Characterization and Prediction of Superload in Florida Using Gradient Boosting Machine Learning Algorithm

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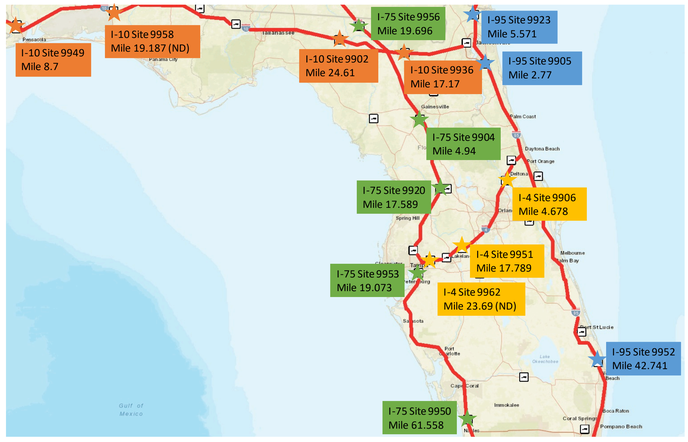
Introduction

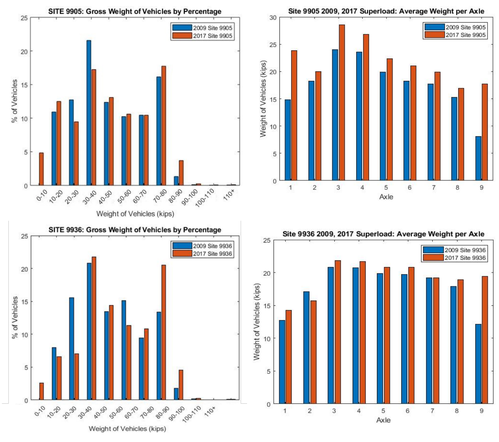
Highway agencies are responsible for protecting billions of taxpayer dollars with respect to the infrastructure. Due to the location of the state of Florida, special considerations must be taken in order to accurately maintain and improve infrastructure resilience. Florida's highways encounter unique multi-hazards and loads, such as unpredictable hurricane forces, causing an interruption of traffic and post-disaster recovery efforts. For the purposes of safety and system preservation, trucking operational characteristics are regulated using federal and state legislation and policies. The effect of truck loads on infrastructure is important in the effort of upgrading and maintaining transportation infrastructure. In order to incorporate special needs from the industry, more irregular vehicles are utilized to transport extremely heavy loads, such as prestressed concrete girders, transformers, and wind turbine components. Thus, there is an urgent need to characterize, evaluate, and predict superload (>150,000 pounds) traveling on the road. This analysis in combination with traffic data, structural performance data, environmental data, and human factor data will provide an optimal management and maintenance plan for Florida's infrastructure.

The initial stage of this research included analyzing the Weigh-In-Motion (WIM) data provided by Florida Department of Transportation (FDOT), which is a dataset of unbiased, time-stamped, per vehicle recording and monitoring of truck movement, weight data, and axle configuration. An analytical procedure for the characterization and prediction of superload was developed using advanced Gradient Boosting Machine (GBM) learning algorithms. The characterization of superload was performed for Florida WIM sites and the prediction of key parameters, such as maximum axle weight and gross vehicle weight, was conducted. The next stage of the research involves compiling big data to derive a plan to optimize allocation of funds and improve resilience of infrastructure under multi-hazards/loads using Artificial Intelligence (AI) algorithms.

Characterization of Superload

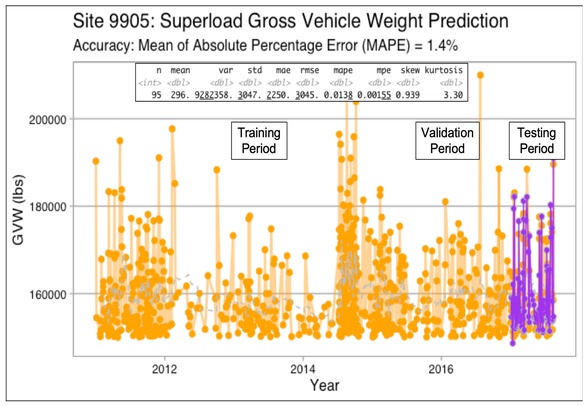
Among 31 sites that FDOT operates, the research team selected 13 sites to represent the traffic loads from four major highways in the state of Florida. There are 3 sites on I-10, 3 sites on I-95, 5 sites on I-75, and 2 sites on I-4.

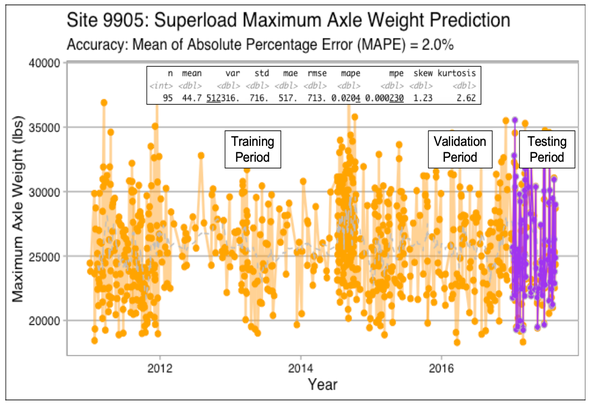




Prediction of Superload

Over the last two decades, significant advancement has been made in machine learning algorithms and applications through extensive research. Machine learning becomes a promising new tool for practicing scientists and engineers. The machine learning algorithm aims at "learning" from input data and then constructing a model by continuously estimating, optimizing, and tuning parameters of the model. The model determines how relevant each parameter in the data set is when predicting, expressing its accuracy in a mean of absolute percentage error against the testing dataset. Two of the most important parameters for deciding agencies provided promising results from the algorithm.





