Zebra DevCon 2023

Leveraging Data Science to Improve Device Uptime

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Leveraging Data Science to Improve Device Uptime

Agenda

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Device uptime and battery performance

The steps
Sense, analyze and act

The algorithm
Remaining useful life (RUL) of battery

Applications of RUL

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Device Uptime and Battery

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Operational challenges that impact device uptime and availability

- Can the battery last the shift – does it have enough capacity
- How many batteries will have enough capacity after 6 months to remain useful for the business purpose
- How to identify batteries that are degraded and approaching end of life, so they can be replaced proactively

Battery challenges for the front-line workers

- Front-line workers need to have sufficient batteries capacity to handle site workload
- Front-line workers need the ability to identify batteries that should be replaced and mark them for removal from battery pool.

This translates to:

- Know your battery inventory
- What is the status of batteries and when they might need replacement
    - Forecasting for Operations Planning

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The Steps

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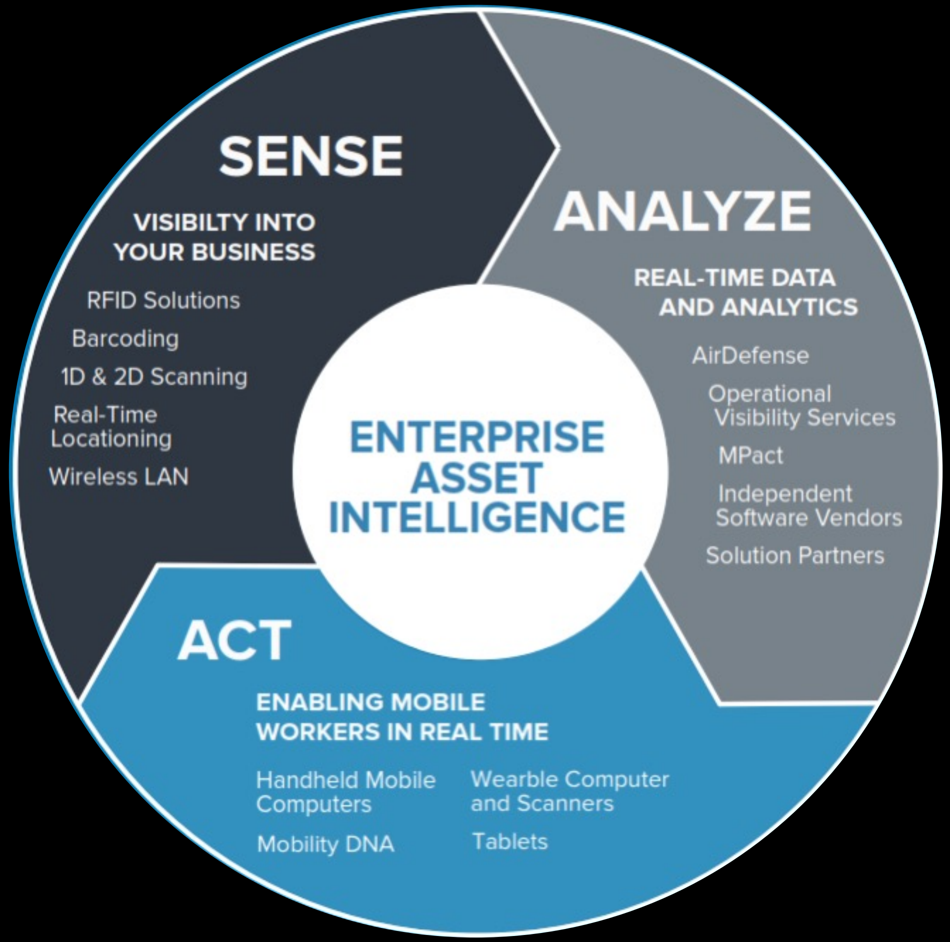

Sense - Device data including battery related data coming from the battery pack. Consider any other relevant data from external sources

Analyze - Go through the data and apply relevant algorithms to generate insights like Remaining Useful Life of the battery

Act - Battery Replacement recommendations based on generated insights

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Outcome - Smart Battery Report

