

# Case Study #2

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*Muscat.auto*

**The Real Autonomous Car**

# *Muscar.auto*

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- Manufactures autonomous systems for vehicles
- Has >10,000 vehicles on the roads right now
- Expects more than 200,000 vehicles by end of year
- Needs to reliably receive telemetry from cars and display data about them



## Requirements

```
graph TD; Requirements[Requirements] --> Functional[Functional]; Requirements --> NonFunctional[Non-Functional];
```

### Functional

What the system should do

1. Web Based
2. Receive telemetry from cars (location, speed, breakdowns, etc)
3. Store telemetry in a persistent store
4. Display dashboards summarizing the data
5. Perform analysis on the data

### Non-Functional

What the system should deal with

## NFR – What We Know

1. Data intensive system
2. Not a lot of users
3. A lot of data
4. Performance is important

## NFR - What We Ask

- |  |       |
|--|-------|
| 1. <i>"How many expected concurrent users?"</i>              | 10    |
| 2. <i>"How many telemetry messages received per second?"</i> | 7,000 |
| 3. <i>"What is the average size of message?"</i>             | 1KB   |
| 4. <i>"Is the message schema-less?"</i>                      | Yes   |

NFR - What We Ask

5. *"Can we tolerate some message loss?"*

Sort of...

6. *"What is the desired SLA?"*

Highest Possible



## Data Volume

- 1 Message = 1KB
  - 7,000 messages / sec = 7MB / sec
    - => ~25GB / hr
    - => ~605GB / day
    - => ~221TB / year
- ← That's a lot!



## Retention Period

Defines for how long records are kept in the database

What happens to them after the retention period?

- Deleted
- Moved to archive data store

## Retention Period

### Motivation:

- Keep database from exploding
- Improve query performance

AWS Config adds the ability to specify a data retention policy for your configuration items

## Retention Period

Muscar needs two types of data:

- Operational, near-real-time (location, speed, etc.)
- Aggregated and ready for analysis (BI – Business Intelligence)

## Retention Period

Data Type	Used for...	Retention Period
Operational	Monitor real time data from cars. Performance is critical	
Aggregated	Reports, BI. Not real time, can be slower.	

## Retention Period

Data Type	Used for...	Retention Period
Operational	Monitor real time data from cars. Performance is critical	1 week
Aggregated	Reports, BI. Not real time, can be slower.	Forever

## Data Volume

- 1 Message = 1KB
- 7,000 messages / sec = 7MB / sec
  - => ~25GB / hr
  - => ~605GB / day
  - => ~221TB / year

## Data Volume

- 1 Message = 1KB
- 7,000 messages / sec = 7MB / sec

=> ~25GB / hr

=> ~605GB / day

=> ~4TB / week



## Requirements

```
graph TD; Requirements[Requirements] --> Functional[Functional]; Requirements --> NonFunctional[Non-Functional];
```

### Functional

What the system should do

1. Web Based
2. Receive telemetry from cars (location, speed, breakdowns, etc)
3. Store telemetry in a persistent store
4. Display dashboards summarizing the data
5. Perform analysis on the data

### Non-Functional

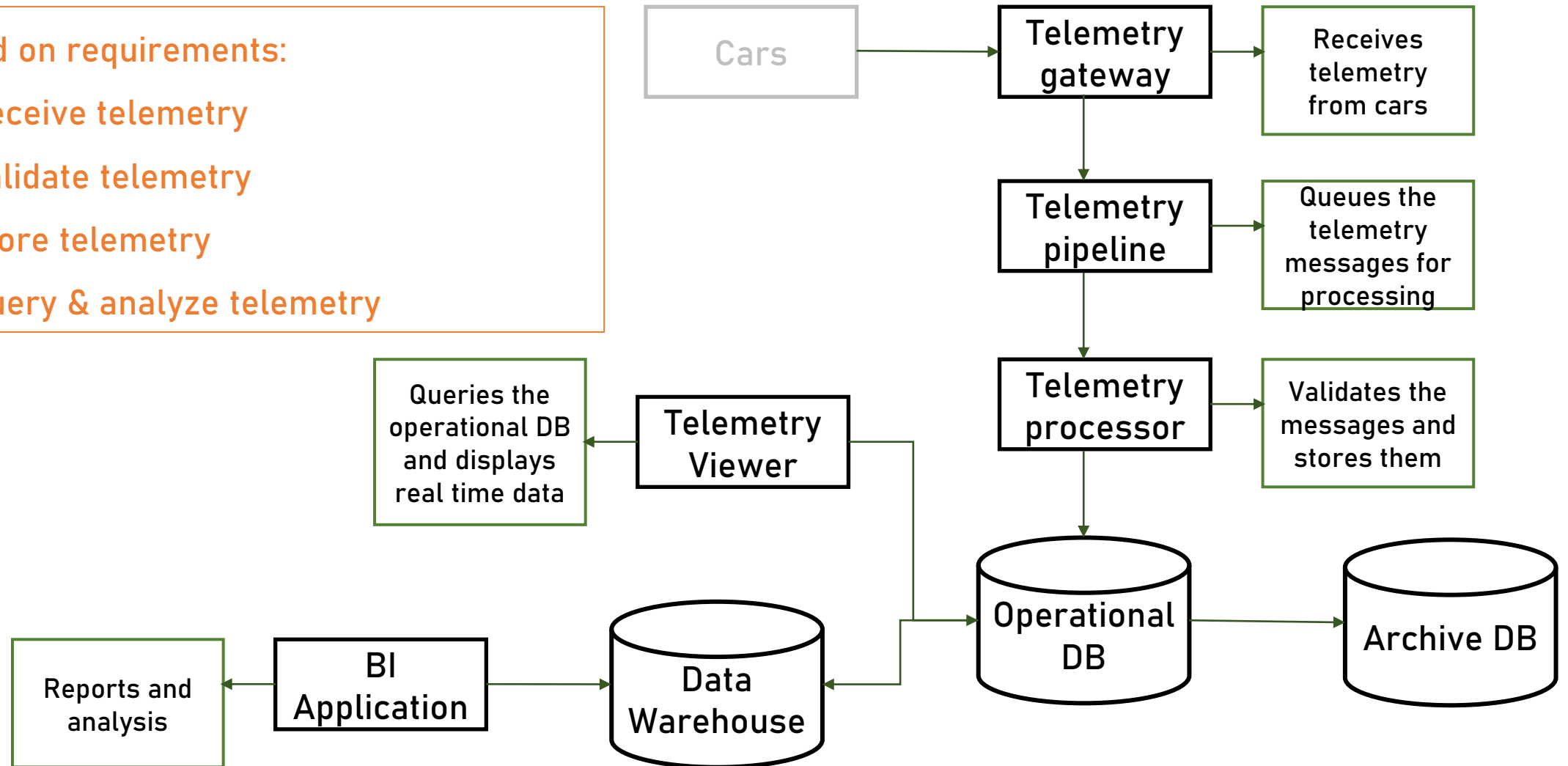
What the system should deal with

1. 10 Concurrent users
2. 7,000 msgs/sec
3. Max data in the operational DB: 4TB
4. Mission critical
5. Performance is critical

## Components

Based on requirements:

