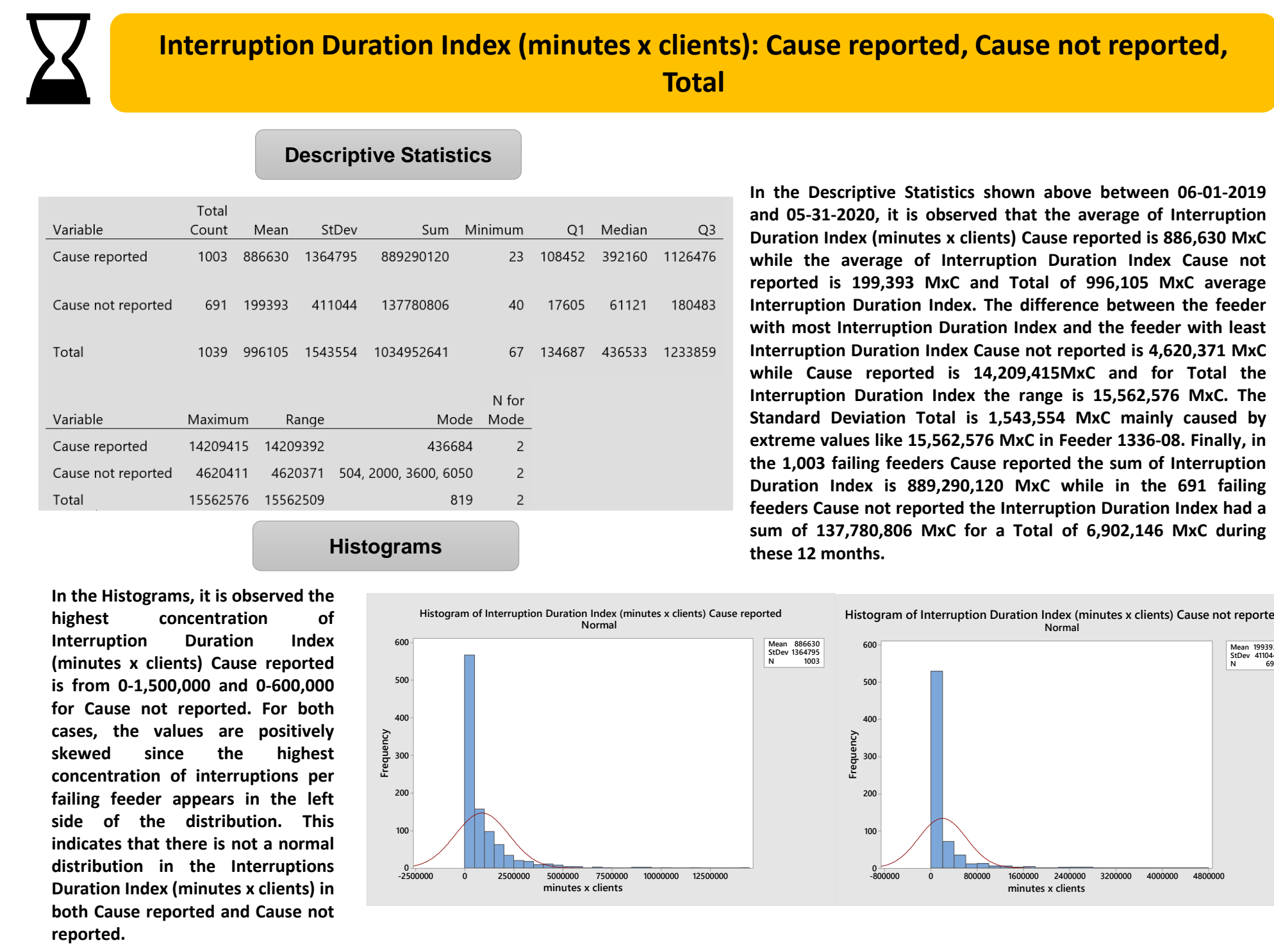
