputs from statistical distributions and varying parameters, multiple TDM outputs can be assessed. Using risk analysis, various potential projects can then be sorted into a 'risk matrix' to ease decision-making. A case study of this approach for the programming of a congestion relief project in one small Indiana (U.S.) Metropolitan Planning Organization (MPO) region will be presented.

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1. BACKGROUND AND OBJECTIVES

The amount of uncertainty in the travel demand model (TDM) may lead to inaccurate results. Planning organizations risk the inefficient use of resources when programming projects based on an uncertain TDM solution. To deal with this risk, management strategies can be applied.

While more commonly applied in the private sector, risk management is an area of increasing research in the transportation planning field. Recent studies have predominantly focused on improving risk management techniques for 'risk due to disasters' and 'risk due to uncertainties in [project] estimation' (*1*). Several studies have focused upon disaster evacuation (*2*,*3*,*4*). Other studies have focused upon uncertainties with project construction costs, schedule, and performance (*5*,*6*). These latter studies focus on 'project risk', which is distinctively different from 'business risk'; as defined in (*7*), "Selecting the right project is business risk. Managing uncertainty to meet the stakeholder's objective is project risk."

For this research, the 'business risk' of choosing the most optimal congestion-relief projects, as determined by a TDM for a small Indiana Metropolitan Planning Organization (MPO), will be analyzed. By managing this initial risk, resources can be focused on projects that are considered more critical. 'Project risk' management strategies can then be applied to the selected program. A brief discussion of risk, typical management frameworks, and general strategies follows.

2. INTRODUCTION TO RISK MANAGEMENT PRACTICES

For this study, risk is best defined as both: (1) "the possibility of suffering damage or loss in the face of uncertainty about the outcome of actions, future events, or circumstances" and (2) "a condition in which there exists a quantifiable dispersion in the possible outcomes from any activity" (*8*).

Two risk analysis frameworks are available: continuous and non-continuous. A continuous approach is generally preferred, where the impact of the chosen risk management strategy is reviewed so as to improve future decision-making; a non-continuous approach considers risks only once in the planning process (*9*). Several variations of the continuous framework exhibited in Figure 1 are applied in industry. The principal steps of a continuous risk analysis are to (1) identify, (2) assess, (3) manage, and (4) review/monitor risks (*10*).

Risk identification should include the description of conditions that may lead to a loss and a rough description of that loss (*9*). The conditions that may lead to a loss are the 'hazard' and 'exposure', where 'risk' is the combined probability and consequence of harm, 'hazard' is the instrument of harm, and 'exposure' is the time/spatial interval during which harm may occur.

Risk assessment is the step used to gather 'information' (*11*). During this step, data are collected to identify the likelihood and consequences of 'risk occurrence' (the realization of the risk). These values can be combined to determine an expected risk value, where Expected Risk = Likelihood (or probability) * Consequence (*7*). Alternatively, a 'risk matrix' can be used to graphically represent the risk (Figure 2). Such a generic format allows for the clear expression of 'risk tolerance' (Figure 3), where agencies can determine the level of risk they are willing to accept based on the risk behavior of the stakeholders (Figure 4). Quantitative and qualitative methods can be used to calculate the likelihood and consequence values. Quantitative methods to assess risk include: sensitivity analyses, fitting statistical distributions, forecasting, simulation, mathematical programming, and econometrics; qualitative methods include: obtaining expert opinion, determining risk value, and risk-cost-benefit trade-offs (*12*).

Risk management is the process of deciding which 'action' will produce the best outcome (*11*). Typical management strategies (or action plans) are to (1) avoid, (2) reduce, (3) retain, or (4) transfer the risk, which can be defined as follows (*13*).

Avoid:	Business chooses to not undertake risky activity
Reduce:	Business takes action to reduce probability and/or consequence of the risk
Retain:	Business accepts risk due to low consequence
Transfer:	Business purchases insurance policy in case risk occurs

When to apply these strategies can be determined based on the location of a project within the 'risk matrix' (Figure 5). More specific management techniques include the use of decision rules and trees, heuristics, incremental strategy, strategic choice approach, multi-objective, multi-attribute theory and goal programming, expected utility theory, surveys, and the formulation of clearer goals, aims, objectives, and policy guidelines (*12*).