Site 9905 on I-95, 2009-2017

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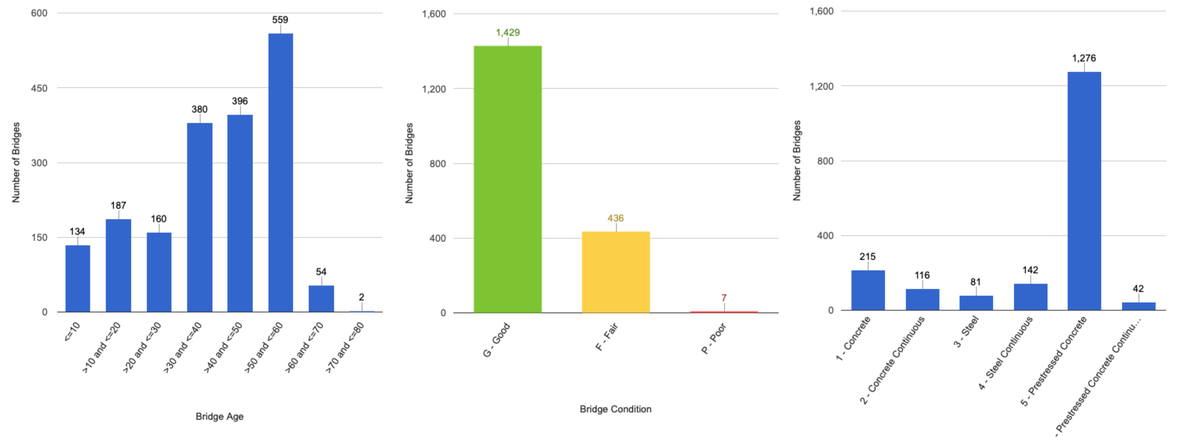
Current Bridge Maintenance Practices

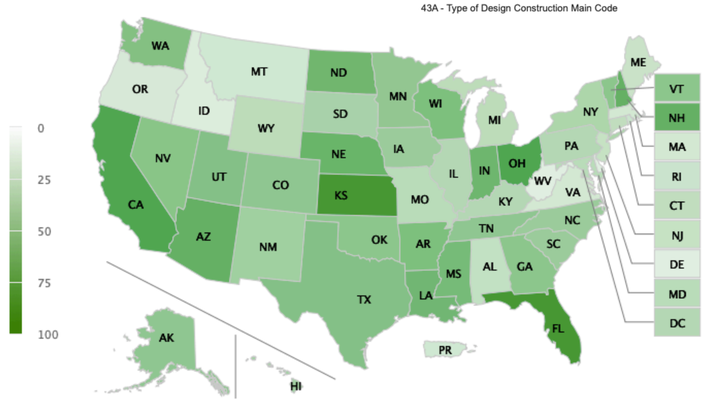
Code	Description	Actions
9	Excellent Condition	Preservation/Cyclic Maintenance
8	Very Good Condition	
7	Good Condition	
6	Satisfactory Condition	Preservation/Condition-Based Maintenance
5	Fair Condition	
4	Poor Condition	Rehabilitation or Replacement
3	Serious Condition	
2	Critical Condition	
1	Imminent Failure Condition	
0	Failed Condition	

There are currently over 600,000 bridges in the United States, and over 40 percent of those are over 50 years old. The ideal plan is to preserve a bridge while it is still in good/fair condition instead of letting it deteriorate to poor/serious/critical condition. There are complications regarding this process due to limited funding, therefore agencies must choose wisely which infrastructure to focus on based on condition, and amount/type of traffic. Preservation and preventative measures include cyclic and condition-based activities. Cyclic maintenance involves cleaning the bridge itself, flushing drains, or sealing the bridge deck, rails, cracks, or concrete. Condition-based maintenance consists of repairing and replacing drains, replacing joint seals, repairing the deck and overlay, or repairing any steel members. Rehabilitation and replacement may include a partial or full bridge replacement on the deck or superstructure. This was provided by the U.S. DOT Federal Highway Administration Bridge Preservation Guide.

Status of Interstate Infrastructure in Florida



An analysis was performed using the Long-Term Bridge Performance InfoBridge web portal on the most important aspects to study when considering an optimal management and maintenance plan. This includes bridge age, current bridge condition, and the material of the bridge. For the state of Florida's interstate bridges (I-4, I-10, I-95, and I-75), most bridges in good condition, between 50 and 60 years old, and constructed of prestressed concrete. Comparing Florida with the rest of the United States, the percentage of interstate bridges in good condition is 76.22%, which ranks #1 in the country based on the number of bridges. Similarly, Florida also has the highest percentage of bridges in good condition (70.19%) based upon total bridge deck area.



Summary and Conclusions

- FDOT operates 31 WIM sites, which provide valuable traffic data, such as gross vehicle weight, axle weight, number of axles, and more. Based on raw WIM data, the characteristics of superloads were extracted.
- From the 2009-2017 WIM data comparison, overweight vehicles increased in gross vehicle weight and the superload data exhibited a rise in individual axle weight.
- Both gross vehicle weight and maximum axle weight prediction showed promising results with 1.4% and 2.0% mean of absolute percentage error, respectively.
- Current practices state that preservation occur, either cyclic or condition-based, whenever the bridge rating is between 5 and 9. Rehabilitation or reconstruction occurs when the bridge rating is 4 or lower.
- Most Florida interstate bridges are in good condition, between 50 and 60 years old, and are constructed of prestressed concrete. An optimized management and maintenance plan will optimize allocation of funds, continue to improve the resilience of infrastructure, and prepare for the future multi-hazard/load impacts.

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