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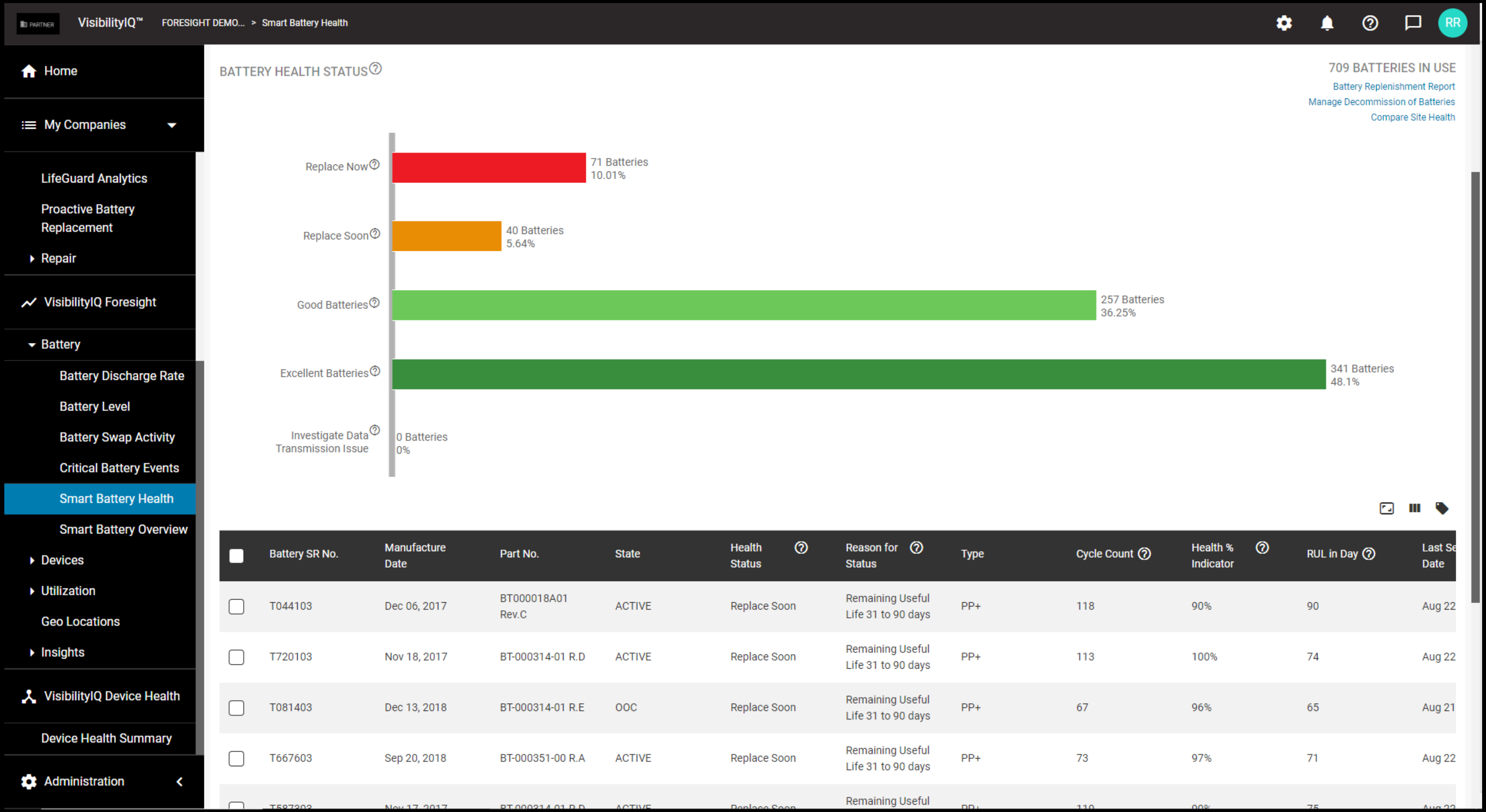

A sample report to recommend batteries to be replaced based on RUL

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Sense – Device and Battery Data Captured in the Cloud