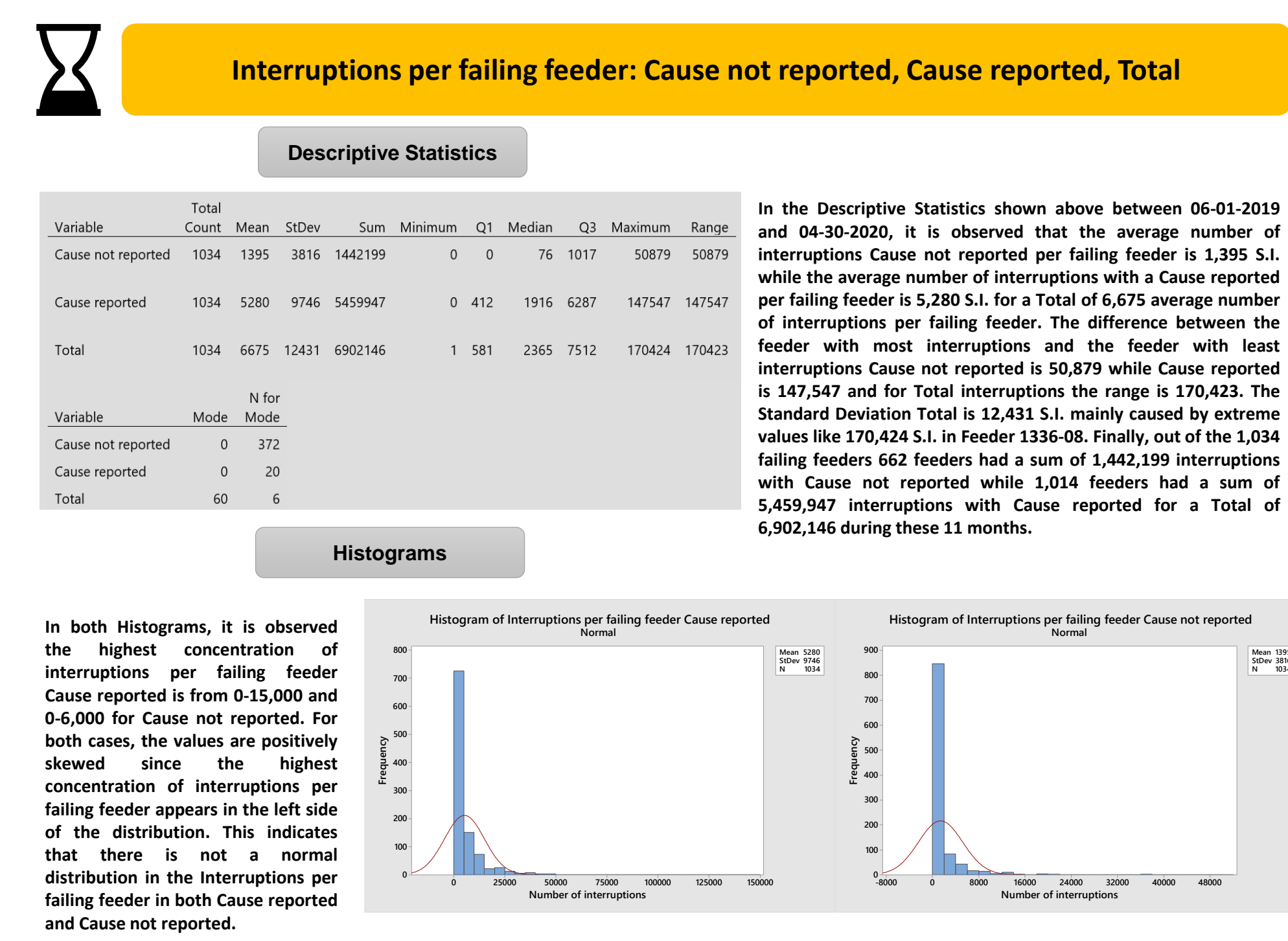


