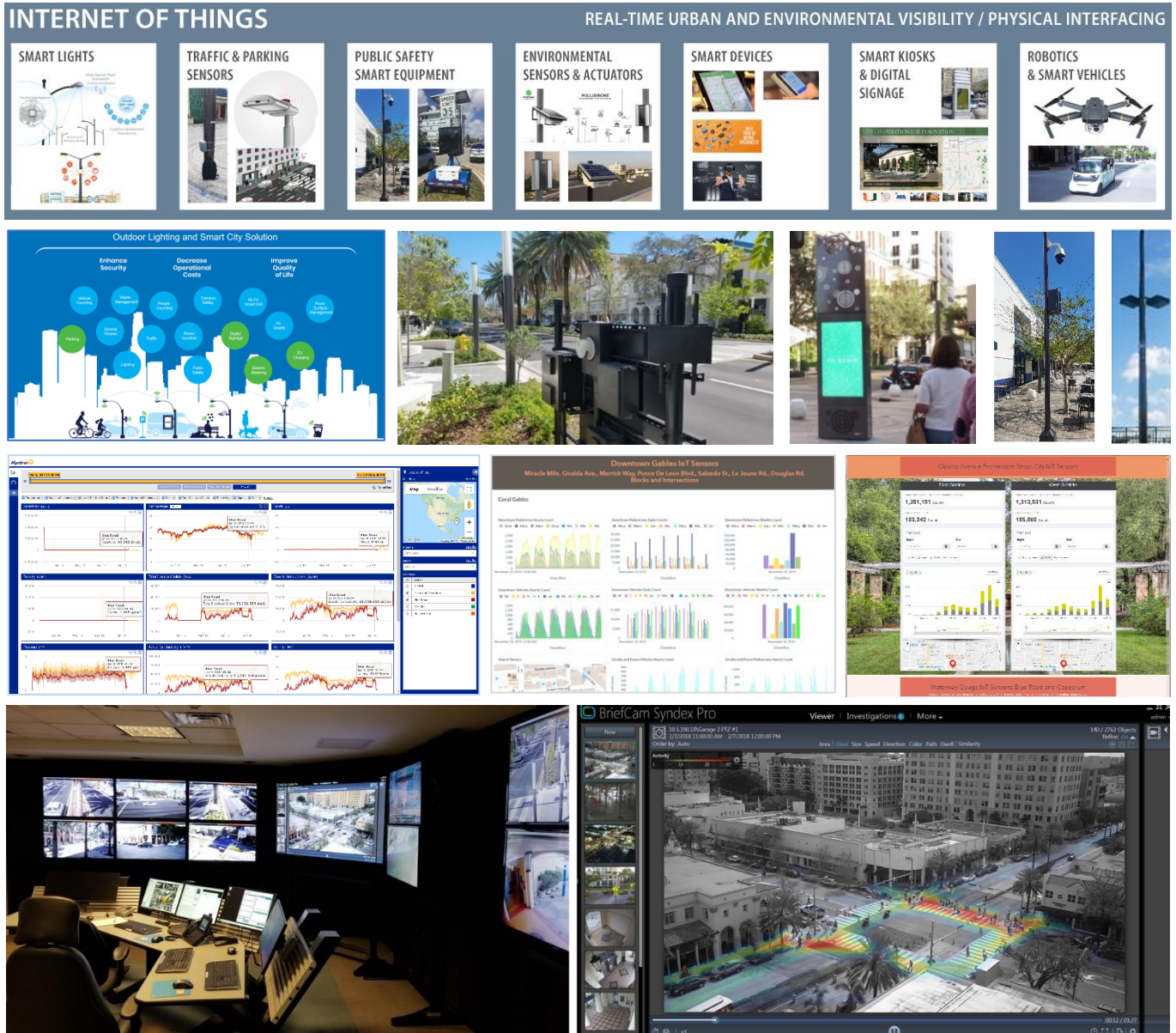




# City of Coral Gables

## Information Technology Department

### Smart City Case Study: City of Coral Gables COVID-19 CPS/IOT Data Analysis



City of Coral Gables CPS/IOT Cyberinfrastructure Use cases

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**Prepared for:** City of Coral Gables, UM IDSC, FIU CEC, NIST GCTC, Data Govs, IEEE, and IISE

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## Smart City Case Study: City of Coral Gables COVID-19 CPS/IOT Data Analysis

### Abstract

The City of Coral Gables, Florida, has implemented a smart city engineering framework that features a diverse array of cyber-physical systems (CPS), internet of things (IOT) platforms and smart connected devices for numerous applications. Real-time IOT data is visualized and presented to the public and all stakeholders for consumption and collaboration via the Coral Gables Smart City Hub public platform. During the COVID-19 pandemic, the gathering and analysis of data from traffic and environmental CPS sensors in Coral Gables provides a visualization of the curves and patterns since the beginning of year 2020 when conditions were still normal in our City, and throughout the crisis phases, from closing to reopening and beyond. Anonymized CPS/IOT data related to this report will be uploaded for further analysis and correlation with other datasets on the City's data processing engines in the cloud and will be submitted to data science research institutes for supercomputer analysis and collaboration purposes.

### Objectives

The objective of this study is to facilitate the observation, analysis and application of CPS/IOT data during the City's response to the Covid-19 pandemic. CPS/IOT data can become an actionable resource during this crisis to help emergency management officers, first responders and public safety personnel with situational awareness and high visibility; help government officials and decisionmakers with insight over current conditions and the effect of policies and response plans; help impacted local businesses improve sales and marketing strategies to stay afloat during the crisis; and help academic researchers conduct pandemic-related studies (environmental, crime, urban, traffic, technology), among many other use cases and benefits for our constituents during the emergency.

### CPS/IOT Use Case Applications Considered for this Study

For our City, CPS/IOT sensors data is strategic and becomes actionable information for staff, stakeholders, and the public in general. Open IOT data aggregated in the Coral Gables smart city hub public platform ([www.coralgables.com/smartcity](http://www.coralgables.com/smartcity)) and private IoT back-end data is studied by university researchers, marketing and city analysts and is actively used by engineers, police and fire officers, entrepreneurs, planners, city officials and other constituents that are part of the smart city ecosystem. IOT systems and data are integrated with citywide enterprise systems and data governance frameworks for efficiency, security, compliance and interoperability.

Some of the City's CPS use cases and applications include traffic sensors (pedestrians, vehicles, bicycles, visitors), RF sensors (traffic behavioral patterns), public safety sensors (ALPR, CCTV cameras, smart policing and street safety devices), environmental sensors (waterways, air quality, noise); smart parking sensors (available/occupied spots detection using computer vision and AI), a street network of smart lighting controllers, smart city digital interactive kiosks, smart building structural health monitoring sensors, telemetry SCADA sensors and actuators, drones, smart fleet management systems, mobile LiDAR photonics and connected vehicles, among other uses.

For the purpose of this Covid-19 CPS study, the following CPS data will be gathered and analyzed:

- Traffic Sensors Data: pedestrian, visitors and vehicle traffic data gathered from various IOT platforms, connected mobility, and street sensors (Page 3).
- Environmental Sensors Data: water quality sensors (buoys) located on City canals and waterways. Additionally, air quality sensor data and noise sensor data are currently in the process of being integrated into the IOT data platform and will be available soon for upcoming studies (Page 14).
- Energy Sensors Data: energy consumption data dashboards from the City's smart light controllers IOT network, and from Florida Power & Light smart meters. Water consumption data dashboards from Miami-Dade Water & Sewer (WASD) smart meters will be added to future studies (Page 17).

## Coral Gables Covid-19 CPS/IOT Data Analysis:

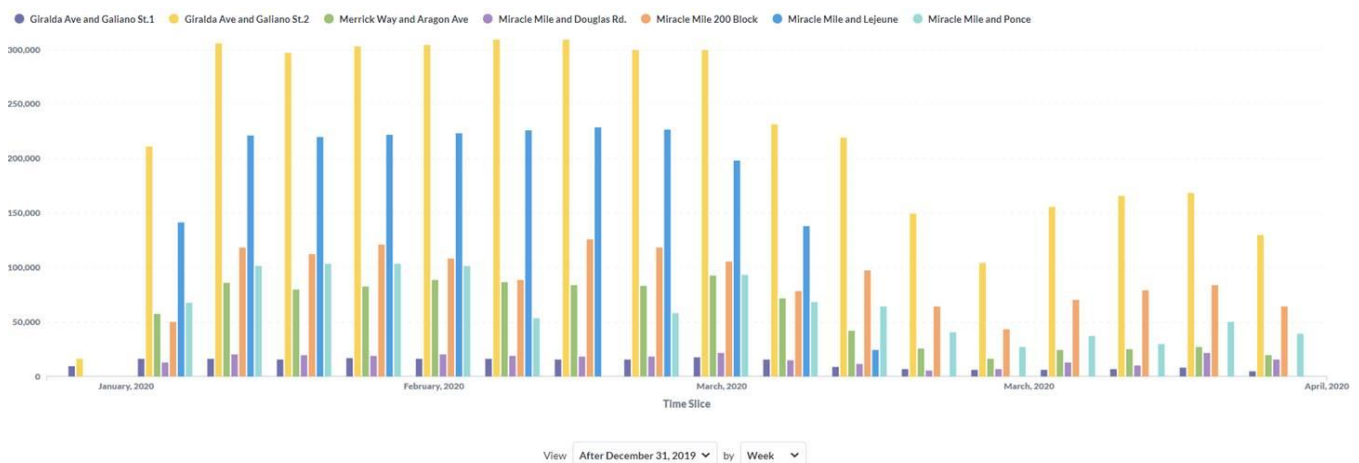
### Traffic Sensors Data:

The City has deployed multiple IOT sensors in Downtown, City limits, critical sites, major arteries, and other Coral Gables areas. Our traffic sensors report vehicle, visitors and pedestrian traffic data in real time from several locations and in multiple directions, including all major blocks and intersections. Smart district applications use various technologies and methodologies such as edge computing, computer vision, laser counters, server analytics, AI/ML, mobile trailers, 360° HD/4K cameras, and other tools. Other sensors such as geofence CPS, CCTV systems, Waze CCP network, speed sensors, Wi-Fi smart mesh networks and RF sensors also provide traffic pattern detection and behavioral analytics, which has been incorporated to this study in various capacity.

