The Framework of Calculating the Measures of Resilience for Intermodal Transportation Systems


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Project Objective

The objective of this research is to develop a framework of calculating the measures of resilience (MORs) for intermodal transportation systems. To accomplish the objective, the following four specific aims are expected to be achieved:

- Define measures of resilience of intermodal transportation systems,
- Propose a framework to calculate the proposed MORs,
- Case study of MORs in the recovery of Mississippi Gulf Coast after Hurricane Katrina, and
- Demonstrate the enhancement strategies of the MORs.

Project Abstract

So far, there is no consent agreement on the measures of resilience (MORs) for intermodal transportation systems in the transportation community (e.g., Pamela 2006, Tierney and Bruneau 2007, and VTPI 2007). In this research, a unified framework of MORs will be developed for all transportation modes from the perspective of system users. Network-wide intermodal travel time and Level of Service (LOS) are selected as major performance indices for intermodal transportation. The percentages of performance indices that drop after a disaster are defined as MORs. Three key data, travel time, Level of Service (LOS) and OD (origin-destination) flows, are needed for using the proposed framework before and after disasters. The pre-disaster data will be collected at the state level and calculated by using regional transportation models, TRANSEARCH INSIGHT freight data, and federal Freight Analysis Framework data. The post-disaster OD flow
will be estimated from weight station truck volume and surveys of major freight carriers and users. Based on the estimated freight OD, the transportation models will be re-run to calculate freight travel time and LOS. The above process will be reviewed in a case study using the Mississippi Gulf Coast. How to improve MORs in the Mississippi Gulf Coast will also be discussed. The final report will summarize the framework and procedures to use the framework and provide guidelines for further studies.

**Intermodal Orientation of the Project**
- Modes of transportation: Waterway, Railway, Highway, and Airway.
- Freight transportation.
- Intermodal transportation system planning, design, improvement, and assessment.

**Task Description**
There are three stages for transportation in disaster response. The transportation system is expected to evacuate residents out of the affected area before a disaster happens, to transport equipment, supplies, and emergency crews into the affected area for emergency rescue, and to move freight and passengers through an area with damaged infrastructure or reduced capacities before the transportation system is fully restored. The last stage is referred as the recovery stage in this proposal. The lessons learned from Hurricanes Katrina and Ivan indicates that the evacuation plan in Mississippi and the massive rescue mission were well executed (USDOT and US DHS). However, the hurricanes caused lasting effects on local economy in the affected area and the effects were spread to a larger region. For example, the St. Louise Bridge and Biloxi Bridge had not been completely restored to their original capacity two years after the Hurricane Katrina. Therefore, the proposal research will concentrate on the intermodal transportation MORs at the recovery stage and include the following major tasks.

**Task 1. Literature Review**
Extensive literature review will be conducted on the following topics:
- Transportation system resilience,
- Transportation system disaster recovery,
- Traffic and freight OD demand patterns before/after disasters,
- Intermodal transportation capacity before/after disasters, and
- MORs used in researches for each transportation mode.

**Task 2. MOR Definition for Intermodal Transportation Systems**
MORs for Intermodal Transportation Systems are tentatively proposed as the percentage of decreasing in intermodal transportation system performance indices such as travel time and LOS.

**Task 3. Framework Development to Calculate Defined MORs**
During the recovery stage, MORs dynamically change with the restoration of transportation facilities. At one or two critical points of time before and after which a major infrastructure is restored, the MORs will be calculated following three steps:
1. Estimate the intermodal OD flow,
2. Calculate the travel time and LOS, and
3. Determine the MORs.
While the first two steps will be detailed as separated tasks, the system-wide performance indices $PI_X$ is determined by:

$$PI_X = \sum_i \left( \sum_j \left( \sum_p \left( \sum_m \left( OD_{ij} \right)_p \left( X_m + \sum_l Y_l \right) \right) \right) \right)$$

Where:

$OD_{ij}$ is the freight OD flow from origin $i$ to destination $j$. It is divided into $P$ pattern: some of freight is transported by one mode while others are transported by intermodal transportation.