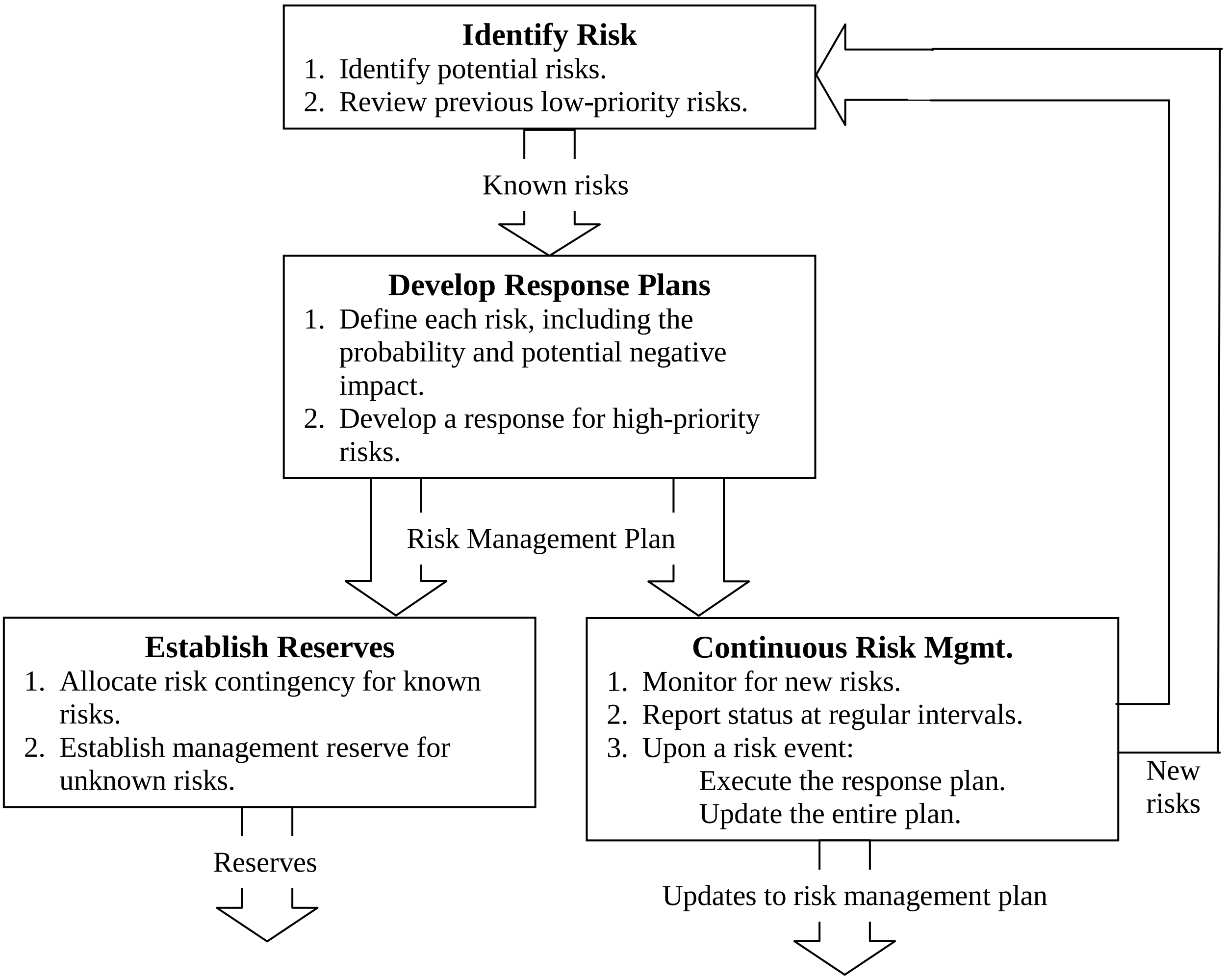


FIGURE 1 Continuous Risk Analysis Framework (*7*)

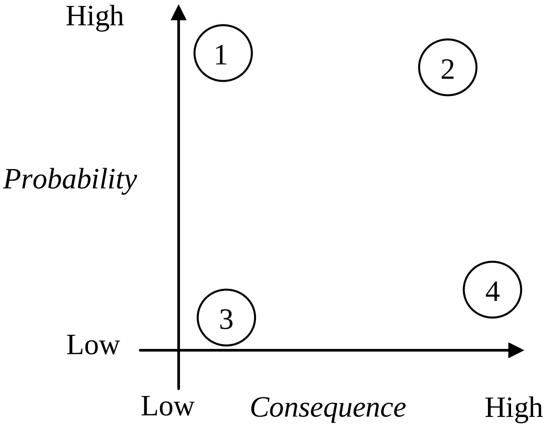
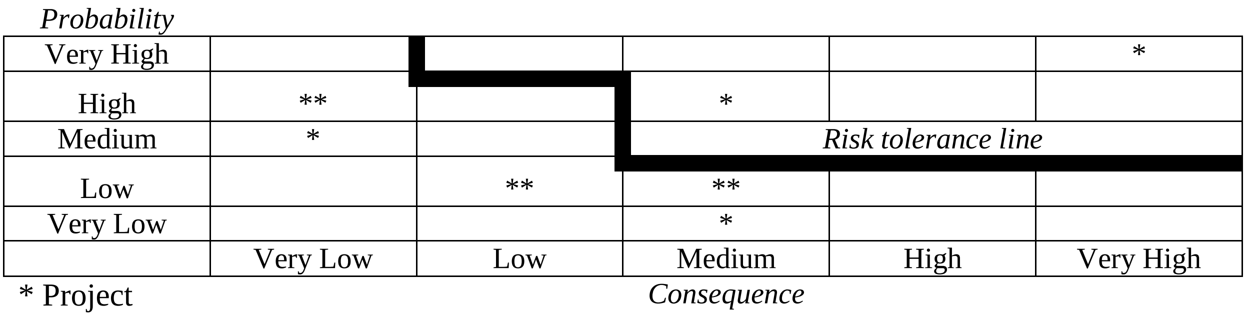


FIGURE 2 Risk Matrix Format (*13*)



Probability					
Very High					*
High	**		*		
Medium	*			*Risk tolerance line*	
Low		**	**		
Very Low			*		
	Very Low	Low	Medium	High	Very High

* Project *Consequence*

FIGURE 3 Use of a Risk Tolerance Line within a Risk Matrix (*14*)

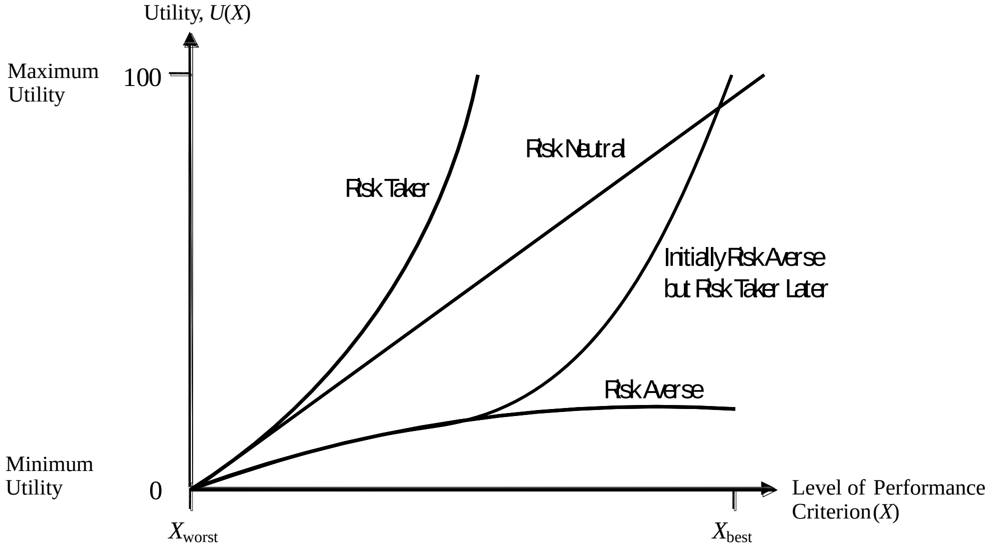


FIGURE 4 Defining Risk Value with Utility Curves (*1*)

