COLLEGE OF ENGINEERING AND COMPUTER SCIENCE

Optimization of Bus System Characteristics in Urban Areas under Normal and Emergency Conditions

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Various catastrophic events in the past, revealed the need for more research in the field of emergency evacuation of a large number of people. During such a procedure, different problems, such as congestion at the related traffic networks because of the large number of the evacuating vehicles, can occur. Current best practices, in order to deal with such problems, try to analyze more the potential most extended and efficient use of busses in a large scale evacuation. On the first part of this study, after identifying the case study area and the related traffic network under analysis, the optimization of the bus system operations will follow. The optimization procedure focuses on optimizing the bus routes and the number of vehicles that should be used, through the application of a non - linear cost analysis model. On the second part, the potential use of the optimized bus routes in emergency conditions during a no-notice evacuation will be analyzed and compared with the use of the existing evacuation routes.

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Introduction

- Traffic congestion in urban areas is a constant issue for transportation networks
- The further development of public transportation and especially buses is suggested for the congestion management
- Routing is one of the most important parameters which affect the quality of bus operations
- Additionally different agencies are interested in identifying how we can efficiently involve buses in emergency evacuation operations

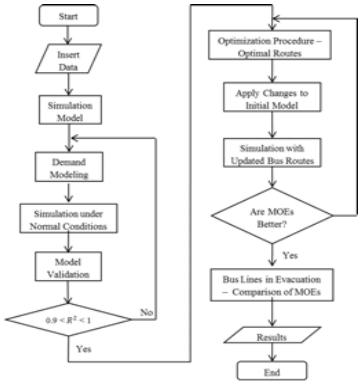
Problem Statement

- The general topic under analysis is the bus system operations under normal and emergency conditions.
- Which parameters and how do they affect the total cost which corresponds to a specific bus line route?
- Which are the optimal routes for different bus lines?
- How does routing affect fuel consumption and gas emissions?
- In a no-notice evacuation how can we improve bus operations?

Objectives

- Develop a non-linear mathematical model which minimizes the cost related to the use of a specific bus line route
- Identify the optimal routes for a system of different bus lines
- Develop a simulation model and identify how routing affects fuel consumption and gas emissions
- Investigate the potential use of regular bus lines routes for evacuation comparing to the use of the existing evacuation routes
- Evaluation of different transit evacuation strategies

Methodology



Objective Function:

$$Minimize \sum_{i=1}^{n}\sum_{j=1}^{m} Ct_{i,j} = Minimize \sum_{i=1}^{n}\sum_{j=1}^{m} Cs_{i,j} + \sum_{i=1}^{n}\sum_{j=1}^{m} Cu_{i,j}$$

Parameters:

- $Ct_{i,j}$ is the total cost $\forall\ i = 1, 2, \dots, n \quad \forall\ j = 1, 2, \dots, m$
- $Cs_{i,j}$ is the supplier cost $\forall\ i = 1, 2, \dots, n \quad \forall\ j = 1, 2, \dots, m$
- $Cu_{i,j}$ is the user cost $\forall\ i = 1, 2, \dots, n \quad \forall\ j = 1, 2, \dots, m$

Variables:

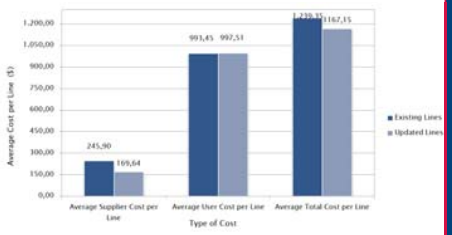
- i corresponds to the different bus lines of the system
- j corresponds to the alternative routes of each bus line

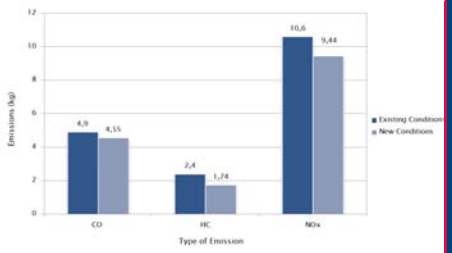
Case Study

- Part of Washington D.C downtown area
- George Washington University for evacuation analysis
- 6 bus lines for the analysis under normal conditions
- 3 bus lines for the analysis of emergency evacuation conditions

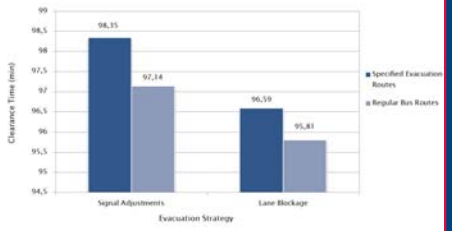
Results

Bus Operations under Normal Conditions





Bus Operations in Evacuation Conditions



Conclusions

- Bus vehicle routing greatly affects the whole network's measures of effectiveness (MOEs)
- Rerouting resulted in a 7%-28% reduction in the gas emissions (depending on the emissions type) from the bus vehicles and 9% reduction to fuel consumption
- Regular-everyday bus line routes can efficiently be used in cases of small scale evacuations with similar clearance times comparing to the use of the existing evacuation routes
- The "Lane Blockage" evacuation strategy resulted in smaller evacuation clearance times comparing to the "Signals Adjustment" strategy because of the left turn vehicle volumes

Limitations of the Study

- Model calibration and validation focused on the Car Following model and the Lane Change model. For all the other parameters, default values were used
- Different assumptions regarding our evacuation analysis had to be made. Information related to the evacuation pickup points or the safe zone areas were classified

Future Work Recommendations

- An application of the suggested methodology in a larger set of bus lines
- Investigation of a different solution approach to the mathematical model
- The application of the evacuation methodology to a larger scale of evacuation demand
- The evaluation of different evacuation strategies

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