Chapter 5. ANALYSIS OF SCHEDULE DEPENDENCIES IN HURRICANE RECOVERY

Introduction

This chapter examines the issue of time to recovery discussed in Chapter 4 on a macro level. A framework is developed for measuring, comparing, and categorizing intra and inter-agency schedule dependencies that exist among the activities of numerous agencies involved in the pre and post-hurricane processes. Scenarios describing potential opportunities for advancing the schedule were researched through interviews of local, regional, and state agencies and organizations that participate in the pre- and post-hurricane processes. Descriptive scenarios are categorized into the functions within the organizational structure of a state DOT in order to determine the functions that are involved in a significant number of scenarios. Further analysis indicates the pairs of functions that, when interacting, are associated with many scenarios. In addition, measuring and comparing the scenarios can highlight the extent of their overall significance to the time to recovery. The framework will aid in the planning of VDOT's emergency operations in order to support a higher level of coordination within VDOT and between agencies.

This chapter contains:

- A compilation of descriptive scenarios gathered from the accounts that Virginia, California, Florida, North Carolina, and South Carolina public agencies hold of their participation in the pre and post-event phases involving natural disasters in the past, specifically in terms of the situations where the agencies were waiting on their state DOT and vice versa. The collection also includes potential scenarios that, although they have not occurred in the past, could arise in the future.
- A record in spreadsheet form of all agencies and organizations contacted for this research (see supplement).
- A categorization of the descriptive scenarios according to the specific individual and pairs of functions involved within VDOT, and an analysis based on this categorization.
- A tool for measuring the magnitude of a delay that takes into account its 'Severity' in regards to its time duration, the number of 'Agencies Involved', its 'Likelihood' of occurring in the future, the range of 'Items Waited On', its 'Controllability' for the future, the number of associated 'Cascading Effects', its 'Maturity', and the 'Prevalence of Similar Scenarios'.
- A demonstration of this tool with a sample descriptive scenario using the eight indices for measurement listed above.
- A method for comparison that utilizes graphical representation of the descriptive scenarios based on the eight indices for measuring delays.
- An exploration of alternatives taking into account pre-hurricane investments of resources that could advance the post-hurricane schedule in the future.
- Recommendations based on this investigation.

Purpose and Scope

The recovery from a natural disaster, which involves the contributions of numerous federal, state, and local agencies and organizations, is so complex that schedule dependencies frequently exist on account of the lack of efficient coordination of these agencies' recovery activities. The dependencies primarily exist because one agency's duties cannot be started until activities that other agencies are responsible for have been completed. The schedule dependencies lengthen the time to recovery, and therefore increase the magnitude of the impacts of the disaster. An analysis of scenarios depicting potential opportunities for schedule improvement can aid in VDOT's decision-making.

Methods and Materials

This section includes:

- A discussion of the research performed
- A spreadsheet with the collected scenarios and their descriptions
- Qualitative analysis of descriptive scenarios in terms of the organizational functions involved within VDOT
- An explanation of the indices used for measuring and comparing delays
- An assessment of a sample delay

Approach to Data Collection

Descriptive scenarios of a particular region's experiences preceding and following a natural disaster in the past were gathered from agencies through phone interviews, and faxed and emailed responses to a list of questions sent to them (see Appendix for questionnaire). Interviews included such questions as "What is a case in which you have not been able to start an activity you are responsible for because you are waiting on VDOT to complete a prerequisite task, and vice versa?" Data were collected from Virginia agencies and organizations regarding the recovery of Hurricane Floyd in September 1999. In addition to VDOT, the agencies include the Virginia Department of Emergency Management, the Virginia Department of Health, and the State Police. Anecdotes were also collected from Florida, North Carolina, and California agencies, including each state's DOT.

North Carolina DOT's report of lessons learned from Hurricane Floyd was examined. The report, which is based on interviews of staff members from the central office and field units, evaluates their department's response to Floyd (NC DOT report, 2000). It identifies their inefficiencies and shortcomings, and develops a set of recommendations for improvement.

A particular descriptive scenario could apply within a range of geographic scales such as a specific city intersection, a whole group of city blocks, or an entire county. A scenario could also exist on any time horizon ranging from the hours and days following the disaster in the short term to the months and years in the long term.

Categorization of Descriptive Scenarios

Each descriptive scenario will be classified into categories according to what organizational function of the state DOT was involved.

These categories include:

- Administration
- Environmental, Planning, and Regulatory Affairs
- Equipment
- Finance
- Information Management (includes the communication and availability of the information to other agencies)
- Legal / Authorization
- Materials
- Operations (includes functions of field units, maintenance units, and loss control units)
- Personnel
- Structure and Bridge (includes the reconstruction or repair of roads, bridges, etc.)

Table 5.1 on the following two pages is a spreadsheet of the researched descriptive scenarios, where each row characterizes a different scenario, and each column represents a different category listed above. Additional columns provide an index number and title associated with the scenario, as well as the name, state, and type (Communication, Environmental, Fire, Health, Military, Police, Transportation, Utility) of the agency involved, the authority level of the agency (local, regional, state), the time horizon involved (short term, medium term, long term), and whether the scenario occurred during the pre- or post-hurricane phase. The scenarios are grouped by state (VA, CA, SC, NC), but they are not listed in a particular order within these groups.

Table 5.1 Categorization of collected descriptive scenarios according to the associated organizational function involved within VA, CA, SC, and NC state DOTs. Each row represents a different descriptive scenario.

Descriptive Scenario #	Descriptive Scenario Name	State	Agency Name	Agency Type	Level of Agency	Pre/Post Disaster	Time Horizon	Administration	Environ., Regulatory Affairs	Equipment	Finance	Information Management	Legal / Authorization	Materials	Operations	Personnel	Structure and Bridge
DS1	Sandbag Requests	VA	Henrico Co. Div. Of Fire	Fire	Local	Post	ST							x			
DS2	Barricade Requests	VA	Henrico Co. Div. Of Fire	Fire	Local	Post	ST			x							
DS3	On-call Personnel	VA	Henrico Co. Div. Of Fire	Fire	Local	Post	ST									x	
DS4	Updated Road Status Info.	VA	Obici Hospital	Health	Local	Post	ST				x						
DS5	Inaccurate Road Information	VA	Obici Hospital	Health	Local	Post	ST				x						
DS6	Bridge Failure	VA	Office of Emerg. Med. Serv.	Health	State	Post	MT										x
DS7	Available Road Status Info.	VA	Office of Emerg. Med. Serv.	Health	State	Post	ST				x						
DS8	Inaccurate Road Information	VA	Office of Emerg. Med. Serv.	Health	State	Post	ST				x						
DS9	Road Access	VA	Dept. of Conserv. and Rec.	Envir.	State	Post	MT										x
DS10	Geological Information	VA	Dept. of Mines,Min.,Energy	Envir.	State	Post	LT				x						
DS11	Road Access	CA	Dept. of Health Services	Health	State	Post	ST								x		
DS12	Long Term Road Access	CA	Hall Ambulances	Health	Local	Post	LT										x
DS13	Road Access & Authorization	CA	Glen.-Cres.Vall. Redcross	Health	Local	Post	ST								x		
DS14	Convoy Use	CA	CA National Guard	Military	State	Post	ST								x		
DS15	Road Repairs	CA	Roseville Transit	Trans.	Local	Post	LT										x
DS16	Road Access and Information	CA	Dept. of Water Resources	Envir.	State	Post	ST								x		
DS17	Transmitter Sites	SC	SCANA Communications	Comm.	State	Post	ST								x		
DS18	Crawler Tractor Use	NC	Div. Of Forest Resources	Envir.	Region.	Post	ST					x					
DS19	Road, Bridge, and Flood Info.	NC	Amat. Radio Emerg. Serv.	Comm.	Region.	Post	ST				x						
DS20	Obtaining Environ. Permits	NC	Div. Of Coastal Manage.	Envir.	State	Post	LT					x					
DS21	Sandbag Debris	NC	Div. Of Coastal Manage.	Envir.	State	Post	LT								x		
DS22	Coastal Inlet Stabilization	NC	Div. Of Coastal Manage.	Envir.	State	Post	MT		x								
DS23	Environmental Violations	NC	Div. Of Coastal Manage.	Envir.	State	Post	MT				x						
DS24	Resource Depletion	NC	Franklin Co. Emerg. Manage	Emerg.	Local	Post	ST									x	
DS25	Deadstock Removal	NC	NC Extension Service	Volun.	State	Post	MT								x		

Table 5.1, continued. Categorization of collected descriptive scenarios according to the associated organizational function involved within VA, CA, SC, and NC state DOTs. Each row represents a different descriptive scenario.