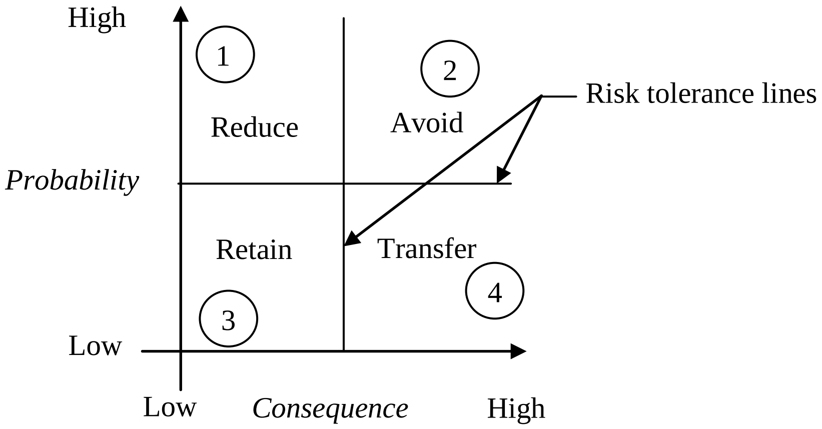


FIGURE 5 Assigning Risk Management Strategies to the Risk Matrix (*13*)

Risk monitoring is the step of a continuous framework where the impact of the selected management strategy is reviewed. A successful monitoring process is one that allocates responsibility, facilitates compliance, and raises awareness through a clear communication plan, such as a risk log (*7*,*15*). Based on the results of the monitoring process, future action plans can be modified and new risks identified.

Given these concepts, a risk analysis of using the travel demand model to program congestion-relief projects for the Columbus, IN MPO follows. The case study is presented on a step-by-step basis according to the continuous risk analysis framework.

3. RISK IDENTIFICATION

The ‘business risk’ in terms of this transportation planning case study can be described as follows:

Risk: Resources may be applied to less critical congestion-relief projects based on the results of the TDM, due to uncertainties in the model.

Hazard: The process of programming projects based on the results of a single TDM output. Often, this hazard is enhanced due to the outsourcing of the development of the TDM. MPOs risk using the model as a ‘black box’, being unaware of the uncertainty involved in the development of the model and unreasonably placing faith in the outcome.

Exposure: The period of time from model development to project programming. During model development, planners are exposed to the risk of using inaccurate inputs and parameters. During project programming, planners are exposed to the risk of programming inefficient projects based on inaccurate outputs.

Loss: The inefficient use of limited financial and human resources on projects that do not optimize the reduction of congestion or other goals.

A framework for dealing with two types of uncertainty will be offered in this paper: (1) input uncertainty created by using socio-economic and demographic point-estimates in the ‘trip generation’ step of the standard four-step model and (2) parameter uncertainty created by transferring values calibrated by external planning agencies, as is typical of small- and medium-sized MPOs. The use of socio-economic and demographic estimates adds uncertainty due to insufficient sample sizes, procedural bias (as constrained by data collection resources), and inherent forecasting errors. Borrowed parameters add uncertainty due to the lack of calibration for the study area.

4. RISK ASSESSMENT

To assess the defined risk, the following quantitative and qualitative techniques are recommended:

Quantitative
  Inputs: Statistical analysis
  Parameters: Sensitivity analysis
Qualitative
  Inputs and Parameters: Expert Opinion for reasonableness/validation checks
  Outputs: Trade-off analysis

The objective of these techniques will be to define the probability and magnitude of potential ‘loss’, given changes in the TDM outcomes due to varied inputs and parameters.

Congestion-relief projects (e.g., capacity-expansion) are typically programmed for links with the highest peak-hour volume-to-capacity (v/c) ratios and by those with the greatest benefits (subject to cost constraints), such as the largest reduction in vehicle-hours-traveled (VHT). Therefore, the v/c ratio is used to determine the ‘likelihood’ of risk, while the ‘consequence’ of risk is taken as a function of expected VHT savings.

To assess risk, the following procedure is recommended:

1. Unless sufficient local data have been collected, make model parameter selections by applying borrowed parameters (sensitivity analysis) and choosing those that best match local estimates (expert opinion) (*16*).
2. Establish a ‘base case’ by running modeling software with current input estimates to determine the top x links with the highest v/c ratios. For this study, x is set to 10, assuming that a planning organization has sufficient resources to complete 10 congestion-relief projects in one programming cycle.
3. Develop normal distributions (statistical analysis) for each of the ‘trip generation’ data inputs at the zonal level where (*16*):
   $\mu \equiv$ the mean or best estimate (expert opinion) achieved through local data collection or through data sources and updating techniques outlined in (*16*).
   $\sigma \equiv$ the zonal standard deviation, taken as (*17*).:

$$\sigma = (\text{ACS } \sigma \,/\, \text{ACS } \mu) * \mu, \text{ with ACS } \sigma = (\text{ACS ‘Margin of Error’} \,/\, 1.645)$$

The *ACS μ* and *ACS 'Margin of Error'* variables represent the American Community Survey (ACS) estimate and margin of error values for the smallest geographic level available in the study area.

4. Establish multiple 'variable cases' by running modeling software *n* times with randomly selected values pulled from the normal distributions established in the previous step. Record the top *x* links with the highest v/c ratios (the most congested links) and the corresponding link and network peak-hour vehicle hours traveled (VHT) values. This study sets *n* to 10. This step is similar to a previous approach, where randomly selected log-normal values were used to construct histograms of potential peak-hour flows for links (*18*).
5. Calculate the 'likelihood' of the links appearing in the top *x* being overlooked during the programming step. As the 'likelihood' increases, the risk increases. To calculate the 'likelihood' of each link, the following equations are recommended:

Likelihood = (1 – Probability of Appearance in *n* model runs) *
(Highest Link Score calculated – Link Score)

Normalized Likelihood = 100 * Likelihood / highest of all Likelihoods calculated

The score is taken as the sum of points awarded at the end of *n* model runs, where after each model run, the link with the highest v/c ratio is given 10 points; the second most congested link is given 9 points, and so on. Links with a lesser score and less appearances in the top *x* are more likely to be overlooked.