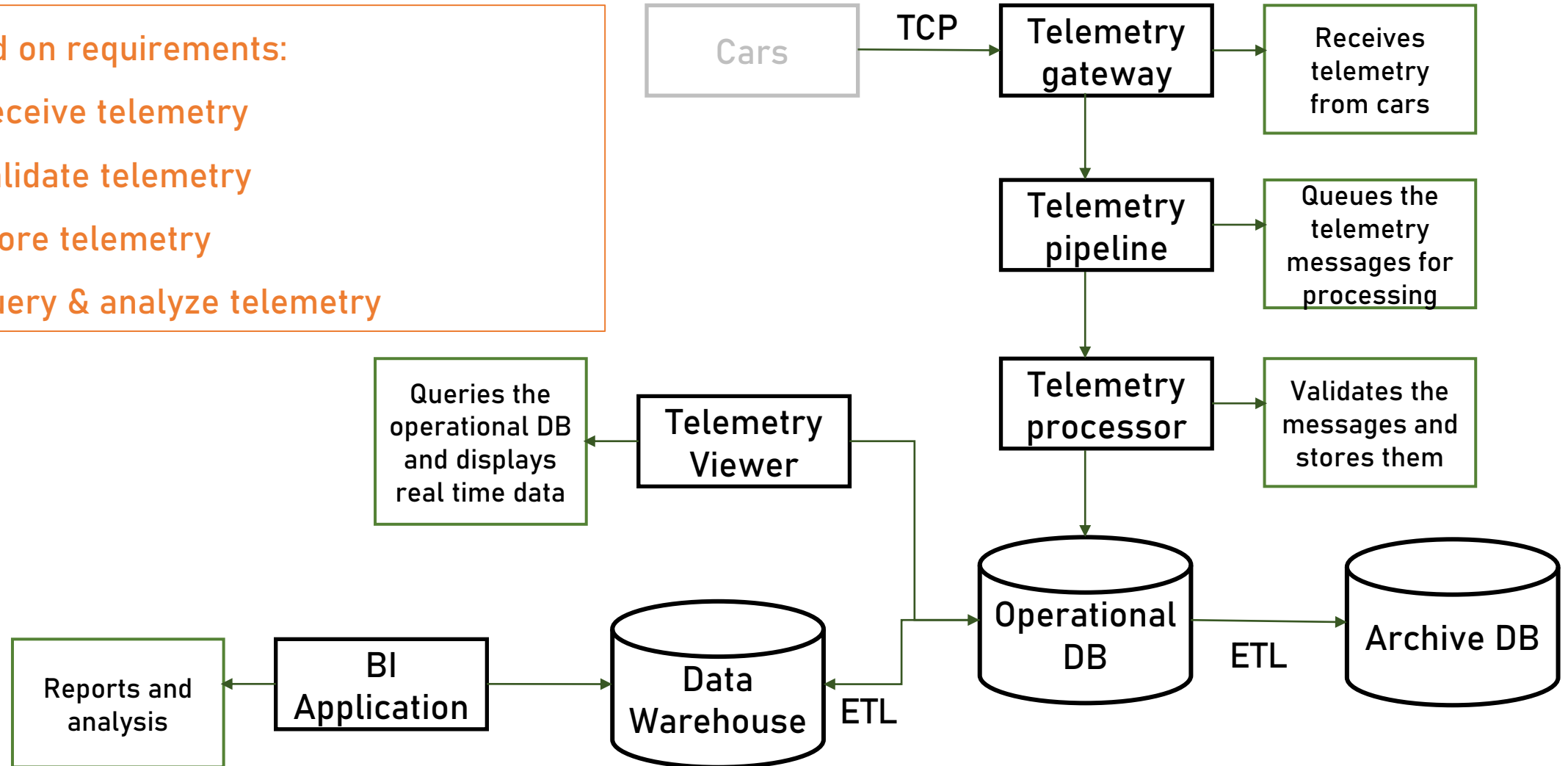
1. Receive telemetry
2. Validate telemetry
3. Store telemetry
4. Query & analyze telemetry



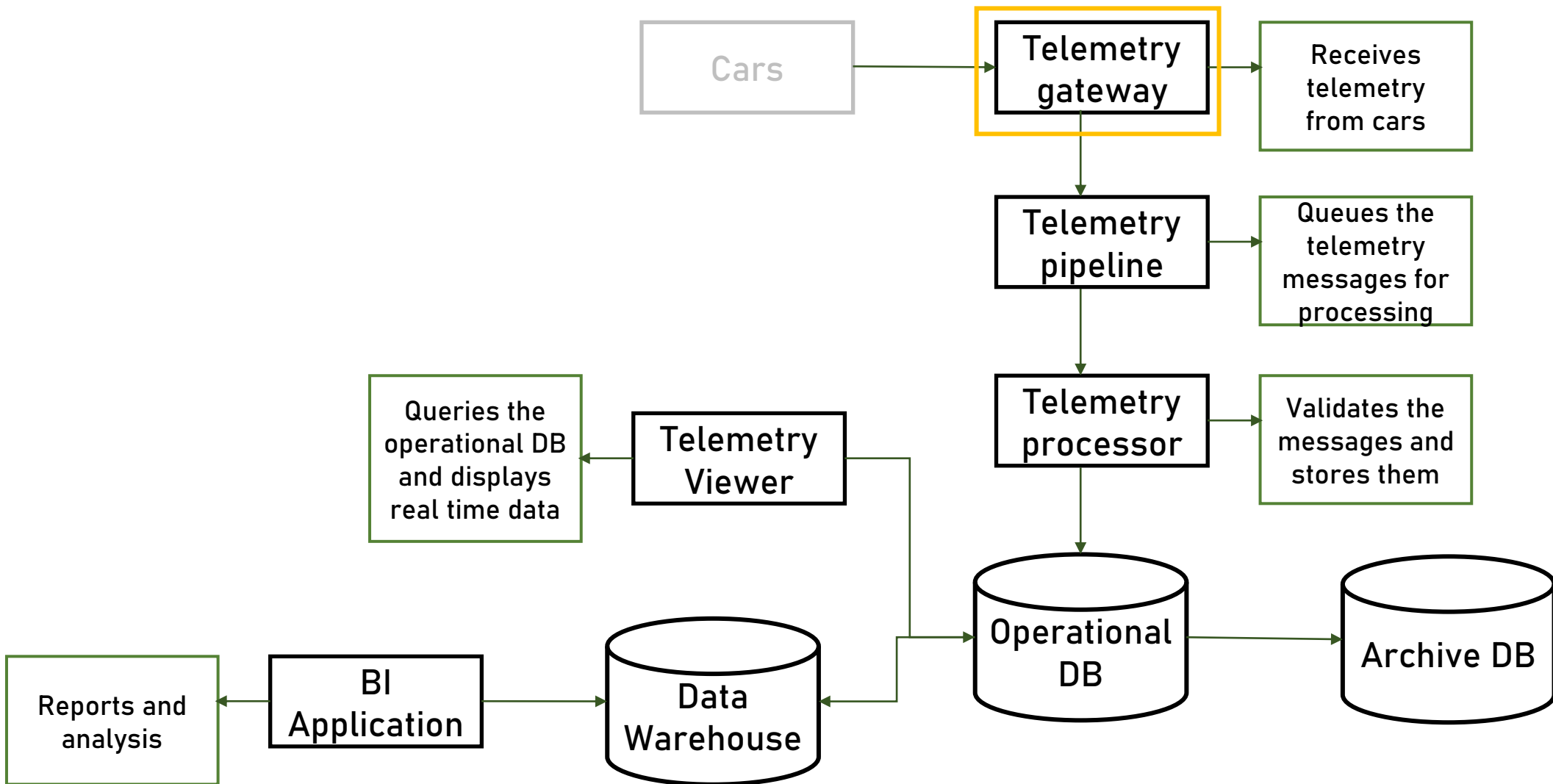
## Messaging

Based on requirements:

1. Receive telemetry
2. Validate telemetry
3. Store telemetry
4. Query & analyze telemetry



# Components







## Telemetry Gateway

What it does:

- Receives telemetry data from cars using TCP
- Pushes the telemetry data to the pipeline

## Application Type

- Web App & Web API 
- Mobile App 
- Console 
- Service 
- Desktop App 

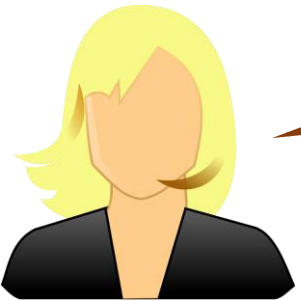
## Technology Stack

### Considerations:

- Load (7,000 msgs/sec)
- Performance
- Team's current knowledge
- Environment (OS, etc)



## Technology Stack



Our developers are familiar with Python,  
and are experts in JavaScript.  
In addition, we use only Linux servers.