Descriptive Scenario #	Descriptive Scenaio Name	State	Agency Name	Agency Type	Level of Agency	Pre/Post Disaster	Time Horizon	Administration	Environ., Regulatory Affairs	Equipment	Finance	Information Management	Legal / Authorization	Materials	Operations	Personnel	Structure and Bridge
DS26	Detour Information	NC	Local Emergency Services	Emerg.	State	Post	ST				x						
DS27	Chainsaw Crews	NC	Dept. of Natural Resources	Envir.	State	Post	ST								x		
DS28	Conflicting Road Information	NC	NC State Highway Patrol	Police	State	Post	ST				x						
DS29	Fund Reimbursements	NC	FEMA	Emerg.	State	Post	LT				x						
DS30	Ineffective Equipment	NC	NC DOT	Trans.	State	Post	ST			x							
DS31	Relocated Personnel	NC	NC DOT	Trans.	State	Post	ST									x	
DS32	Equipment Distribution	NC	NC DOT	Trans.	State	Post	ST			x							
DS33	Undefined Roles	NC	NC DOT	Trans.	State	Post	ST	x									
DS34	Excessive Workloads	NC	NC DOT	Trans.	State	Post	LT	x									
DS35	Structure Repairs	NC	NC DOT	Trans.	State	Post	MT								x		
DS36	Insufficient Traffic Manage.	NC	NC DOT	Trans.	State	Post	ST				x						
DS37	Fuel Confusion	NC	NC DOT	Trans.	State	Post	ST				x						
DS38	Conference Calls	NC	NC DOT	Trans.	State	Post	MT	x									
DS39	Email Communication	NC	NC DOT	Trans.	State	Post	MT				x						
DS40	Unconfirmed Equipment	NC	NC DOT	Trans.	State	Post	ST				x						
DS41	Road Closure Reports	NC	NC DOT	Trans.	State	Post	ST								x		
DS42	Restricted Access	NC	NC DOT	Trans.	State	Post	ST		x								
DS43	Inconsistent Barricades	NC	NC DOT	Trans.	State	Post	ST			x							
DS44	Refueling	NC	NC DOT	Trans.	State	Post	ST							x			
DS45	Restricted Communication	NC	NC DOT	Trans.	State	Post	ST				x						
DS46	HazMat Information	NC	NC DOT	Trans.	State	Post	ST				x						
DS47	Disposal Sites	NC	NC DOT	Trans.	State	Post	MT								x		
DS48	Processing Reimbursements	NC	NC DOT	Trans.	State	Post	LT				x						

Descriptions of Scenarios

The following is a list of descriptions of the scenarios recorded in Table 5.1. The descriptions of scenarios 1 through 25 were taken from the interview responses (the contact name and agency are included), and scenarios 26 through 48 were taken from NC DOT's report of lessons learned from Hurricane Floyd and from an interview with one if its authors, Kelly Hutchinson. The scenario descriptions are listed chronologically by their associated Descriptive scenario Number, which can be found in the first column of Table 5.1. Their "names", which correspond to the entries in the second column of Table 5.1 ("Descriptive Scenario Name"), are indicated in bold.

Virginia

DS1. Sandbag Requests -- A potential delay could take place between the time when the Henrico County Division of Fire requests materials over the phone from VDOT such as sand bags and the time when they actually receive it. (R. C. Dawson, Jr., Deputy Fire Chief, Henrico County Division of Fire)

DS2. Barricade Requests -- A potential delay could take place between the time when the Henrico County Division of Fire requests equipment over the phone from VDOT such as traffic barricades and the time when they actually receive it. (R. C. Dawson, Jr., Deputy Fire Chief, Henrico County Division of Fire)

DS3. On-call personnel -- A potential delay could take place between Henrico County Division of Fire if there are an inadequate number of on-call personnel at VDOT during emergency response. (R. C. Dawson, Jr., Deputy Fire Chief, Henrico County Division of Fire)

DS4. Updated Road Status Information -- Obici Hospital had to wait on VDOT for the availability to current, updated road status and closure information following Hurricane Floyd. (Randy Vick, Obici Hospital)

DS5. Inaccurate Road Status Information -- Obici Hospital experienced delays following Hurricane Floyd because the road status information that was provided by VDOT was inaccurate. (Randy Vick, Obici Hospital)

DS6. Bridge Failure -- The response of the Office of Emergency Medical Services in the future to an isolated area could be delayed if there is a road or bridge failure that is waiting to be repaired by VDOT. (C. Everette Vaughan, Jr., Director of Emergency Operations at the Office of Emergency Medical Services)

DS7. Available Road Status Information -- The Office of Emergency Medical Services had to wait on VDOT for the availability of current, updated road status information following Hurricane Floyd. (C. Everette Vaughan, Jr., Director of Emergency Operations at the Office of Emergency Medical Services)

DS8. Inaccurate Road Status Information -- The Office of Emergency Medical Services' response to Franklin, VA following Hurricane Floyd was delayed because the road status and

closure information provided by VDOT was inaccurate. (C. Everette Vaughan, Jr., Director of Emergency Operations at the Office of Emergency Medical Service)

DS9. Road Access-- The Department of Conservation and Recreation could potentially be waiting on VDOT in the future to make a bridge or road passable. (Corey Garyotis, Senior Floodplain Engineer, Department of Conservation and Recreation)

DS10. Geological Information-- VDOT could potentially be waiting on the Department of Mines, Minerals, and Energy in the future to provide geological information or information on where road building materials can be found. (Cheryl Cashman, Department of Mines, Minerals, and Energy)

California

DS11. Road Access-- The California Department of Health Services medical response could potentially be delayed if roads are impassable. (Dave Abbott, CA Department of Health Services)

DS12. Long Term Road Access-- The Hall Ambulance Service, Inc. of Bakersfield is still experiencing delays from closed and almost non-accessible roads due to flooding 2 years ago. (Louis Cox, Hall Ambulance Service, Inc.)

DS13. Road Access and Authorization-- The Glendale-Crescenta Valley Chapter of the Redcross has waited on CalTrans to clear roads and to give them authorization for use in order to provide equipment and supplies where necessary. (Robert Reynoso, Glendale-Crescenta Valley Chapter, Redcross)

DS14. Convoy Use-- The California National Guard could potentially be waiting on CalTrans in the future, because their convoys cannot be used until the roads are passable. (Maj Terry Edinboro, CA National Guard)

DS15. Road Repairs-- Roseville Transit has waited on CalTrans for highway repairs and openings of overcrossings. (Michael Wixon, Roseville Transit)

DS16. Road Access and Status Information-- The Department of Water Resources has experienced delays due to blocked roads, and a lack of communication and information regarding road status. (Sonny Fong, Department of Water Resources)

North Carolina and South Carolina

DS17. Transmitter Sites-- When trying to access transmitter sites in order to provide two-way communication for government and utility officials, SCANA Communications waited on the SC DOT to clear roads. (George Crouch, SCANA Communications)

DS18. Crawler Tractor Use-- During major snow disasters, the Division of Forest Resources has waited on NC DOT for a request before bringing out their crawler tractors. (Vic Owen, Division of Forest Resources)

DS19. Road, Bridge, and Flood Status Info.-- When directing relief radio operators to affected areas in order to provide backup communication, the ARES has waited on NC DOT for information on road closures, damaged bridges, and flooded highways. (David Fleming, Amateur Radio Emergency Service)