Business Case: By reducing the number and duration of interruptions in residential and commercial by 25%, PREPA will be able to see an increase in profit of around \$701,065.63 annually. This will not only help in achieving higher amounts of profits but will also increase client satisfaction by offering a more stable and trustworthy service.

ABSTRACT

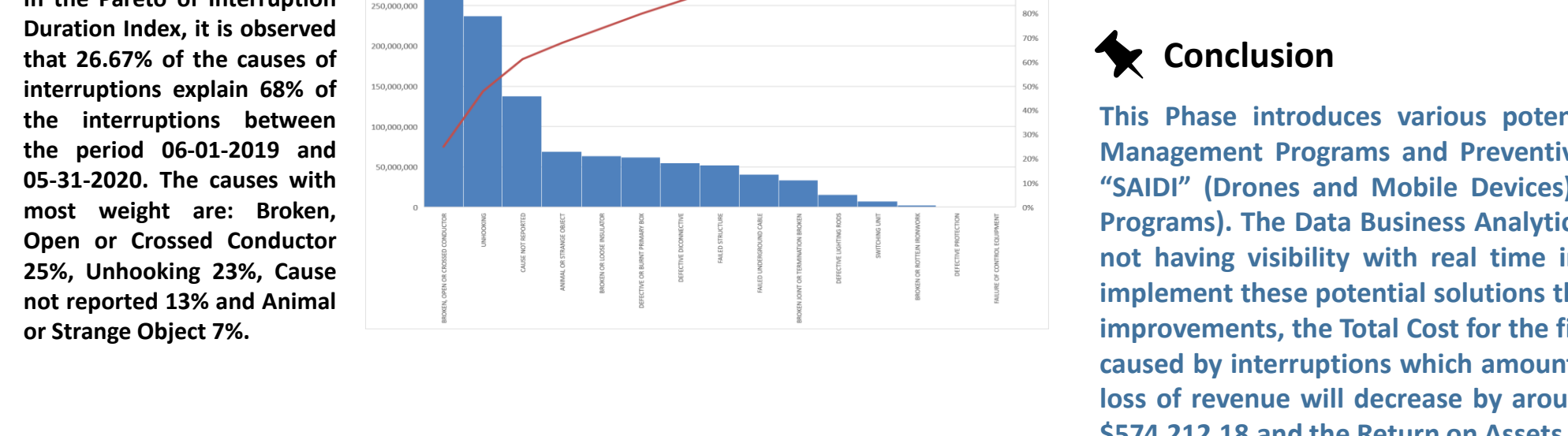
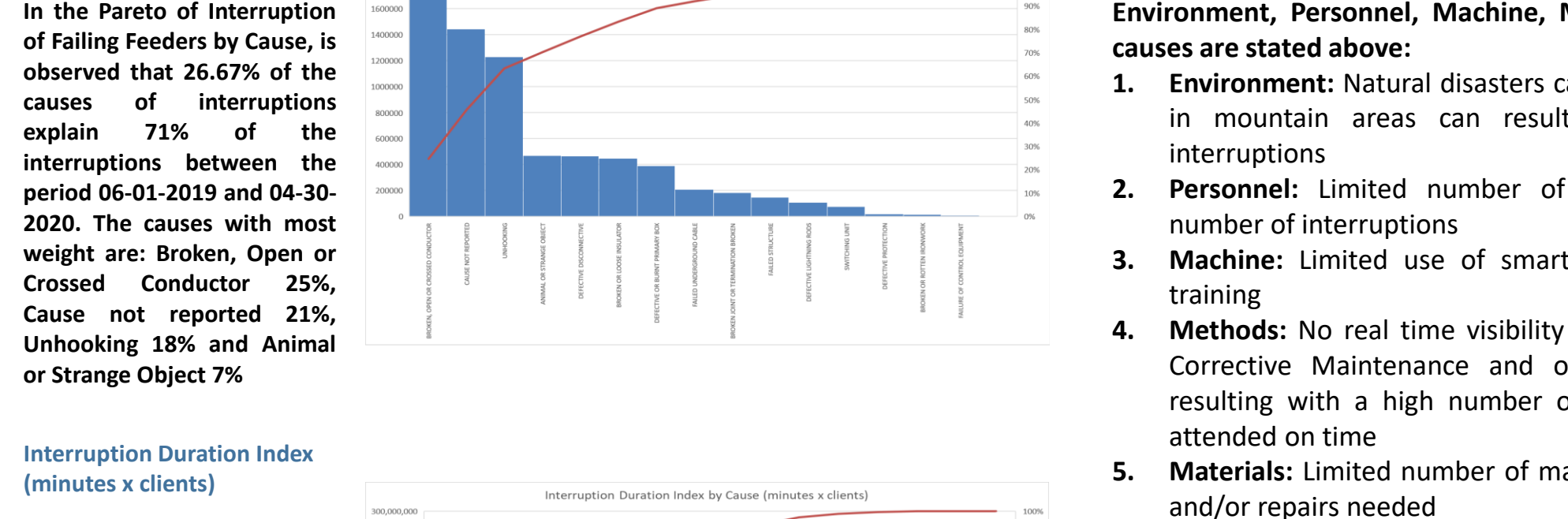
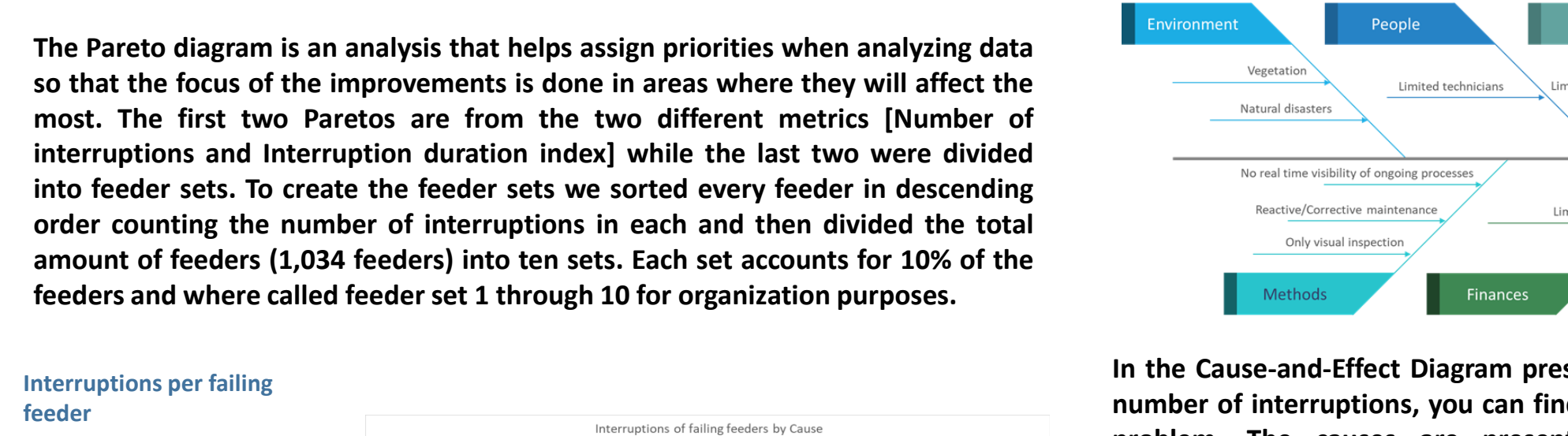
MEASURE

