The goal of this research is to explore and assess the use of the probability of breakdown concept to improve operations at critical bottlenecks utilizing fuzzy logic ramp metering.

**Objectives**
- Integrate the probability of breakdown concept into the fuzzy logic ramp metering algorithm
- Replicate a study site using the CORSIM microsimulator
- Identify bottleneck locations on the study site where implementation of the new ramp metering algorithm is feasible (merge junctions)
- Generate the probability of breakdown curve for each bottleneck location
- Run simulations in CORSIM using the base fuzzy logic ramp metering algorithm and the modified fuzzy logic metering algorithm
- Evaluate the impacts of the new algorithm by comparing average travel time, average travel speed, time to breakdown, duration of congestion, queue discharge, and throughput

**Study Site**
- I-95 Miami, Fl. from I-395 to Miami Gardens DR.
- 13-mile Section
- Currently Uses HOT Lanes and Ramp Metering

An analysis was performed to see where recurring congestion occurs. Three locations were identified, but only two of these were merge junctions. These two were identified as critical ramps, and the probability of breakdown concept will be applied here.

**Critical Ramps**
- On-ramp from NW 103rd St
- On-ramp from NW 81st St

A probability of breakdown curve must be generated for each critical ramp. Data must be screened, and days where incidents or inclement weather impact the immediate area must be removed. Two years of data were used and a total of 79 days were identified for use.

**Probability of Breakdown**
- Estimates the probability that a particular freeway flow (or combination of ramp and freeway flows) would lead to breakdown
- Estimates the proportion of flows that have resulted in breakdown. That proportion can then be used as the probability that a given flow would lead to breakdown
- To accomplish this numerically, flows at breakdown \( B \) and flows prior to breakdown (F) are obtained and used in the Product Limit Method

\[
F(q) = 1 - \prod_{i: q \leq qi} \frac{k_i - 1}{k_i}; \in \{B\}
\]

Where:
- \( F(q) \) = distribution function of breakdown volume
- \( q \) = traffic volume (veh/h/ln)
- \( qi \) = traffic volume in interval i, which is the one prior to the drop in speeds, i.e., the breakdown flow (veh/h/ln)
- \( ki \) = number of intervals with a traffic volume of \( q \geq qi \)
- \( B \) = set of breakdown intervals (1-minute observations)

**Enhancements to the Fuzzy Logic Algorithm**
- **Enhancement 1 – Initialization Threshold**
  An initialization threshold is set to the lowest evaluation parameter where breakdown has occurred. It is recommended to use a buffer range where if the threshold is reached it must stay above the threshold for at least 5 minutes.

- **Enhancement 2 – Inclusion of the Probability of Breakdown Curve**
  The Product Limit Method is used to generate a plot of the probability of breakdown. A breakdown is defined as having a speed drop of 10 mph for at least 5 minutes. The plot can be derived based on volume, occupancy or speed.

  Different distributions can be tested to see which one best fits the PLM plot. A logistic regression has been applied to this PLM plot. Fitting to a distribution allows the data to be more readily usable.

  A different curve may be generated for different levels of ramp demand. This plot shows how the metering rate would change if a maximum acceptable probability of breakdown was selected.

**Simulation and Expected Results**
- The CORSIM simulation will be calibrated based on typical days data
- The simulation will be tested with days showing varying traffic volumes to ensure the model is robust
- The simulation will be run with the fuzzy logic enhancements and results will be compared to the current ramp metering operations
- It is expected that the results will show an improvement in all identified performance measures