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Architecture Overview

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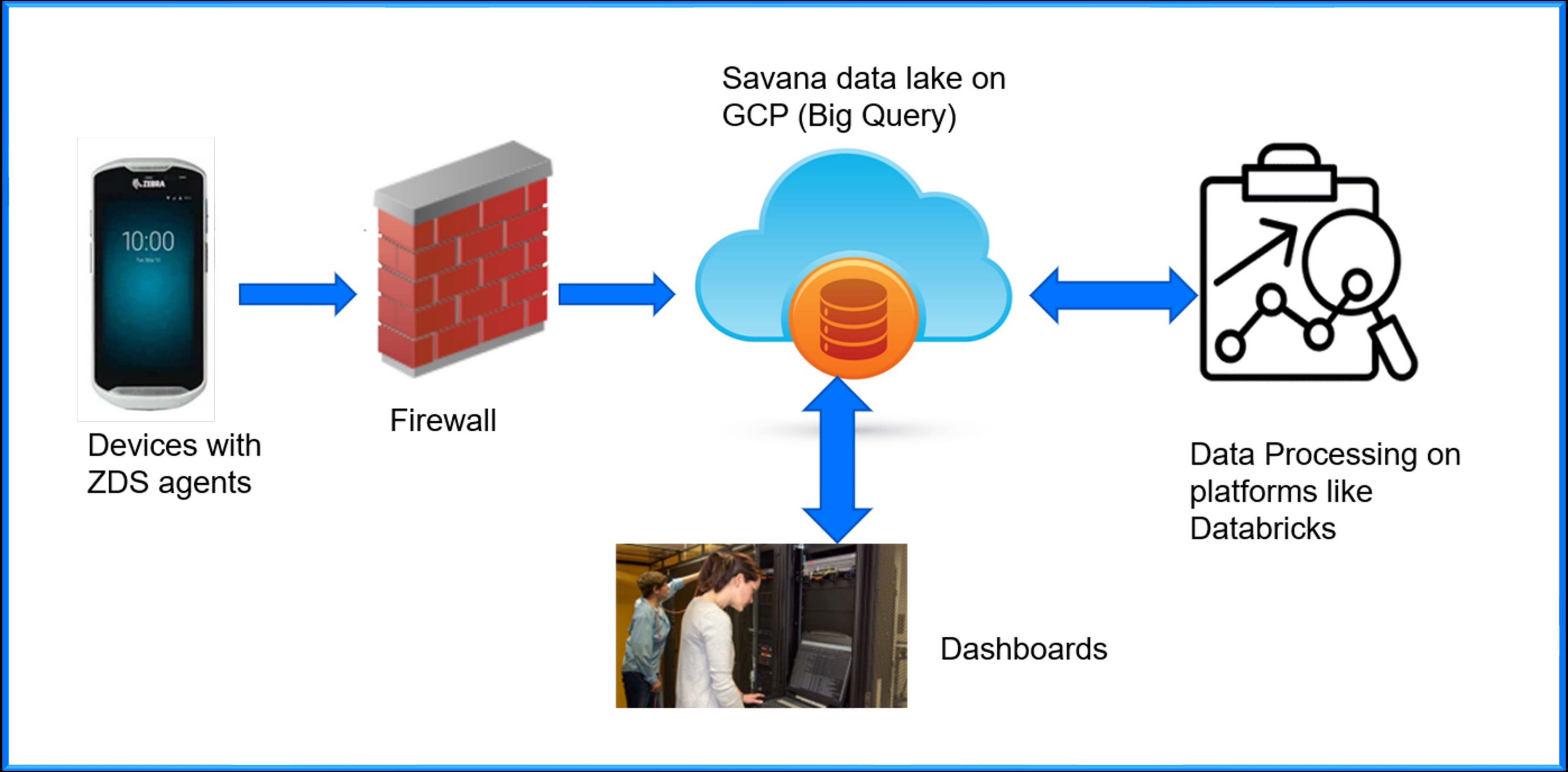

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Data Available from Zebra Data Services (ZDS) agent

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Zebra Data Services collects data on the device

Along with battery related information, ZDS agent collects and transmits useful parameters like
- Screen on time
- Screen brightness
- Scans (total and successful)
- Application usage
- User Behavior parameters
- Battery Parameters