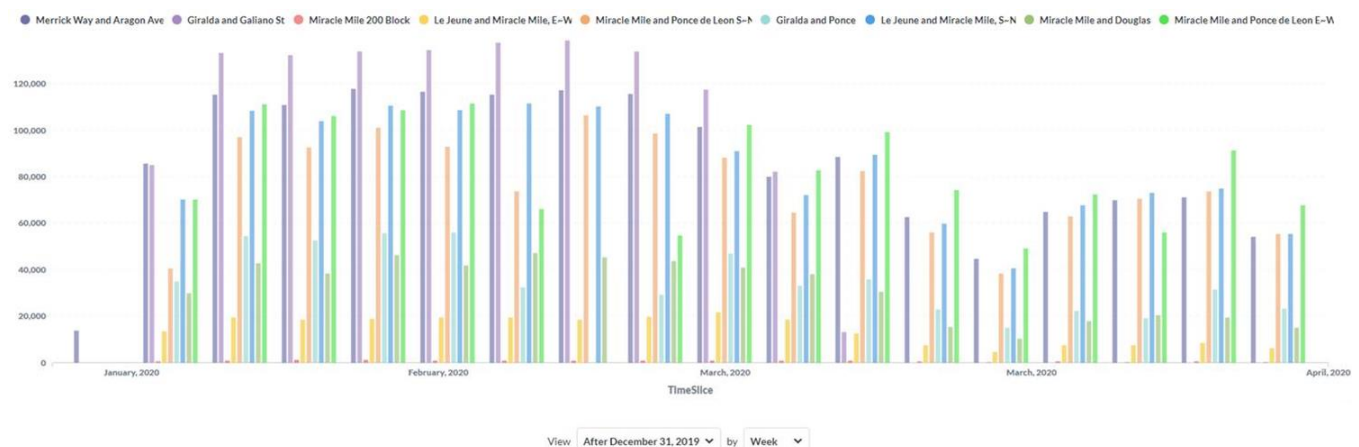
The IoT traffic sensor dashboards are available to the public on the Coral Gables smart city hub platform under the Internet of Things section of the portal. The following graphics show the effect of the pandemic on traffic in different areas and arteries of the City, including the Downtown smart district and major arteries in the geofence:

- **CPS/IOT Sensors:** traffic optical sensors, smart lighting controllers, edge analytics and computer vision. Video analytics, AI and ML for detection/classification/counting processing.
- **Source:** IOT Platforms (Cisco CKC, Quantella analytics, intuVision) and Coral Gables Smart City Hub
- **Data collection period:** 1/1/2020 to 5/1/2020

### Downtown Pedestrian Counts by week



### Downtown Vehicle Counts by week

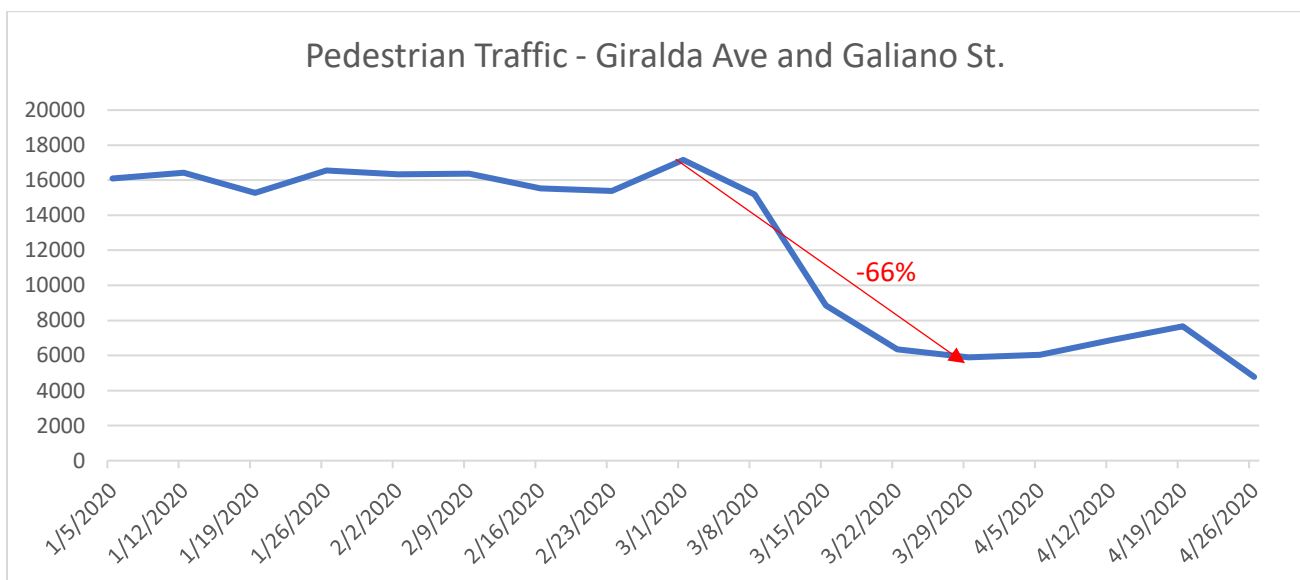
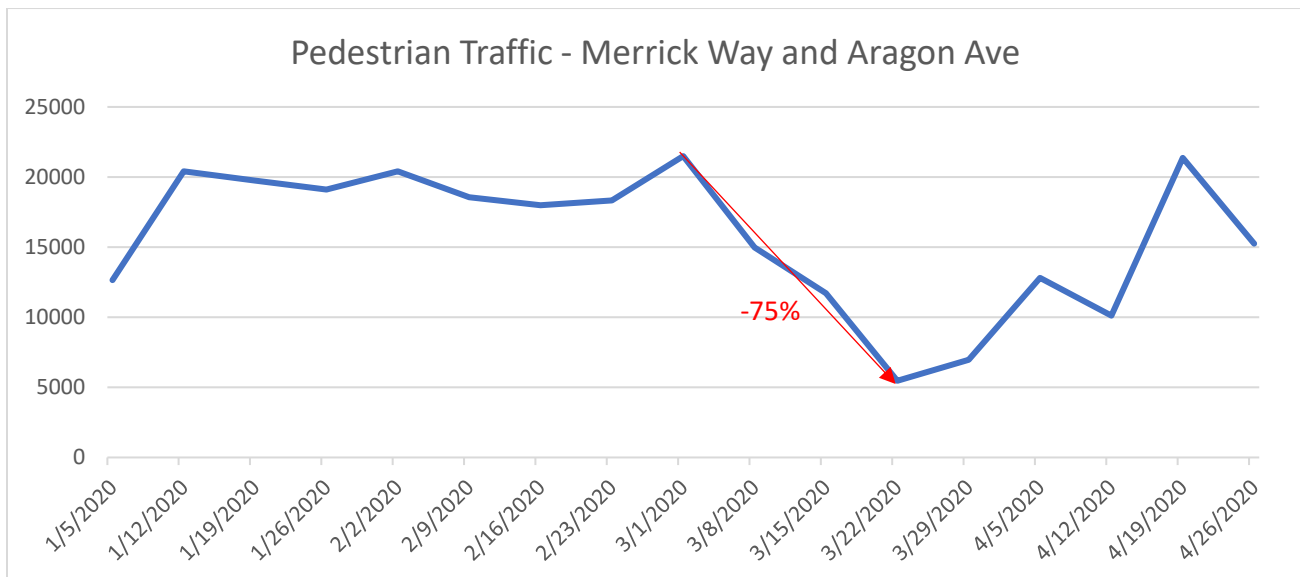


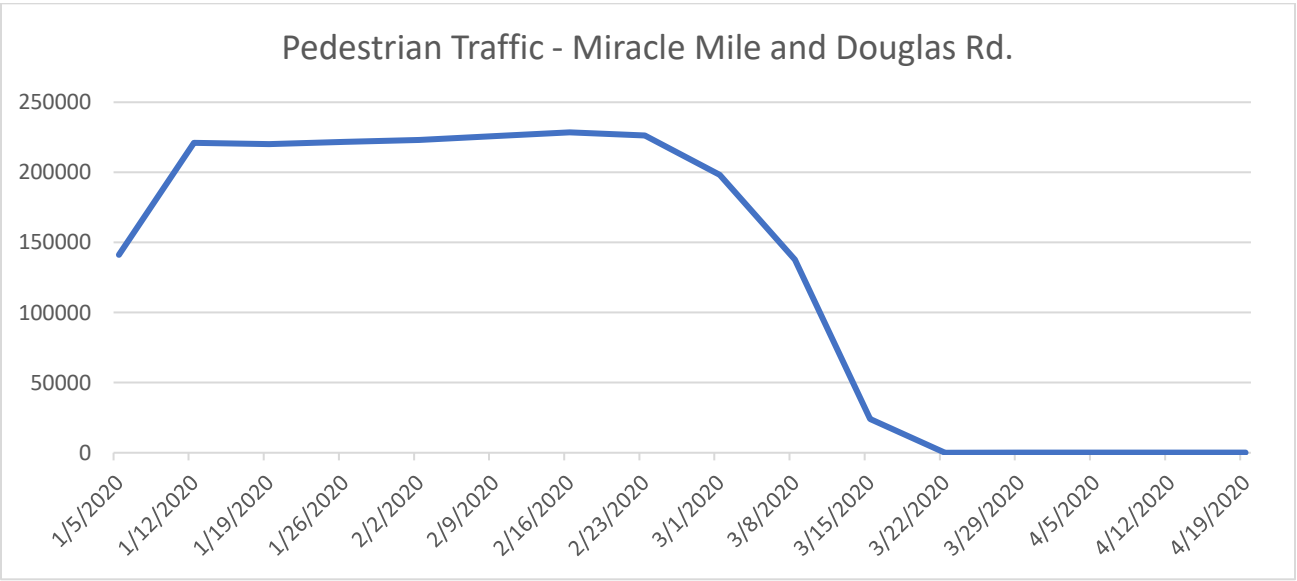
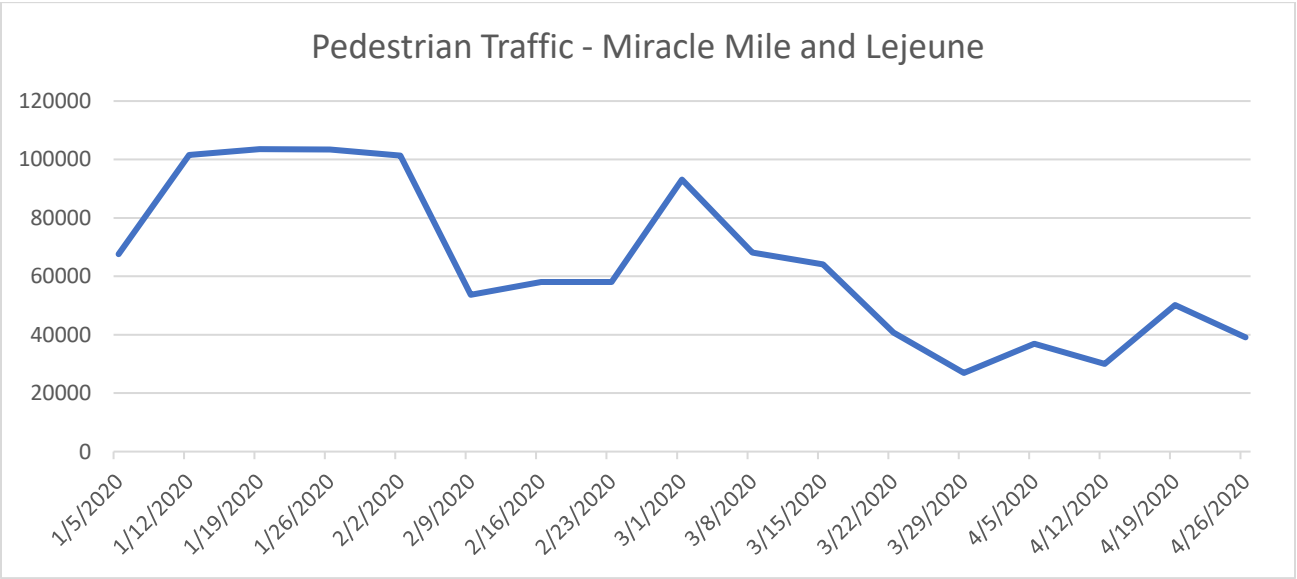
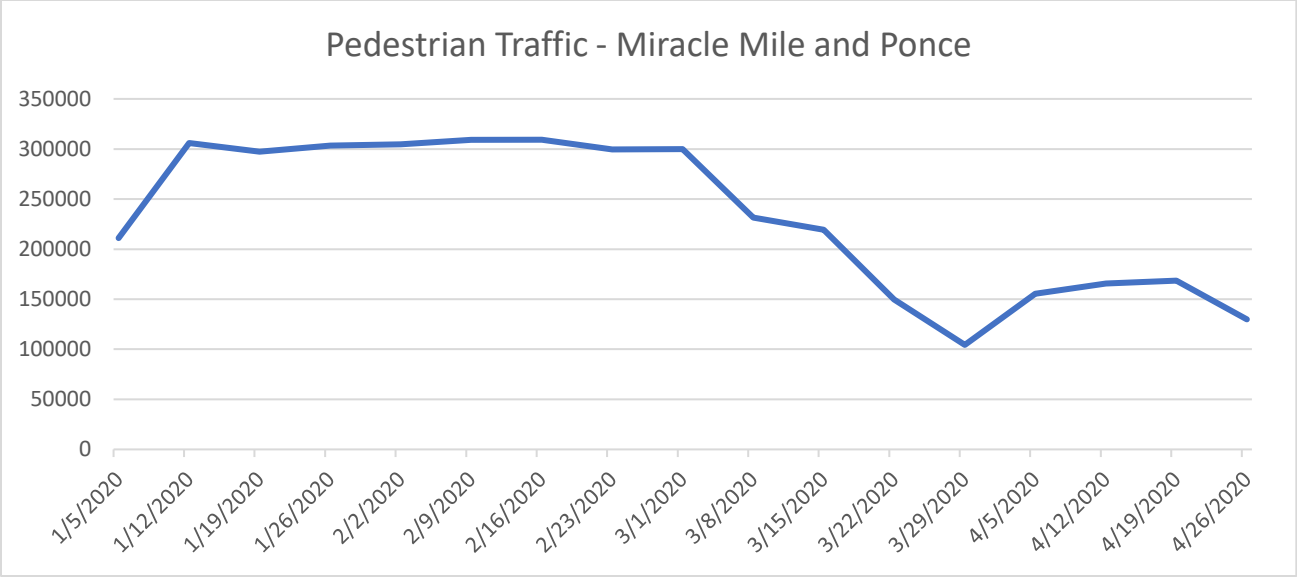
As shown in the above charts, the lowest traffic on all categories and all points of observation during this period occurred consistently during the last week of March 2020. The curves for vehicle traffic show a steadier behavior throughout the month of April (while pedestrian traffic trends down significantly in the last week of April).