$X_m$ is the intermodal facility $PI$ when transferring freight from modal $m-1$ to modal $m$.

$Y_l$ is travel time or production of LOS and link length on link $l$.

$i$: origin index ($i=1, \ldots, I$).

$j$: destination index ($j=1, \ldots, J$).

$p$: pattern for transporting freight.

$m$: transportation mode within a pattern. $m=1, \ldots, M$.

The MOR is defined as:

$$MOR = \frac{PI_{Before} - PI_{After}}{PI_{Before}} \times 100\%$$

**Task 4. Methodology Development to Calculate Travel Time and LOS**

There are two major components in the freight travel time: terminal time and link travel time. The terminal time includes freight gate/terminal waiting time, unloading time (from one transportation), and loading time (to another transportation mode). Link travel time and LOS will be extracted from State or Regional plan models. In the State of Mississippi, the statewide transportation plan is modeled by TransCAD. The Highway LOS would be obtained by the same way as travel time. For other transportation modes, the LOS would be difficult to obtain. We will assume that the LOS of other modes does not change as easily as highways. For calculating the travel time and LOS after the disaster, once the new intermodal OD flow is determined (see the next task), the traffic model will be adjusted and re-run to estimate new travel time and post-disaster LOS.

**Task 5. Intermodal OD Flow Estimation**

Estimating intermodal OD flow is one of the most challenging tasks in the transportation community (Guelat et al. 1990). The time and funding resource of this project will not allow the project team to develop new estimation models. Instead, the existing models or database will be used to extract OD flow for this project. There are multiple sources of freight OD data. TRANSEARCH INSIGHT freight data licensed to Mississippi State University will provide a county level OD. Calibrated transportation models (TransCAD from Mississippi Department of Transportation and the Gulf Regional Planning Commission) will provide a disaggregated freight to traffic analysis zone (TAZ). Furthermore, if necessary, OD from Freight Analysis Framework by FHWA might provide supplemental materials for this project. The post-disaster OD flow will be
estimated from weight station truck volumes and surveys of major freight carriers and users. Available traffic detector count data may be used to calibrate and verify the OD flows.

**Task 5. Mississippi Gulf Coast Case Studies**
Information about intermodal transportation facility interruption, capacity reduction and restoration will be collected from Mississippi Department of Transportation. For example, CSX railroad and I-10 were disrupted and US 90 and the port in Gulfport were totally gone after Hurricane Katrina. The survey of major freight carriers in the Gulf Coast and CSX railroad will provide freight OD flow data sources. The data of truck flow through weight stations in Mississippi and neighborhood states will provide estimated highway freight OD flows. Synthesizing those data, we will obtain a reasonable estimation of modal shift and re-routing freight volume. This case study will provide a test bed for the above proposed framework.

**Task 6. Identification of Strategies to Enhance MORs**
There are two types of strategies to enhance MORs, freight flow rerouting and infrastructure improvement. Limited by time and funding, this project will not explore optimization models but use a manual process of re-routing and/or modal changes to identify and show potential MOR enhancement. A showcase will be used to demonstrate the infrastructure improvement strategy. This task will be conducted with the sponsorship from Mississippi Department of Transportation.

**Task 7. Final Report**
The final report will summarize the result of all above tasks. The report will also provide guidelines for further studies.

**Technology Transfer**
A scholar paper will be submitted to TRB for presentation and publication. Two presentations will be delivered in the meetings at Jackson, MS and Gulfport, MS. The audience will include Mississippi Department of Transportation, Gulf Coast Regional Planning Commission, other state and local agencies, and intermodal carriers and users. Reports will be shared with them as well as major freight carriers and intermodal transportation users. The report will also be available on web site. The framework will be introduced in transportation engineering courses at MSU to help students understand MORs and consider MORs in their future transportation careers.

**Benefits of Project**
The proposed MORs will enhance scientific research on intermodal transportation research in disaster response. The MORs could be used as an objective function to optimize the complex intermodal freight flow once a natural or manmade disaster of significance happens. The developed MORs are expected to benefit the intermodal engineering design as well. Before actually building intermodal facilities, professionals should include MORs in performance indices to evaluate facility design alternatives.