"ONE-WAY-OUT": CONTRAFLOW FREEWAY OPERATION FOR HURRICANE EVACUATION

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ABSTRACT: Over the past 20 years the coastal population of the southeastern United States that is vulnerable to hurricanes has increased significantly. Much of the recent planning and construction of infrastructure in these regions has taken place during a two-decade lull in hurricane activity. It is now apparent that these areas are not all suitably equipped to deal with the threat of severe hurricanes. As a result, a significant percentage of the coastal population is forced to evacuate under the threat of major hurricanes. This has been demonstrated recently during Hurricane Floyd in 1999 and during Hurricane Georges in 1998. One method suggested to meet the need to evacuate large numbers of people in a rapid and efficient manner is to contraflow segments of interstate freeway. Under contraflow operation, some or all inbound lanes of a freeway are used for outbound evacuation. While the concept is simple, implementation is complex. This paper discusses the advantages and disadvantages of contraflow operation on freeways during hurricane evacuations, including the capacity benefits, critical planning, design, and operational issues, and current contraflow operation plans from threatened states. The paper also provides a list of recommendations and needs that should be considered in the planning and implementation of contraflow evacuations.

INTRODUCTION

The United States is at an increasing risk from hurricanes. Recent population growth patterns in the United States have tended to concentrate people in at-risk coastal areas. Forty-five million Americans live in the coastal counties from Texas to Maine (Jarrell et al. 1992). These coastal counties also have the highest population growth rates in the United States (FEMA 1997). The increased development and urbanization of the coastal zone, together with long-term climactic trends, rising sea levels, and numerous other factors, have combined to expose growing numbers of people to hurricane threats in these areas of the country.

New Orleans is a prime example of such a location. Over 1 million people live in the New Orleans metropolitan area. Even in the best of circumstances, only about half of the population can or will evacuate. With most of the city below sea level, a major hurricane could flood vast portions of the city with 3–6 m (10–20 ft) of water, resulting in massive loss of life and property damage. While these people are generally at the highest risk, damaging winds and severe flooding can also threaten residents much farther inland as well (Levitan 2000).

Following the recent series of hurricanes that have struck the eastern seaboard and gulf coasts of the United States, there has been a call from the public and lawmakers for the widespread use of contraflow operations during hurricane evacuations. Contraflow operation, lane reversals, or ''one-way-out'' and as it is commonly called, involves the use of one or more lanes of inbound travel for traffic movement in the outbound direction. Contraflow is viewed as a potential remedy for the colossal traffic jams that were a part of the evacuation for Hurricane Floyd in the Carolinas and Georgia and for Hurricane Georges in Louisiana and Mississippi. It is also viewed by most states as a measure to be employed only in the event of major storm threats (Categories 4 and 5). Contraflow was used on Interstate 16 (I-16) out of Savannah Georgia and on I-26 out of Charleston, S.C., during Hurricane Floyd. While it did increase the capacity of outbound flow on these roadways, it also brought to light several issues ranging from minor inconveniences to potentially life-threatening situations.

Contraflow operation on roadways is not a new concept. Reverse lane operation has been used to effectively accommodate routine unbalanced flow for decades. Contraflow operation is common on bridges where one or more outbound lanes are used for inbound commuters during the morning rush hour and one or more inbound lanes are used for outbound traffic during the evening peak period. In Washington, D.C., the center two lanes of Connecticut Avenue are used in contraflow fashion to add capacity during morning and evening peak periods. Contraflow operation is also common at special events where all lanes are converted to accommodate outbound traffic at the end of the concert or football game.

These examples of contraflow operation significantly improve the outflow of traffic in the areas where they exist. They typically do not significantly degrade traffic safety, since they are usually well controlled and drivers are familiar with their location and operation. However, there are significant differences between contraflow operation on urban arterial roadways and that proposed for long sections of interstate freeways during hurricane evac-

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uations. Some of the key issues that arise during evacuation lane reversals are traffic control, access, merging, use of roadside facilities, safety, labor requirements, and cost. This paper reviews lessons learned from several recent contraflow evacuations and highlights the advantages and disadvantages of its use. This paper also summarizes the current and proposed plans for contraflow evacuation and provides a list of needs and recommended practices that have been developed from past experience.