DS20. Obtaining Environmental Permits-- NC DOT has waited on the Division of Coastal Management to provide permits. There is potential for the delay to increase since the DCM must meet legislated requirements for public notification and comment. If the proposed new development for recovery is thought to cause significant negative environmental impacts, NC DOT experiences further delays. (Ted Sampson, Division of Coastal Management)

DS21. Sandbag Debris-- The DCM is currently still waiting on NC DOT to remove sandbag debris from the coast. (Ted Sampson, Division of Coastal Management)

DS22. Coastal Inlet Stabilization-- The DCM waited on NC DOT following Hurricane Fran to stabilize and close a storm generated inlet under SR 1568. (Bob Stroud, Division of Coastal Management)

DS23. Environmental Violations-- The environmental unit has waited on the Division of Coastal Management for information regarding what recovery activities violate coastal development restrictions. Various repairs were delayed due to a lack of information regarding new environmental requirements. Some repairs were made before NC DOT was aware of the requirement changes. (NC DOT report, 2000)

DS24. Resource Depletion-- Franklin County Emergency Management experienced delays when they were left with few equipment and personnel after NC DOT requested that they aid another larger county. (Angie Callihan, Franklin County Emergency Management)

DS25. Deadstock Removal-- The NC Extension Service was delayed in delivering feed and removing deadstock due to blocked roads. (W. Simmons, NC Extension Service)

DS26. Detour Information-- Local emergency service providers experienced travel delays because they were not informed that a certain route had become a detour, and subsequently they unexpectedly faced added volumes of traffic. (NC DOT report, 2000)

DS27. Chainsaw Crews-- The Department of Natural Resources were delayed in evaluating environmental hazards and distribute chain saw crews due to a lack of accessible ground routes and information from NC DOT. Specifically, NC DOT lacked updated information regarding floodplain locations. (Mike Kelly, Department of Natural Resources)

DS28. Conflicting Road Information-- Widespread delays occurred during the height of the flooding due to conflicting road condition information from NC DOT and the NC State Highway Patrol. (NC DOT report, 2000)

DS29. Fund Reimbursements-- Finance unit had to wait and is still waiting on FEMA and FHWA for fund reimbursements. (NC DOT report, 2000)

Intra-Agency, NC DOT

The following intra-agency descriptive scenarios concern North Carolina's Department of Transportation efforts following Hurricane Floyd.

DS30. Ineffective Equipment-- Field operations experienced a delay repairing roads and bridges, because the equipment provided were ineffective due to the water impacts. (NC DOT report, 2000)

DS31. Relocated Personnel-- Areas needing assistance waited on personnel, because many of the reinforcement workforce coming from the western, less affected area of the state were initially sent to the wrong location, only to be relocated to another. (NC DOT report, 2000)

DS32. Equipment Distribution-- Because of the large transfer of equipment between districts, there were delays in the distribution of supplies, i.e. in getting the right supplies to the right people. (NC DOT report, 2000)

DS33. Undefined Roles-- Widespread delays occurred with fields units' tasks such as debris removal, EOC staffing, and signs and signals because internal miscommunication resulted in the field force lacking a clearly defined role. (NC DOT report, 2000)

DS34. Excessive Workloads-- In the months following Hurricane Floyd, the responsibilities of the field units increased to include not only routine tasks and recovery efforts, but special reporting as well. Various duties performed by the field units were subsequently delayed in the long term because of their excessive workload. (NC DOT report, 2000)

DS35. Structure Repairs-- The repairs of structures were delayed because the loss control unit did not effectively communicate needs to the structure units. (NC DOT report, 2000)

DS36. Insufficient Traffic Management-- Evacuation was delayed from insufficient traffic management resources, a lack of real-time road condition information, and a lack of communication among surrounding states regarding traffic information. In particular, lane closures for work zones were reopened later than planned due to miscommunication. (NC DOT report, 2000)

DS37. Fuel Confusion-- A lack of communication resulted in field units refueling their vehicles only when their tanks approached empty. They were not informed that they were authorized to refuel at any time, regardless of the amount in their tank. This could have caused unnecessary setbacks due to vehicles running out of fuel. (NC DOT report, 2000)

DS38. Conference Calls-- Communication among administration units and officials was delayed due to conference call participants waiting on each other to assemble for the call. (NC DOT report, 2000)

DS39. Email Communication-- Communication among units was delayed when using email. (NC DOT report, 2000)

DS40. Unconfirmed Equipment-- Equipment units experienced unnecessary setbacks because they filled equipment requests from other state agencies that were not verified first, causing supplies to be sent that were not needed. (NC DOT report, 2000)

DS41. Road Closure Reports-- Road repairs by field units were delayed because they were spending too much time reporting road closures. (NC DOT report, 2000)

DS42. Restricted Access-- Personnel delays occurred because the DOT emergency staff's ID badges only gave them access to NC DOT facilities during limited hours. (NC DOT report, 2000)

DS43. Inconsistent Barricades-- Field units had to wait on the equipment unit for reinforcement barricades because suppliers sent barricade parts that were not standardized. (NC DOT report, 2000)

DS44. Refueling-- Poor road conditions forced field units to wait for fuel. The field units could be delayed further in the future if fuel resources are too low. (NC DOT report, 2000)

DS45. Restricted Communication-- The central office experienced delays obtaining various information from field units because communication lines were frequently all tied up. (NC DOT report, 2000)

DS46. HazMat Information-- NC DOT's administrative officials waited on commercial entities to provide accurate locations of hazardous materials within the proximity of areas needing repair. Field units were subsequently delayed waiting for authorization on these locations. (NC DOT report, 2000)

DS47. Disposal Sites-- Because landfills and disposal sites had limited access and hours of operation, field units experienced delays with debris removal. (NC DOT report, 2000)

DS48. Processing Reimbursements-- The finance unit experienced delays for reimbursement even before submission to FEMA due to the extensive manual work involved with compiling the necessary documents. (NC DOT report, 2000)

Analysis of Scenarios According to Organizational Functions Involved

Table 5.2 depicts the percentage of descriptive scenarios with respect to each type of organizational function involved within a state DOT.

Table 5.2 Percentage of descriptive scenarios in sample associated with each organizational function

Organizational Function Type	Number of Cases	Percent of Total
Administration	3	6.2
Environmental, Regulatory Affairs	2	4.2
Equipment	4	8.3
Finance	2	4.2
Information Management	15	31.3
Legal / Authorization	2	4.2
Materials	2	4.2
Operations	11	22.9
Personnel	3	6.2
Structure	4	8.3
Total	48	100

Table 5.2 highlights those functions that are associated with a minimal number of scenarios (*Environmental and Regulatory Affairs*, *Finance*, *Legal/Authorization*, *Materials*), and those involved with a significant number of them like *Operations* and *Information Management*, which together account for over half of the total number of descriptive scenarios. It is important to note that the calculations only reflect a small collected sample of schedule dependencies incurred during the phases before and after a natural disaster.

The numbers of descriptive scenarios for each organizational function in the state DOT are graphically represented in Figure 5.1.