All these parameters impact battery performance

Analyzing these factors could suggest correlation between these factors and battery usage and if batteries will last the shift

Machine learning models have been developed and are being developed to generalize the correlations between the above factors and battery discharge during a shift

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Defining Remaining Useful Life

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Either of the conditions could be met

- Battery cannot receive or hold charge above a certain threshold
- Battery has undergone a threshold quantity of charge cycles

When one of the conditions is met

- Battery may not be able to provide sufficient capacity
- Reliability of battery may decrease

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Defining Remaining Useful Life

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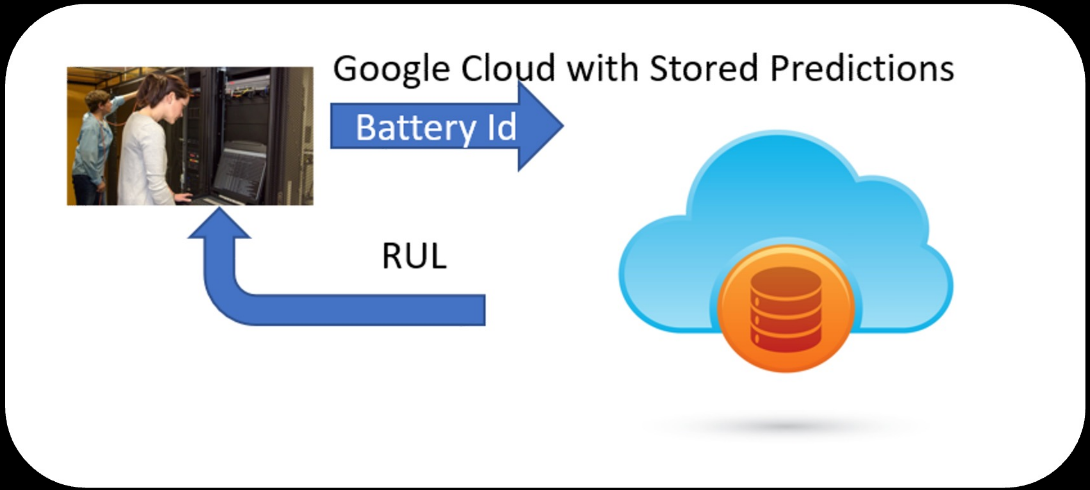
Factors that lead to battery degradation over time:

- Battery Cells
- Environment
- Usage patterns



Remaining Useful Life – The predicted number of days before the batteries key indicators fall below recommended levels

Number of days after which we expect the battery parameters to cross the manufacturer recommended threshold

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The Input Data

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Battery Data being considered

- Data reported from the battery gauge
  - Battery Design Capacity – A measure of how much capacity a new battery of a particular type can deliver
  - Battery Present Capacity – a measure of how much charge the battery can deliver when fully charged.
  - Health Percentage = Battery Present Capacity/Battery Design Capacity.
  - Total cumulative charge – A measure of how much charge has flown through the battery since beginning of its use
  - Charge Cycles - A measures of how many complete charge and discharge cycles the battery has gone through. This is a usage measurement pattern of the battery
- Other Useful Data for RUL
  - Manufacturer recommendations on permissible health percentage and/or charge cycles

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Analyze – Battery RUL Algorithm