For example, the likelihood of a link appearing in the top 10 (as sorted by v/c ratio), through 10 model runs, with the following breakdown can be calculated.

1st most congested: appeared once
3rd most congested: appeared twice
5th most congested: appeared thrice

The Probability of Appearance = (1 + 2 + 3) / 10 = 0.60
The Score = (10 * 1) + (8 * 2) + (6 * 3) = 44

Assume another link scored a value of 90 (the highest score of all links that appeared in the top 10 during the 10 model runs). The Likelihood for the link with a Probability of 0.60 and a Score of 44 is:

Likelihood = (1 – 0.60) * (90 – 44) = 18.4

Assume another link had a likelihood value of 50 and that this was the highest likelihood of all links that appeared in the top 10 during the 10 model runs. The Normalized Likelihood for the link with a Likelihood of 18.4 is:

Normalized Likelihood = 100 * 18.4 / 50 = 37

6. Calculate the 'consequence' of choosing one link over another (trade-off analysis) for capacity-building projects in terms of expected VHT savings on the link, as well as in the network. In this analysis, the capacity-building project, for simplicity, will be assumed to be the addition of one lane per direction. Using modeling software, the new link and network VHT values can be compared to the original link and network VHT values. The difference between the new and old values represents the VHT savings expected for each appearance in the top *x*. The consequence then represents the 'loss' of potential VHT savings on the link and network, if a less critical capacity-building project was constructed. To calculate the 'consequence' for each link, the following equations are recommended:

Link Consequence = average Link VHT savings – the smallest of all average Link VHT savings calculated
Network Consequence = average Network VHT savings – the smallest of all average Network VHT savings calculated
Normalized Consequence =
(50 * Link Consequence / the largest of all Link Consequences calculated) +
(50 * Network Consequence / the largest of all Network Consequences calculated)

For example, assume a link with the following characteristics.

Lanes per Direction = 2
Original Peak-hour Capacity C = 338 vph
New Peak-hour Capacity C =338 * (2+1)/2 = 507 vph

Link VHT average savings = 500 VHT
Network VHT average savings = 4,000 VHT

Also assume that another link has a calculated average Link VHT savings of 50 (the smallest of all average Link VHT savings calculated) and a calculated average Network VHT savings of 100 (the smallest of all average Link VHT savings calculated).

Link Consequence = 500 – 50 = 450 VHT
Network Consequence = 4,000 – 100 = 3,900 VHT

Assume the largest Link Consequence calculated was found to be 700, and the largest Network Consequence was calculated as 7,000.

Normalized Consequence = (50 * 450/700) + (50 * 3,900/7,000) = 60

7. Calculate the 'expected risk value' with

Expected Risk Value = Normalized Likelihood * Normalized Consequence.

For this example (from Steps 5 and 6), Expected Risk Value = 37 * 60 = 2,220.

A plot or 'risk matrix' of 'likelihood' on the ordinate against 'consequence' on the abscissa can graphically represent the risk value as the rectangular area bounded by the axes and a specific link point. For example, this project would be located on a risk matrix shown in Figure 6.

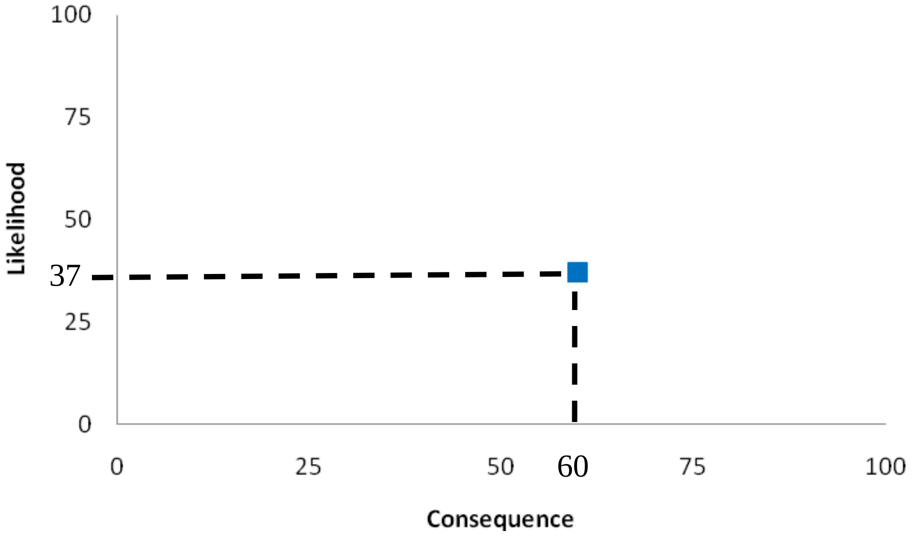


FIGURE 6 Risk Matrix Location for Sample Calculation

To demonstrate further how this procedure works, data from the Columbus Area Metropolitan Planning Organization (CAMPO) study region will be used.

The 'base case' can be established by first applying the model parameter selections in (*16*) chosen after conducting a sensitivity analysis to the CAMPO input data. Using travel demand modeling software, the top ten v/c links in Table 1 would likely be recommended for project programming.

TABLE 1 Links with the top 10 v/c ratios using the current data

Link ID	*Street Name*	*v/c*	*Priority*
10871959	Lincoln Park Dr.	1.25	1
10871342	S.R. 46	1.19	2
665547	S.R. 46	1.19	2
665537	S.R. 46	1.15	4
665831	Indianapolis Rd.	1.11	5
10873321	Indianapolis Rd.	1.11	5
10873325	Indianapolis Rd.	1.11	5
10873328	Indianapolis Rd.	1.11	5
699967	Lincoln Park Dr.	1.07	9
639574	I 65 ramp to S.R. 58	1.06	10

The locations of these links, primarily in the central business district (CBD), are shown in Figure 7.