CONTRAFLOW OPERATIONS FOR EVACUATION

Contraflow operation for hurricane evacuation can take on several different forms. In the past, states have varied the number of inbound lanes used for outbound evacuees using one or more of the inbound freeway lanes for outbound flow. In a single lane configuration, the adjacent lane of a four-lane freeway was maintained in the inbound direction for emergency and service vehicles. Some states have also used shoulder lanes for evacuation and service traffic. Fig. 1 schematically illustrates several contraflow operation configurations for four-lane freeway segments. This section discusses the various types of contraflow operation, the capacity benefits they provide, and examples of locations where they are used.

Contraflow Configurations and Flow Rates

Since it offers the largest increase in capacity, the most common contraflow strategy is to reverse both inbound lanes of the freeway to the outbound direction, shown in Fig. 1(d). These four-lane evacuations are referred to as one-way-out. Under this type of operation no inbound vehicles are permitted on the freeway, and they are prohibited from entering the contraflow lanes by barricades on all ramps. The major advantage to an all-lanes-out operation is the significant increase in outbound capacity. However, the closure of these ramps also eliminates egress from the contraflow lanes and prohibits vehicles in these lanes from using roadside facilities. While this minimizes confusion and keeps traffic moving, it also has inherent problems (discussed later).

The use of shoulders for the movement of outbound traffic can be accomplished in several different ways. In the South Caroline evacuation for Hurricane Floyd, the shoulder adjacent to one of the outbound lanes was used, shown in Fig. 1(c). Other agencies have suggested the use of the shoulder adjacent to the median contraflow lane. This configuration will allow the inner inbound lane to remain open for emergency vehicles. Other suggested configurations have proposed the use of both shoulders in the normal outbound direction.

Although shoulders can increase the capacity of evacuation routes, a high degree of care must be exercised because they are typically more narrow than the travel lanes, constructed with a thinner pavement cross section, and have a greater cross-slope. They also reduce the area available to accommodate vehicle breakdowns. An additional problem associated with using shoulders is that their widths can vary significantly along interstate segments, particularly on bridges.

During the 1999 Hurricane Floyd evacuation, the South Carolina Department of Transportation (SCDOT) analyzed traffic flow on segments of Interstate 26 under various contraflow configurations (FEMA 2000). The data showed that a single freeway lane operating under evacuation conditions had a flow rate of approximately 1,500 vehicles/h. This is in contrast to a typical urban freeway lane that would be expected to have a flow rate in excess of 2,000 vehicles/h during daily commute conditions. The decreased level of flow during evacuation is due a number of different factors, including the high traffic stream densities and the tendency of evacuees to heavily load vehi-

