Infrastructure Condition Assessment Using Drones

By Imad Atra[1] / Advisor: Prof. Gustavo Pacheco Crosetti[2], PhD, PE

Polytechnic University of Puerto Rico – HSI STEM Grant – San Juan, PR

[1]Senior Student, Civil Engineering Program. [2]Professor, Department of Civil and Environmental Engineering and Land Surveying

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ABSTRACT

The condition assessment in pavement is carried out by performing a traditional visual inspection, and by applying the *Pavement Condition Index -PCI* (Vásquez, 2002). The visual inspection implies to access the roadway and to measure the defects, thus producing interruptions to the traffic flow and/or imposing risks to the technicians.

To avoid these interruptions and risks, this research explores the possibility of using drones with high-resolution cameras to gather road condition; then process the images with a GIS linked software and inspect these images to identify and measure the defects.

The outcomes of this evaluation were compared to the findings obtained by an independent crew using the traditional method, and the agreement was excellent. These results show that the proposed methodology has a great potential as an alternative pavement assessment process.

INTRODUCTION

Regarding roads resilience, importance, and condition in PR, one can summarize:

- NIAC (2010) defines *Infrastructure resilience* as the ability to reduce the magnitude and/or duration of disruptive events; and encourages governments to develop and adopt flexible resilience strategies that match their needs.
- Roads are a crucial component of the infrastructure to provide accessibility and mobility, in the society daily routinely activities, and in case of emergencies and natural disasters. To have a resilient road system a continuous condition assessment and maintenance is imperative.
- Hurricane María demonstrated the consequences of isolation of many PR sectors produced by the lack of a functional road system (FEMA, 2018).
- ASCE Reports Cards (ASCE, 2019), rated PR roads condition with a qualification of D-; the report express "Pavement maintenance and resurfacing activities on local municipal roads could be substantially improved by promoting quality control standards…".

These items justify the selection of roads as the component of the infrastructure to be studied in this project to evaluate the use of drones in the infrastructure condition assessment.

OBJECTIVE

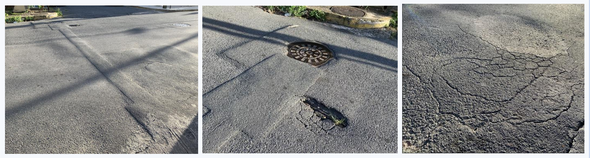
The main objective of this investigation was to evaluate the viability of replacing the traditional field inspection used in pavement condition assessment, by a procedure that uses drones with HD cameras, image processing software, and image evaluation.

METHODOLOGY

1. **Study the different branch of the infrastructure, and select one as an appropriate case study**
   - Roadways were selected
2. **Study the different pavement condition assessment methods. Summarize the Pavement Condition Index (PCI), and perform an evaluation by the traditional inspection procedure.**

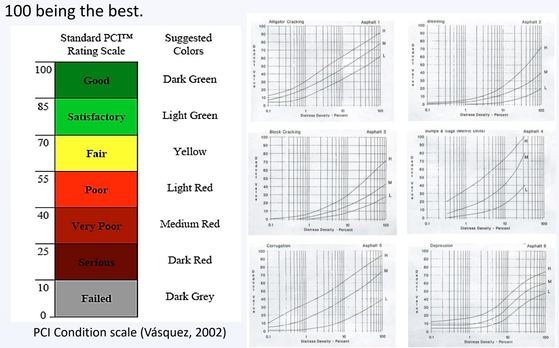
   The practice took place in José Martí Street, located in the north end of Polytechnic University of Puerto Rico, next to the students parking exit. The practice was performed to have a complete understanding on how the PCI method works with the traditional visual inspection. The colored blocks were used to separate the area of study in different numbered units (areas) for more detailed analysis and ease of identification.

By visual inspection of the site the damages to the pavement are identified, located, and measured. This is the data collection necessary for the PCI method to assess the pavement condition. Some of the common faults found in the road are:



Patching Pothole Alligator Cracking

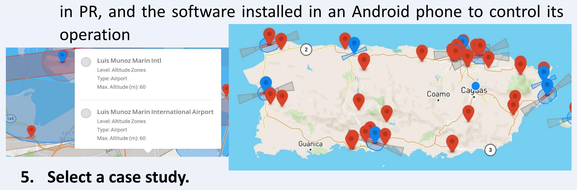
PCI uses a rigorous process that includes formulas, graphs, and calculations which results in a number from 0-100 in the scale shown below. This number determines how good or how bad the road is by 0 being worst and 100 being the best.



PCI Condition scale (Vásquez, 2002)

3. **Evaluate different drone alternatives and software alternatives**
   - The evaluation of drones was performed based on quality of the HD camera, price, and general reviews. DJI Mavic 2 Pro Drone was selected and acquired.

   - The evaluation of software for image processing was performed based on their ability to orthorectify the images and link them to a GIS positioning. Pix4D Photogrammetry Program was selected. A free trail was used.
4. **Study the use, operation, and requirements of drones. Register the Drone in Federal Aviation Administration (FAA) database under Part 107 Regulations**
   - The following images represent the areas of operation of the drone in PR, and the software installed in an Android phone to control its operation



5. **Select a case study.**

   The first case study selected was the San Patricio Avenue. After completion of all the methodology process, a second case was selected on the Eleanor Roosevelt Avenue. Due to COVID-19, the last two stages of the methodology were not implemented in this second case study.