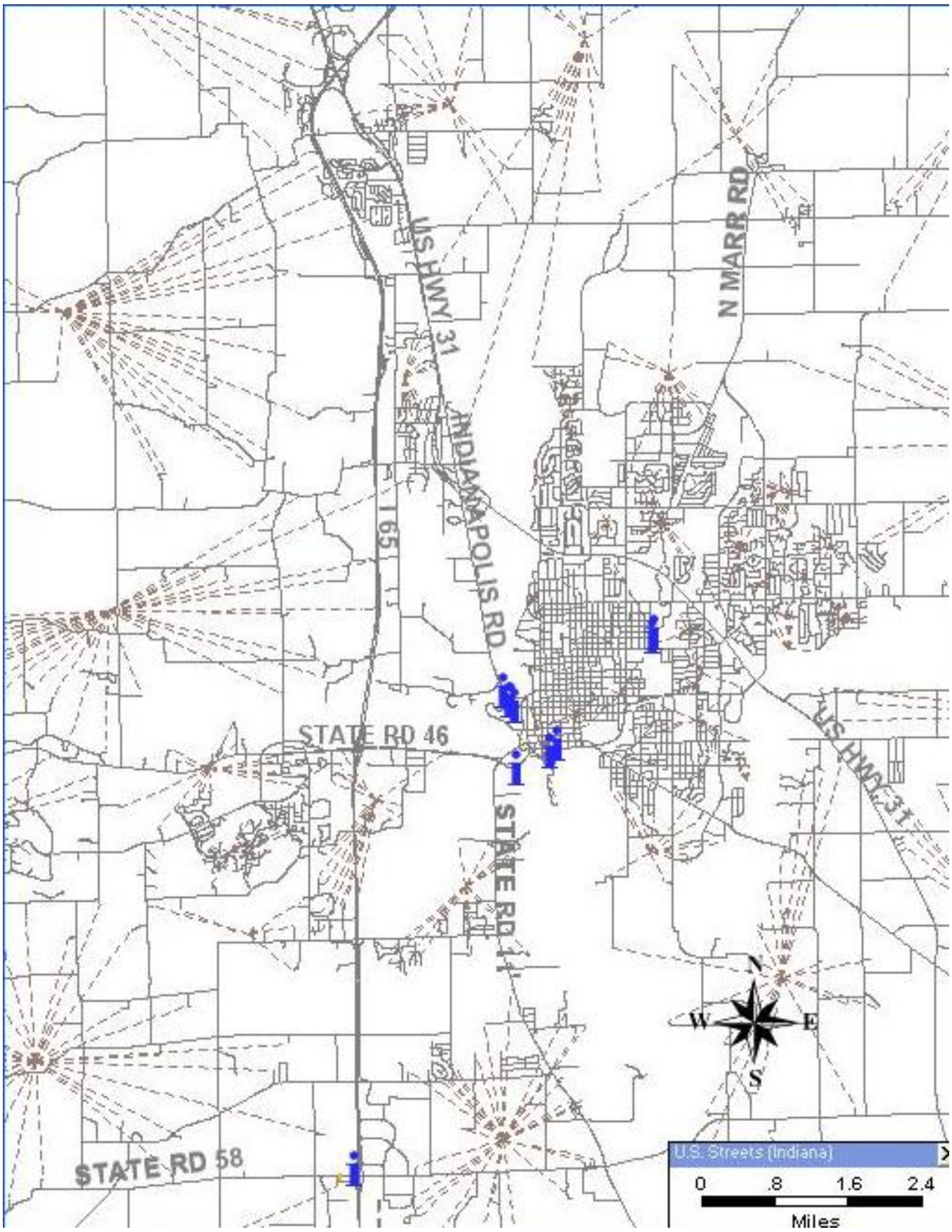


FIGURE 7 Locations for the Top 10 links sorted by v/c ratio using current data

The solution in Table 1, however, is just one of several possible solutions. Considering the sampling error for the inputs, multiple outputs can occur. To demonstrate the volatility of such results, statistical analysis can be used. By using input values within the sampling error, each 'variable case' represents a feasible solution. With the normal distributions developed for each input variable in (*16*), the 'variable case' analysis begins by randomly generating normal inputs. [For those zonal inputs with $\sigma > \mu$, the lower limit that can be randomly selected should be set to zero, so as to avoid negative inputs].

The 'variable cases' are developed by applying a set of random normal values to the selected model parameters for each of the ten model runs. Having done so, it was found that 26 different links, as located in Figure 8, appeared in the top 10 at least once during the ten model runs. Some of these links are in locations not considered to be congested in the 'base case'. This suggests that a broader range of projects should be considered when programming.