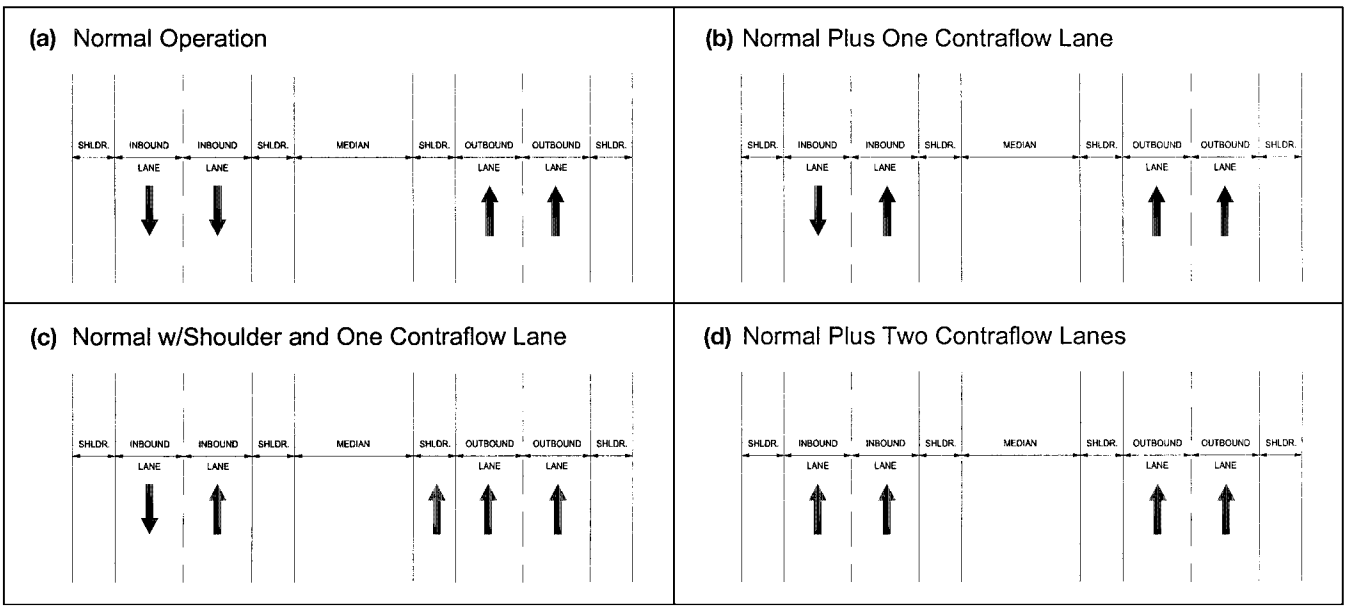

FIG. 1. Freeway Contraflow Lane Use Configurations for Evacuations

TABLE 1. Evacuation Traffic Flow Rates

Use configuration	Estimated average outbound flow rate (vehicles/h)
Normal (two-lanes outbound)	3,000
Normal plus one contraflow lane	3,900
Normal and shoulder plus one contraflow lane	4,200
Normal plus two contraflow lanes	5,000

Note: From FEMA (2000).

cles and pull trailers with valued personal possessions. In 1999 during Hurricane Floyd, the SCDOT measured flow rates for evacuation traffic under various reversed lane use configurations. These are shown in Table 1.

As seen in Table 1, the flow rates in the added lane(s) of outbound travel, whether a shoulder or lane of opposing traffic, are not as high as those measured in a normal outbound lane. The limited increases are due to several factors including driver unfamiliarity or uneasiness in driving on a shoulder or in a contraflow lane. The flow rate for two outbound lanes and a single contraflow lane (with traffic in the adjacent lane continuing to travel inbound) was estimated at 3,900 vehicles/h. This was an increase of approximately 30% over two normal outbound lanes, or an additional outflow of 900 vehicles/h. When the shoulder was used, the outflow increased by an additional 300 vehicles/h or a gain of 8% over single lane contraflow operation. Under full contraflow operation (e.g., one-way-out) the SCDOT recorded average flow rates of 5,000 vehicles/h. This was a two-thirds gain (67%) over a standard two-lane evacuation, or an additional 2,000 vehicles/h. These flow rates demonstrate that substantial gains can be made through the use of contraflow operations during evacuations. However, these gains must be contrasted with the substantial cost required to put it into action.

Design and Operational Plans

Under typical conditions, the design of a road is a function of demand. The nature of evacuations presumes that the traffic demand will greatly exceed the capacity provided by the highway. As a result, the design of contraflow segments is based on an attempt to provide the maximum outflow while maintaining acceptable levels of safety and efficiency. On a strategic level, the contraflow design will be affected by the existing transportation infrastructure, topographic geography, and shelter locations. Each design is unique in terms of its length, origin and termination points, merge configuration, and operation. The following are examples of contraflow designs and operational plans from Louisiana, Georgia, South Carolina, and North Carolina [North Carolina Department of Transportation (NCDOT) 2000].