IMPROVE



ANALYZE

Pareto Diagrams



Insights

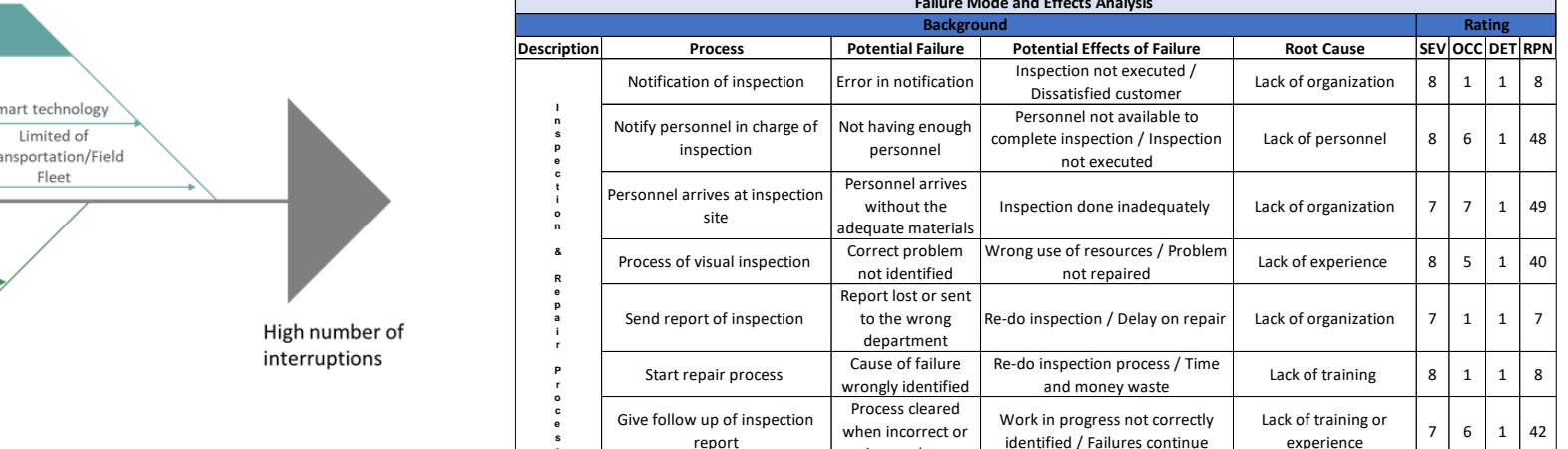
- In the variable Interruptions per failing feeder, the average of Total Interruptions per failing feeder is 6,675 S.I., but there is a significant difference between the average of Cause reported and Cause not reported (5,280 and 1,395), respectively
- When talking about Interruption Duration Index, the behavior of the data is similar since Cause reported (886,630 MxC) had a significantly higher average than Cause not reported (199,393 MxC)
- It was found that the Feeder 1336-08 in both variables is the feeder with most frequency of interruptions and duration index

Conclusion

In the Measure phase, historical data was collected from PREPA which was used to verify the frequency and duration of interruptions in failing feeders. The decision to separate variables as Cause reported and Cause not reported was to verify and compare if there are meaningful differences in the duration and frequency of both variables. In the variable Interruptions per failing feeder, the average of Total Interruptions per failing feeder is 6,675 S.I., but there is a significant difference between the average of Cause reported and Cause not reported (5,280 and 1,395), respectively. This indicates that there are more causes that are reported rather than not reported per failing feeder. When talking about Interruption Duration Index, the behavior of the data is similar since Cause reported (886,630 MxC) had a significantly higher average than Cause not reported (199,393 MxC). It was found that the Feeder 1336-08 in both variables is the feeder with most frequency of interruptions and duration index.

The Boxplots and Histograms show that the Interruptions per failing feeder in Cause reported and Cause not reported it is observed that there are 84 outliers and 348 outliers, respectively. The median for Cause reported is 1,916 S.I. while the median for Cause not reported is 76 S.I. On both cases, the top 50% of the values have more variation than the bottom 50%. The Interruptions Duration Index (minutes x clients) in Cause reported and Cause not reported it is observed that there are 80 outliers and 85 outliers, respectively. The median for Cause reported is 392,160 S.I while the median for Cause not reported is 61,121 S.I. On both cases, the top 50% of the values have more variation than the bottom 50%. In the Histograms of Interruptions per failing feeder in Cause reported and Cause not reported the highest concentration of interruptions is from 0-15,000 and 0-6,000, respectively. While in the Histograms of Interruption Duration Index the highest concentration of Cause reported and Cause not reported is 0-1,500,000 and 0-600,000, respectively.