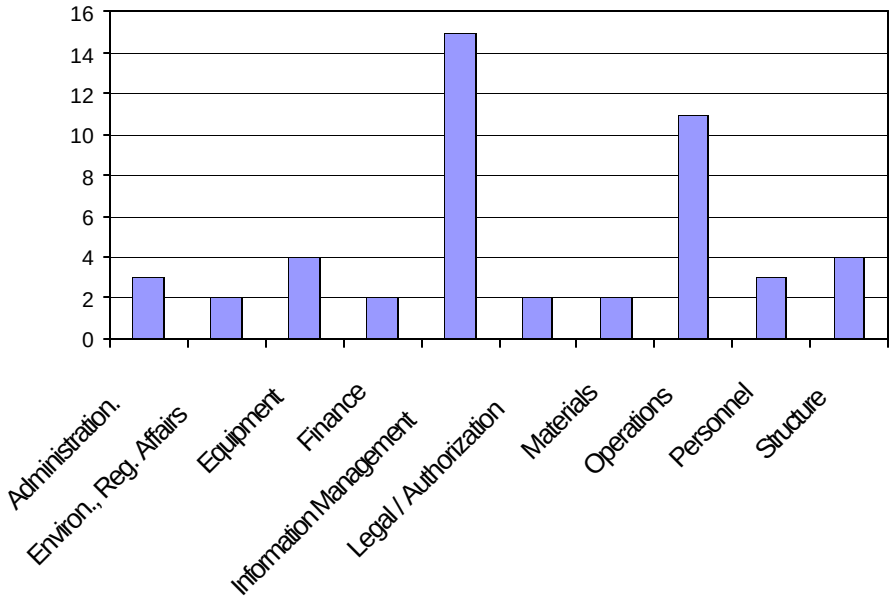


Figure 5.1 Number of scenarios in sample associated with each organizational function in a state DOT

This categorization of descriptive scenarios in terms of the involved organizational functions is replicated in Table 5.3 and Figure 5.2 using only scenarios collected from Virginia agencies, as opposed to multi-state data. It can be observed that, corresponding to what was found with the data inclusive of all the states, VDOT in itself incurred a significant number of *Information Management* related dependencies.

Table 5.3 Percentage of descriptive scenarios in sample associated with each organizational function in a state DOT

Organizational Function Type	Number of Cases	Percent of Total
Administration	0	0.0
Environmental, Regulatory Affairs	0	0.0
Equipment	1	10.0
Finance	0	0.0
Information Management	5	50.0
Legal / Authorization	0	0.0
Materials	1	10.0
Operations	0	0.0
Personnel	1	10.0
Structure	2	20.0
Total	10	100

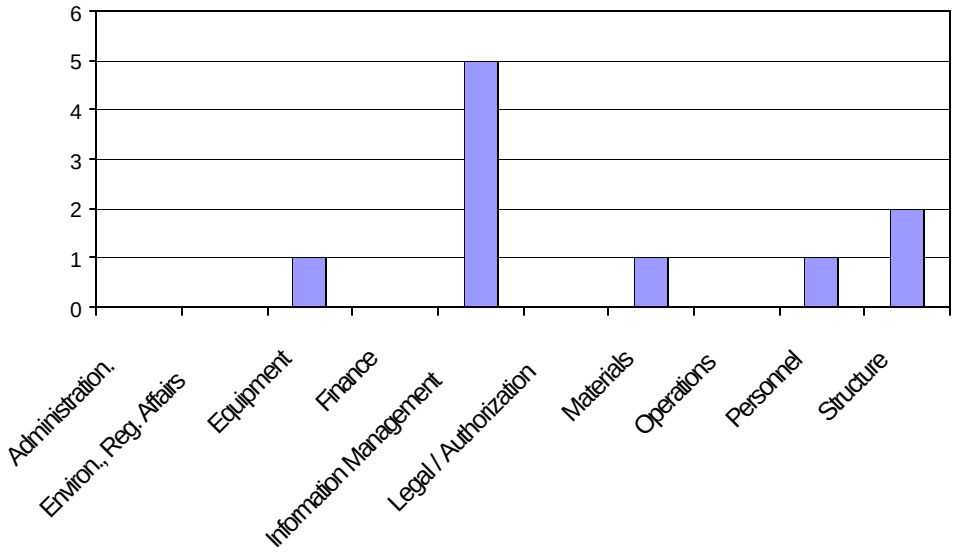


Figure 5.2 Number of descriptive scenarios in sample associated with each organizational function in a state DOT

Figure 5.3 is a graph depicting the number of inter-agency descriptive scenarios (inclusive of all states) associated with each type of involved agency.

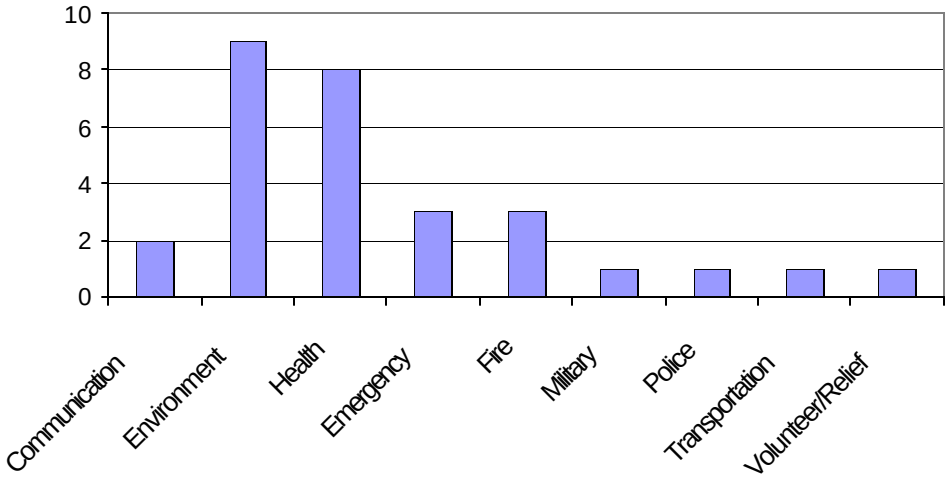


Figure 5.3 Number of descriptive scenarios in sample for each type of involved agency

Table 5.6 on the following two pages is a spreadsheet containing each descriptive scenario, and the primary organizational function of the state DOT that was involved as illustrated above, along with a secondary function associated with the scenario. A scenario of delay can often be a result of the interaction between the primary and secondary functions. A similar analysis was performed in terms of the pairs of functions involved in each scenario. There are 45 total pairs of functions.

Table 5.5(b) displays the number of descriptive scenarios respective to each pair of functions involved, and Table 5.5(a) is a key explaining how the pairs are recorded. For example, if *Administration* and *Environmental and Regulatory Affairs* were both concerned in a scenario, an entry would be placed in the first row, second column. All empty entries represent zero scenarios.

Table 5.5a Key for denoting pairs of state DOT functions involved in scenarios

	Admin.	Environ., Reg. Aff.	Equipment	Finance	Inform. Manage.	Legal/ Authoriz.	Materials	Operations	Personnel	Structure
Admin.		Ad-Env	Ad-Eq	Ad-Fin	Ad-Info	Ad-Leg	Ad-Mat	Ad-Op	Ad-Per	Ad-Str
Env., Reg. Aff.			Env-Eq	Env-Fin	Env-Infc	Env-Leg	Env-Mat	Env-Op	Env-Per	Env-Str
Equipment				Eq-Fin	Eq-Info	Eq-Leg	Eq-Mat	Eq-Op	Eq-Per	Eq-Str
Finance					Fin-Info	Fin-Leg	Fin-Mat	Fin-Op	Fin-Per	Fin-Str
Infor. Manage.						Info-Leg	Info-Mat	Info-Op	Info-Per	Info-Str
Legal/ Auth.							Leg-Mat	Leg-Op	Leg-Per	Leg-Str
Materials								Mat-Op	Mat-Per	Mat-Str
Operations									Op-Per	Op-Str
Personnel										Per-Str
Structure										

Table 5.5b Number of descriptive scenarios in sample associated with each pair of organizational functions in a state DOT

	Admin.	Environ., Reg. Aff.	Equipment	Finance	Inform. Manage.	Legal/ Authoriz.	Materials	Operations	Personnel	Structure
Admin.				2	2			1	2	
Env., Reg. Aff.			2		3	1		3	2	
Equipment					3	1				
Finance										
Infor. Manage.						1	2	11		
Legal/ Auth.								1		
Materials								1		
Operations									1	9
Personnel										
Structure										

Table 5.6 Categorization of collected descriptive scenarios according to the associated *pair* of organizational functions involved within VA, CA, SC, and NC state DOTs. Each row represents a different descriptive scenario. A letter 'P' indicates the primary function involved while a letter 'S indicates the secondary function.