**Python can't be used for the gateway**

**Too slow**

We look for a language with great performance,  
runs on linux, and leverages current skills  
(Python & JavaScript)



## Technology Stack



Great performance



Runs on Linux



Leverages JS skills

## Listeners in Azure



IoT Hub



Event Grid



App Service



Functions

No raw TCP support

## Listeners in Azure



- Not ideal
- Requires the most manual maintenance
- ...but allows most flexibility

## Scaling

Remember:

- Load (7,000 msgs/sec)
- Performance

*Muscar.auto*

Scaling



VM

## Scaling



+





## Virtual Machine Scale Sets

REGION:

West Europe

OPERATING SYSTEM:

Linux

TYPE:

Ubuntu

TIER:

Standard

CATEGORY:

All

VM SERIES:

Dsv4-series

INSTANCE:

D4s v4: 4 vCPUs, 16 GB RAM, {2} GB Temporary storage, \$0.087/hour

VIRTUAL MACHINES

2

### Savings Options

Save up to 72% on pay-as-you-go prices with 1-year or 3-year Reserved Virtual Machine Instances. Reserved Instances are great for applications with steady-state usage and applications that require reserved capacity. [Learn more about Reserved VM Instances pricing.](#)

#### Compute (D4s v4)

- ☐ Pay as you go
- ☐ 1 year reserved (~41% discount)
- ☒ 3 year reserved (~62% discount)

COMPUTE PAYMENT OPTIONS:

Monthly

\$127.60

Average per month

(\$0.00 charged upfront)

= \$127.60

Average per month

(\$0.00 charged upfront)

Upfront cost

\$0.00

Monthly cost

\$127.60

Load Balancer

REGION:

West Europe

TIER:

Standard

Load Balancer rules

5

Rules

= \$18.25

NAT rules

NAT rules are free.

= \$0.00

Data processed

1000

GB

×

\$0.005

Per GB

= \$5.00

Upfront cost

\$0.00

Monthly cost

\$23.25

## Architecture

Traditional:

User Interface /  
Service Interface

Business Logic

Data Access

Data Store



## Architecture

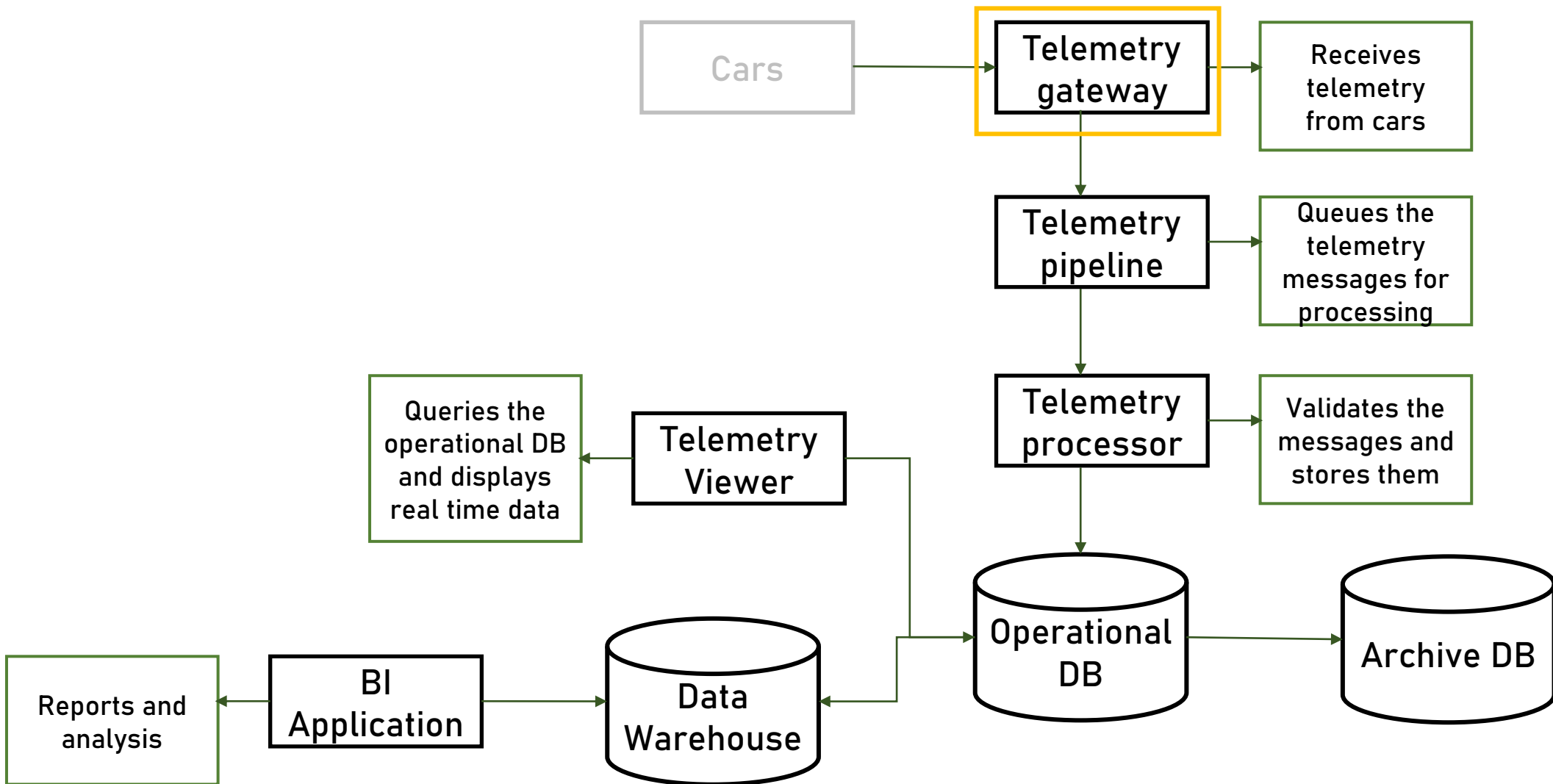
In our case:

Service Interface

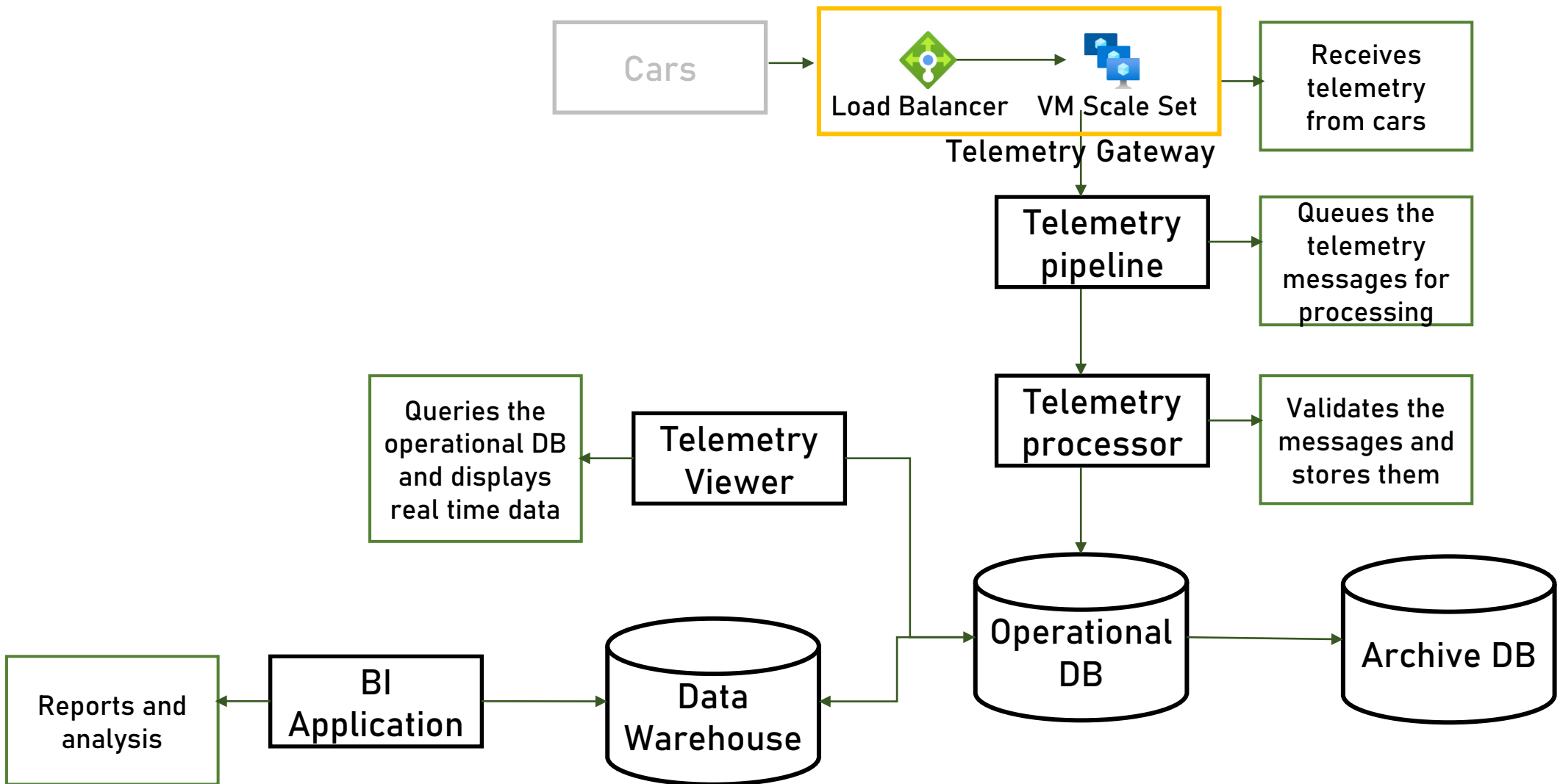


Pipeline

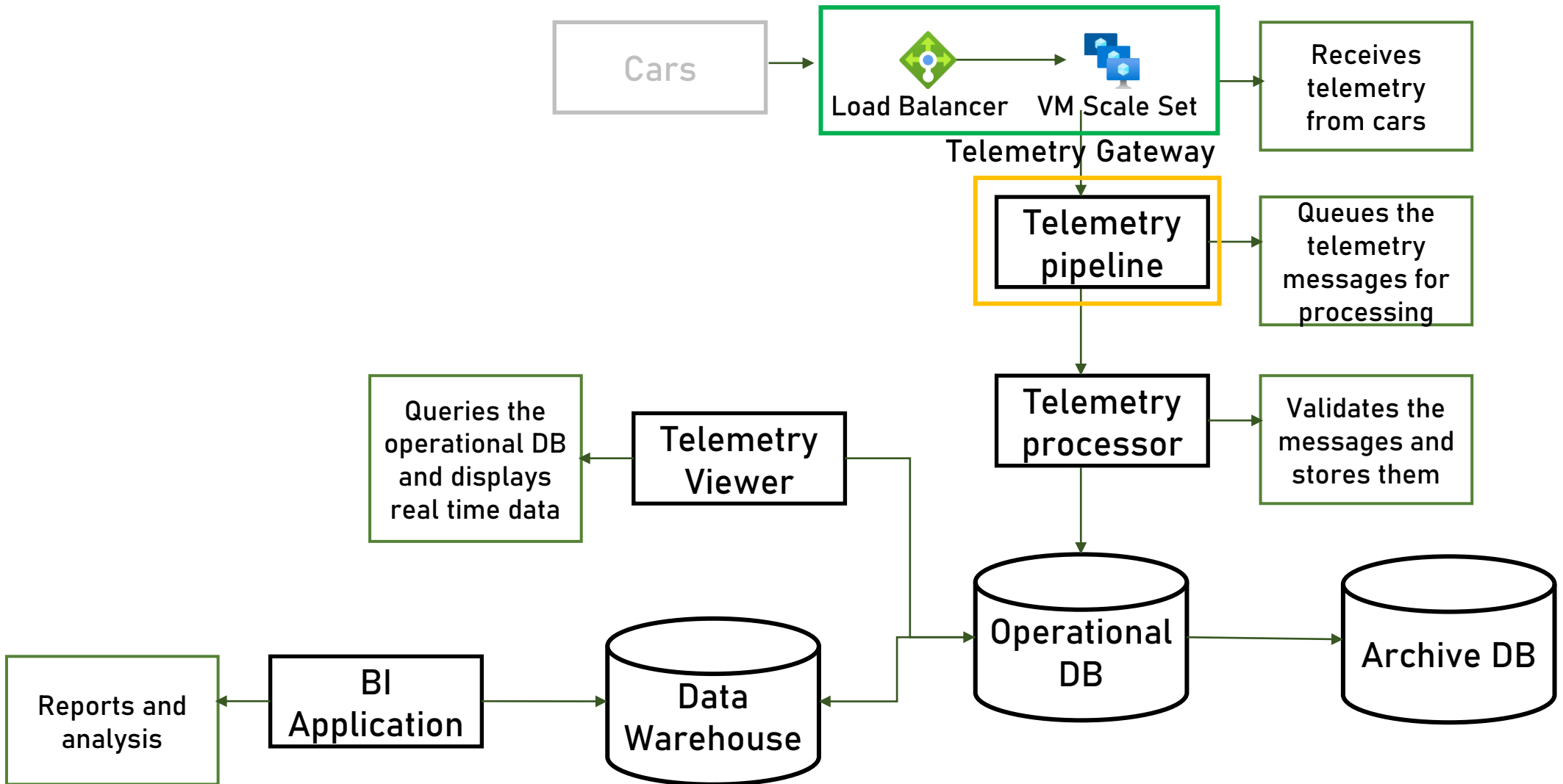
# Components



# Components



# Components









## Telemetry Pipeline

What it does:

- Gets the telemetry messages from the gateway
- Queues the telemetry for further processing
- Basically – a queue for streaming high volume data

## Messaging in Azure

Service	Used For...	Guarantees Order	Max Msg Size	And also...
Storage Queue 	Dead simple queueing	Yes	64KB	Extremely simple, no additional cost
Event Grid 	Event driven architectures	No	1MB	Great integration with other services
Service Bus 	Advanced queueing solutions	Yes	256KB	Advanced messaging features, durable
Event Hubs 	Big data streaming	Yes	1MB	Low latency, designed for heavy load