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The Process

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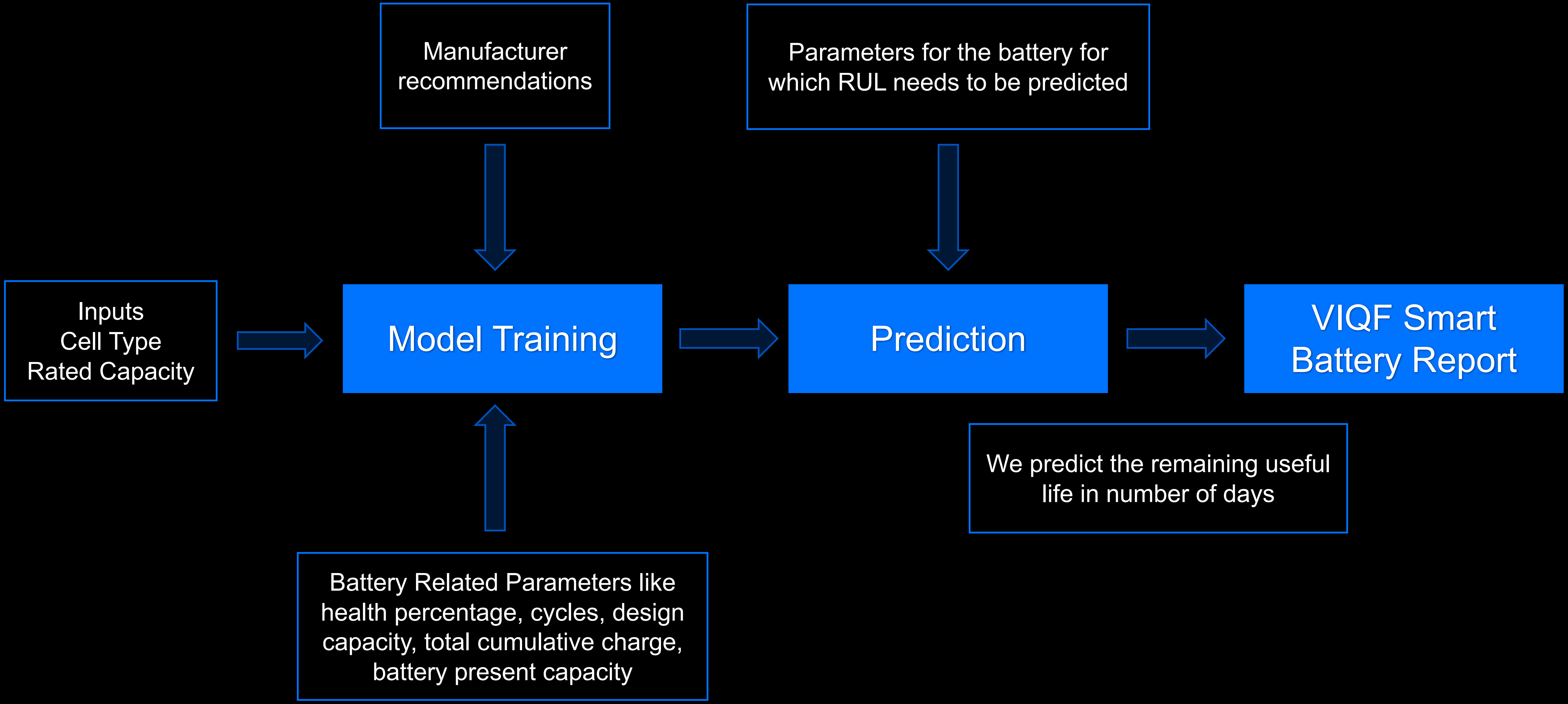

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Data Analysis and Data Quality

Battery should be uniquely identifiable

Battery Charge cycles should be positive and monotonically increasing

Battery Present Capacity should go down over a period of time. It cannot go up defying laws of nature