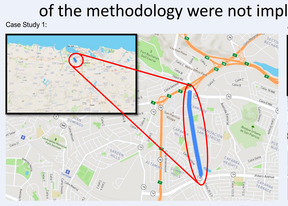
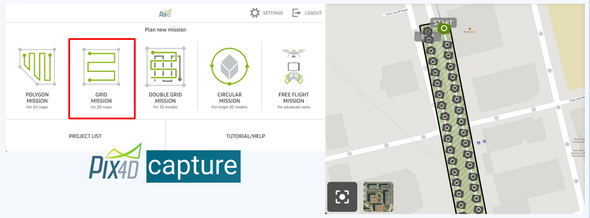


Figure 1: Research Investigation Site - San Patricio Avenue, Guaynabo, PR – Pix4D

Figure 2 Research Investigation Site - Eleanor Roosevelt Avenue, San Juan, PR – Pix4D

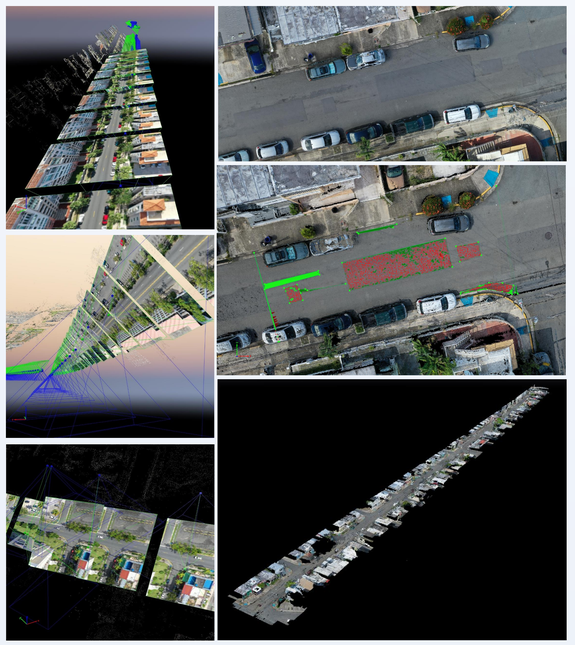
6. **Study how to process images taken by drone and the appropriate computer tools.**
   - **Pix4D Capture** is utilized for flight control of drones which allows the user to program the path they want the drone fly over.
   - **Pix4D Mapper** is a photogrammetry software that is used for professional drone mapping that can produce accurate 3D maps and models, purely from images. It can easily measure surfaces, volumes, areas, distances, and elevation.
7. **Develop a strategy to use drones to collect pavement data.**

   By using Pix4D Capture to give routing and instructions to the drone. The Grid Mission was used:



8. **Evaluate the case study using drone technology.**

   By processing and merging all the pictures taken, a pavement section is created into an Orthorectified mosaic, and each defect can be identified and measured. The software Pix4D mapper was used.



The following image represents a Spatial Digital Surface Model (DSM) for the Orthomosaic process for Case Study 2:

9. **Obtain the evaluation of the case study with traditional ("walk and look") method.**

   Case study 1 was evaluated by Gustavo Albelo, Kevin Gómez, and Jaime Santiago in a special project corresponding to the class CE 3320 in Winter 2019.
10. **Compare results (visual vs aerial) and draw conclusions.**

RESULT ANALYSIS

The following table summarizes the type of defects measured on the images, and the computations performed to obtain the PCI

The final result of the whole process for the two case studies are:

Case Study One	
- The (Aerial) result for Case Study #1:	93.6
- The (Visual) result for Case Study #1:	93.1
= Good Condition	
Case Study Two	
- The (Aerial) result for Case Study #2:	69.9
- The (Visual) result for Case Study #2:	to be determined
= Fair Condition	

CONCLUSIONS

The Pavement Condition Index (PCI) is one of the oldest and most trustworthy ways of evaluating a road condition. The method implies a traditional visual inspection: walk the road, identify, locate, and measure defects. The process may imply interrupting the traffic flow, may possess risks to the operating crew, and requires diverse equipment (such as measuring devices, cameras, security equipment, etc.).

This research successfully implemented an alternative to data gathering, consisting on the use of a drone with HD camera, and image processing software that allows the orthorectification and geo-location of the images. The results of the process were:

- The images had the adequate definition to identify and measure the defects
- The PCI obtained with this method showed an excellent agreement with the PCI obtained by an independent crew using the traditional inspection method.
  - This result leads to infer that this methodology has a great potential to be used as an alternative pavement evaluation procedure.
- The main advantages of the proposed methodology can be summarized as follows:
  - It does not produce traffic flow interruption
  - It reduces risks to personnel, since they do not need to access the road
  - It requires only one person and one equipment (the drone) in the field for data gathering
  - It requires only one person for data processing and PCI computing at home/office
  - It provides the ability to have the route fully documented with HD pictures and have the defects geo-localized
- This type of projects contributes to the establishment of plans and methods that improve infrastructure resilience, extremely appropriate in these times of COVID-19, providing alternatives that warranties social distancing.

RECOMMENDATIONS

- Complete the traditional evaluation of case study 2 by an independent crew, and evaluate if there is a good agreement on the resulting PCI
- Select more case studies, with pavements that lead to other conditions, such as satisfactory, poor, very poor and serious. Compare both results.
- A second stage of the project could be the automatic image processing to determine PCI. This research would imply the development of some kind of expert system.

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