Each TU  
supports up to  
1k msgs / sec

Event Hubs

REGION:  
West Europe

TIER:  
Standard

Units

7

Throughput units

×

730

Hours

×

\$0.030

Per unit/hour

=

\$153.30

Enable Capture

Ingress

10

Million Events per month

×

\$0.028

Per million  
Events / month

=

\$0.28

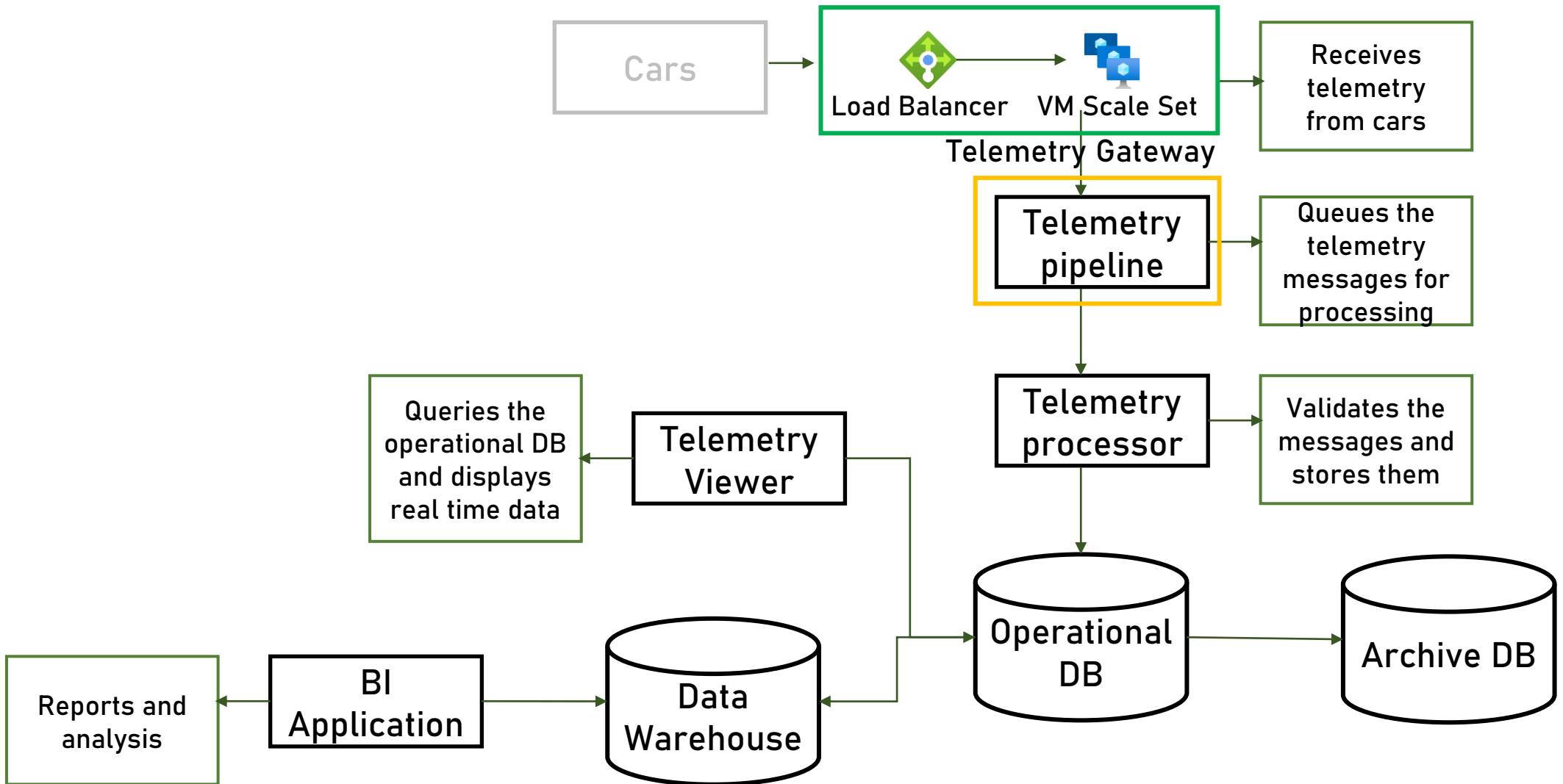
Upfront cost

\$0.00

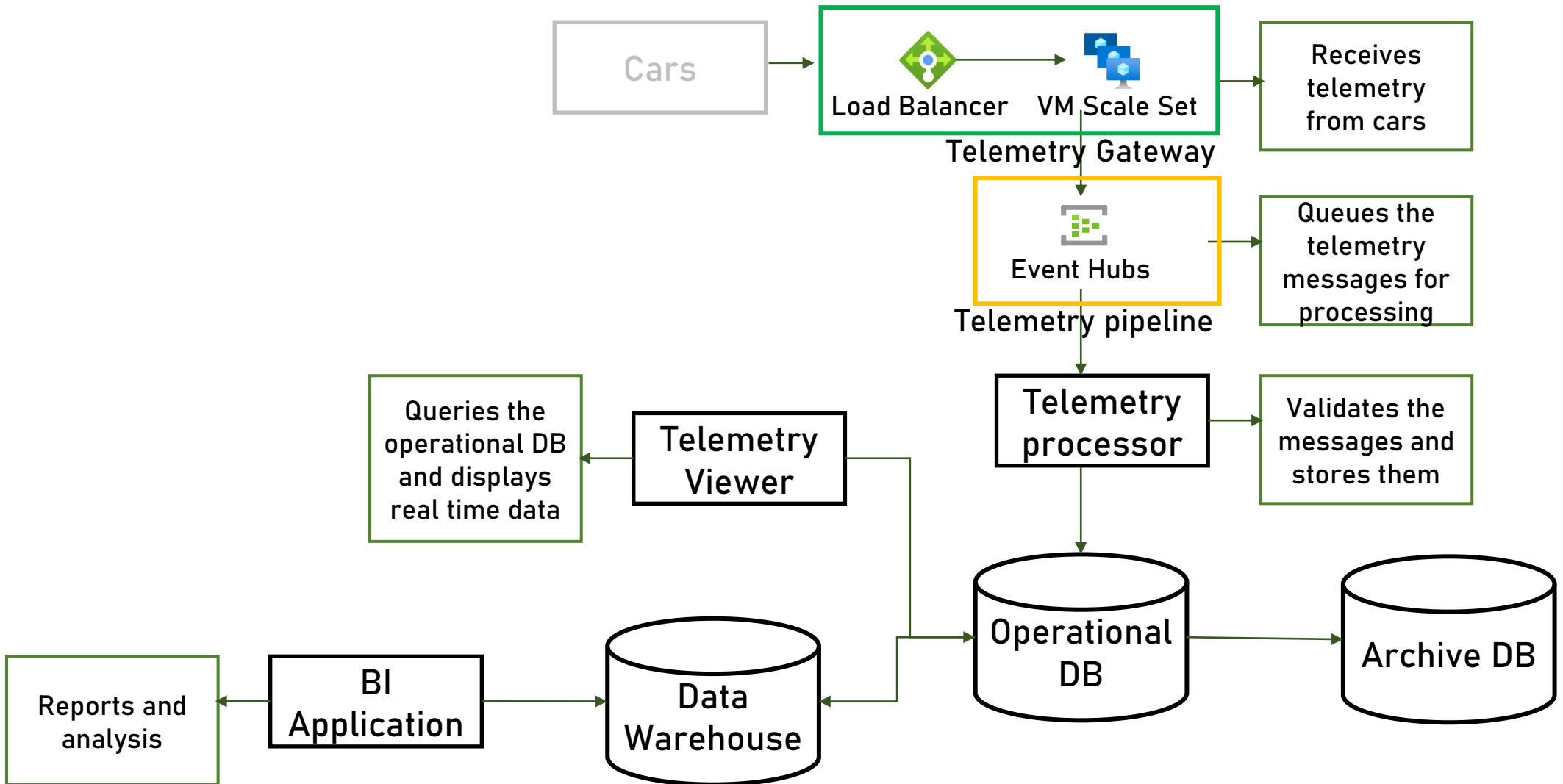
Monthly cost

\$153.58

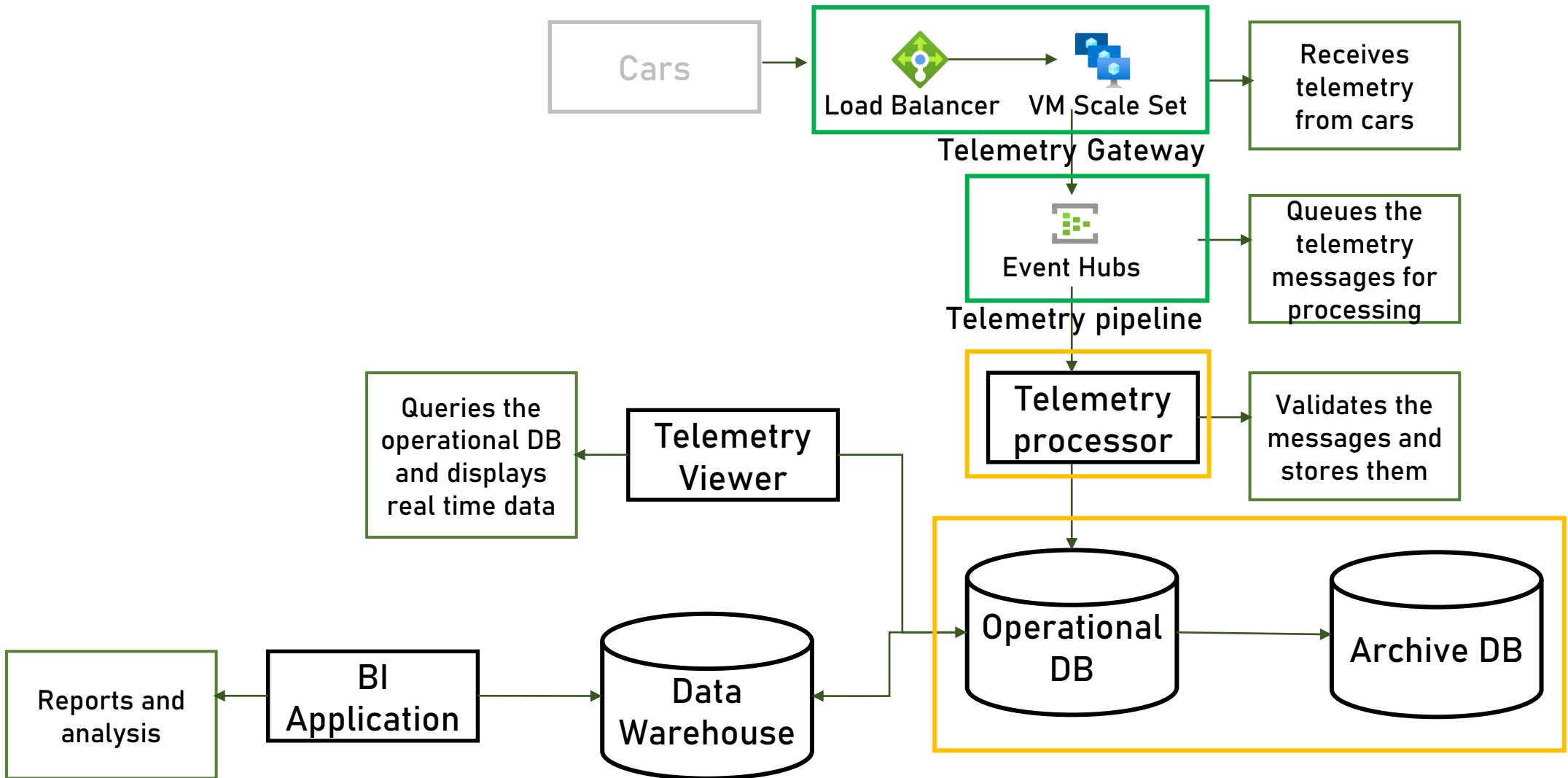
# Components



# Components



# Components



## Telemetry Processor

What it does:

- Receives the messages from the pipeline
- Processes the messages (mainly validation)
- Stores the messages in a data store

## Cloud Services

For:

- The processor
- The datastore



## Processor



## Function App

- Designed for lightweight operations
- Great, built-in integration with Event Hubs
- Cost effective
- Autoscaling

### Azure Functions

REGION:  
West Europe

TIER:  
Consumption

The first 400,000 GB/s of execution and 1,000,000 executions are free.

#### Executions

Memory size: 128 × Execution time (in milliseconds) 100 × Executions per month 10000000 = \$0.00

Requests

10,000,000  
Execution count

= \$1.80

Upfront cost

\$0.00

Monthly cost

\$1.80

## Data store

What we're looking for:

- Schema-less message support
- Quick retrieval
- No complex queries

## Technology Stack



- Schema-less message support
- Quick retrieval
- No complex queries
- In addition:
  - Multi-region read / write
  - Multiple APIs
  - Great performance



No need for  
7000 RU/s,  
Event Hubs  
balances load

Azure Cosmos DB

DATABASE OPERATIONS:

Standard provisioned throughput (manual)

WRITE REGIONS:

Single Region Write (Single-Master)

Savings Options

Save up to 65% on pay-as-you-go prices with 1 year or 3 year Reserved Capacity options.

Pay as you go

1 year reserved capacity

3 year reserved capacity

\$23.36

Average per month

(\$0.00 charged upfront)

Request units per second (RU/s)

400

RU/s

×

730

Hours

▼

Write Region:

West Europe

400

RU/s

×

730

Hours

×

\$0.008

Per 100 RU/s per hour

Enable Availability Zones

=

\$23.36

Storage

Transactional Storage

4000

GB

Analytical Storage

Enable Analytical Storage

Regional Storage Costs

\$1,000.00

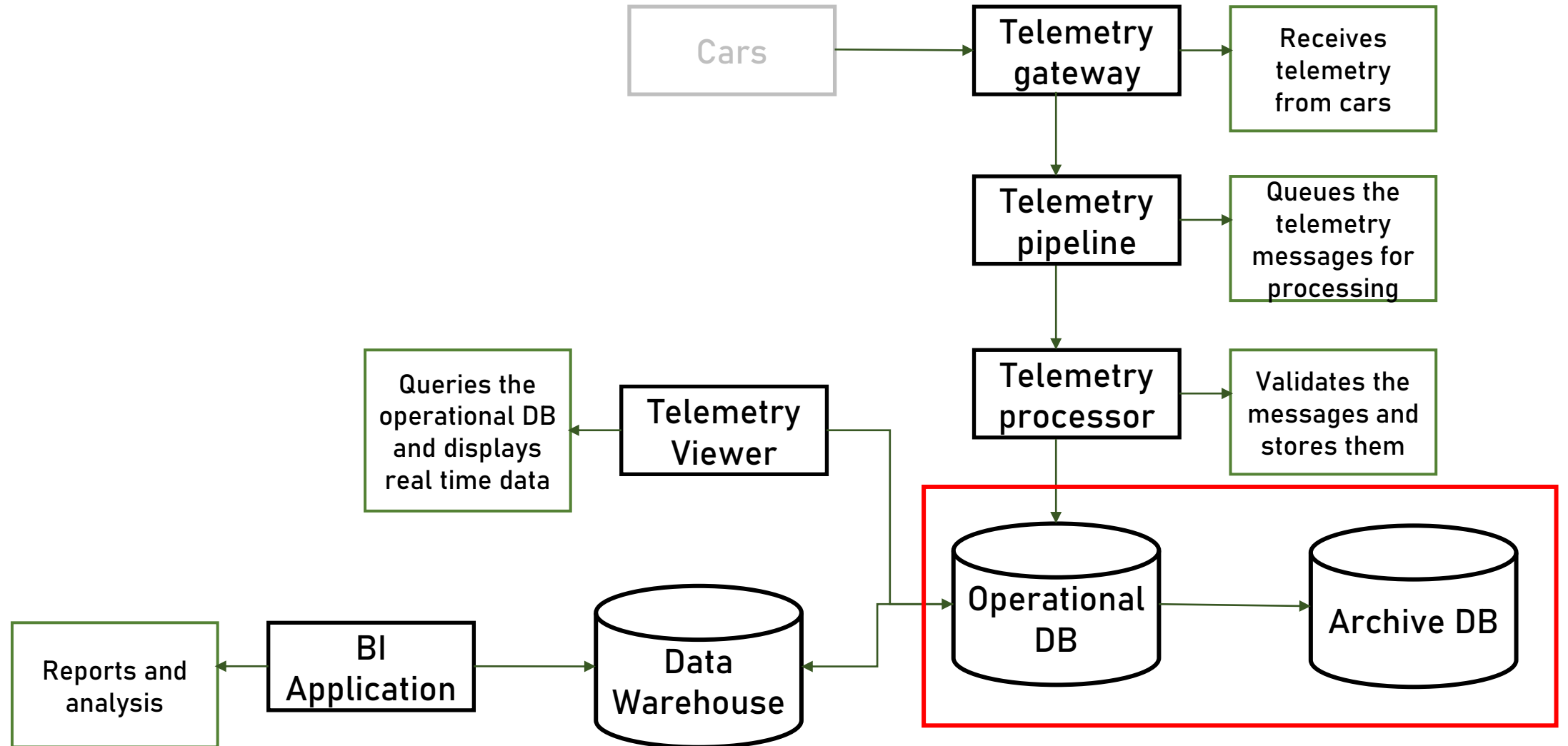
Upfront cost

\$0.00

Monthly cost

\$1,023.36

# Components



## Archive– what we're looking for:

- Support for a huge amount of data (221TB / Year)
- Not accessed frequently
- No need for fast retrieval
- Save costs