Battery Rated Capacity should not be negative or zero

Battery health percentage should be a number between 0 and 100

Data anomalies need to be handled

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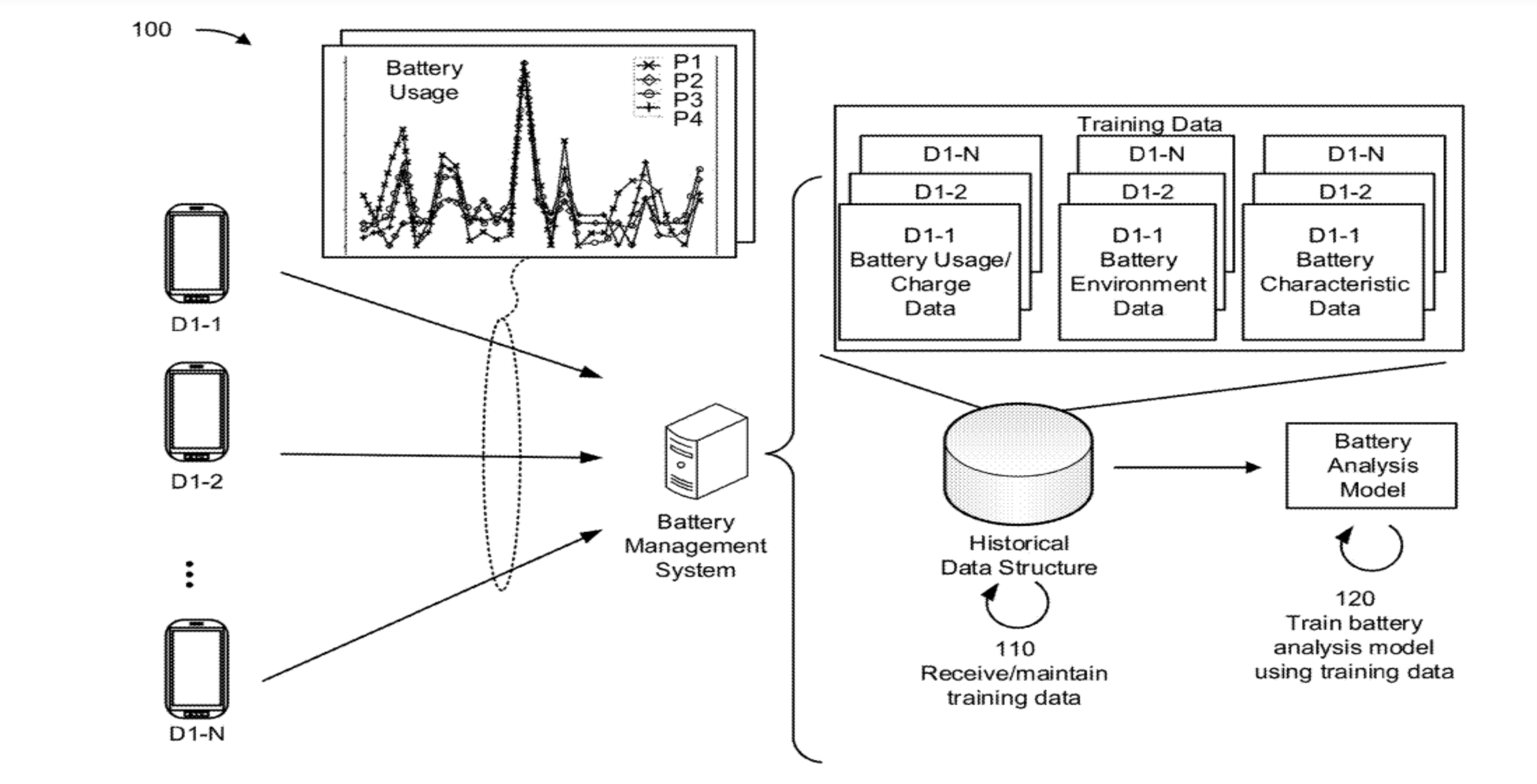
Training



Reference - https://patentimages.storage.googleapis.com/65/52/6d/57ad11a747540e/US20220294027A1.pdf

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The Model

Model gives values for degradation rates of health

These degradation rates are then converted to number of days based on usage patterns

The degradations are nonlinear due to varying environmental factors and battery cell characteristics