Cause-and-Effect Diagram



- In the Cause-and-Effect Diagram presented of the Causes of High number of interruptions, you can find the different causes of this problem. The causes are presented for the 5 categories: Environment, Personnel, Machine, Methods and Materials. The causes are stated above:
1. **Environment:** Natural disasters can occur, and feeders located in mountain areas can result with a high number of interruptions
 2. **Personnel:** Limited number of technicians to attend the number of interruptions
 3. **Machine:** Limited use of smart technology due to lack of training
 4. **Methods:** No real time visibility of ongoing processes, doing Corrective Maintenance and only doing visual inspection resulting with a high number of interruptions that are not attended on time
 5. **Materials:** Limited number of materials to use for inspections and/or repairs needed

Conclusion

This Phase introduces various potential solutions such as: Drones, Mobile Devices, creating a Data Business Analytics Team, Vegetation Management Programs and Preventive/Predictive Maintenance. These potential solutions address in reducing both duration of interruptions "SAIDI" (Drones and Mobile Devices) and number of interruptions "SAIFI" (Preventive/Predictive Maintenance and Vegetation Management Programs). The Data Business Analytics Team was mentioned as a potential solution since PREPA is not collecting data in an effective way and is not having visibility with real time in ongoing processes. A Cost Analysis is mentioned illustrating all the investments that are needed to implement these potential solutions that are being recommended (such investments are not included with taxes and insurances). By adding these improvements, the Total Cost for the first year is around \$574,212.18 and \$261,672 the following years. As the team calculated the loss of revenue caused by interruptions which amounted to a total of \$2,804,252.52 per year (approximately). When assuming a 40% reduction in the SAIDI, the loss of revenue will decrease by around \$1,121,701.20 which means that in less than a year PREPA will be able to recover their investment of \$574,212.18 and the Return on Assets (ROA) was additionally calculated with had a total of 195%.

Potential Solutions

Since the team is trying to reduce the SAIDI and SAIFI, the improvements are geared toward reaching these goals. The first part of these improvements is tailored into conducting inspections faster, with less people and with readily available live information, which will reduce the duration of interruptions (SAIDI). The second part (Preventive/Predictive Maintenance) is directly associated with reducing the number of interruptions (SAIFI). Right now, PREPA deals on a case-by-case basis while doing Corrective Maintenance but it is expected that even with low personnel PREPA can get to a point of Preventive/Predictive Maintenance which yields huge advantages and has been proven to reduce maintenance costs by up to a 30%. Also, a better quality of inspections will reduce the number of cases where a Cause was not found which will in return help PREPA assess problems correctly and get the correct fix on the first try.

Drones

- Benefits:
- Performs inspections faster and more regularly.
 - Reduced disruption and inconvenience to the public and road users.
 - Helps inspectors avoid having to place themselves in dangerous situations.
 - Potential problems can be surfaced and addressed more quickly.
 - Collects and archives visual data that can be accessed at any time.
 - Reduce corresponding liability insurance costs when reducing the amount of time personnel are placed in hazardous situations.
 - Reduce downtime and provide accurate data on an asset's life history.
 - Reduces expenses of scaffolding by as much as 90%.

Mobile Devices

- Benefits:
- Takes less time to fill out digital forms.
 - Easy access to digital information.
 - Share anywhere and anytime.
 - Real time reporting.
 - Cuts down time on data gathering/compilation.
 - Paperless safety inspections.
 - Influence modernization and digitalization.

Business Data Analytics Team

- Benefits:
- Helping you on budget.
 - Better decision making.
 - The ability to measure accomplishments against overall goals.
 - Staying in the know.
 - Building efficiency.