Proposed next steps: further analysis of this data (not part in this study) could include the exercise of overlaying on these charts a timeline of events related to the policies implemented by the City of Coral Gables, Miami-Dade County, the State of Florida and the federal government to control traffic and enforce social distancing and other safety measures throughout the different phases of the pandemic.

#### **Pedestrian traffic charts by IOT endpoint node:**

For pedestrian traffic, a steady linear decline is observed throughout the month of March (approximately 70% decline in average), followed by a steady increase trend during the first part of April (in some areas reaching values close to normal in the third week of April), followed by a sharp decline starting in the last week of April, as shown in the analysis charts below.



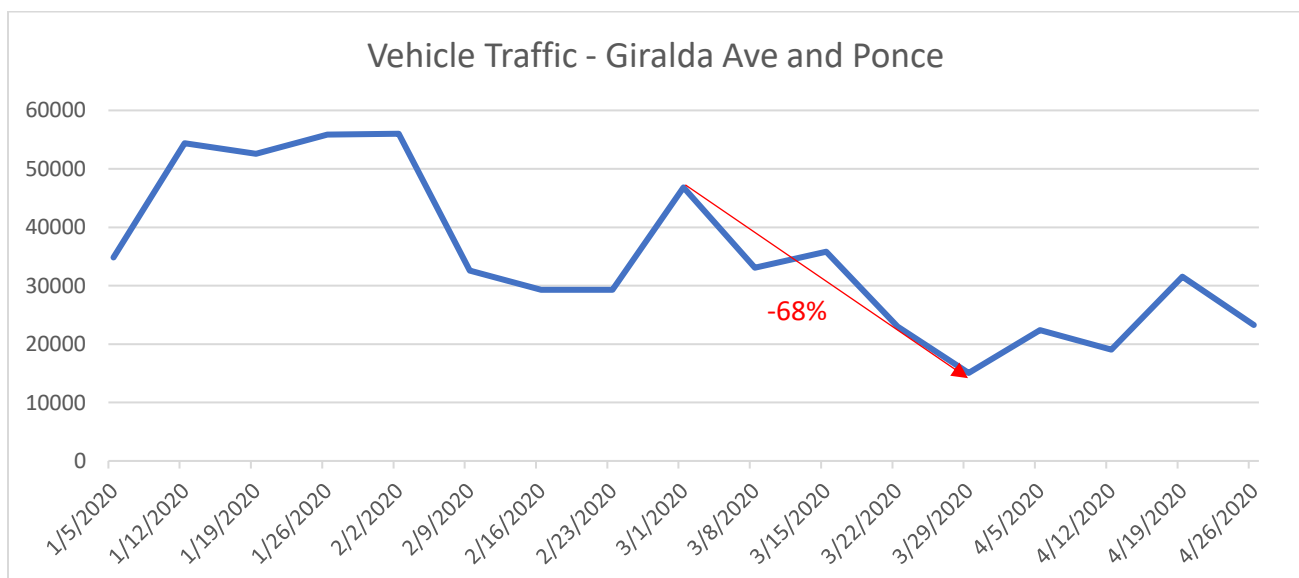
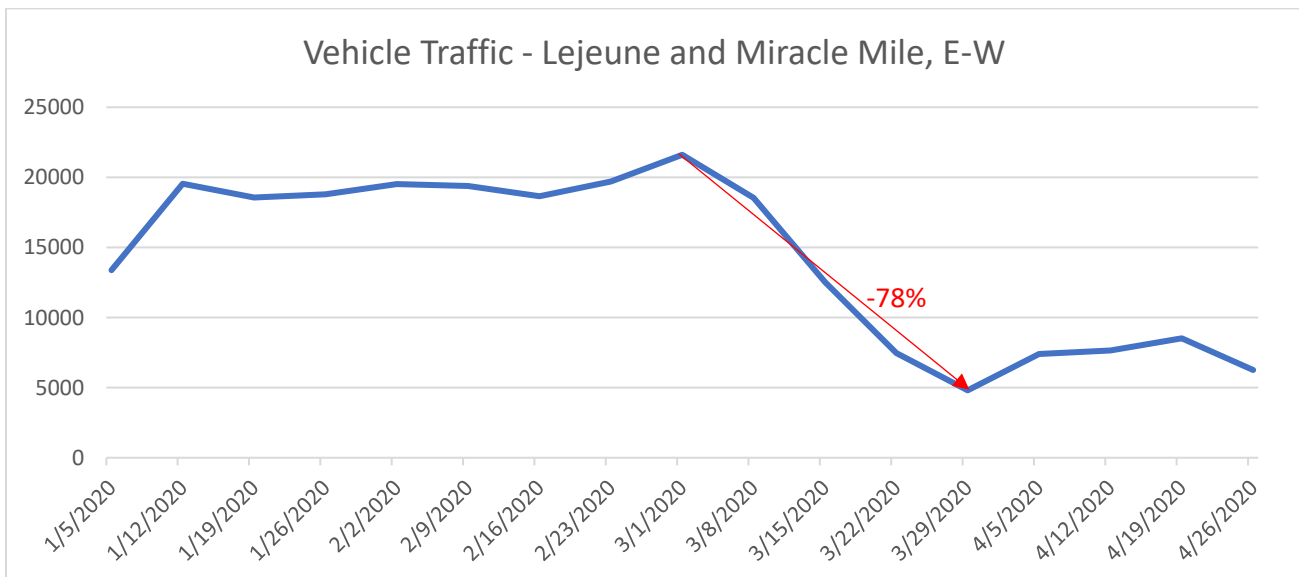


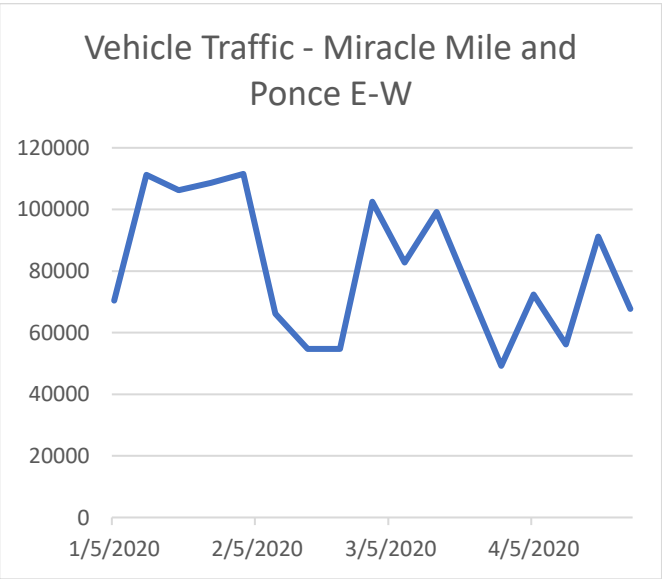
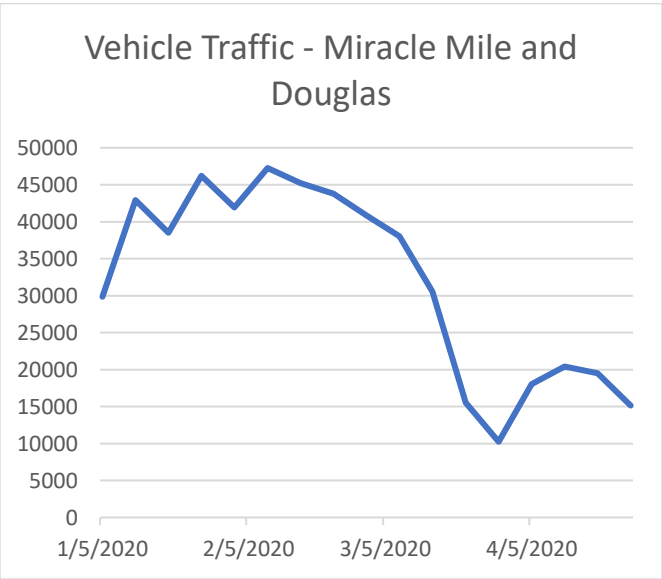
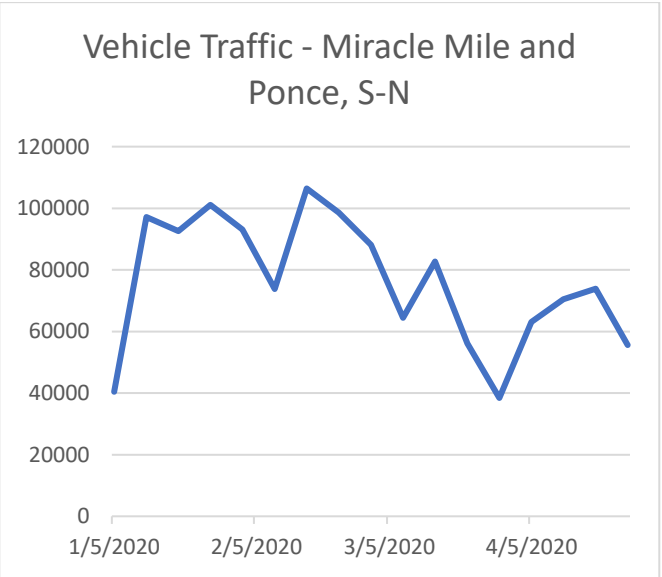
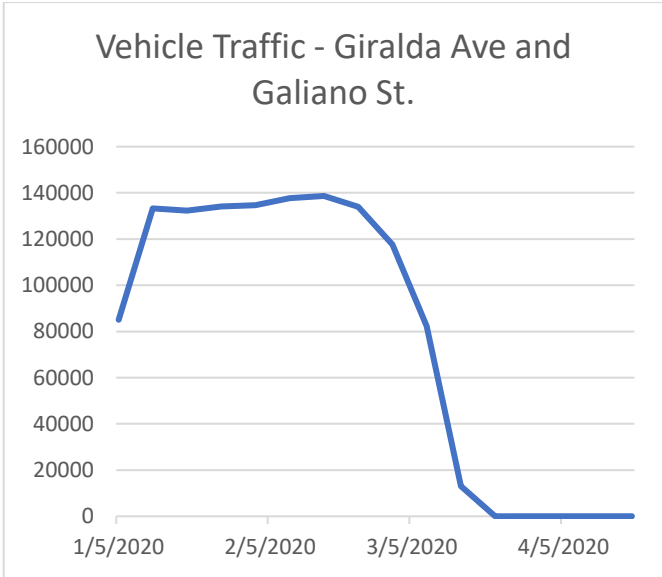
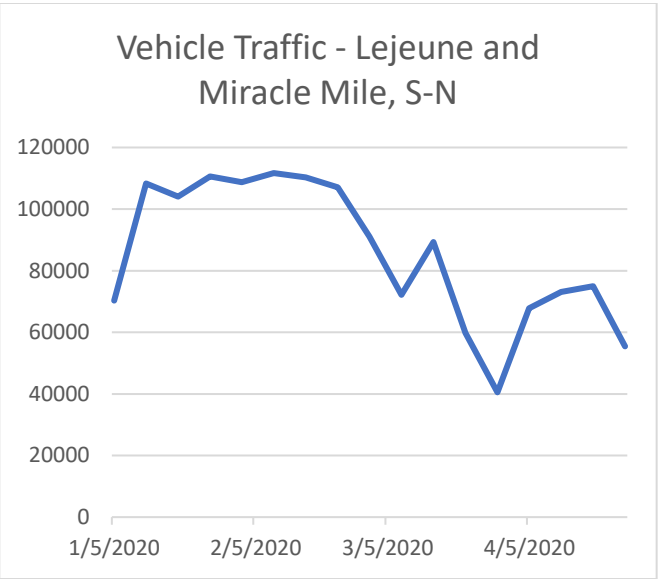
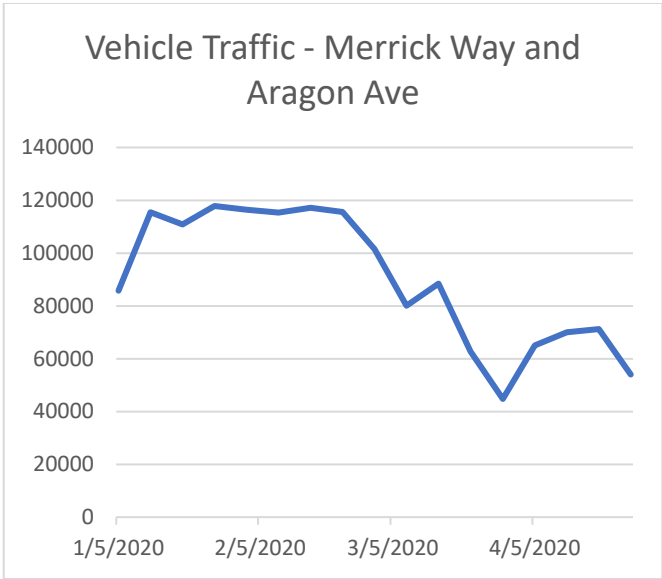