In New Orleans, the contraflow plan was developed to provide maximum capacity over the bodies of water that surround the city. The length of New Orleans contraflow section is short compared to other locations, but it is efficient because there is no traffic merge point at its termination and unique because there are no entrance or exit ramps along its entire length. The geography of the city and layout of the freeway network allow this to occur.

Under the New Orleans plan, traffic evacuating the western metropolitan area will cross into the inbound lanes using a two-lane paved median crossover located prior to the I-10/I-310 interchange. Lightweight water-filled barriers are used to prohibit median crossings during nonevacuation periods. These will be removed by Louisiana DOT personnel at the initiation of the evacuation. The New Orleans traffic will contraflow over the south shore of Lake Pontchartrain. Evacuating traffic moving north on I-310 from parishes south of New Orleans will travel in the normal outbound lanes. Some 20 miles later, at I-10/I-55 interchange, all traffic moving in the normal outbound lanes will be forced to exit to northbound I-55. After the interchange, the contraflow New Orleans traffic will cross the median back into the normal outbound lanes.

While the contraflow segment does not carry vehicles for a long distance, it will facilitate rapid evacuation by dividing the westbound evacuation traffic stream, reducing both the volume and density on this primary evacuation route. Plans to contraflow I-10 out of the east side of New Orleans are currently under development. However, there are a number of factors that complicate plans for reverse flow operations on that side of the city (discussed later).

Contraflow plans in the Carolinas call for reverse lane operation for considerably longer distances. The NCDOT reversal plan proposes the closure of 18 interchanges to contraflow 92 miles of eastbound I-40 from Wilmington to I-95 (NCDOT 2000). Like the Louisiana plan, the NCDOT plan will not merge the contraflow lanes into the normal outbound lanes. Instead, all contraflow traffic will be forced to exit I-40, 6 mi prior to I-95. This traffic will then use a parallel state highway to reenter I-40 or connect to I-95. The contraflow plan used in South Carolina covers a distance about 115 mi on I-26 between Charleston and Columbia. Outside of Charleston, crossovers have been constructed into the I-26/I-526 interchange ramps. When opened, the ramp crossovers will permit vehicles to cross into the contraflow lanes. While the plans and construction are in place, none of these crossover facilities in the Carolinas or Louisiana have actually been used during an evacuation.

The Georgia Department of Transportation (GDOT) I-16 contraflow plan was put into operation during Hurricane Floyd. Contraflow operations originally extended approximately 65 miles from Savannah to U.S.-1 and egress from the contraflow lanes was not permitted. In the wake of the Hurricane Floyd experience, GDOT now plans to extend the I-16 contraflow operations 95 miles from Savannah to Dublin and include eight contraflow exit ramps. In contrast to the plans in Louisiana and the Carolinas, the Georgia contraflow plan will merge vehi-

cles from the contraflow lanes back into normal lanes at its terminus. It is anticipated that its length and numerous exit opportunities will reduce the traffic stream volumes and potential for significant queuing at the merge point. A temporary traffic signal to regulate the merging flows at the contraflow merge point has also been suggested, though not seriously considered.

Most other Atlantic and Gulf Coast states threatened by hurricanes also have contraflow plans in place. The most extensive is in the state of Florida where the DOT has developed seven contraflow routes for each segment of every interstate freeway in the state (State of Florida 2000). Both Maryland and Virginia also have contraflow plans in place. In Maryland, contraflow evacuation is planned for State Route 90 and U.S. Highway 50 out of the Ocean City area. In Virginia, eastbound I-64 will be reversed between the Norfolk/Virginia Beach area to Richmond during a major hurricane threat. In Texas, despite an enormous coastal population, only I-37 between Corpus Christi and San Antonio has been designated for contraflow evacuation. The Alabama DOT is also developing plans for the reversal of northbound I-65 out of Mobile.

The only southeastern coastal state without a contraflow plan is Mississippi. The relatively low and evenly distributed coastal population and the arrangement and number of coastal evacuation routes has led the Mississippi Department of Transportation (MDOT) to determine that contraflow is not warranted in that state. The MDOT position is also based on the large number of safety concerns and operational issues associated with contraflow operations.