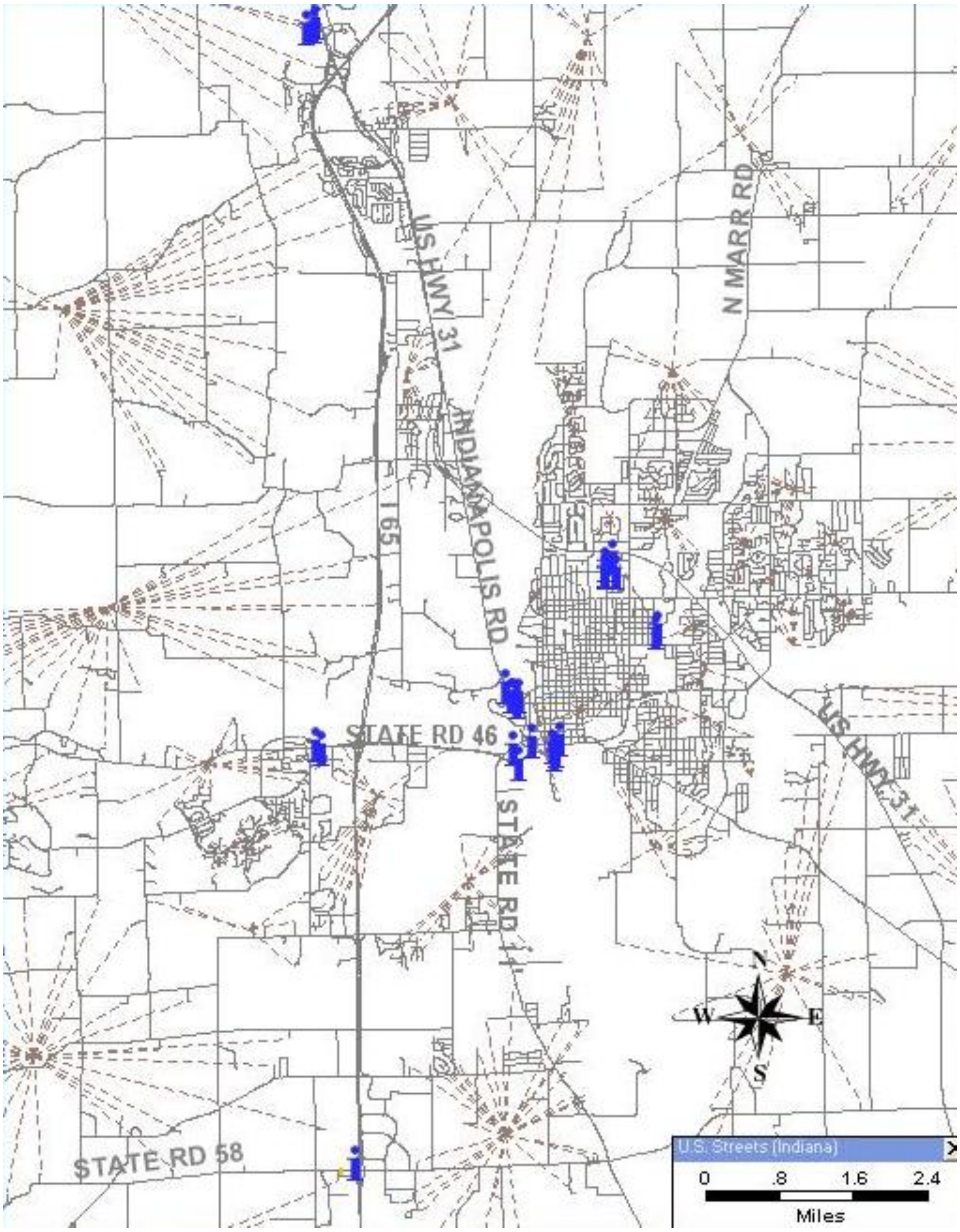


FIGURE 8 Location of all links appearing in the Top 10 through 10 model runs

Table 2 summarizes the probability of appearance, score, and average link and network VHT Savings for each of the 26 links. For example, link 705395 (Maple St.) appeared in the top ten in 3 out of 10 model runs. This is a probability of appearance of 30%. With one appearance each as the 3rd, 4th, and 7th most congested links (8, 7, and 4 points respectively), the final score for link 705395 is then 19. The link peak-hour VHT saving, over the 3 appearances, was found to be 229 (Model Run 1), 269 (Model Run 6), and 202 (Model Run 10). The average link VHT saving is then 233. The network peak-hour VHT saving, over the 3 appearances, was found to be 91 (Model Run 1), 217 (Model Run 6), and 256 (Model Run 10). The average network VHT saving is then 188.

TABLE 2 Risk assessment data for links Appearing in the top 10 links as sorted by the v/c ratio for 10 model runs

Link ID	*Street Name*	*Probability of Appearance*	*Score*	*Average Link VHT Savings*	*Average Network VHT Savings*
10871959	Lincoln Park Dr.	90%	82	1,220	2,384
10871342	S.R. 46	100%	85	173	1,274
705386	Maple St.	30%	24	279	374
705395	Maple St.	30%	19	233	188
705492	Maple St.	30%	24	1,311	1,893
705552	Tipton Ln.	30%	24	613	549
665537	S.R. 46	50%	40	356	-54
665831	Indianapolis Rd.	100%	53	194	-147
10873321	Indianapolis Rd.	100%	53	281	-66
10873325	Indianapolis Rd.	100%	53	29	-44
10873328	Indianapolis Rd.	100%	53	105	-39
639574	I 65 ramp to S.R. 58	40%	10	145	-24
10873324	Lowell Rd.	10%	2	167	212
10873327	Lowell Rd.	10%	2	52	552
665547	S.R. 46	60%	35	46	-144
678388	U.S. 31 Access Rd.	20%	8	207	74
678415	U.S. 31 Access Rd.	20%	8	201	-37
678423	U.S. 31 Access Rd.	20%	8	53	90
665148	S.R. 46	10%	3	122	-872
664902	S.R. 46	20%	3	541	-436
699967	Lincoln Park Dr.	50%	29	474	-337
665434	1st St.	20%	3	107	-49
665528	Lafayette Ave.	20%	3	118	-23
705467	Wildwood Pl.	10%	9	3	38
10873349	W Carlos Folger Dr.	10%	1	16	47
10872330	W Carlos Folger Dr.	10%	1	67	-561

The ‘likelihood’ of each link being overlooked increases with a lower probability of appearance and a lower score. Planning organizations are less likely to consider programming projects with a high ‘likelihood’ value. The ‘consequence’ of not programming a link increases with higher potential VHT savings. The largest ‘expected risk value’, shown in Table 3, increases when a project likely to be overlooked is considered to have the highest savings. Resources may be inefficiently used if projects with a high ‘consequence’ are overlooked when programming. With link 705395, the ‘likelihood’ is found by multiplying the probability of not appearing (100 – 30 = 70%) by the trade-off of a higher score being possible (85 (the highest score found) – 19 = 66). This ‘likelihood’ comes out to be 46, as compared to the highest calculated ‘likelihood’ of 76 for another link. However, when normalized on a scale of zero to 100, the likelihood becomes 100 * (46/76) = 61.