## Archive Database



## Storage Account

- Huge amounts of data (221TB / Year)
- Not accessed frequently
- No need for fast retrieval
- Save costs





Storage Accounts

REGION:  
West Europe

TYPE:  
Block Blob Storage

PERFORMANCE TIER:  
Standard

STORAGE ACCOUNT TYPE:  
General Purpose V2

ACCESS TIER:  
Archive

REDUNDANCY:  
LRS

Capacity

221 TB

Early deletion fees may apply and are not included. [Learn more about early deletion fees.](#)

Savings Options

Save up to 38% on pay-as-you-go prices with 1-year or 3-year Azure Storage Reserved Capacity. [Learn more about Azure Storage Reserved Capacity pricing.](#)

Pay as you go

1 year reserved

3 year reserved

\$407.35

Average per month

(\$0.00 charged upfront)

= \$407.35

Average per month

(\$0.00 charged upfront)

All other operations

1 Operations

×

\$0.004

Per 10,000 operations

= \$0.01

Data Retrieval

1000 GB

×

\$0.024

Per GB

= \$24.00

Archive high priority retrieval

1 GB

×

\$0.130

Per GB

= \$0.13

Data write

1000 GB

×

\$0.000

Per GB

= \$0.00

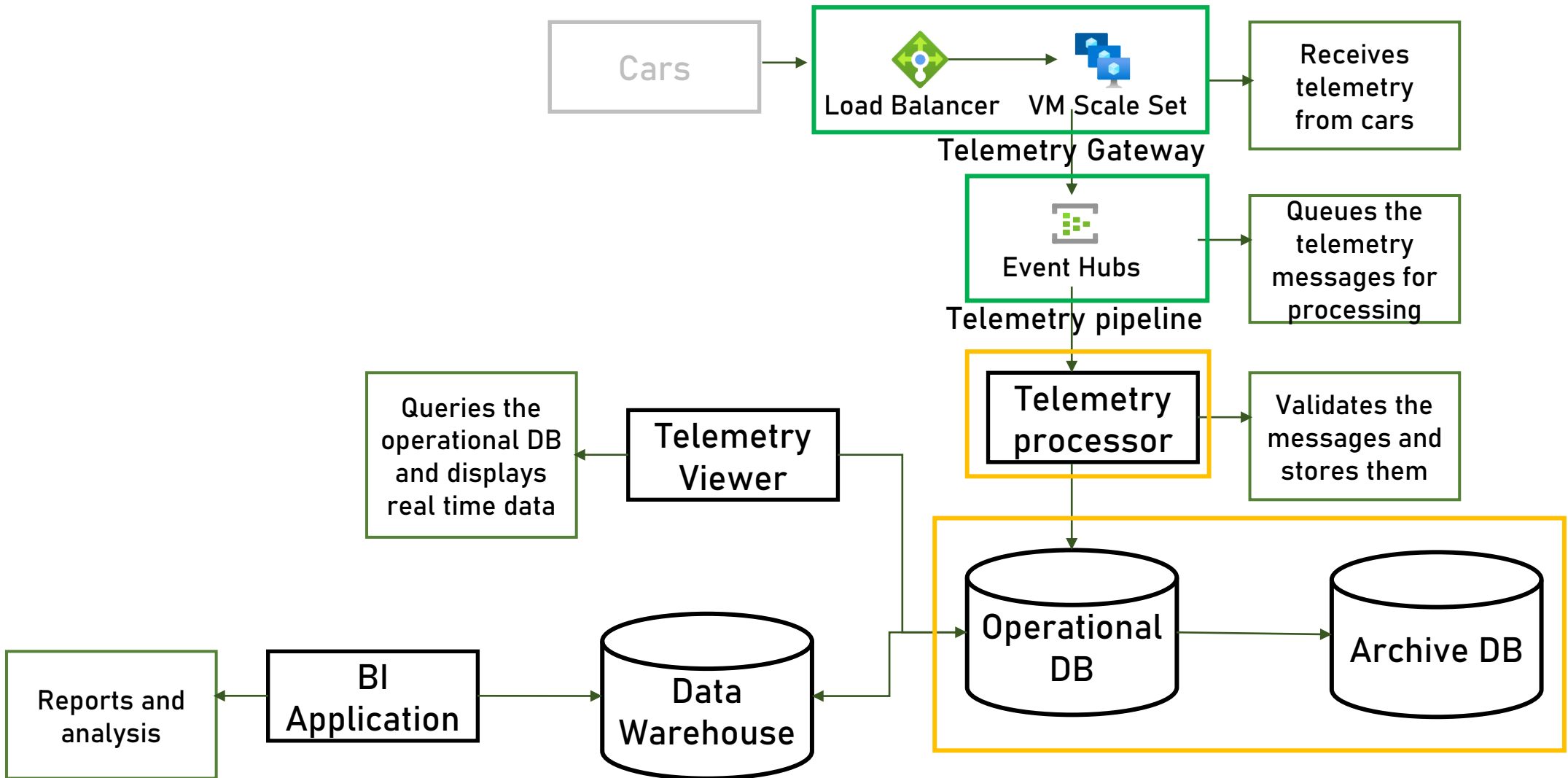
Upfront cost

\$0.00

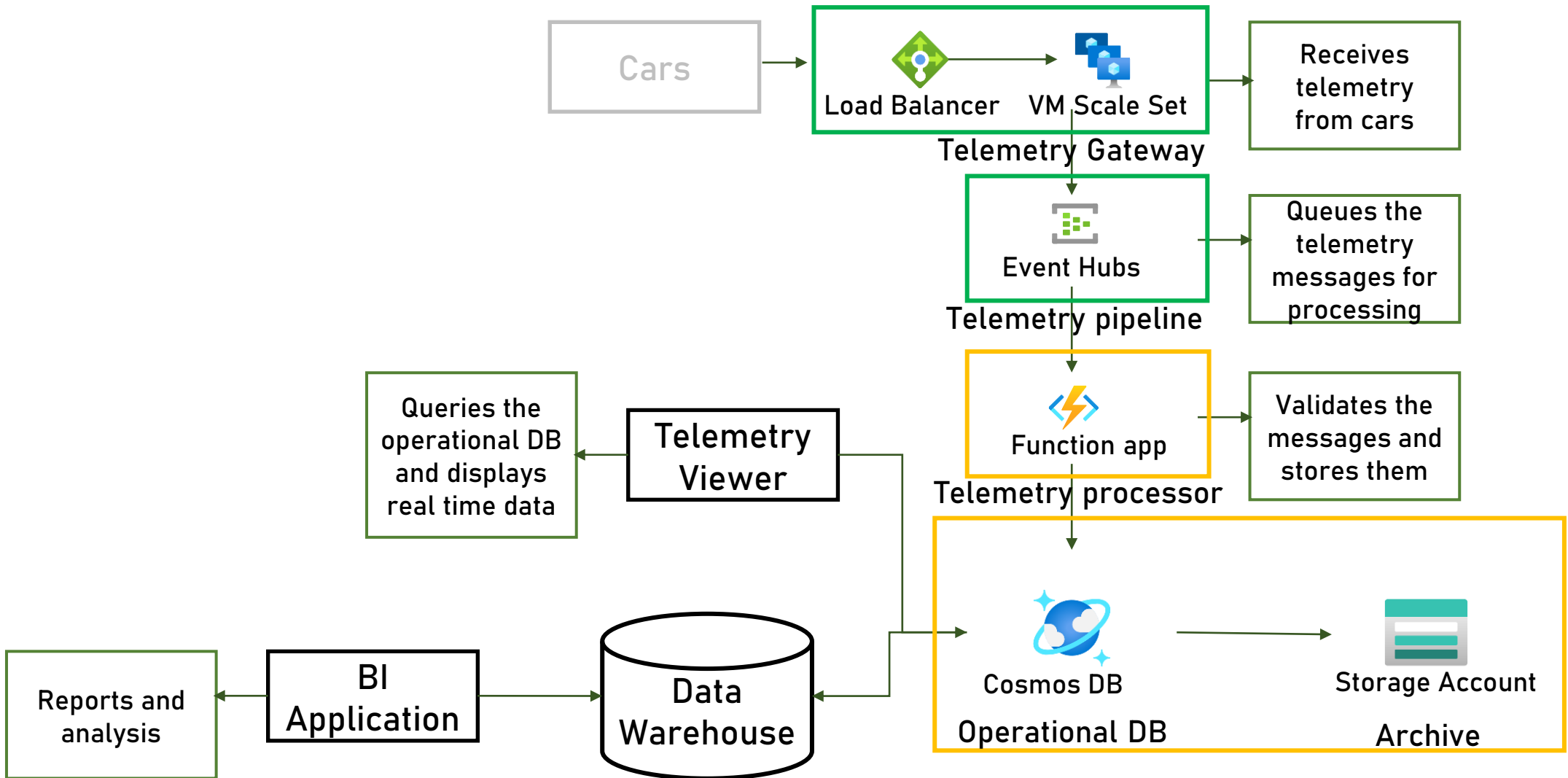
Monthly cost

\$433.22

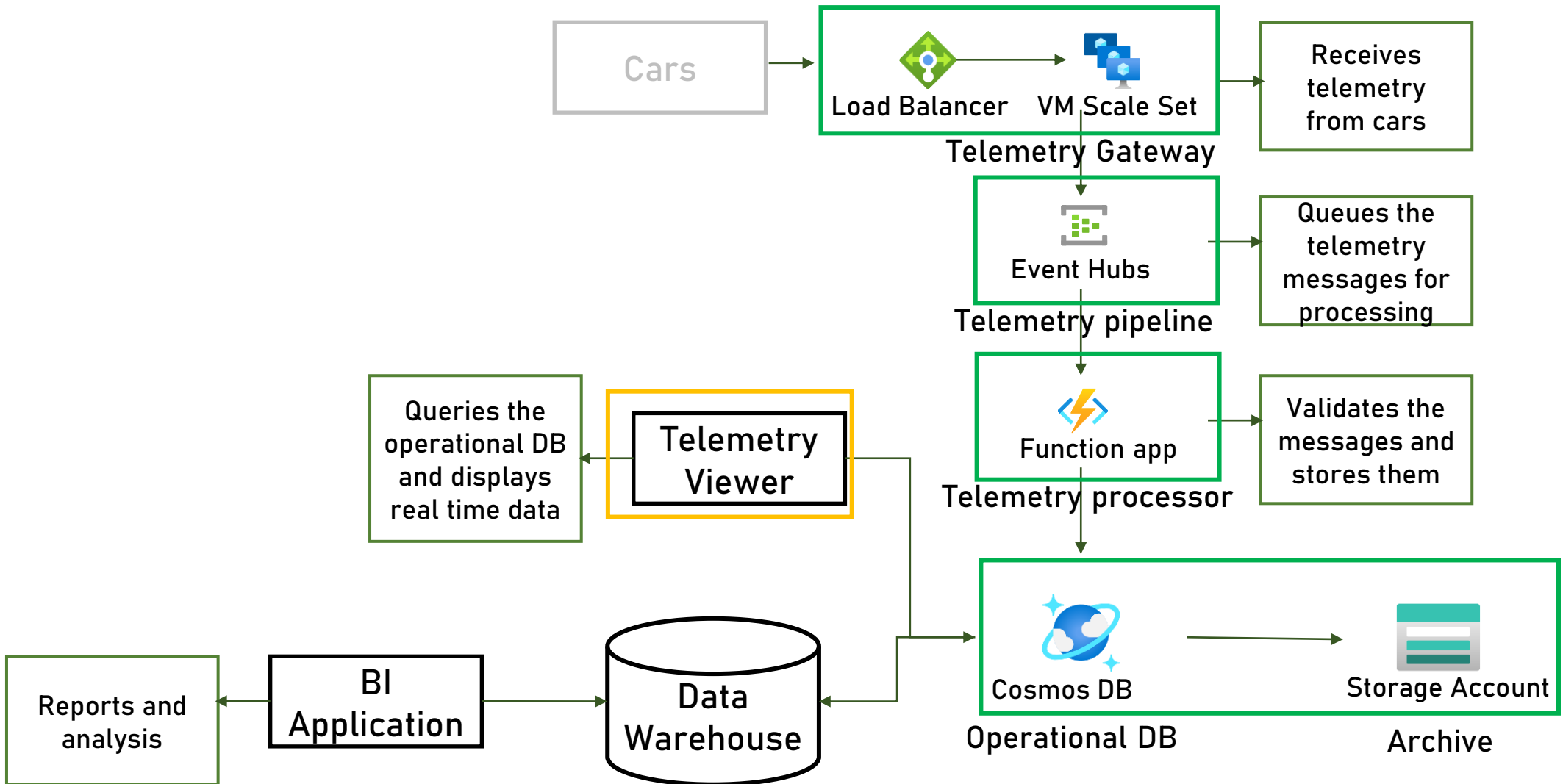
# Components



# Components



# Components



## Telemetry Viewer

What it does:

- Allows end users to query telemetry data
- Displays real time data

What it doesn't:

- Analyzes the data

## Application Type

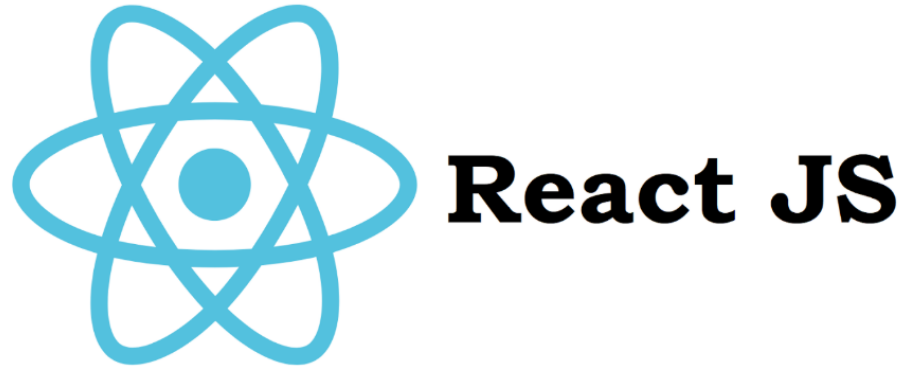
- Web App & Web API ✓
- Mobile App ✗
- Console ✗
- Service ✗
- Desktop App ✗