Descriptive Scenario #	Descriptive Scenario Name	State	Agency Name	Agency Type	Level of Agency	Pre/Post Disaster	Time Horizon	Administration	Environ., Regulatory Affairs	Equipment	Finance	Information Management	Legal / Authorization	Materials	Operations	Personnel	Structure and Bridge
DS1	Sandbag Requests	VA	Henrico Co. Div. Of Fire	Fire	Local	Post	ST				S		P				
DS2	Barricade Requests	VA	Henrico Co. Div. Of Fire	Fire	Local	Post	ST			P	S						
DS3	On-call Personnel	VA	Henrico Co. Div. Of Fire	Fire	Local	Post	ST	S								P	
DS4	Updated Road Status Info.	VA	Obici Hospital	Health	Local	Post	ST				P			S			
DS5	Inaccurate Road Information	VA	Obici Hospital	Health	Local	Post	ST				P			S			
DS6	Bridge Failure	VA	Office of Emerg. Med. Serv	Health	State	Post	MT							S			P
DS7	Available Road Status Info.	VA	Office of Emerg. Med. Serv	Health	State	Post	ST				P			S			
DS8	Inaccurate Road Information	VA	Office of Emerg. Med. Serv	Health	State	Post	ST				P			S			
DS9	Road Access	VA	Dept. of Conserv. and Rec.	Envir.	State	Post	MT							S			P
DS10	Geological Information	VA	Dept. of Mines,Min.,Energy	Envir.	State	Post	LT				P		S				
DS11	Road Access	CA	Dept. of Health Services	Health	State	Post	ST							P			S
DS12	Long Term Road Access	CA	Hall Ambulances	Health	Local	Post	LT							S			P
DS13	Road Access & Authorization	CA	Glen.-Cres.Vall. Redcross	Health	Local	Post	ST					S		P			
DS14	Convoy Use	CA	CA National Guard	Military	State	Post	ST							P			S
DS15	Road Repairs	CA	Roseville Transit	Trans.	Local	Post	LT							S			P
DS16	Road Access and Information	CA	Dept. of Water Resources	Envir.	State	Post	ST				S			P			
DS17	Transmitter Sites	SC	SCANA Communications	Comm.	State	Post	ST							P			S
DS18	Crawler Tractor Use	NC	Div. Of Forest Resources	Envir.	Region.	Post	ST			S		P					
DS19	Road, Bridge, and Flood Info.	NC	Amat. Radio Emerg. Serv.	Comm.	Region.	Post	ST				P			S			
DS20	Obtaining Environ. Permits	NC	Div. Of Coastal Manage.	Envir.	State	Post	LT		S			P					
DS21	Sandbag Debris	NC	Div. Of Coastal Manage.	Envir.	State	Post	LT		S					P			
DS22	Coastal Inlet Stabilization	NC	Div. Of Coastal Manage.	Envir.	State	Post	MT		P					S			
DS23	Environmental Violations	NC	Div. Of Coastal Manage.	Envir.	State	Post	MT		S		P						
DS24	Resource Depletion	NC	Franklin Co. Emerg. Manag	Emerg.	Local	Post	ST	S								P	
DS25	Deadstock Removal	NC	NC Extension Service	Volun.	State	Post	MT							P			S

Table 5.6, continued. Categorization of collected descriptive scenarios according to the associated *pair* of organizational functions involved within VA, CA, SC, and NC state DOTs. Each row represents a different descriptive scenario. A letter 'P' indicates the primary function involved while a letter 'S' indicates the secondary function.

Descriptive Scenario #	Descriptive Scenaio Name	State	Agency Name	Agency Type	Level of Agency	Pre/Post Disaster Time Horizon	Administration	Environ., Regulatory Affairs	Equipment	Finance	Information Management	Legal / Authorization	Materials	Operations	Personnel	Structure and Bridge
DS26	Detour Information	NC	Local Emergency Services	Emerg.	State	Post ST					P			S		
DS27	Chainsaw Crews	NC	Dept. of Natural Resources	Envir.	State	Post ST					S			P		
DS28	Conflicting Road Information	NC	NC State Highway Patrol	Police	State	Post ST					P			S		
DS29	Fund Reimbursements	NC	FEMA	Emerg.	State	Post LT	S			P						
DS30	Ineffective Equipment	NC	NC DOT	Trans.	State	Post ST		S	P							
DS31	Relocated Personnel	NC	NC DOT	Trans.	State	Post ST		S							P	
DS32	Equipment Distribution	NC	NC DOT	Trans.	State	Post ST			P		S					
DS33	Undefined Roles	NC	NC DOT	Trans.	State	Post ST	P				S					
DS34	Excessive Workloads	NC	NC DOT	Trans.	State	Post LT	P							S		
DS35	Structure Repairs	NC	NC DOT	Trans.	State	Post MT								P		S
DS36	Insufficient Traffic Manage.	NC	NC DOT	Trans.	State	Post ST					P			S		
DS37	Fuel Confusion	NC	NC DOT	Trans.	State	Post ST					P			S		
DS38	Conference Calls	NC	NC DOT	Trans.	State	Post MT	P				S					
DS39	Email Communication	NC	NC DOT	Trans.	State	Post MT		S			P					
DS40	Unconfirmed Equipment	NC	NC DOT	Trans.	State	Post ST			S		P					
DS41	Road Closure Reports	NC	NC DOT	Trans.	State	Post ST								P	S	
DS42	Restricted Access	NC	NC DOT	Trans.	State	Post ST		P							S	
DS43	Inconsistent Barricades	NC	NC DOT	Trans.	State	Post ST		S	P							
DS44	Refueling	NC	NC DOT	Trans.	State	Post ST							P	S		
DS45	Restricted Communication	NC	NC DOT	Trans.	State	Post ST		S			P					
DS46	HazMat Information	NC	NC DOT	Trans.	State	Post ST					P	S				
DS47	Disposal Sites	NC	NC DOT	Trans.	State	Post MT		S						P		
DS48	Processing Reimbursements	NC	NC DOT	Trans.	State	Post LT	S			P						

As in Tables 5.2 and 5.3, Table 5.7 displays the percentage of descriptive scenarios for the pairs of functions involved within a state DOT (inclusive to all states). The pairs of functions that had no scenarios associated with them are not included in the table. The table identifies those pairs of functions that are associated with a significant amount of scenarios. Again, it is important to note that these calculations only reflect the scenarios of the sample collected.

Table 5.7 Percentage of descriptive scenarios in sample associated with each pair of organizational functions in a state DOT

Pairs of Organizational Functions	Number of Cases	Percent of Total
Information Management - Operations	11.0	22.9
Operations - Structure	9.0	18.8
Environmental, Regulatory Affairs - Information Management	3.0	1.4
Environmental, Regulatory Affairs - Operations	3.0	6.3
Equipment - Information Management	3.0	6.3
Information Management - Materials	2.0	4.2
Administration - Personnel	2.0	4.2
Environmental, Regulatory Affairs - Equipment	2.0	4.2
Environmetnal, Regulatory Affairs - Personnel	2.0	4.2
Administration - Information Management	2.0	4.2
Administration - Finance	2.0	4.2
Administration - Operations	1.0	2.1
Environmental, Regulatory Affairs - Legal / Authorization	1.0	2.1
Equipment - Legal / Authorization	1.0	2.1
Information Management - Legal / Authorizatoin	1.0	2.1
Legal / Authorization - Operations	1.0	2.1
Materials - Operations	1.0	2.1
Operations - Personnel	1.0	2.1
Total	48	100

The numbers of scenarios of the pairs listed in Table 5.7 are graphically represented below.