**Vehicle traffic charts by IOT endpoint node:**

For vehicle traffic, a steady linear decline is observed throughout the month of March (approximately 70% decline in average), followed by a steady increase trend during the first part of April (in some areas reaching values close to normal in the third week of April), followed by a slow decline starting in the last week of April, as shown in the analysis charts below.

Proposed next steps: further analysis of this data (not part in this study) could include the exercise of overlaying data from the air quality sensors located in Downtown, to also show a correlation between vehicle traffic variations and carbon emissions and pollutants in the air (CO, CO<sub>2</sub>, PPM, VOC) during the pandemic. Also, an overlay of multimodal transportation data on bicycles and micromobility (scooters, etc.) could add a more complete picture on traffic. And, as mentioned previously in this study, overlaying on these charts a timeline of events related to the policies implemented by the City of Coral Gables, Miami-Dade County, the State of Florida and the federal government to control traffic and enforce social distancing and other safety measures throughout the different phases of the pandemic.

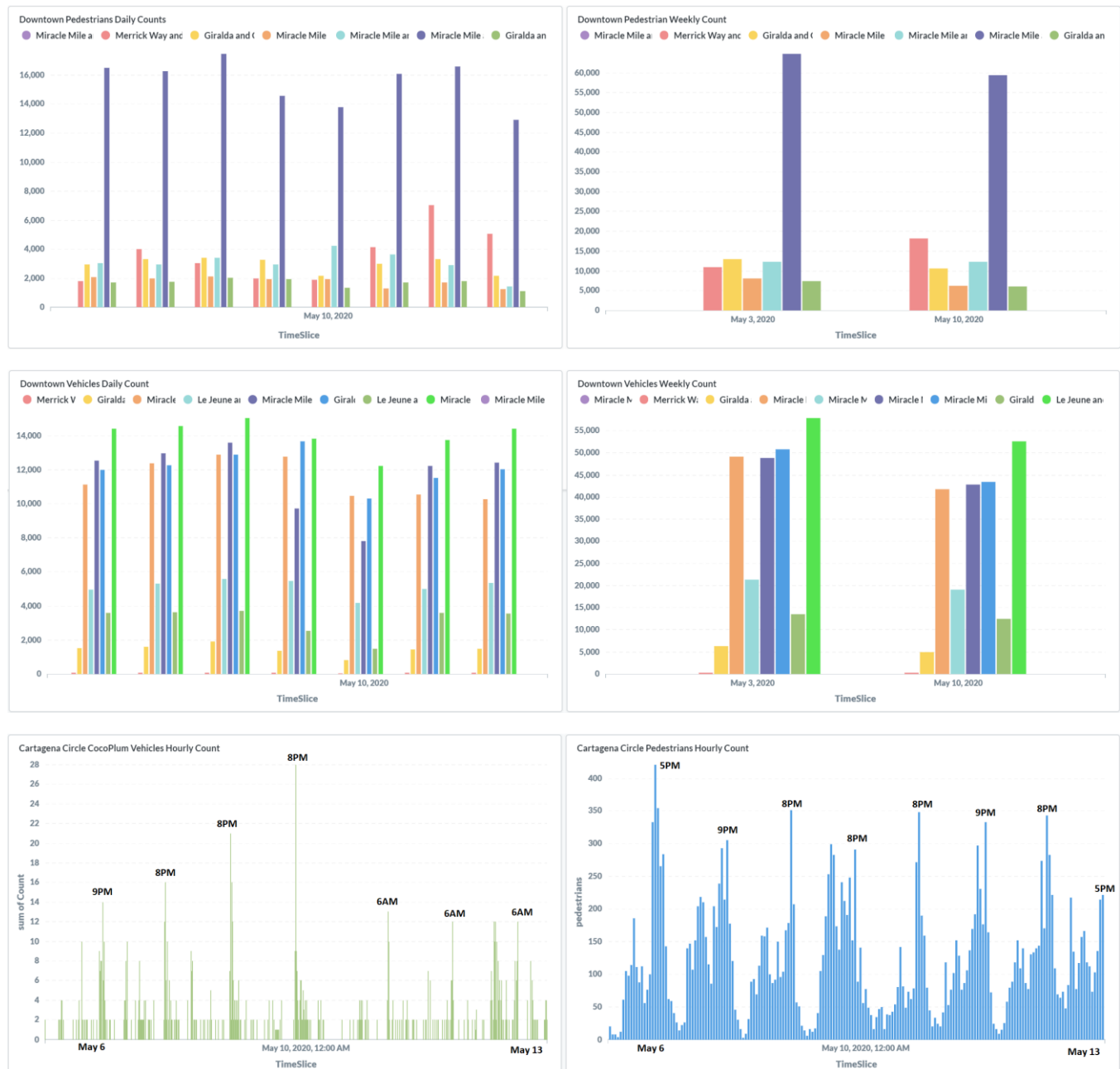




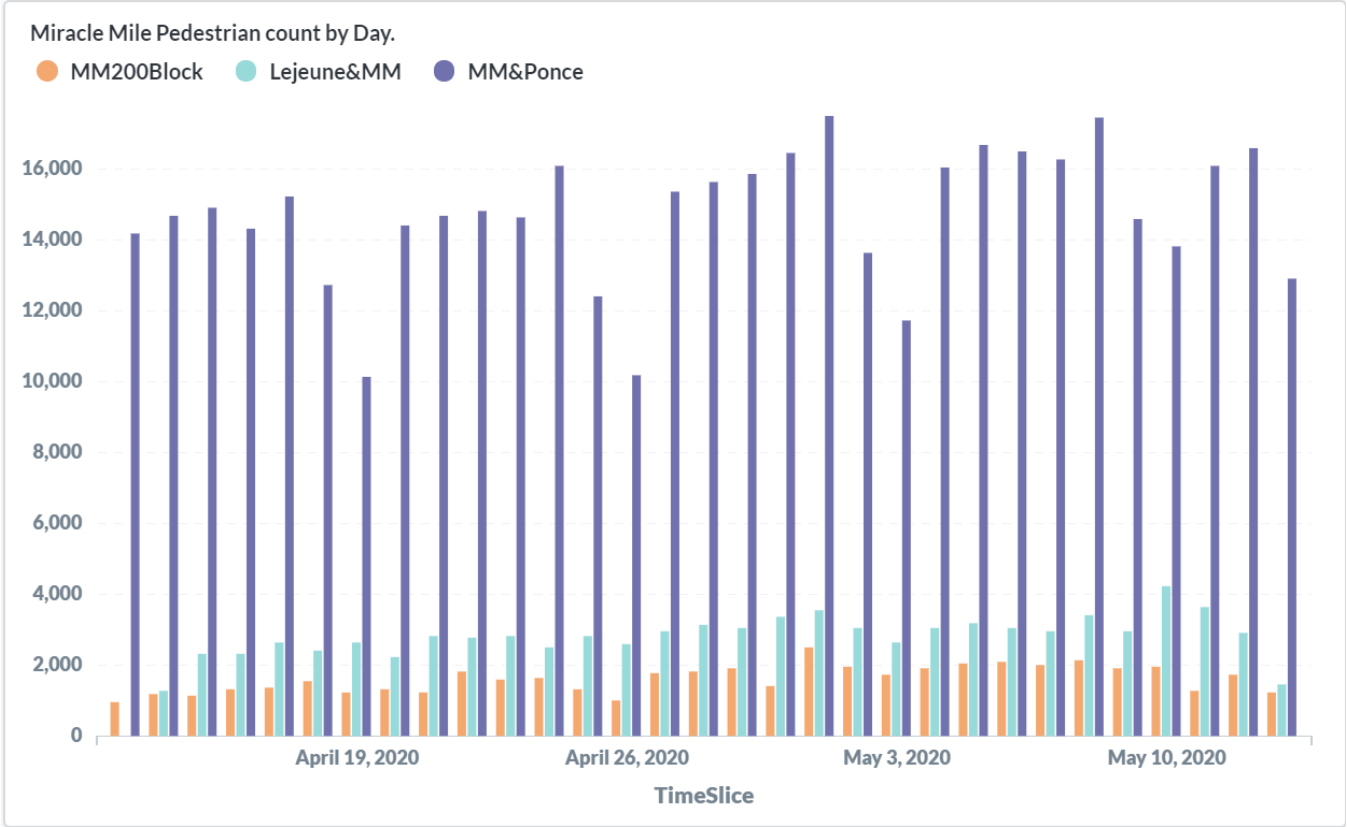
The following charts are focused on the month of April (showing the preceding last week of March, with the lowest traffic of the decrease trend). They show a more gradual traffic increase in April for pedestrians than vehicles, and similar weekly cyclical patterns (in shape, not numbers) than historic trends before the pandemic: lowest traffic on weekends, highest traffic on Friday, etc.