PLANNING AND IMPLEMENTATION ISSUES

The drawbacks of contraflow evacuation operations can seem nearly equal to the advantages it affords. From a safety standpoint, contraflow operation of any kind on freeways can be risky. Freeways are designed for travel in one direction. Signs, pavement markings, and safety features will not necessarily be visible to drivers traveling in the opposite direction. Reverse flow can also be confusing for drivers not familiar with this type of operation. Additionally, recent experience has shown that contraflow is inconvenient at best and, typically, physically taxing on drivers who are not able to exit the freeway for fuel, food, and use of relief facilities.

Another factor to be considered in reverse lane evacuations is access for inbound service vehicles. Before a hurricane, access for public safety personnel must be maintained to protect the health and safety of evacuees and their property. After the event, utility and construction crews need to be able to quickly access affected areas to restore utilities and clear or reconstruct infrastructure systems. Contraflow operation, particularly one-way-out, virtually prohibits inbound access for any vehicles during the reversal. Finally, the cost to plan, design, construct, and operate a contraflow operation is also an important consideration. By no means comprehensive, this list of issues has been identified as some of the most critical by transportation and emergency management officials experienced in contraflow evacuation.

Safety

The most significant issue of contraflow operation during hurricane evacuations is the potential for traffic accidents, particularly from opposing traffic. Thus, one of the most critical needs is the prevention of inbound vehicles from entering into the contraflow lanes. In most plans this will be accomplished using road closure barricades at all access points to the contraflow lanes. Since it is felt that traffic control devices alone will not eliminate illegal entries, all states will (or plan to) post State Police or National Guard troops at ramp locations. In the NCDOT plan, at least one ''Road Closed—Do Not Enter'' type III barricade and one police officer with a vehicle will be positioned at each on-ramp into the contraflow lanes (NCDOT 2000).

Opposing vehicles left over in the contraflow lanes at the start of operations can also be a problem. To address this issue, all states will complete a full visual verification prior to the crossover to make sure that all vehicles have been cleared. In Florida and Texas the contraflow traffic platoon will be led by state police vehicles directly in front of the evacuees and another driving approximately 0.8 km (0.5 mi) ahead. Some states have also proposed the use of aircraft to verify the clearance of vehicles prior to the start of contraflow operations.

Since freeways have not historically been designed for reversed flow, signs and pavement markings will not be visible to drivers. Safety appurtenances such as guardrail transitions, crash attenuators, and post support bases have not been designed to provide the adequate protection at hazardous locations from the opposite direction of travel. To address this issue some states are planning to redesign or retrofit existing systems to provide increased levels of safety protection. The NCDOT has proposed the reconstruction of guardrails and end treatments along designated reverse flow sections of I-40 to protect vehicles traveling in the opposite direction (NCDOT 2000). Similar protection for blunt objects, such as bridge abutments, using crash impact attenuators was also proposed. Both the NCDOT and the SCDOT have also suggested the construction of permanent overhead dynamic message signs that are readable from both the normal and contraflow directions.

Regional and Interstate Traffic

The crossing of political boundaries, both within and between states, is another critical issue that must also be addressed during the contraflow planning process. Until recently, relatively little regional hurricane evacuation planning was done. Evacuations have been largely regarded as the responsibility of local emergency manage-

ment officials. Thus, evacuations are implemented on a local county-by-county basis. In the state of Florida, the DOT found that this lack of coordination caused significant congestion as traffic from one county evacuated onto the already-congested roads of a neighboring county. They are now addressing these problems in one of the first statewide hurricane evacuation programs (State of Florida 2000).

Interstate planning is also important. A major state-to-state overlap of interstate evacuating traffic occurred during Hurricane Floyd in 1999. During the Hurricane Floyd evacuation, traffic from both Florida and Georgia contributed to the monumental traffic congestion on evacuation routes in South Carolina. Some of these evacuees traveled as far as Tennessee. The South Carolina, Georgia, and Florida DOTs are now working together to correct these deficiencies. Interstate regional plans will now consider interstate contraflow and the use of secondary highways to keep local traffic off interstate routes whenever possible.