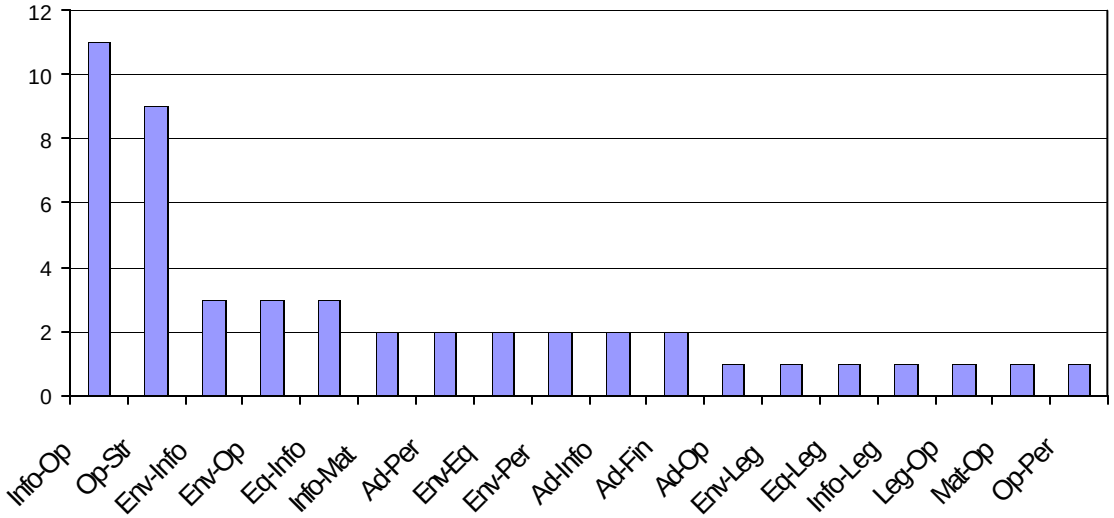
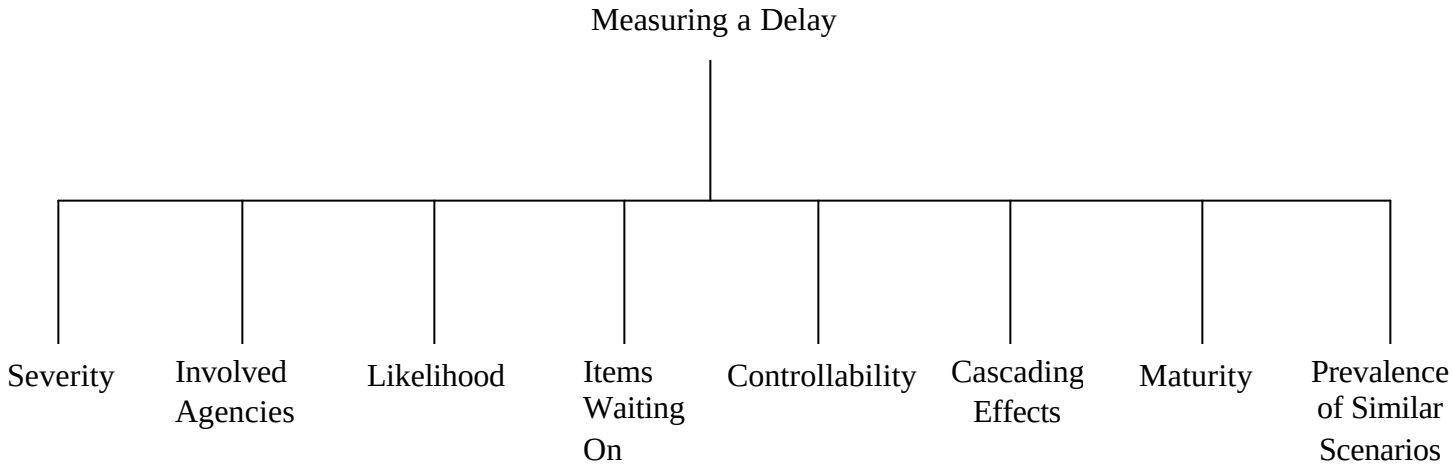


Figure 5.5 Number of descriptive scenarios in sample associated with each pair of organizational functions within a state DOT

Out of the forty-five total pairs of organizational functions, only eighteen pairs are associated with at least one descriptive scenario. The remaining twenty-seven pairs, which are not displayed in Figure 5.5 or Table 5.7, are not involved with any of the descriptive scenarios collected.

Table 5.7 and Figure 5.5 highlight those pairs of organizational functions within a state DOT that are associated with a significant number of scenarios. According to the sample of descriptive scenarios collected, the interaction of *Information Management* and *Operations* and the interaction of *Operations* and *Structure and Bridge* both are involved in a large number of scenarios. Combined, these two pairs of functions account for over forty percent of the total number of scenarios. The pairs of organizational functions associated with only few of the descriptive scenarios in the sample are displayed on the right side of the Figure 5.5.

Indices for Measuring a Delay



Scenarios are measured using eight indices that express the "size" of the delay according to three-level scale: LOW, MODERATE, and HIGH. These indices and their definitions are:

1. **Severity:** The length of time of the delay relative to the time horizons:
   Short Term (hours, days),
   Medium Term (days, weeks),
   Long Term (months, years).

Severity is represented according to the three-level scale as follows:

Table 5.8 A measure of severity using time horizon in order to measure the magnitude of a delay

	Horizon		
Length of Time of Delay	Short Term	Medium Term	Long Term
Hours	Moderate	Low	Low
Days	High	Moderate	Low
Weeks	High	High	Moderate
Months	High	High	High
Years	High	High	High

2. **Involved Agencies**: The number of agencies affected by the delay. The agencies involved are measured according to:

- A value of LOW indicates an intra-agency delay within VDOT and that no other agencies were involved.
- A value of MODERATE indicates that a few other agencies were involved.
- A value of HIGH indicates that multiple other agencies were involved.

3. **Likelihood:** The potential or odds that the delay will happen in the future based on its history of occurring in the past. Likelihood is measured according to:

- A value of LOW indicates that the delay is unlikely to occur.
- A value of MODERATE indicates that it is has not occurred in the past, yet it is likely to occur in the future nonetheless.
- A value of HIGH indicates that it has occurred in the past, and is likely to occur again.

4. **Items Waited On:** An agency could be waiting on personnel, materials, equipment, authorization, etc. The items being waited on are measured according to:

- A value of LOW indicates no items were waited on.
- A value of MODERATE indicates one item was waited on.
- A value of HIGH indicates there was a combination of many items being waited on.

5. **Controllability:** The ability to control the cause(s) or components of the delay. Controllability is measured according to:

- A value of LOW indicates that a resolution is being developed for the future at a low cost.
- A value of MODERATE indicates that alternatives are being considered for the future, but a resolution would have a high cost.
- A value of HIGH indicates that nothing can be done to avoid this delay in the future.

6. **Cascading Effects:** The extent to which the delay serves as input to more delays and/or problems. The scope of the succession of subsequent delays and/or problems that arise from the delay.

7. **Maturity:** The level of preparation and development associated with the procedures or activities involved. For example, the level of training performed and instruction received by the workforce involved, or the extent of which the procedures involved have been practiced.

8. Prevalence of Similar Scenarios: This accounts for whether the scenario is an isolated instance, or if it occurs in numerous situations.

Table 5.9 Summary of index definitions for measuring the magnitude of a delay according to a three-level scale

Indices	Low	Moderate	High
Severity	Low	Moderate	High
Involved Agencies	No other agencies	Few agencies	Multiple agencies
Likelihood	Unlikely to Occur	Has not occurred in the past, but likely to occur	Has occurred in the past, likely to occur again
Items Waiting on (personnel, materials, equipment, authorization)	None	One Item	Combination of many
Controllability	Controllable at Low cost	Controllable at High Cost	Uncontrollable
Cascading Effects	None	One	Multiple
Maturity	Mature	Immature	Highly Immature
Number of Similar Scenarios	None	Few	Many

Demonstration of Indices: Measuring a Delay

The following is a scenario that is measured with the eight indices:

Following Hurricane Floyd, The Virginia Office of Emergency Medical Services had to wait on VDOT for the availability to current, updated road status information. (C. Everette Vaughan, Jr., Director of Emergency Operations at the Office of Emergency Medical Services, Oct. 9, 2000)

It was assumed that this type of delay is likely to happen again in the future because VDOT's existing system is not capable of displaying real-time road conditions on a very recurrent basis. The system is currently updated with new information every four hours (Toth, 2000). In addition, on site personnel do not have the ability to automatically input information themselves from the field. It was assumed that a system with these features could be available at a relatively low cost.