CONTROL

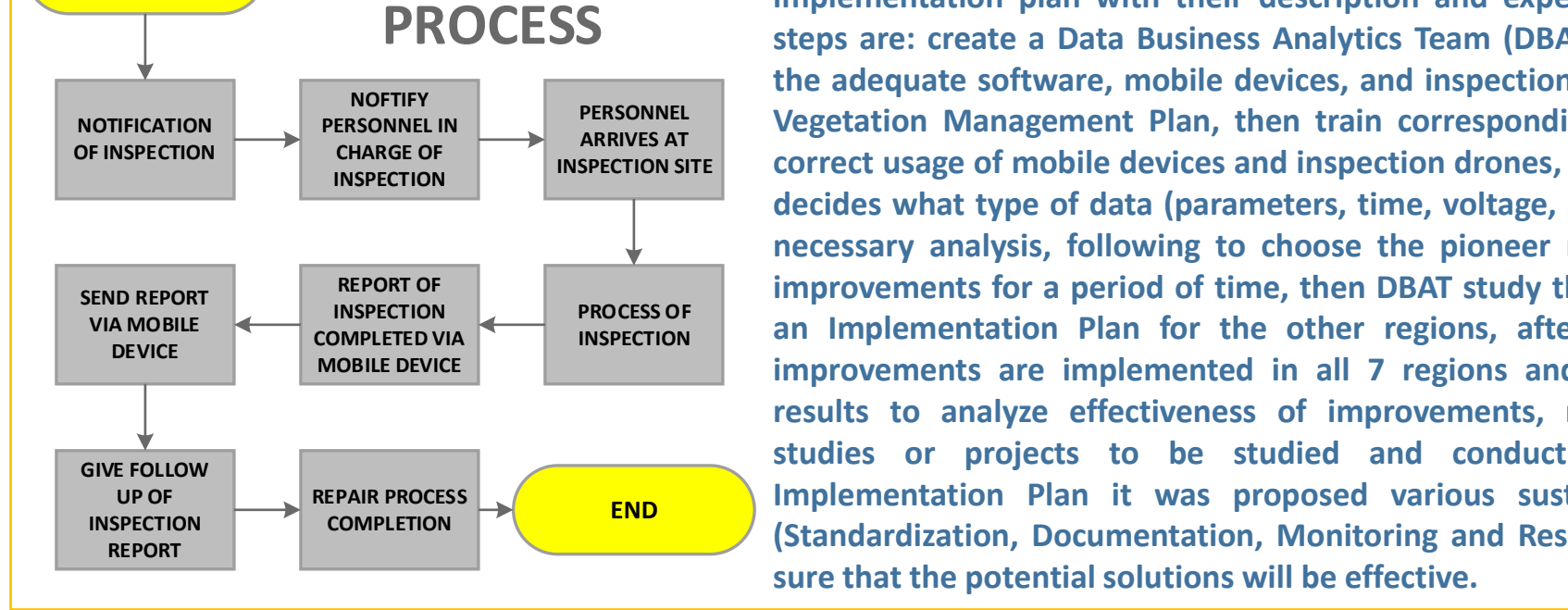
Implementation Plan

The main goal is to reach Preventive/Predictive Maintenance. Since PREPA resources are limited, the goal when looking at improvements is making processes more efficient in terms of time and resources needed so PREPA can attend service interruptions and correctly assess the cause of the interruptions and the possible fix. Mobile devices, drones and the other improvements will help monitoring and data gathering so that repairs will be easier to apply and completed sooner. By standardizing processes and making them more efficient, eventually PREPA can clear problems and start Preventive/Predictive Maintenance. Preventive/Predictive Maintenance is a sure way to decrease service interruptions which will eventually make PREPA more profit and increase client satisfaction.

Sustainment for Potential Solutions

- Monitoring Plan
- Assign the team that will be responsible of monitoring this potential solution.
 - Collect the data with the correct sequence and parameters. (the data should be always collected during the inspection and repair process)
 - Beware of the maintenance required of the equipment to be up to date.
 - Have all trainings up to date for the employees.
- Response Plan
- Response team will act on an out-of-control event in the process.
 - The Data Business Analytics Team will be based on the data collected.
 - Response team will have a backup plan for inspections in case malfunction with the electronic devices (drones, mobile devices).

RECOMMENDED PROCESS



ACKNOWLEDGEMENT

We thank the Puerto Rico Electric Power Authority for giving us the opportunity to carry out our Capstone Project with their PMO Department. We also thank you for this unique experience, it has helped us evolve as future professionals' workers in the Industrial Engineering field. Developing new skills on how to address big and complex problems. We also thank Humberto Campán from PREPA that helped us during the development and understanding of the project for his support. Finally, we thank Dr. Carlos González for always being available during Capstone and mentoring us during the project so we could achieve the expected goals, and for his commitment to providing a quality Capstone course.

Vegetation Management

- Benefits: (Integrated Vegetation Management on Rights-On-Way):
- Improve transmission reliability.
 - Reduce vegetation management costs.
 - Improve native plant and songbird habitat.
 - Provide other ecological benefits (e.g., reduce runoff, control invasive species, create wildlife habitat, etc.).
 - Tree-related outages can be reduced by 30%, and total outage hours can decrease by 45%.

Preventive/Predictive Maintenance

- Preventive Benefits:
- Decreases failures.
 - Maintenance costs would lower by approximately 30%. (percentage taken from a Statistical Quality Control project completed by members of the team in Central Aguirre Power Plant 2019)
 - Extends equipment life.
 - Prevents delays of work activities by unforeseen events.
 - Emergency repairs are avoided.
- Predictive Benefits:
- Minimizing the time, the equipment is being maintained.
 - Minimizing the production hours lost to maintenance.
 - Minimizing the cost of spare parts and supplies.
 - Predictive maintenance programs have been shown to lead to a tenfold increase in ROI, a 25%-30% reduction in maintenance costs, a 70%-75% decrease of breakdowns and a 35%-45% reduction in downtime.