One location where contraflow operation could cross over state lines is the I-59 border crossing between Louisiana and Mississippi. The existing road network and geography will force a significant percentage of New Orleans evacuees to shelter in Mississippi. Because of the number of people that need to evacuate southeast Louisiana (estimated in excess of 1 million), current Louisiana evacuation proposals seek to contraflow all lanes of I-10 eastbound out of New Orleans. From a practical standpoint, the locations of interchanges and orientation of the freeways do not permit a reasonable merge point until well after the Mississippi state line. Due to safety, personnel, and cost issues, the MDOT is relunctant to continue the Louisiana contraflow operation into their state. At this time negotiations are underway to resolve this issue.

Accessibility

Issues of accessibility for both the evacuees and emergency service personnel are critical in the planning of contraflow evacuations. By definition, one-way-out evacuation strategies prohibit the movement of inbound vehicles into threatened areas. However, police, National Guard, DOT, and utility service vehicles often need access into the evacuation zone before and after the storm. One way to accomplish this is by keeping a single lane of travel open in the inbound direction on the freeway. However, as shown in Table 1, this can significantly decrease the outflow from the threatened region. To overcome this problem many agencies have proposed the use of parallel U.S. and State Highway secondary routes for service access (FHWA 2000).

Accessibility is also an issue for evacuees. An important consideration is the ability to egress contraflow segments for evacuees requiring vehicle or medical services, food, fuel, and access to restroom facilities. The Georgia experience during Hurricane Floyd showed that numerous vehicles overheated or ran out of fuel while sitting in traffic gridlock. For this reason the new GDOT plans will now permit exits from all interchanges on its 95-mile contraflow segment out of Savannah.

Cost

When compared to the potential for mass loss of life, issues of cost seem insignificant. However, they must still be considered. States have varied in their plans to make significant investments to modify existing or to construct new roadway infrastructure to facilitate contraflow evacuation. Most state DOTs, like Florida, feel that contraflow evacuations are relatively rare and exceptional situations and have attempted to limit major investments in highway redesign. Except for the cost of capital infrastructure improvements, the primary source of cost for contraflow evacuation is related to the personnel needs for the implementation and enforcement of the operation.

Labor and personnel cost considerations start with the time for personnel involved in the preoperational planning and engineering of the contraflow plan. Once the plan is initiated, field operations personnel will be required to set up all temporary traffic control devices and ramp barricades. Once in effect, state police, National Guard, and other law enforcement personnel will need to be stationed at all inbound entrance ramps to prevent unauthorized access into the contraflow lanes. For the 18 interchanges involved in the NCDOT lane reversal, it is estimated that 30 uniformed officers with cruisers will be needed to prohibit entry into the contraflow lanes. They also estimate the need for 38 DOT field personnel to close the ramps and 4 DOT personnel to assist with motorist information at rest areas on the route (NCDOT 2000). In Louisiana plans call for the use of both National Guard troops and law enforcement agents from all available state agencies. The Florida plan calls for 30% of its traffic control and enforcement manpower to come from state law enforcement agencies, with the remaining 70% coming from Florida National Guard troops.

Most states are reluctant to use personnel other than DOT or traffic enforcement police. This reluctance is based on the lack of traffic direction expertise in other personnel. The Florida DOT plans to use only police and has estimated the need for more than 300 law enforcement personnel to implement their contraflow operation. Managerial DOT and police staff will also be required to monitor the flow conditions and manage the operation on a strategic level.

In states where infrastructure improvements were required to facilitate contraflow evacuation the upgrades typically involved only minimal capital investments. The only significant infrastructure enhancements required for contraflow in the Carolinas and Louisiana were the construction of permanent paved crossover lanes between the outbound to inbound lanes. The NCDOT estimated the total cost of construction items for the reversal of I-40 at $275,000 (NCDOT 2000). This amount included all pav-

ing and the enhancement of safety and traffic control devices in the contraflow lanes. The purchase of the traffic control devices including barricades, variable messages signs, and highway advisory ratio transmitters have additional benefits since they can be used for routine incident management functions.