The ‘consequence’ for the link is found by the trade-off of a higher average link and network VHT savings being possible. With the smallest average link VHT saving in Table 3, calculated to be 3, and an average link VHT saving for link 705395 of 233, the ‘link consequence’ is 233 – 3 = 231 (not 230 due to rounding). Once normalized on a scale of 50, with the highest ‘link consequence’ of 1,309 being calculated, the ‘link consequence’ is found to be 50 * (231/1,309) = 9. The smallest average network VHT saving, calculated to be -872 (the project actually increased congestion due to latent demand) and an average network VHT saving for link 705395 of 188, the ‘link consequence’ is

188 – -872 = 1,060. Once normalized on a scale of 50, with the highest 'network consequence' of 3,256 being calculated, the 'network consequence' is found to be 50 * (1,060/3,256) = 16. The overall 'consequence', taken as the sum of the average link and network VHT savings, was found to be 9 + 16 = 25. Multiplying the 'likelihood' and 'consequence' together yields a risk value of 61 * 25 = 1,533 (not 1,525 due to rounding).

TABLE 3 CAMPO Likelihood, Consequence, and Expected Risk Values by Link

Link ID	*Street Name*	*Likelihood*	*Consequence*	*Expected Risk Value*
10871959	Lincoln Park Dr.	0	97	38
10871342	S.R. 46	0	39	0
705386	Maple St.	56	30	1,678
705395	Maple St.	61	25	1,533
705492	Maple St.	56	92	5,222
705552	Tipton Ln.	56	45	2,550
665537	S.R. 46	30	26	775
665831	Indianapolis Rd.	0	18	0
10873321	Indianapolis Rd.	0	23	0
10873325	Indianapolis Rd.	0	14	0
10873328	Indianapolis Rd.	0	17	0
639574	I 65 ramp to S.R. 58	60	18	1,099
10873324	Lowell Rd.	99	23	2,266
10873327	Lowell Rd.	99	24	2,345
665547	S.R. 46	26	13	339
678388	U.S. 31 Access Rd.	81	22	1,819
678415	U.S. 31 Access Rd.	81	20	1,661
678423	U.S. 31 Access Rd.	81	17	1,361
665148	S.R. 46	98	5	446
664902	S.R. 46	87	27	2,364
699967	Lincoln Park Dr.	37	26	972
665434	1st St.	87	0	0
665528	Lafayette Ave.	87	0	0
705467	Wildwood Pl.	90	0	0
10873349	W Carlos Folger Dr.	100	0	0
10872330	W Carlos Folger Dr.	100	0	0

These results can also be presented graphically with the 'risk matrix' in Figure 9, where the points represent the individual links or potential projects. The diamond-shaped points represent the top 10 most congested links using the current data (or a deterministic approach).

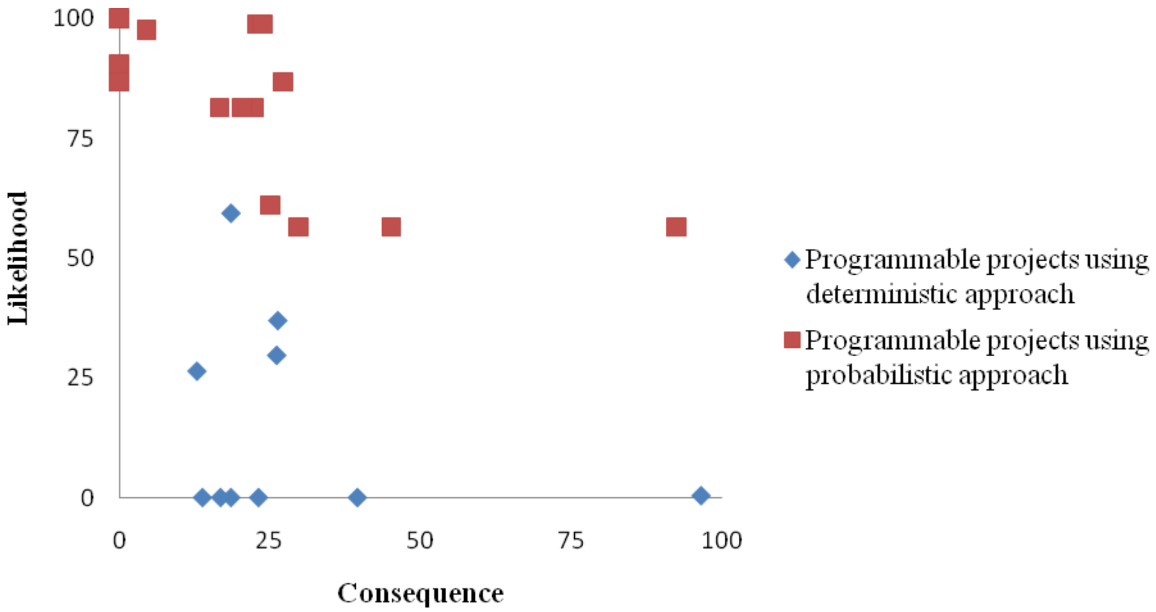


FIGURE 9 CAMPO Risk Matrix

5. RISK MANAGEMENT

The four common risk management strategies, applied to the travel demand model (TDM) results, can be interpreted as follows:

(1) Avoid

Do not pursue the project.

(2) Reduce

Consider pursuing the project. Collect more input data using the methods detailed in (*16*) and perform traffic counts on the 26 links to verify the v/c ratios. Expert opinion, field observations, and improved public involvement could also be used to validate the consideration of each project for programming. The link capacity, travel times, and travel speeds entered into the TDM should also be validated. If possible, parameters should be calibrated to match local conditions.

(3) Retain

Pursue the project. This strategy represents the common practice of accepting model outputs and using expert opinion for reasonableness/validation checks.

(4) Transfer

Consider pursuing the project with contingency funds. Planning organizations can seek more state and federal funding such as for Regional Surface Transportation Program (RSTP) and/or Congestion Mitigation and Air Quality (CMAQ) Improvement Program projects.

The location of each link in a ‘risk matrix’ (Figure 10) can be used to decide which strategy to apply (*13*).