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Predictions

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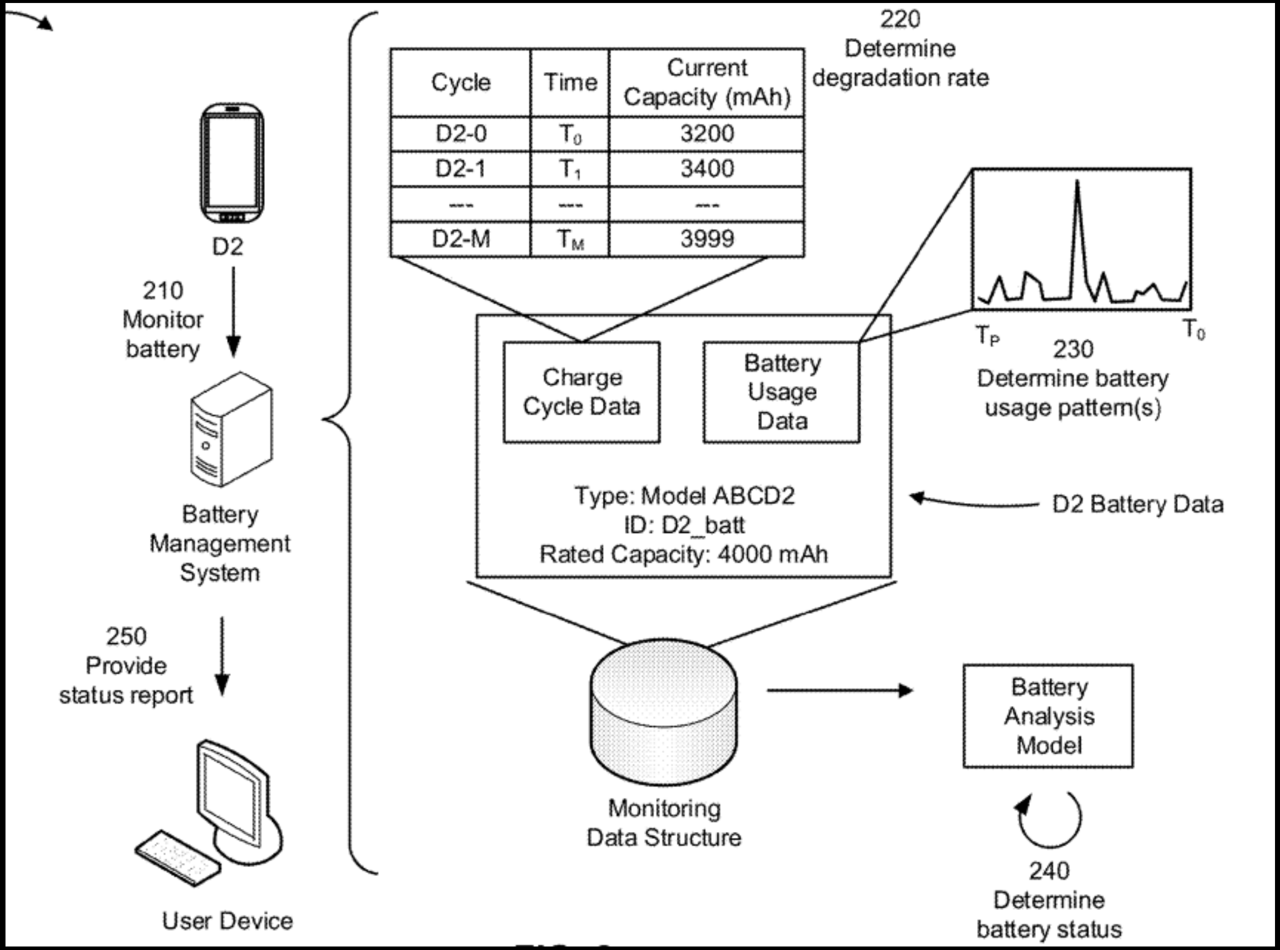

Reference - https://patentimages.storage.googleapis.com/65/52/6d/57ad11a747540e/US20220294027A1.pdf

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Sample Prediction Using the Model Output

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Sample Calculationfor Remaining Useful Life in Number of days

Assuming the batteryspec sheet is as shown below,

cell number BT-000315-01 and
Zebra part number asBT-000314-01

Manufacturer Rating	
specified cycle# at RT	**specified capacity remaining%**
500	80%

Current charge cycle of the battery(cc):	150
Current capacity of the battery(bpc):	3600
Rated capacity of the battery(brc):	4000
Calculated health percentage(bhp):	3600/4000 = 90
Charge cycle valueobtained from the model where the battery reaches the manufacturer Recommended threshold	270
Predicted Remaining useful charge cycles(pcc):	270-150 = 120
Battery usage pattern(dc/dt):	0.5
Predicted remaining useful life in days	120/0.5 = 240 days.