NEEDS AND RECOMMENDATIONS

Many lessons about mass-scale hurricane evacuations have been learned since the 1998 and 1999 hurricane seasons. However, little of this type of information has been widely disseminated. Technical presentations at several recent conferences, including the 2000 National Hurricane Conference, the FHWA's 2000 Hurricane Evacuation Workshop, and the 79th Annual Meeting of the Transportation Research Board, have brought many of these issues to light. This section summarizes the consensus of needs and recommendations for the planning and operation of one-way-out strategies.

Do It Sooner Rather Than Later

Some states still feel that they would rather take things in a one-step-at-a-time fashion, increasing the capacity of the evacuation routes in response to the demand. The advantage to this is that it is flexible and can permit the implementation of contraflow operations only as a last resort. However, the number of lives at stake in evacuations is enormous. As such, most agencies prefer to err on the side of caution and exercise all means necessary to evacuate people as soon as possible. For this reason all states that have used contraflow operations recommend their use as soon as possible after an evacuation order.

Get Citizen Involvement and Provide Public Education

The single most critical component of the contraflow evacuation strategy is the driver. Evacuees are under an enormous amount of stress; thus guidance needs to be clear, obvious, and purposeful. The proper time to educate drivers is not during the evacuation. The public needs to be informed and educated on how contraflow lane operation will work during an emergency. They also need to be aware of what routes will take them to what destinations, which segment will be reversed, and which alternate routes are available to them. Motorists must also be informed on safety issues associated with this type of operation. The GDOT has attempted to address this need by distributing evacuation handbooks to it citizens. These guides explain the contraflow plan and include route maps and exit locations.

Consider Needs of Motorists in Contraflow Lanes

Under contraflow operation it is likely that some, many, or all agress points from the roadway will be eliminated. In past one-way-out evacuations, drivers were unable to obtain food, fuel, medical services, or access to restroom facilities. In some cases vehicles ran out of fuel or overheated further, decreasing the outbound capacity of the contraflow lanes. Additionally, it is common for evacuees to travel with pets, children, the elderly, and special needs passengers. These needs must be considered during the planning of contraflow operation. These problems can be addressed by permitting exits using existing on ramps, providing effective guidance information through signs and radio, and by providing on-road incident response vehicles.

Communicate between Agencies before, during, and after Event

During the Hurricane Floyd evacuation, state agency personnel found themselves unable to directly communicate within and across agencies. For example, DOT operations staff in South Carolina was at times unable to communicate with the state police and other field personnel because these agencies used separate field radio systems. Such a lack of communication obviously makes it difficult for agencies to coordinate activities with one another. More critically, a lack of communication can leave critical information gaps for the decision makers. Effective communication is a necessity both within and between agencies and, in some cases, between states.

Provide Timely and Accurate Data for Decision Makers

Timely and accurate information is vital to decision makers during hurricane evacuation. In the past, factors such as limited remote data sensors, poor communication, and limited personnel resources have restricted the timely flow of vital traffic flow information. Often, the information, when it was available, was not always usable because it was qualitative rather than quantitative or was in a format that needed to be condensed and summarized.

Over time it is expected that intelligent transportation system technologies such as remote traffic flow monitoring sensors and video surveillance cameras will be able to bring live traffic information to the decision makers in real time. However, most intelligent transportation systems are limited to urban freeway networks, sparsely available along rural interstates, or are still in development stages. To overcome information gaps in the short term, state highway agencies are taking advantage of existing internet-based sources of data. Currently, the Louisiana and South Carolina DOTs are adapting existing pavement loop traffic count stations, internet-based traffic video, and remote weather monitoring for use in near-real-time monitoring systems (Wolshon et al. 2000). The Florida DOT has already integrated all its highway count stations into its evacuation monitoring system.