Conclusion

By adding these improvements, the Total Cost for the first year is around \$574,212.18 and \$261,672 the following years. As the team calculated the loss of revenue caused by interruptions which amounted to a total of \$2,804,252.52 per year (approximately). When assuming a 40% reduction in the SAIDI, the loss of revenue will decrease by around \$1,121,701.20 which means that in less than a year PREPA will be able to recover their investment of \$574,212.18 and the Return on Assets (ROA) was additionally calculated with had a total of 195%. (such investments are not included with taxes and insurances)

CONCLUSION

The team's main goal is to try reducing the SAIDI and SAIFI, the improvements are geared toward reaching these goals. The first part of the improvements chosen (Drones and Mobile Devices) are tailored into conducting inspections faster, with less people and with readily available live information, which will reduce the duration of interruptions (SAIDI). The second part (Data Business Analytics team and Preventive/Predictive Maintenance) is directly associated with reducing the number of interruptions (SAIFI). Right now, PREPA deals on a case-by-case basis while doing Corrective Maintenance but it is expected that even with low personnel PREPA can get to a point of Preventive/Predictive Maintenance which yields huge advantages and have been shown to lead to a tenfold increase in ROI, a 25%-30% reduction in maintenance costs, a 70%-75% decrease of breakdowns and a 35%-45% reduction in downtime. Finally, while doing research and benchmarking it was realized the importance of having a Vegetation Management Program since in the Pareto analysis the second highest cause of interruptions is caused by Vegetation (Unhooking) and currently PREPA invests around \$50,000,000 on vegetation related issues each year. Because of this it is also recommended a Vegetation Management Program comprised of multiple initiatives designed to reduce the average time customers are without electricity because of vegetation-related interruptions. This includes Preventive Maintenance initiatives (planned cycle and mid-cycle maintenance), Corrective Maintenance (trouble work and service restoration efforts), customer trim requests, and support of system improvement and expansion projects. The last part of the improve Phase was a Cost Analysis where the benefits of the improvements were evaluated against their costs and estimated that the Return of Investment (ROI) for the first year would be around 195%. Having completed the improvements, it was proceeded with an Implementation Plan followed by a Monitoring and Response Plan in the Control Phase.

Conclusion

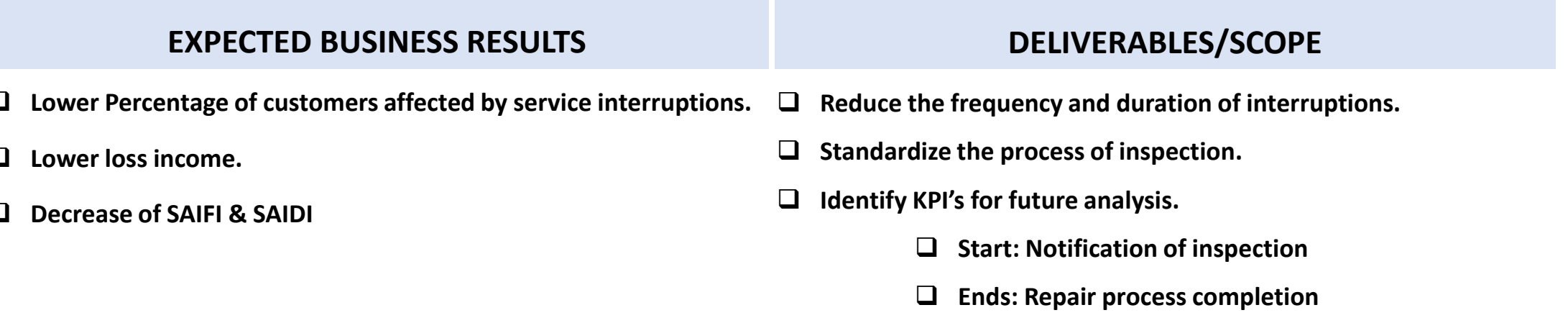
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DEFINE

- ### Key Terms and Definitions:
1. PREPA – Puerto Rico Energy Power Authority
 2. Interruption per failing feeder – Number of interruptions during the period of time studied per failing feeders. Only the feeders that have failed at least once during the studied period will be included. Metric to be used will be S.I. (service interruptions).
 3. Interruption Duration Index – Amount of time without service (minutes) times the number of clients affected during the period of time studied. Metric to be used will be MxC (Minutes x Clients).
 4. SAIDI – Average outage duration for each customer served.
 5. SAIFI – Average number of interruptions that a customer would experience.
 6. Failing feeders cause reported – Electric feeders in which the cause of failure is reported.
 7. Failing feeders cause not reported – Electric feeders in which the cause of failure is not reported.

Problem Statement

Puerto Rico Energy Power Authority during the period of June 2019-April 2020 had a 4.70 average interruptions per client (SAIFI), while during June 2019-May 2020 PREPA had a 705.01 min average outage durations per client (SAIDI). PREPA seeks to reduce the frequency and magnitude of service interruptions by 25% to better serve customers and increase profit.