Also, In the Cartagena Circle Cocoplum residential area, hourly traffic counts in the second week of May show higher vehicle traffic in the early morning (~6 AM), versus higher pedestrian traffic in the late evening (~8 PM).

- **CPS/IOT Sensors:** traffic optical sensors, smart lighting controllers, edge analytics and computer vision. Video analytics, AI and ML for detection/classification/counting processing.
- **Source:** IOT Platforms (Cisco CKC, Quantella analytics, intuVision) and Coral Gables Smart City Hub
- **Data collection period:** 3/22/2020 to 5/1/2020





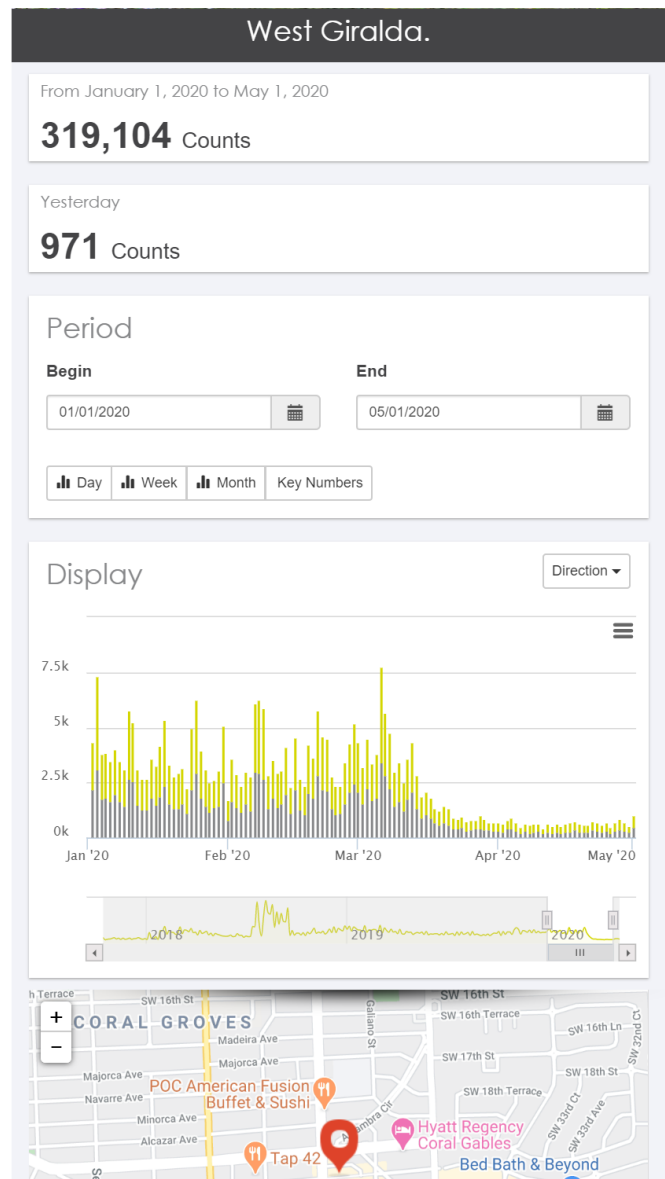
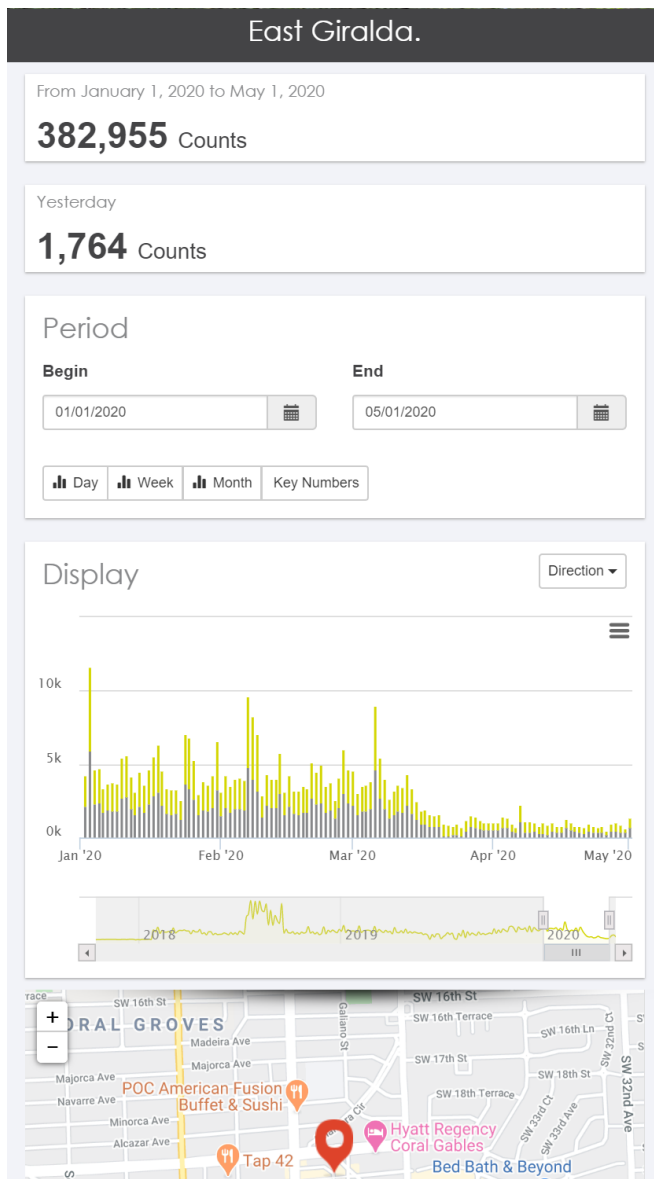


**Foot traffic counters data from pedestrian-only area in Downtown:**

The data from pedestrian counters (laser counters) at Giralda Plaza in Downtown (a pedestrian-only area) show similar trends in March (a steady quasi-linear decrease), but do not show an increase in April like the IOT sensors in other areas of Downtown show. The foot traffic metrics from these counters remain very low (less than 1,000 counts per day in average) in both the East side (Galiano intersection) and the West side (Ponce intersection) of the Giralda promenade. Since Giralda Plaza is a small business corridor with mostly restaurants and bars, this traffic is also related to the reduction of opening hours or closure by these businesses during the pandemic.

Proposed next steps: a more in-depth data analysis could include overlaying a timeline of business-related events in the City during the pandemic and a layer of business-related data from the City's enterprise systems (licensing, permits, real estate, etc.) and from local business organizations (Chamber, BID, MDBC).

- **CPS/IOT Sensors:** Pedestrian laser counters on Giralda Plaza (Downtown)
- **Source:** IOT Platform (EcoCounter) and Coral Gables Smart City Hub
- **Data collection period:** 1/1/2020 to 5/1/2020



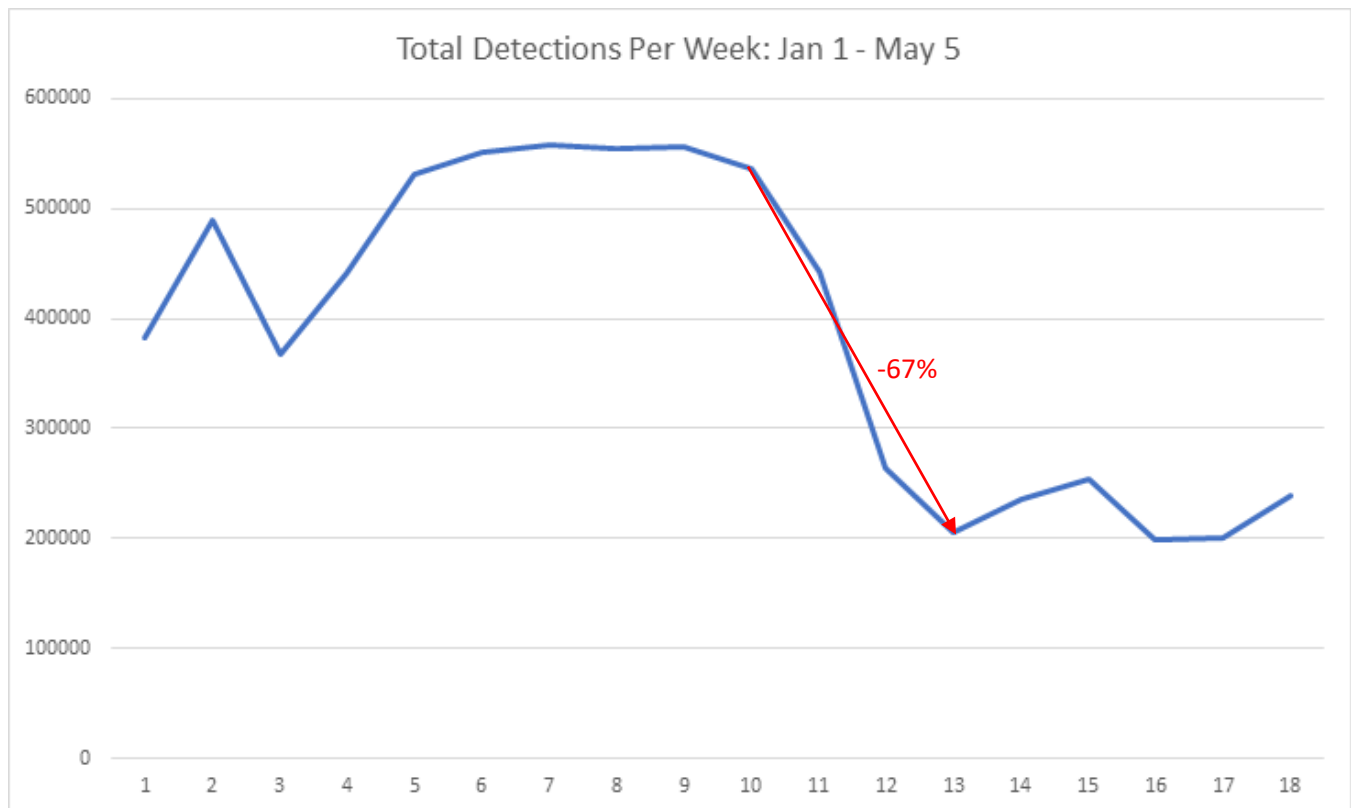
### Geofence vehicle traffic analysis:

This traffic data comes from geofence sensors and cameras located in City limits and major arteries such as US-1 (highway), Bird Road, Red Road, and 8<sup>th</sup> Street, among other locations. The trends shown in the chart are consistent with the ones observed in data charts from Downtown and Cocoplum sensors (analyzed above in this study), i.e.: *i.* the lowest traffic on all points of observation during this period occurred consistently during the last week of March 2020; and *ii.* through the entire month of March, the total geofence traffic decreased to approximately 67% of its normal values from February of this year.

Like Downtown, the curves for vehicle traffic show an upward trend at the beginning of April, but a second valley and a second peak are observed in the second and last week of April, respectively. Since Coral Gables is in the middle of the County and absorbs a big volume of transient traffic, this trend may also reflect Countywide factors and events outside of the City, such as Covid-related emergency management, academic activities, business and healthcare-driven traffic, public transportation, and resident traffic from other cities and zones in the counties, as well as inter-county traffic.

Proposed next steps: further analysis of this data could include overlaying a timeline of Covid-related Miami-Dade County and State of Florida events, enacted and enforced emergency policies, curfews and restrictions, and other safety measures; as well as overlaying countywide data layers, University of Miami and FDOT data layers. Additionally, since these analyses come from higher traffic density areas, a correlation with public safety data (crime, accidents, crashes) and environmental impact data such as air quality measurements (CO/CO<sub>2</sub>, PPM) would add value and insight to this analysis (for further analysis by data science academic/research institutions.)