Develop Adaptable Plans

Hurricane forecasting, while vastly improved, remains limited in its ability to pinpoint precise locations and times that a storm will make landfall. Hurricanes are also notorious for making abrupt and unanticipated turns and changing in both size and strength. This high degree of variability also makes the process of hurricane evacuation very fluid. Emergency preparedness officials are often required to initiate and modify evacuation plans over short periods of time. Evacuation plans, and more importantly highway agency managers, need to be flexible in their planning processes to permit them to adapt to rapidly changing conditions.

Historically, DOT officials have played only a supporting role to emergency managers during the evacuation events. Now, this support role has been expanded into full route planning, engineering, and operational expertise. In this new role, transportation professionals working in evacuation planning need to develop routes and operations that are flexible and can be adapted to changing conditions in short periods of time.

Consider Traffic Coming from Bordering States

Most evacuation decisions are made on a local county-by-county basis in response to the level of threat. Until relatively recently, the effect of regional intrastate evacuations was rarely considered. This was one of the lessons learned from the Hurricane Floyd evacuation. During Hurricane Floyd, evacuations from the coastal communities of Florida resulted in a significant number of Florida evacuees moving north into Georgia. The slow northerly track of the storm then precipitated evacuations into coastal Georgia and then South Carolina. This series of events resulted in evacuees from Florida and Georgia traveling to the saturated routes of South Carolina. During Hurricane Georges, hundreds of thousands of New Orleans residents evacuated into Mississippi on I-10, I-55, and I-59. For these reasons highway officials must communicate with neighboring states to coordinate plans and share information about where and how many people are moving from one area into another.

CONCLUSIONS

Contraflow freeway evacuation has been shown to be a successful method to rapidly and efficiently move large numbers of people during major hurricanes. Under contraflow operation, one or more of the inbound lanes are used for outbound evacuation. Recent studies of contraflow operation have shown that it can increase the flow rates of evacuating traffic by nearly 70%.

However, reverse flow scenarios are not without significant problems. There are the inherent safety risks associated with reverse flow on interstate freeways. Traffic control devices and safety appurtenances have not been designed to accommodate reverse flow. The costs to plan, design, implement, enforce, and terminate the lane reversals can also be significant, as are the costs for specialized equipment and construction required to operate it. Some contraflow operations eliminate the ability of service vehicles to enter into the evacuated area during the evacuation. They may also limit the ability of evacuees from exiting the contraflow lanes to service their vehicles and accommodate personal needs.

Traffic and transportation engineers are typically concerned with traffic safety and capacity under routine conditions. As such, rules and practices have been developed to safely and efficiently move traffic under routine conditions. No life and death consequences are attached to travel time and delay. In contrast, during hurricane evacuations, time is of the essence, and delays can mean catastrophic loss of life. The point is to get as many people out of a threatened area as quickly as possible. While great attention is paid to traffic safety during evacuations, it is not necessarily the primary consideration. Because of this, the traffic professionals must be willing to take actions that may be outside of standards of accepted practice and think in new and innovative ways. Contraflow operations are one valuable tool to help move the maximum number of people from high-risk coastal areas.

Unfortunately, contraflow is not a cure to all evacuation needs. Emergency managers and highway engineers should look upon contraflow as an extreme response to an extreme threat, not as a way to solve all the problems associated with evacuations. The point is that these agencies have few other capacity increasing options. Hurricane evacuations, unlike almost any other function of traffic and transportation engineering, can have an immediate and direct impact on tens of thousands of lives.

Since the widespread application of contraflow traffic operation for hurricane evacuation is a relatively new development, there are many issues associated with its use that have not been fully evaluated or are not fully understood. These include the accurate quantification of what increases in capacity can be gained from various contraflow uses, as well as the simulation of these scenarios. Additional assessments are also needed to determine the most efficient use of labor to set up, operate, and terminate the contraflow segments. Other potential research areas could focus on the use of freeway traffic control devices and markings for two-way travel, making roadside safety features (crash cushions, breakaway supports, etc.) effective from an opposite flow direction, the incorporation of contraflow considerations (median and ramp crossovers) into original design plans, and the use of contraflow operations for post storm re-entry.

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