Table 5.10 Values of each index for the scenario measured

Severity	Involved Agencies	Likelihood	Items Waiting On	Controllability	Cascading Effects	Maturity	Number of Same Scenarios
Hours in Short Term	Few other agencies	Has occurred in the past, likely to occur again	Information Only	Controllable at Low Cost	Multiple	Mature	Many
Moderate	Moderate	High	Moderate	Low	High	Low	High

This delay can be better understood using graphical representation:

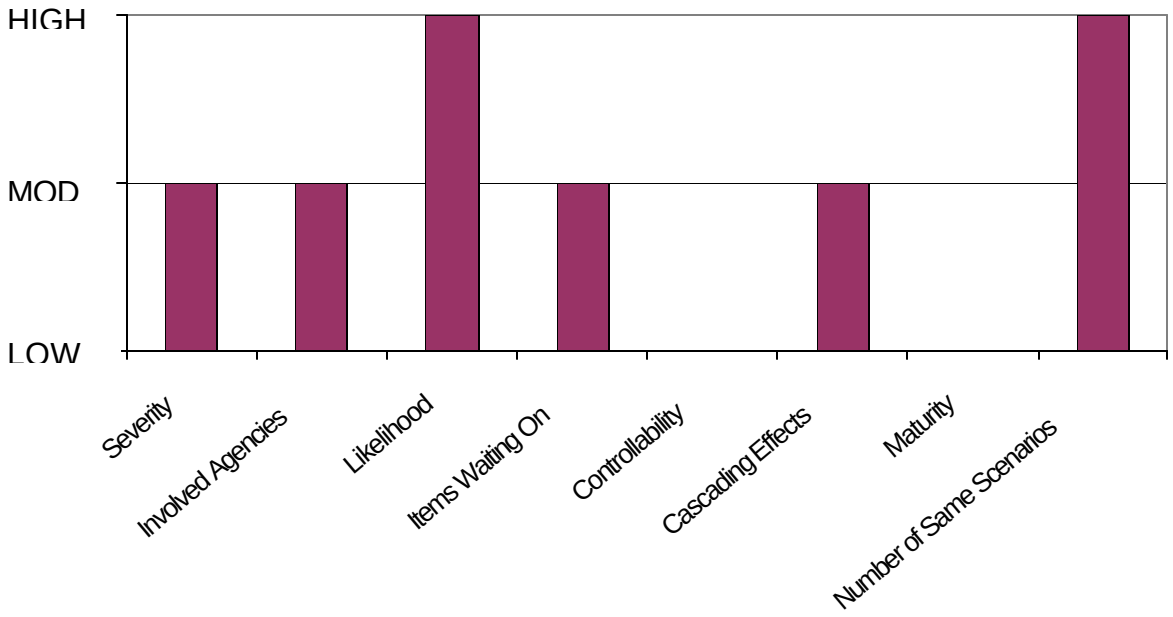
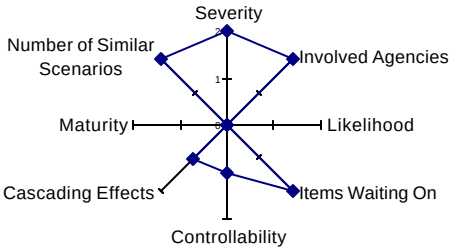


Figure 5.6 Representation of the descriptive scenario according to the values measured for each index

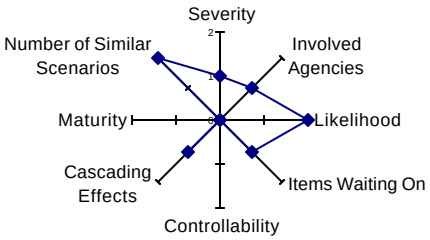
Comparing Delays

The graphical representation also provides a medium for comparing the magnitudes of multiple scenarios. The graphs in Figure 5.7 assume the same axes (the eight indices versus the three levels of LOW, MODERATE, and HIGH) as in Figure 5.6.

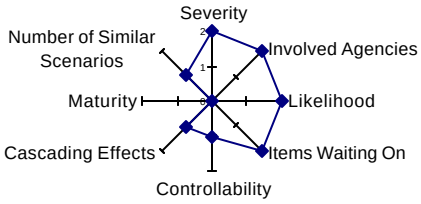
Descriptive Scenario #6
Bridge Failure



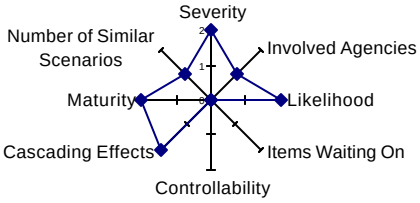
Descriptive Scenario #7
Available Road Status Information



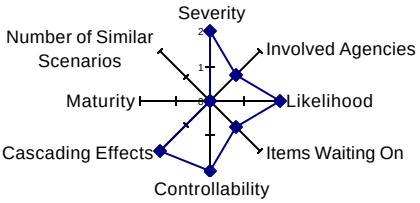
Descriptive Scenario #12
Long Term Road Access



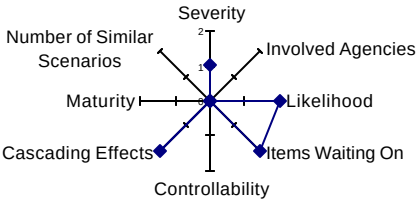
Descriptive Scenario #23
Environmental Violations



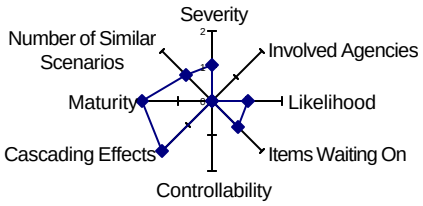
Descriptive Scenario #29
Fund Reimbursements



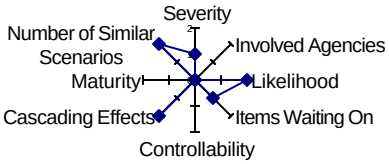
Descriptive Scenario #36
Insufficient Traffic Management



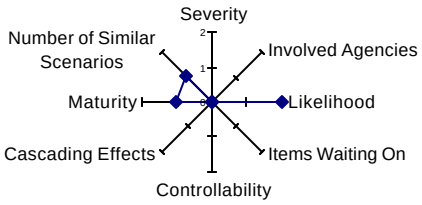
Descriptive Scenario #42
Restricted Access



Descriptive Scenario #43
Inconsistent Barricades



Descriptive Scenario #47
Disposal Sites



Descriptive Scenario #48
Processing Reimbursements

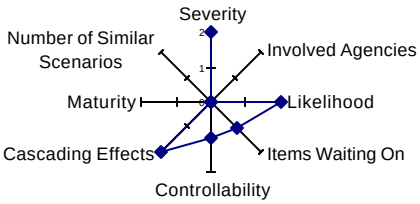


Figure 5.7 Comparison of descriptive scenarios collected using the eight indices developed

The graphs illustrate the differences between scenarios. For instance, the bottom left graph represents a scenario that has low severity, no other agencies involved, has occurred in the past and is likely to occur again, involves no items being waited on, is controllable at a low cost, has no cascading effects, is immature, and has a few other similar scenarios. The bottom right graph, however, represents a scenario that has high severity, no other agencies involved, has occurred in the past and is likely to occur again, involves one item being waited on, is controllable at a high cost, has a multiple cascading effects, is mature, and is not similar to any other scenarios, it is an isolated instance of a delay. Clearly these two scenarios are very different, and therefore should be regarded and resolved differently.

Conclusion

Many of the recommendations discussed in the following two sections originated from NC DOT's report *Hurricane Floyd Lessons Learned*.

Information

Enhancing VOIS System to Increase the Sharing of Information

Many of the interviewed agencies maintained that they have waited on their state DOT for current and accurate road condition information. The responses from the Virginia agencies are consistent with this discovery; nearly half of the Virginia agencies spoken to could not obtain updated status on roads during Hurricane Floyd. Other information that was not available to agencies includes the locations of hazardous materials to guarantee the safety of field forces, the current locations of floodplains, and the requirements for environmental permits and the actions constituting environmental violations.