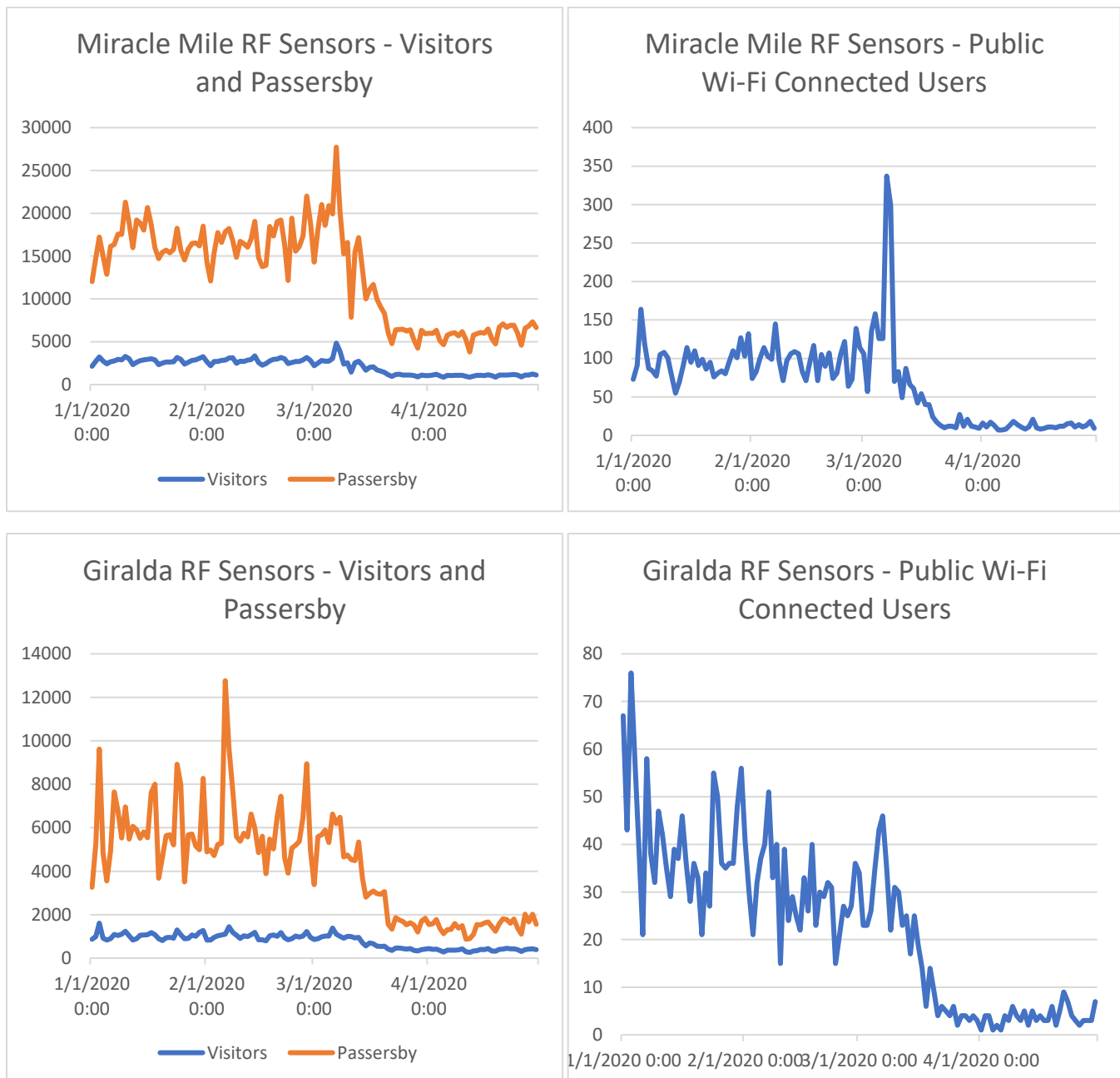
- **CPS/IOT Sensors:** Geofence sensors/cameras in City limits and major arteries (US-1, Bird Rd, Red Rd, 8<sup>th</sup> St...)
- **Source:** IOT Platforms (Geofence CPS analytics)
- **Data collection period:** 1/1/2020 to 5/1/2020



### Traffic and behavioral data:

This data is gathered from the City's metropolitan Wi-Fi smart mesh networks and RF Sensors in Downtown. The trends shown in these charts are consistent with the ones observed in other data charts from Downtown and Cocoplum traffic sensors (analyzed above in this study) in the sense that they show a sharp decrease in traffic during the month of March; however, there are a couple notable differences: *i.* a steadier low count level during the entire month of April, and *ii.* a high-peak outlier in the second week of March (most likely due to the Carnival on the Mile event).

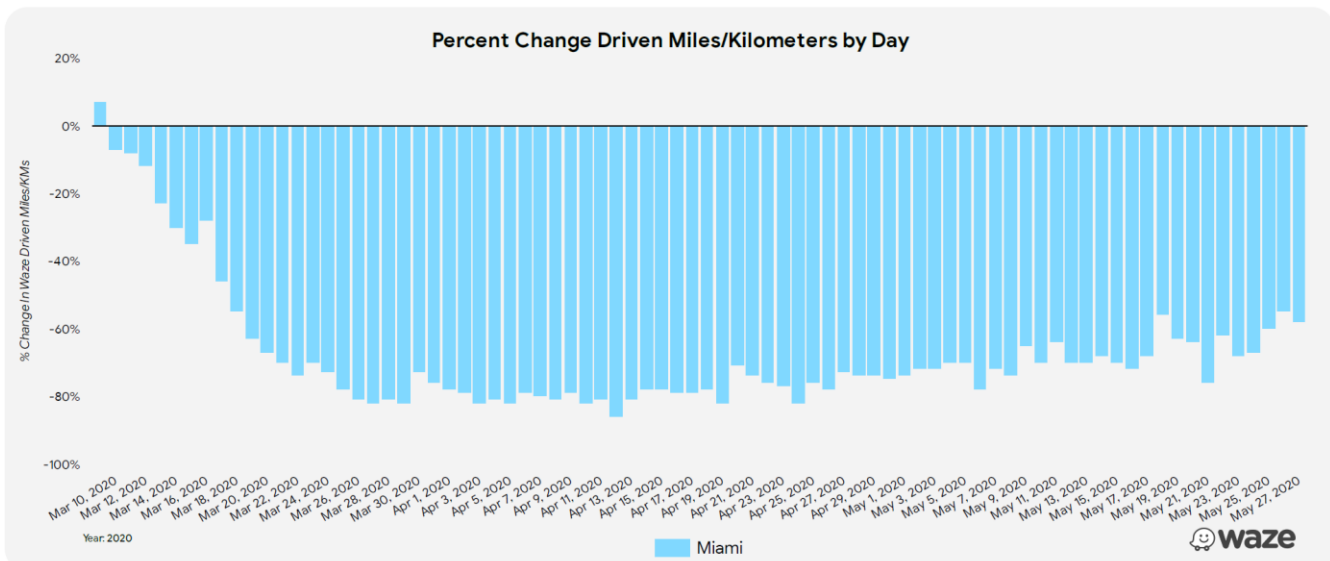
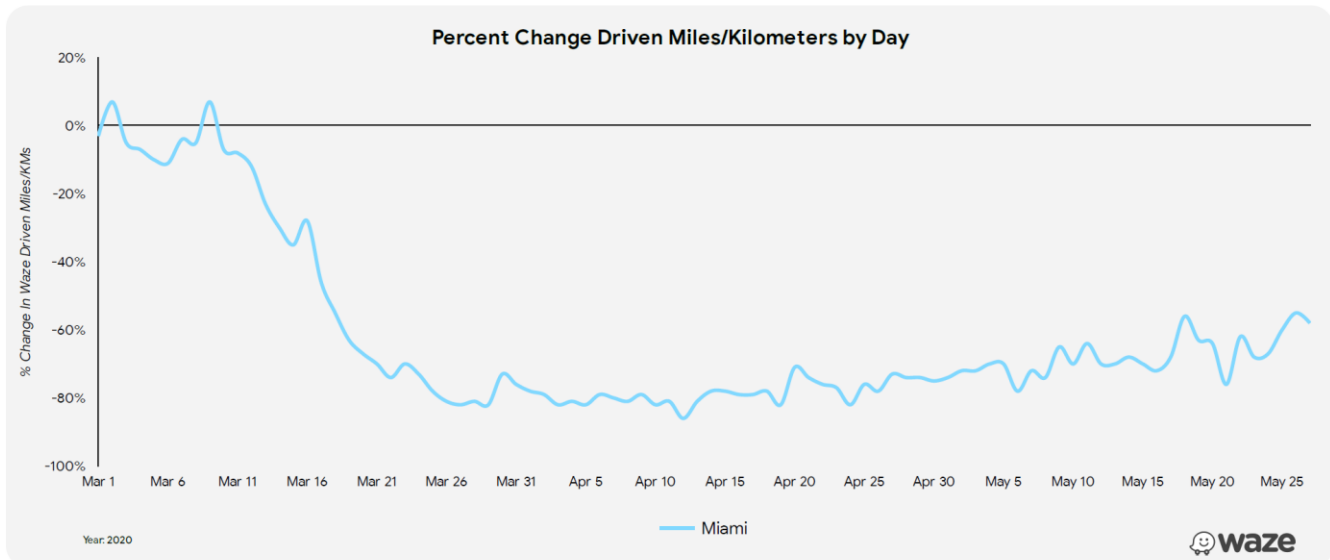
- **CPS/IOT Sensors:** City RF Sensors and smart metropolitan Wi-Fi mesh networks in Downtown.
- **Source:** IOT and Network Management Platforms (Cisco CKC and Cisco Meraki)
- **Data collection period:** 1/1/2020 to 5/1/2020



### Connected mobility data:

This data is gathered from the City's Waze Connected Citizens Partnership (CCP) situational awareness dashboard in the smart city hub platform, and from County-level data of COVID-19 Impact from the Waze CCP program. The trends shown in these charts are consistent with the ones observed in data charts from Geofence, Downtown and Cocoplum sensors (analyzed above in this study); however, they show a deeper change in numbers during the lockdown (approximately 10% lower). Through the entire month of March, the percent of driven miles per day decreased approximately 80% of its normal values from February of this year (v. ~70% of traffic reduction in Coral Gables). A quasi-linear slow increase is shown over the month of April from ~-80% to -70%, followed by a similar increase during the month of May from ~-70% to -60%. Note that these CCP statistics are County-wide (v. other hyperlocal data from Coral Gables analyzed in this report) and reflect trip data and other traffic behavioral factors.