For CAMPO, it is recommended to *avoid* projects that are not likely to appear among the most congested links in the TDM and also have low expected VHT savings. Those links with a high probability of appearing among the most congested links, but with low expected VHT savings, are recommended to be *transferred* or only pursued with excess funding, because they may not be as critical. Projects with potentially high VHT savings that are also more likely to appear are recommended to be *retained*. Projects not likely to appear in the TDM results, but likely to have high VHT savings, are recommended to have their risks *reduced*. Once reduced, through data collection or expert opinion, the continuous framework allows for reassessment of the risk.

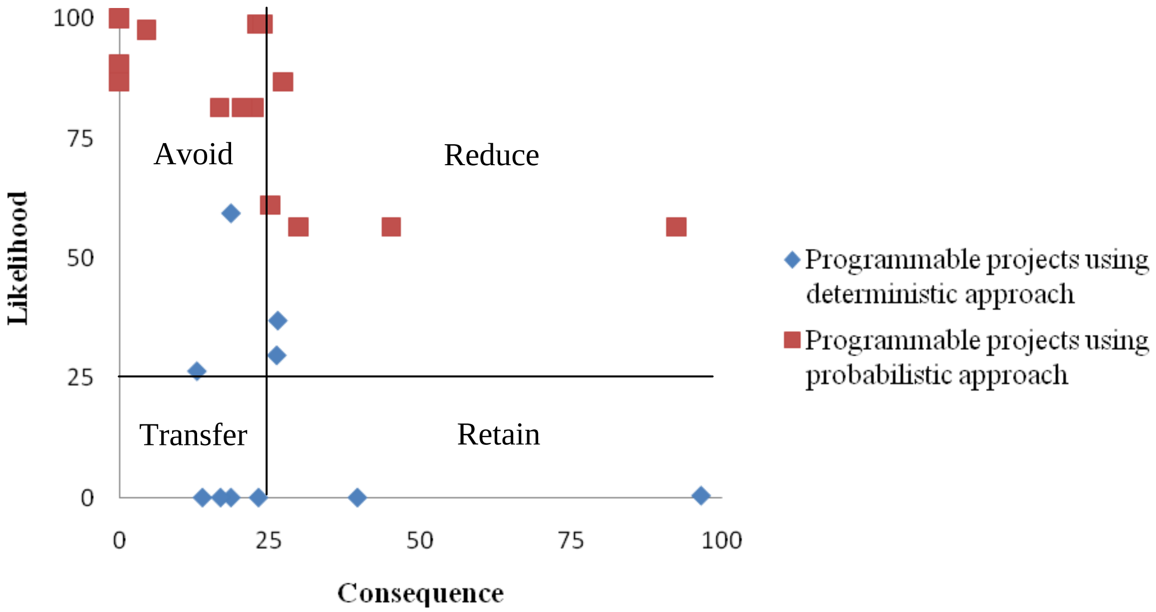


FIGURE 10 CAMPO Risk Management Recommendations

Ideally, running the TDM using the current data would result in all critical projects falling in the *retain* quadrant of a risk matrix, due to a high ‘consequence’ and low ‘likelihood. This means that the projects with the highest return (or VHT savings) are the most likely to appear in the output of the TDM. Basically, the calculation of ‘likelihood’ is used as a screening process, while the calculation of ‘consequence’ is used for the decision-making process.

In tabular form, Table 4 further shows the recommended versus the likely CAMPO strategies, where the ‘likely strategy’ is to accept the single solution of the TDM, with current data, and retain the projects on the most congested links.

The recommended and ‘likely’ strategies differ significantly. Several projects retained under the ‘likely strategy’ are recommended to be *avoided transferred*, or *reduced*. By avoiding risk, planners can reserve more resources for projects that are considered more likely to have higher VHT savings. By transferring risk, planners can risk another organization’s money or use non-essential funds to pursue a project that may not yield the highest VHT savings. By reducing risk, planners can be more certain that a congestion-relief project will bring about significant VHT savings.

TABLE 4 Recommended versus Likely CAMPO Strategies

Link ID	*Street Name*	*Recommended Strategy*	*Likely CAMPO Strategy*
10871959	Lincoln Park Dr.	Retain	Retain
10871342	S.R. 46	Retain	Retain
705386	Maple St.	Reduce	--
705395	Maple St.	Reduce	--
705492	Maple St.	Reduce	--
705552	Tipton Ln.	Reduce	--
665537	S.R. 46	Reduce	Retain
665831	Indianapolis Rd.	Transfer	Retain
10873321	Indianapolis Rd.	Transfer	Retain
10873325	Indianapolis Rd.	Transfer	Retain
10873328	Indianapolis Rd.	Transfer	Retain
639574	I 65 ramp to S.R. 58	Avoid	Retain
10873324	Lowell Rd.	Avoid	--
10873327	Lowell Rd.	Avoid	--
665547	S.R. 46	Avoid	Retain
678388	U.S. 31 Access Rd.	Avoid	--
678415	U.S. 31 Access Rd.	Avoid	--
678423	U.S. 31 Access Rd.	Avoid	--
665148	S.R. 46	Avoid	--
664902	S.R. 46	Reduce	--
699967	Lincoln Park Dr.	Reduce	Retain
665434	1st St.	Avoid	--
665528	Lafayette Ave.	Avoid	--
705467	Wildwood Pl.	Avoid	--
10873349	W Carlos Folger Dr.	Avoid	--
10872330	W Carlos Folger Dr.	Avoid	--

6. RISK MONITORING

Due to the use of a continuous framework, risk monitoring is appropriate. In terms of CAMPO, this would mean monitoring how congestion has improved or worsened on the studied links and in the network. The effectiveness of the selected risk management strategy can come in terms of how the v/c ratio or VHT has changed over time. This information is recommended to be stored in a 'risk log' and reassessed during the next programming cycle.

7. CONCLUSIONS AND RECOMMENDATIONS

Considering the number of uncertainties associated with the use of the traditional travel demand model, it seems unreasonable to make policy decisions based on a single model output. Instead, risk analysis can be used to prevent the inefficient application of resources. By borrowing risk frameworks commonly used in private industry, the number of links considered for programming can be expanded to ensure that the most optimal projects are undertaken. Once the most efficient projects have been programmed, planners can then focus on 'project risk' management.

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Indiana Department of Transportation, nor do the contents constitute a standard, specification, or regulation.

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