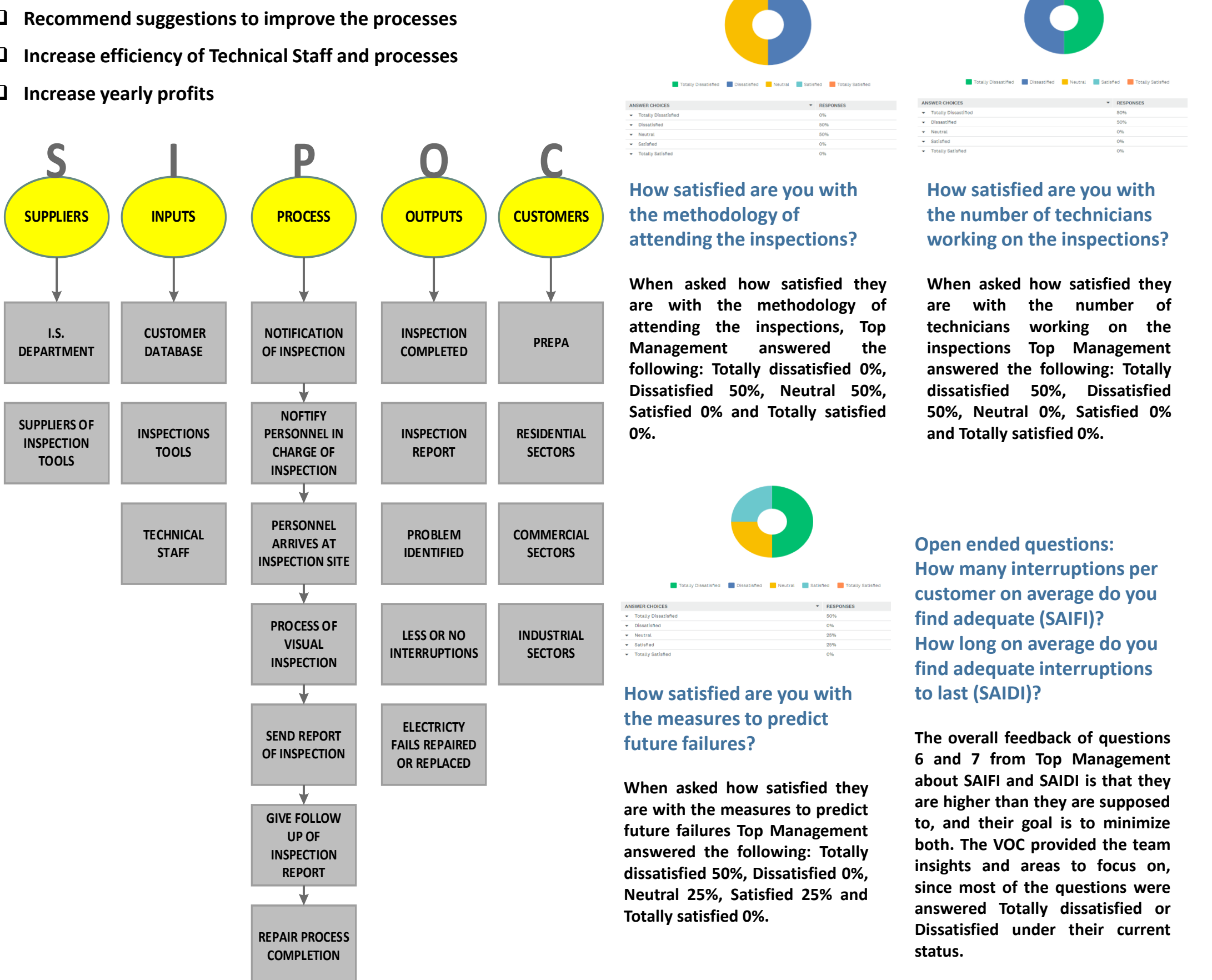


OBJECTIVES

- Reduce the frequency and duration of interruptions
- Decrease the amount of non-identified causes for interruptions
- Improve the visibility and management of ongoing processes and data recollection
- Increase the use of historical data
- Move from reactive maintenance to predictive/preventive maintenance
- Recommend suggestions to improve the processes
- Increase efficiency of Technical Staff and processes
- Increase yearly profits

VOC

To better understand the needs of both, Top Management and Technical Staff, a series of questions were developed. This method helped get valuable feedback and an easy way to quantify answers in terms of how strongly they agree or disagree with the statements made in the questions. The goal of this tool is to get suggestions and ideas which will give a better understanding of the problems which then can be used as guidance when venturing into further sections of the project.



Conclusion

The Define Phase of the DMAIC method allowed us to define PREPA's problem and to better understand the processes and people involved in the different parts of our studied process. Also, from the VOC, a valuable feedback was gathered which will be considered in all stages of the project. In addition, the team learned various specific terms used in the electric utility's companies like SAIDI and SAIFI that will be used in the Measure and Analyze phases of the project. Finally, the Define phase helped identify the purpose of the project in terms of the objectives of the project and beneficial expected results.