- **CPS/IOT Sensors:** Connected mobility network of Waze app users driving in our region.
- **Source:** CCP Connected Mobility Platform (Waze CCP)
- **Data collection period:** 3/1/2020 to 5/27/2020



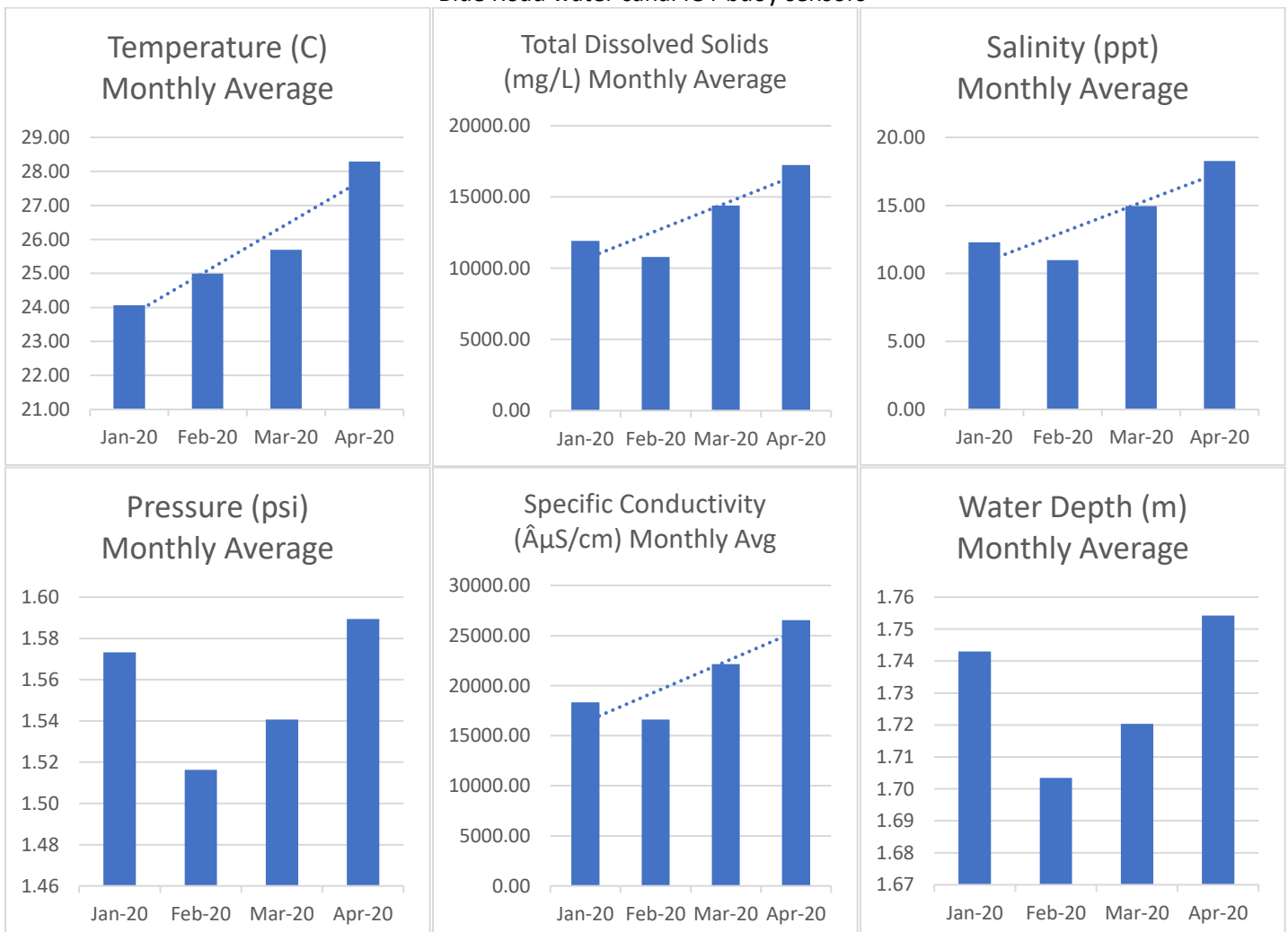
**Environmental Sensors Data:**

The City deployed in collaboration with Florida International University (FIU) researchers multiple buoy sensors in the City's main water canals. Real-time waterway sensor data includes salinity, resistivity, conductivity, depth (flooding detection), density, pressure, temperature, dissolved oxygen, and other valuable data. Air quality environmental sensors are also installed in Downtown Coral Gables (now expanding to major traffic arteries in the City) measuring air quality data including carbon emissions (CO/CO<sub>2</sub>) and air pollutants (PPM, VOC). Also, noise sensors measure dBs in Downtown and will be deployed in various smart light nodes of the public safety geofence. The IoT water sensor dashboards are available to the public on the Coral Gables smart city hub platform.

The following graphics show the evolution of water quality and level parameters in different canals and waterways of the City. A constant increase in the monthly average values of density, salinity and conductivity is observed starting in the month of February, which is related to seasonal climate conditions (see temperature chart). Since confound effects of climatological variables make difficult correlating this data with Covid-related factors, this study also shows a comparison between water quality measures from Jan-Apr 2019 (control) and Jan-Apr 2020.

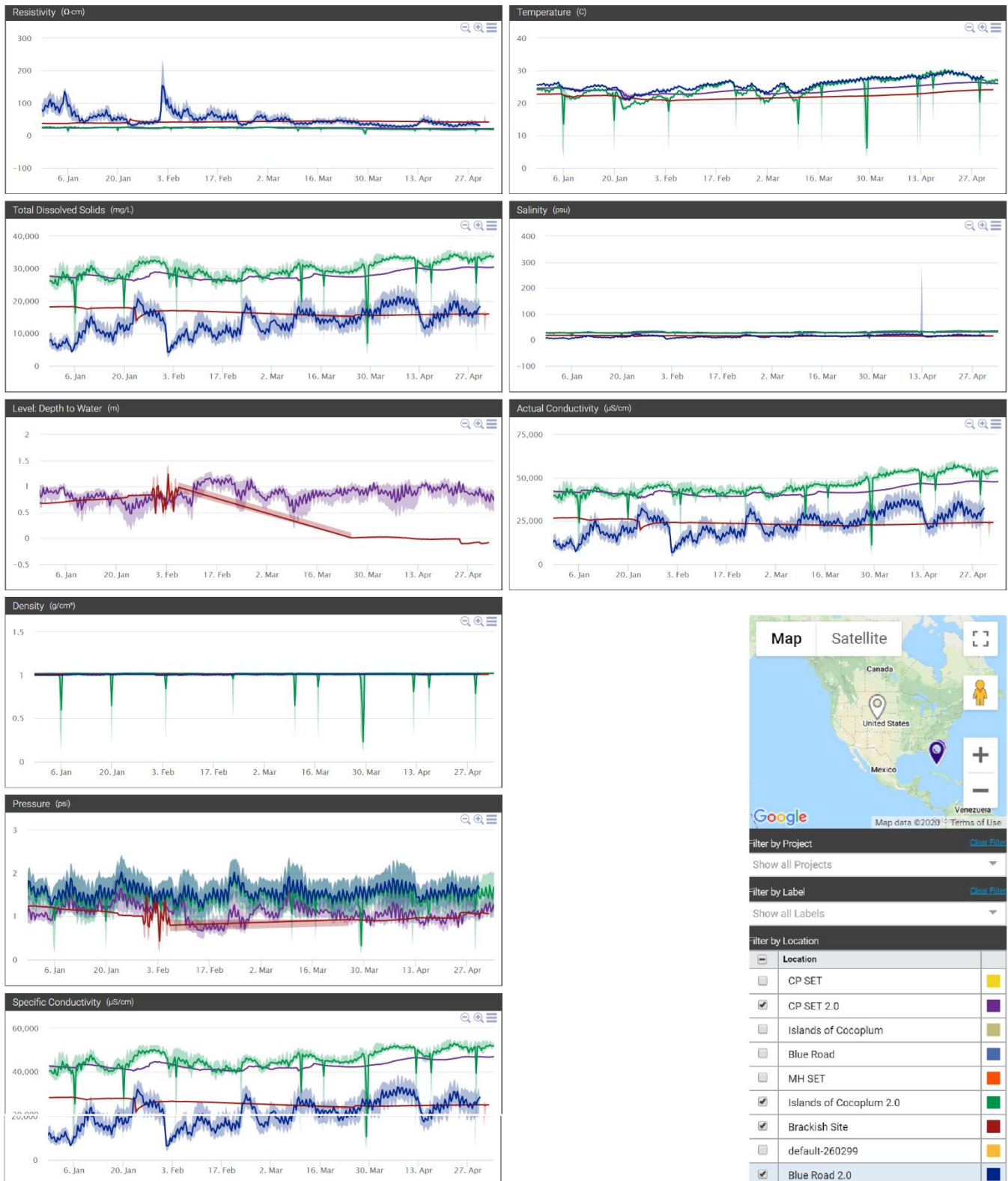
- **CPS/IOT Sensors:** IOT buoys on various canals and waterways in Coral Gables
- **Source:** Water IOT platform (HidroVU, FIU Environmental Research Center) and Coral Gables Smart City Hub
- **Data collection period:** 1/1/2020 to 4/30/2020

Blue Road water canal IOT buoy sensors





The following graphics visualize buoy sensor data throughout year 2020 from four waterway locations in Coral Gables, two in Cocoplum, one in Matheson Hammock park and one in Blue Road canals. Even though the level values of the water quality parameters vary from location to location, the chemical parameters follow similar curves in all four waterways:

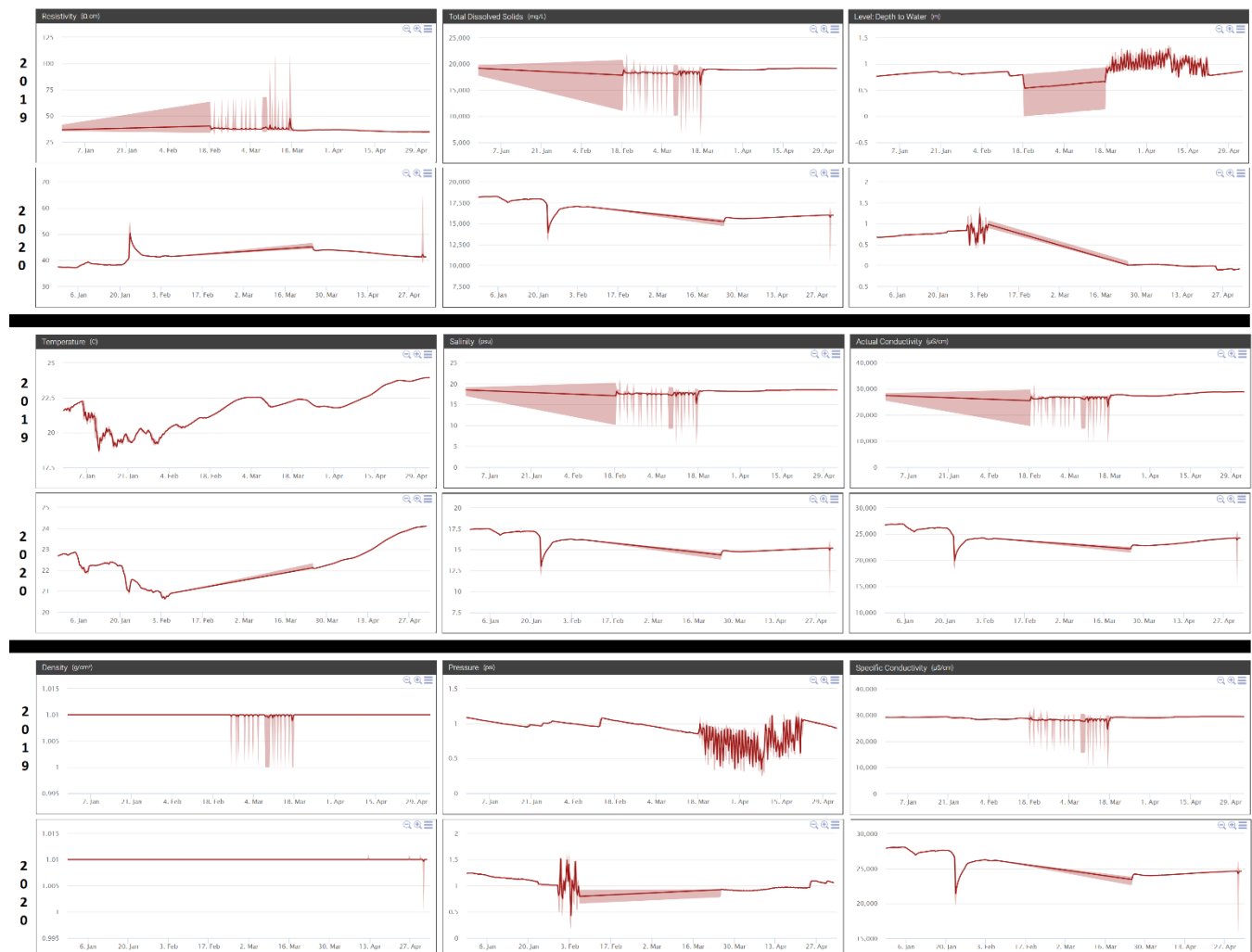


The following charts show a comparison between water quality measures from Jan-Apr 2019 (control) and Jan-Apr 2020 in one of the four measurement locations. Many differences are evident in the curves of water chemical and electrochemical parameters such as dissolved solids, density, salinity and conductivity (approximately 10% lower in 2020 than 2019 and showing a particular downward trend in February 2020 that didn't occur in 2019).