Ensuring the availability of all pertinent information to involved agencies could prevent these delays in the future, and could be accomplished by enhancing VDOT's current system, VOIS. Although VOIS has improved communication among stakeholders, clearly there are still numerous potential inter and intra agency schedule dependencies that could be prevented through an expanded system that encourages a higher level of shared information among local and state agencies. Suggestions for this expanded system are included in the next section, *Recommendations*.

Communication

Common Radio System

Without a common statewide radio system for communication between the DOT, State Highway Patrol, Emergency Management, Emergency Medical Services, and any other relevant agencies, all operations risk being inefficient, and in turn become the cause of delays, which subsequently increase the overall time to recovery following the natural disaster. A universal radio system with the required frequencies set in the pre-disaster phase supports an effective evacuation and curtails the time wasted locating necessary radio equipment for responding to emergency personnel, which was a delay suffered by NC DOT (NC DOT Report, 2000). In addition, because a common system serves as another source of real-time information, it provides a secure means of backup for the expanded information system discussed above.

Intra-Agency Communication

The results of the research and analysis indicate a need for increased communication specifically between the structure and bridge units and loss control units in terms of necessary repairs and road and bridge status, and between the field units and central offices concerning road conditions. By providing truck-to-truck communication possibly via cellular phones and by purchasing additional phone lines for the central office, designating them as secure lines for

emergency use (the phone numbers should only be known by DOT personnel), the potential for such delays in the future could be decreased (NC DOT Report, 2000).

Equipment and Materials

Standardization

Often during hurricane recovery, personnel from unaffected regions relocate to provide assistance to areas in need. In addition, spare equipment is often shipped to the areas in need from other regions. To be of use, it is important for all relevant DOT employees to be able to operate all equipment that could be required to accomplish the necessary recovery activities regardless of its source. This problem arose during NC DOT's recovery following Hurricane Floyd. NC DOT's recovery activities were delayed because various equipment was not operable by transferred personnel who lacked the necessary training (NC DOT Report, 2000). In order to prevent this setback in the future, equipment likely to be used during the post-disaster process should be standardized across the state, and relevant personnel should receive the appropriate training required for use.

Also needing standardization is the labeling format on requests for equipment. During Floyd, equipment that various NC DOT personnel asked for ended up in the wrong units because their labels were unclear (NC DOT Report, 2000). Many requests were unnecessarily filled twice. To ensure requests are not duplicated in the future, the general equipment process should be reviewed. It is important to maintain one statewide format for the equipment labels, and to educate personnel on how to read and process them.

Packaging

In order to optimize the deployment of equipment and materials that are frequently shipped around the state during recovery, it is necessary to ensure their packaging is appropriate and allows for easy transport. A way to potentially speed the time to recovery is to pre-package those resources likely to be needed in post-disaster procedures, which can be determined by reviewing past equipment request orders (NC DOT Report, 2000).

Personnel and Operations

Partnering Residencies

Personnel coming to help from regions that escaped the natural disaster may be unfamiliar with certain procedures and information that are specific to the residencies in need. Delays can arise while the relocated workers learn how to follow and become acquainted with these new processes and methods. Though personnel from across the state need not know all information about the area they are assisting such as the local topography, it is necessary for them to be trained and competent with the equipment, materials, and internal operations employed by the units involved (NC DOT Report, 2000). Assigning "partner residencies" could effectively resolve this issue. If the same personnel aid the same designated residency every time they are

needed when a natural disaster hits, the relearning of information and the re-training of procedures are limited.

Field Unit and EOC Coordination for Prioritizing Tasks

The interaction of the field units and the emergency operations center should be examined to develop a systematic way of delegating and prioritizing recovery activities. Currently, VDOT's EOC assigns tasks to their field forces according to the precedence of human life and safety over property and property over the environment (Toth, 2000). This approach lacks efficiency in that there is no further task classification to follow to determine order of completion within these three general priorities of (1) Human life, (2) Property, (3) Environment. For instance, if multiple calls come into the EOC requiring field response and they all have potential to harm the environment in relatively the same capacity, how should the EOC decide which task to send field units to first? NC DOT experienced related problems during their recovery from Floyd, particularly with their prioritization of resources. Their prioritization became ineffective as the flow of information from the EOC passed through so many levels of field command unit (NC DOT Report, 2000).

Following a natural disaster, the responsibilities of the field units become overwhelming. Their workload includes reporting road conditions, completing recovery activities such as repairing roads, and performing routine tasks (NC DOT Report, 2000). The field units' duties should be clearly defined and possibly even prioritized or organized into a schedule for pre and post disaster phases. The central office should ensure the feasibility of field personnel's workloads and consider temporarily transferring personnel from other units to share the duties if necessary.

Recommendations

Many of the recommendations discussed in the following section originated from NC DOT's report *Hurricane Floyd Lessons Learned*.

The recommendations are divided into sections:

1. Information/Technology
2. Communication
3. Evacuation
4. Equipment & Materials
5. Personnel & Operations

1. Information/Technology

- ?? Expand and enhance existing VOIS information system in order to increase the sharing of information among agencies
  - o Consider installing more powerful web servers and increasing Internet access speed in order to handle more users
  - o Provide a query tool allowing users to search information by route or county
  - o Ensure that VOIS is available to all pertinent local and state agencies without sacrificing security
  - o Install VOIS input devices such as automated phone-in equipment in field vehicles to allow a direct flow of information
  - o Create a tool within VOIS for prioritizing equipment requests and tasks based on input from field personnel regarding their urgency
  - o Prevent conflicting information regarding the same incident by establishing a chain of command that respects the authority level and type of agency providing the information and only allows access to the most pertinent agency's report
  - o Continually update road condition information to ensure real-time road condition information for agencies and public is really "real-time"
  - o Consider including reimbursement forms in system to allow for continuous filling out and processing, which could shorten the wait for repayment
- ?? Improve the speed and efficiency of accounting and processing of federal reimbursement documents through automation

2. Communication

- ?? Prevent conflicting road closure information from SHP by developing explicit universal guidelines for use in determining a road's status.
  - o Guidelines could differ authorization for road use between the general public and emergency personnel
- ?? Consider implementing video conferencing
  - o Pre-set a schedule of times for conference calls for use following the disaster
- ?? Avoid state field units acting independently of local authority

3. Evacuation

- ?? Improve evacuation planning including traffic management and operations procedures
- ?? Increase regional evacuation planning and coordination among surrounding states
- ?? Consider implementing a lane reversal plan for each evacuation route
    - o Weigh the costs and benefits associated with the plan in terms of the additional personnel and equipment required and the actual clearance time saved
    - o Develop procedures that include an event timeline outlining the circumstance and time when the plan should be invoked
    - o Evaluate the plan with a pseudo-evacuation
    - o Make the necessary roadway adjustments in the pre-disaster stage that support the plan

4. Equipment and Materials

- ?? Evaluate current equipment to ensure its effectiveness in flood conditions
- ?? Verify equipment requests before filling them
- ?? Ensure adequate levels of fuel are available
    - o Consider increasing the capacity at field centers or purchasing a fuel tanker
- ?? Increase traffic control resources in order to improve traffic management

5. Personnel and Operations

- ?? Frequently review and/or revise policies and procedures for emergency road repair and debris removal
- ?? Provide all appropriate personnel with badges allowing 24 hour access to DOT facilities
- ?? Assign debris disposal sites in the pre-disaster stage and verify them with local government
- ?? Assign DOT personnel assisting from unaffected regions with a particular residency during the pre-disaster stage, and employ the same assignments in the future
    - o Ensure assisting DOT personnel are competent and practiced with their partner residency's internal processes, operations, equipment, and materials

Areas of Further Study

Recommended areas of further study of schedule dependencies include:

- ✍ Perform a more extensive delay scenario collection for analysis that is more representative of the agencies involved in recovery.
- ✍ Analyze delay scenarios using PERT, an activity network modeling tool, to identify ways of reducing the delays in the future
- ✍ Perform a cost-benefit tradeoff analysis on the alternatives identified from the PERT models.