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Act – Proactive Battery Replacement Service
An application of RUL

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PBR service

For a Proactive Battery Replacement (PBR) customer, VIQ supporting the PBR service will facilitate battery orders to Siebel based on the current RUL reporting for customer who have batteries with an RUL < 30 days

These batteries which are marked “replacement required” on the PBR report will be shipped to end user customer locations

Other categories could be “Good Battery” or “Excellent Battery”

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Application of RUL – Planning Battery Inventory

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Input Factors for Machine learning/simulations for battery

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- Power Demand Profile - Demands on the battery (indicated by battery discharge in milli Ampere Hours (mAh))
- Supply Profile - Present capacity of the battery (mAh that the battery can supply on full supply)
- The battery present charge at start of shift (the capacity to which the battery is charged at start of shift)
- Number of hours of use. Shift durations, Number of Shifts
- Impact of battery degradation over time on battery requirements – RUL helps predict capacity in future quarters

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Natural Degradation of Battery

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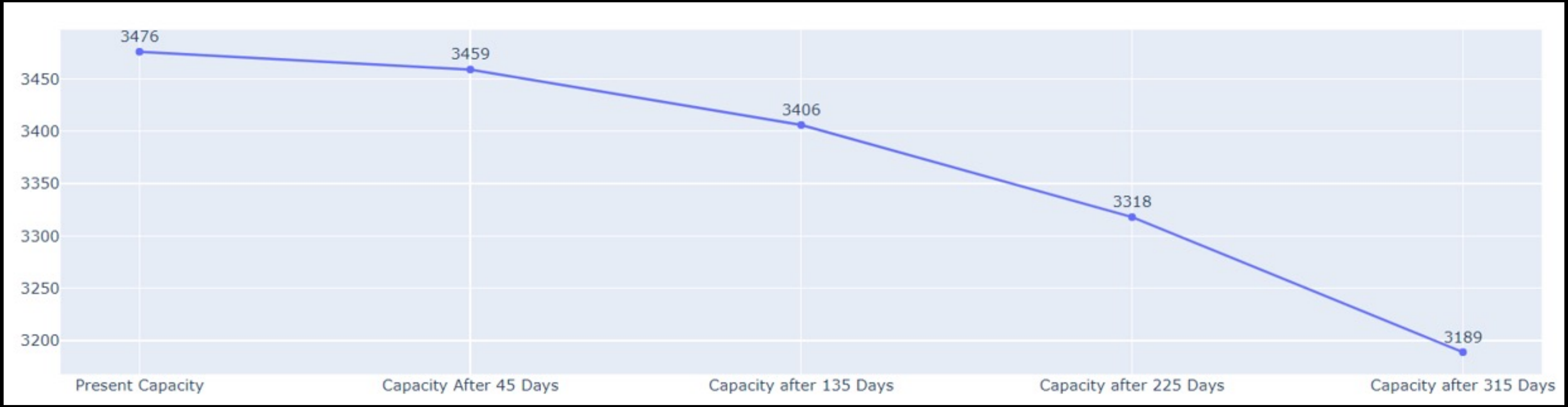
Average Capacity Over Time



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Demand and Supply Profiling Across Sites – A Sample

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Demand (mAh)

3000 - 4000

Demand (mAh)	< 1000	1000-2000	2000-3000	3000-4000	> 4000
Share of devices	32%	50%	15%	0.5%	0.01%

Distribution of devices based on Demand

3000-4000: This case has the possibility of falling short of supply

> 4000: ✓ Battery Swap Required to avoid productivity loss

Conditions Considered:
- Shift Timing
- On a given day

Sample Recommendations to minimize disruptions

Actions to Minimize Business Disruptions

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	Impact			
	Q1	Q2	Q3	Q4
	Potential Productivity Loss on busy days (in hours)			
Forecast if no action is taken and Devices are charged as per associates charging behavior	56	57	58	61
Forecast if no action is taken and Devices are completely charged	0	0	0	0
Estimate if Battery replacement recommendation is followed	0	0	0	0
Estimate if Battery replacement recommendation is followed and Extra Batteries / Mobile Chargers are utilized	0	0	0	0

Recommendations

Number of Batteries to be replaced	0	0	0	0
Number of devices to carry spare battery OR Mobile / Truck mountable charger	0			

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Thank You