The graphics below show a ten percent improvement in water quality (cleaner) at this time from 2019 to 2020. Since confound effects of climatological variables and periodical sensor accuracy and calibration changes make very difficult correlating this data with Covid-driven factors, we can't directly infer a potential relationship between the abovementioned differences and the Covid-19 pandemic in 2020 (see for example the slight differences in water temperature, pressure, and water level between those two years over the same months.)

Proposed next steps: further analysis of this data could include overlaying a timeline of Covid-related events in Coral Gables, Miami-Dade County and the State of Florida, enacted and enforced emergency policies and restrictions, and other safety measures; as well as overlaying countywide relevant data layers. Additionally, a geospatial analysis correlating these parameters with County utility data on water consumption (from the Water and Sewer department), with City of Coral Gables SCADA telemetry data from water flow gates and pumps; and with sea level data (tidal events and other oceanic and coastal data), UM marine biology research data, as well as meteorological data such as rain and weather metrics from environmental IOT stations in the proximity of the waterways (for further analysis by data science academic/research institutions.)

#### Comparison between water quality measures from Jan-Apr 2019 (control) and Jan-Apr 2020:

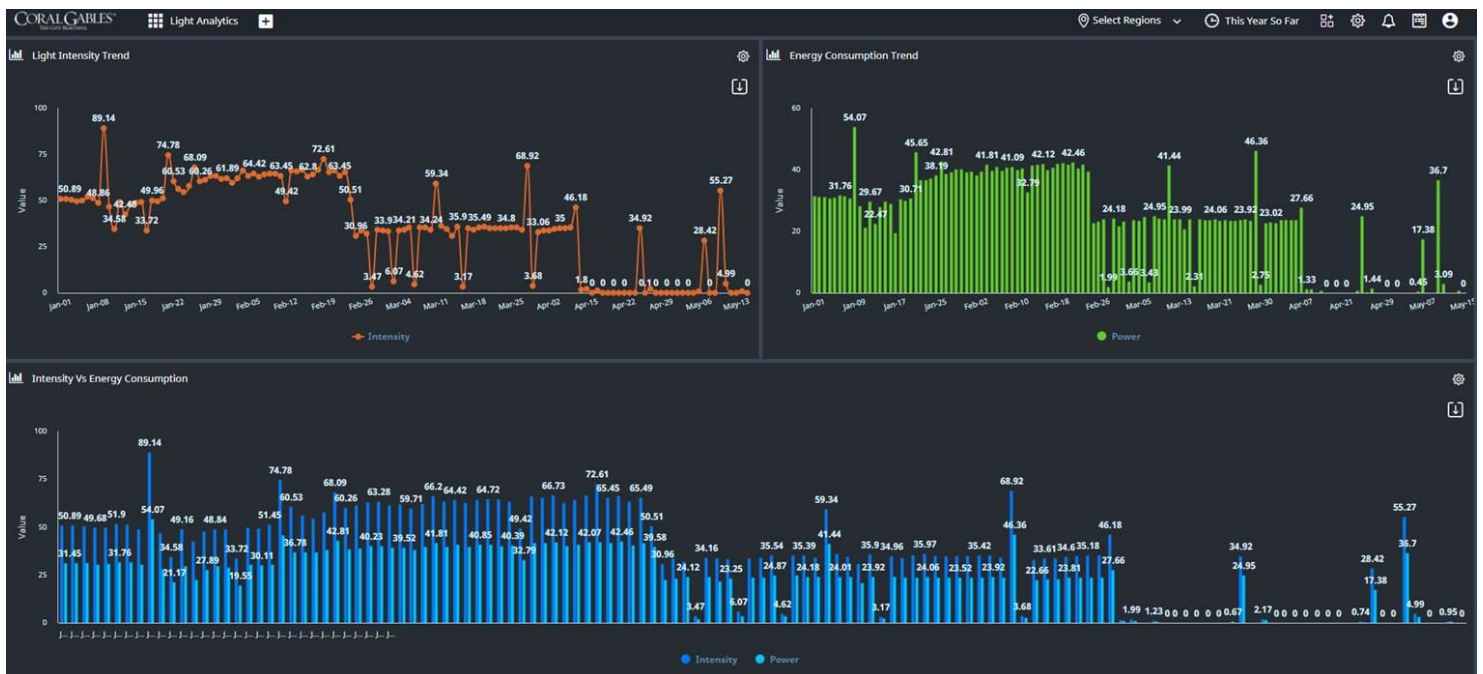
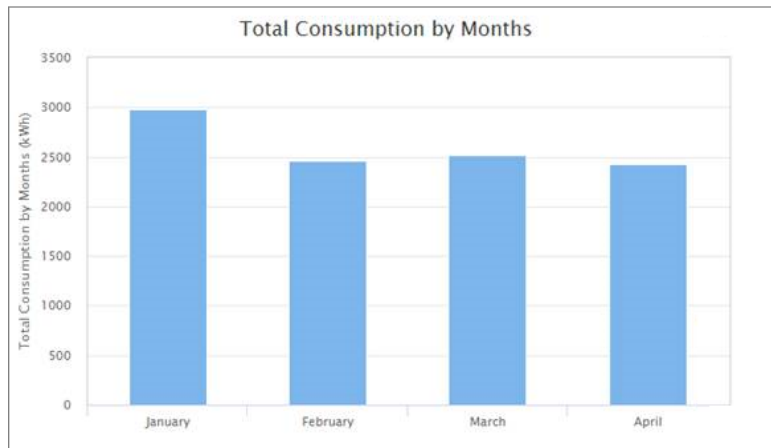


### Energy Sensors Data:

The City installed multiple smart lighting controllers on LED light poles in Downtown Coral Gables. These controllers provide intelligent ON/OFF switching, dimming control, GPS, highly accurate power metering, analog and digital sensor inputs and constant status and health monitoring of the City's lighting fixtures. They also allow City staff to manage the lights either individually or as a group and apply business intelligence rules for energy and cost efficiencies, through a centralized management system that also runs reports on energy consumption, LED burn hours, and generate automatic alerts when there are issues affecting the light fixtures.

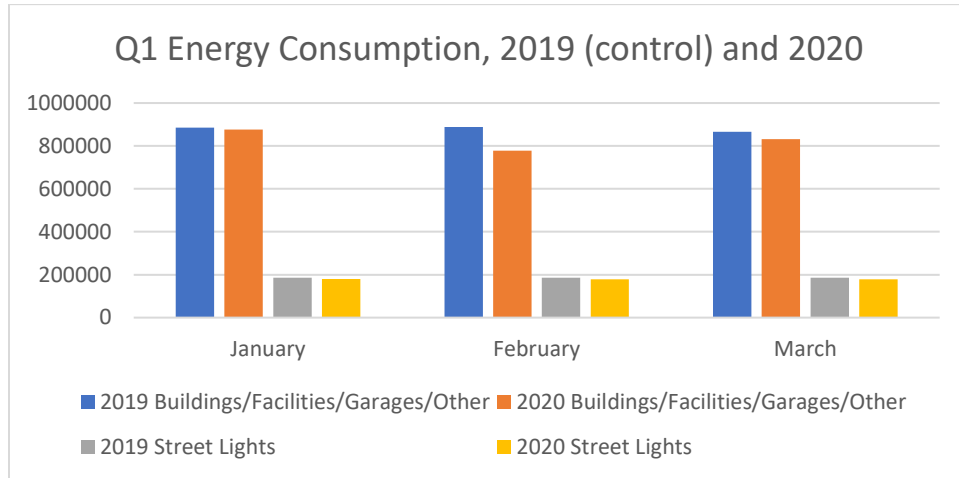
The charts below from the smart lighting controllers on Miracle Mile in Downtown show a 17% reduction in energy consumption (kWh) starting in February and even lower during April with a 19% reduction compared to January numbers. This trend is consistent with data from the electric utility company smart meters shown in the next page.

- **CPS/IOT Sensors:** smart lighting controllers on LED light poles in Downtown Coral Gables
- **Source:** Energy IOT platforms (CimCon StreetVibe, Quantella Atlantis) and Coral Gables Smart City Hub
- **Data collection period:** 1/1/2020 to 4/30/2020



### Utility Smart Meters Data:

The chart below visualizes energy consumption data on City-owned streetlights, facilities, buildings, and garages from January to March 2020 (data from April is not available yet) and compares it with the same period in 2019 (control). In general, this chart shows a reduction from last year in energy consumption (kWh) in all City-owned facilities and streetlights on all months (1% in January, 13% in February, and 4% in March). The significant reduction in February comes out as an outlier when compared to the more linear curve from 2019 and is consistent with the above data from the City's smart lights. March 2020 shows a slight increase from February's valley, to a more predictable level. The streetlight consumption curve in 2020 so far shows a more predictable linear reduction with no outliers. An expected correlation between this data and the Covid-19 pandemic could be driven by work-from-home policies, but a longer period of data will be required to derive more informed conclusions.



### IOT Research and Collaboration

The City of Coral Gables collaborates with research institutions and professional organizations in government, industry, science and academia in the fields of Smart Cities, STEM, Emergency Management and Innovation. Some of our strategic partners in IOT projects include University of Miami (UM), Florida International University (FIU), IEEE, IISE, NIST GCTC superclusters, NTIA, IOT Consortium (IOTC), Intelligence Edge/IOT Evolution Expo, Center for Digital Government, Smart Cities Connect, Smart Cities Council, Smart City Expo, other municipalities, local hospitals, chambers of commerce, economic development and business organizations, and tech providers. These active collaborations include joint research projects and initiatives, community programs, papers in STEM journals and publications, presentations at conferences and expos, competitions/hackathons, demo labs, and R&D pilots. During the Covid-19 pandemic, we have leveraged the partnership with some of these organizations by working together on joint response initiatives and by sharing data, resources and insight that add value to the ongoing emergency response and recovery efforts, and ultimately to our communities impacted by this crisis.

### Conclusions

Actionable CPS/IOT data visualization and analytics can provide insight and situational awareness to researchers, decisionmakers, emergency management personnel and first responders during the Covid-19 pandemic. For example: traffic IOT data analyzed in this paper shows an evident correlation with the timeline of events and the known impact factors of the pandemic. The Internet of Things provides City of Coral Gables with an interface to the physical world that enables real-time visibility over urban and environmental conditions, boosting situational awareness, early detection, faster response, and actionable business intelligence for decision making in the smart city ecosystem during both normal and emergency conditions. The social and environmental CPS data analyzed in this report can be correlated with other Covid-19 data to observe and predict patterns related to the impact of the crisis and the policies implemented to address it. More information at: [www.coralgables.com/itdocs](http://www.coralgables.com/itdocs)

**Information Technology Department**

## LIVABILITY