

Problem that further
repairs are needed
on

Business



Problem statement: In March of 2017, the city of Atlanta, GA experienced one of its worst transportation crisis.

A section of the Interstate 85 bridge collapsed leaving the city paralyzed for weeks. 250, 000 commuters were rerouted for weeks choking the city's transportation network. The cause of the bridge was due to a fire that raged for hours damaging the bridge's structure. Yet, this bridge was cleared by the DOT just months ago. The fire which was started by vandals was not caught until it was too late. (Not sure, should we use this to open ?) According to the American Road and Transport Builders Association, there are 14, 835 bridges in Georgia.

Out of these 700 are structurally deficient meaning one or more elements are in unacceptable condition, 1604 are classified as functionally obsolete meaning they do not serve the purpose for which they were intended, and 1487 bridges are restrictive in the type of load they allow. The state has identified that further repairs are needed on at least 13, 544 bridges. In other words, the opportunities for a large-scale disaster to strike again are ample and imminent. This is further substantiated by the 2017 ASCE's Infrastructure Report Card which gives the bridges in GA a C+ rating. Simply put, a substantial number of bridges in Georgia are nearing the end of their design life and opportunities for a large-scale disaster to strike again are ample and imminent. Between 2005 and 2014, 2 billion dollars in federal funds have been used for bridge maintenance. The state has further estimated that a sum of 27 billion dollars will be needed to repair 13, 544 bridges.

Detection and prediction of bridge failure therefore are key elements to prevent widespread transportation crisis and loss to life and property while ensuring that repairs are timely, necessary and adequate. The question to ask is how do we then cost-effectively maintain bridges? How can we predict when and how to invest in critical bridge maintenance - preventing both catastrophic failures on one end of the spectrum yet avoid unnecessary replacements on the other? (Should we talk about cost of replacement earlier) How can we use tax- dollars effectively to provide the best return on infrastructure spend ? Multiple points of failure - difficult to monitor individually and take action to prevent another catastrophe. There is a need for real time monitoring of multiple performance indicators of bridges, handling and processing the data and using the data to intelligently and proactively predict failure points and maintenance needs. Background Information: The following are the main components of a bridge: Foundation: The foundation of a bridge is the element that connects the structure to the ground and bears the load. Substructure: is made of the abutment, piers, and other support elements that holds the Deck.

The deck is the surface of the bridge that carries vehicular and human traffic. Superstructure: The superstructure is the part of the bridge that absorbs the live load. Why Bridges Fail: Some of the causes that lead to bridge failures are: Vehicle loads Atmospheric conditions (Wind, Rain, Temperature, Humidity, Ice etc.) Arson and Fire Material fatigue Vibration and Strain Weight overload Vehicular and Vessel accidents Some of the metrics that impacts bridge performance are the constant stresses, strains, external and reactive forces that the bridges are subject to. A significant metric is

deformation. Manual inspection has been the traditional method for inspecting and maintaining bridges.

The Federal Highway Administration Agency mandates 6 types of manual inspection - inventory, routine, damage, underwater, in depth and special, and interim inspection. But these methods are cumbersome, time consuming, utilize enormous man power and are expensive. Moreover, they are prone to error in human judgement. More recently, wireless sensor technology has gained popularity and has been accepted as a viable alternative.

Sensors are being used currently to gather information about load patterns and structural integrity. Researchers at the Georgia Institute of Technology have developed low cost wireless strain and crack sensors that can be placed on bridges at very low cost. As IOT and sensor technologies mature and become economically affordable, the use of sensors for the health monitoring of infrastructures, such as bridges, will continue to grow. The trend for bridge monitoring will involve installation of hundreds and thousands of sensors to collect valuable information about the state of the bridge structure. Together with routine maintenance and inspection reports, the collected sensor data will enable the diagnosis of potential structural problems and the prognosis for the need of structural strengthening and repairs. Developments of advanced sensing materials and devices, can provide measurements for detailed and precise structural evaluation but also entail enormous amount of data because of high sampling rate of the sensors . Structural monitoring systems will be inundated with data that need to be processed, interpreted and brought forth to support lifecycle

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bridge management. While current structural health monitoring research continues to develop and explore new sensor technologies, very little efforts have been spent to investigate proper data management tools to efficiently store, manage, and retrieve sensor data.

(citation) The data issues are of fundamental importance that need to be dealt with before sensing technologies can truly find useful for bridge lifecycle assessment and management. Solution Objective: The objective is to develop a solution that would proactively monitor the health of bridges and keep the city officials informed of the state of the bridge so that appropriate maintenance actions may be taken. . In addition, the system must alert city officials about potential failure's and dynamically re-route traffic away from the failing bridges to prevent catastrophic loss of lives and property. Approach: Develop an Open Analytical Framework (OAF) that can be used to process multiple data sources to produce actionable events. This single Open Analytical Framework can then be used to solve multiple infrastructure related problems. While, we are limiting this proposal to the maintenance of bridges, the software solution proposed here is engineered such that it could handle data feeds coming in from a plethora of other infrastructure areas such as water and sewer departments, road transportation, public safety, health and human services and financial, regulatory and compliance etc. This way the city has one integrated platform that can analyze events across multiple infrastructure areas.

This will establish the framework for the City's Operating Dashboard and will give the city engineers, planners and administrators a 360 degree view into all of the aspects of running the city. Implementation of an OAF relies heavily <https://assignbuster.com/problem-that-further-repairs-are-needed-on/>

on IOT (Internet of Things) and AOT (Analytics of Things). Successful AOT typically employ Predictive Analytics . Predictive Analytics(PA) is a technique that uses transactional or event generated data and then applies machine learning, statistical and mathematical algorithms to generate models that are then used , to forecast the likelihood of future outcomes based on historical data. The objective is to go past the traditional historical analysis of what happened and why to discovering insights about the future. Predictive models use known results to develop (or train) a model that can be used to predict values for different or new data.

Modeling provides results in the form of predictions that represents a probability of the target variable. (Paraphrase) The OAF solution proposed here defines architecture that involves engineering in multiple disciplines that includes Civil, Electronics and Communications and Software engineering. To implement the OAF, we propose the use of a network of sensors in an IOT framework that captures and transmits data using broadband or cellular networks to a central server where the data is collected, aggregated, cleansed and stored for further analysis by a predictive analytics platform. The PA platform will use this data and build regression models that is then used to process the data and make predictions of future events. This platform will make recommendations of when to perform maintenance on bridges and forecast pending problems and bridge failures. Having such a system will help the city save millions of dollars in the maintenance of bridges and prevent catastrophic loss of property and lives. While the system can be used to predict potential failures of the bridges, on the flip side, it can also be used to evaluate the remaining

life of the bridge thereby preventing unnecessary costly replacements saving tax dollars. The system is implemented using a scalable modular architecture that consists of the following modules: Automatic data acquisition and monitoring modules using sensors in an IOT framework.

Data management and processing module (this is where the data is collected, cleansed and aggregated and stored in non-relational high-speed file structures). The Predictive Analytics platform that uses the data from the data management and processing module and develops models using regression modelling techniques. Intelligent event notification module, that is a part of the Predictive Analytics platform that uses the models and sensor data to predict an outcome and to issue real time warnings and alerts.

External interface module that allows the OAF to interface with external systems such as the traffic signaling system, GPS systems, interface with other city departments and State and Federal systems using an open architectural interface. A network of sensors is installed on the bridges using an IOT model to detect and capture attributes related to vehicle loads, wind loads, environmental temperature and humidity, vibrations, structural temperature, strain, beam deflection, bearing displacement, and crack and fatigue of bridge elements.

Additional three directional seismometers are installed on the bridge piers to gather data due to earthquakes. This data is then transmitted over the internet to a central server and processed using a predictive analytics platform to obtain insights into the health of the bridges. These insights allow city engineers to make better informed decisions on maintenance of the bridges. The event notification module of the OAF can directly interface <https://assignbuster.com/problem-that-further-repairs-are-needed-on/>

with the city's traffic signaling systems to dynamically re-route traffic away from the pending failure points and avoid catastrophic loss of property and lives. Additionally, this system can interface with GPS data to provide drivers with real time information about possible re—routing and prevent traffic choke points. The Predictive analytical platforms are developed using Java and Python and makes extensive use of regression models. The design makes use of non-relational state-of-the-art NoSQL database systems.

Non-relational databases were chosen for fast and diverse query performance and for handling persistent data store and for storing and retrieving time series data. Data schemas using standard models were developed to store the sensing data, the sensor information, and bridge related information. Additional Interfaces were developed to capture data related to weather and traffic information. We evaluated SQL based relational databases for storage as well as non-relational high-speed file structures. While the relational technology allowed us to design databases and develop data queries much faster, their run time performance proved to be inadequate and extremely slow for handling large volumes of data. As a result, we re-engineered the back-end and implemented the data stores in an non-relational implementation using high speed file structures. Second, we evaluated a Bayesian Network and a Regression model for the modelling engine of the predictive analytics platform. Bayesian networks comprise of graphical models.

The nodes in the network represent a variable, while the nodes' edges represent probabilistic dependencies among the corresponding variables. Regression analysis is a form of predictive modelling technique that provides

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a functional relationship between two or more related variables, a dependent (target) and independent variable (predictor). This technique is used for forecasting and finding the causal effect relationship between the variables. We found that the Bayesian models easily handled missing data and data inconsistencies much better than the Logistics Regression model while training models (database learning) or during predictive applications.

Regression models were highly impacted by sample size and missing data. Bayesian models overcame the limitations of regression models while generating similar if not better outcomes. As a result, our predictive analytics platform was engineered using a Bayesian Network model instead of the regression model.