## Technology Stack

Back End



Front End



## Azure Web API



### App Service

- Fully managed web app & API
- Supports many platforms
- Autoscale
- Support for WebJobs



# Azure Web API

App Service

REGION:

West Europe

OPERATING SYSTEM:

Windows

TIER:

Standard

Standard

INSTANCE:

S1: 1 Cores(s), 1.75 GB RAM, 50 GB Storage, \$0.100

1

×

730

Hours

= \$73.00

SSL Connections

Upfront cost

\$0.00

Monthly cost

\$73.00

## Architecture

Service Interface

Business Logic

Data Access

Data Store



## API


- Get latest errors for all cars
- Get latest telemetry for specific car
- Get latest errors for specific car

API


Functionality	Path	Return Codes
Get latest errors for all cars	GET /api/v1/telemetry/errors	200 OK
Get latest telemetry for specific car	GET /api/v1/telemetry/{carId}	200 OK 404 Not Found
Get latest errors for specific car	GET /api/v1/telemetry/errors/{carId}	200 Ok 404 Not Found

## Telemetry Viewer Redundancy

### App service auto scale

**Default\*** Auto created scale condition 


Delete warning

 The very last or default recurrence rule cannot be deleted. Instead, you can disable autoscale to turn off autoscale.

Scale mode

☒ Scale based on a metric ☐ Scale to a specific instance count

Rules

 It is recommended to have at least one scale in rule. To create new rules, click [Add a rule](#).

Scale out

When	Default1	(Average) CpuPercentage > 70	Increase count by 1
Or	Default1	(Average) HttpQueueLength > ...	Increase count by 1

[+ Add a rule](#)

Instance limits

Minimum ⓘ

Maximum ⓘ

Default ⓘ

1 ✓

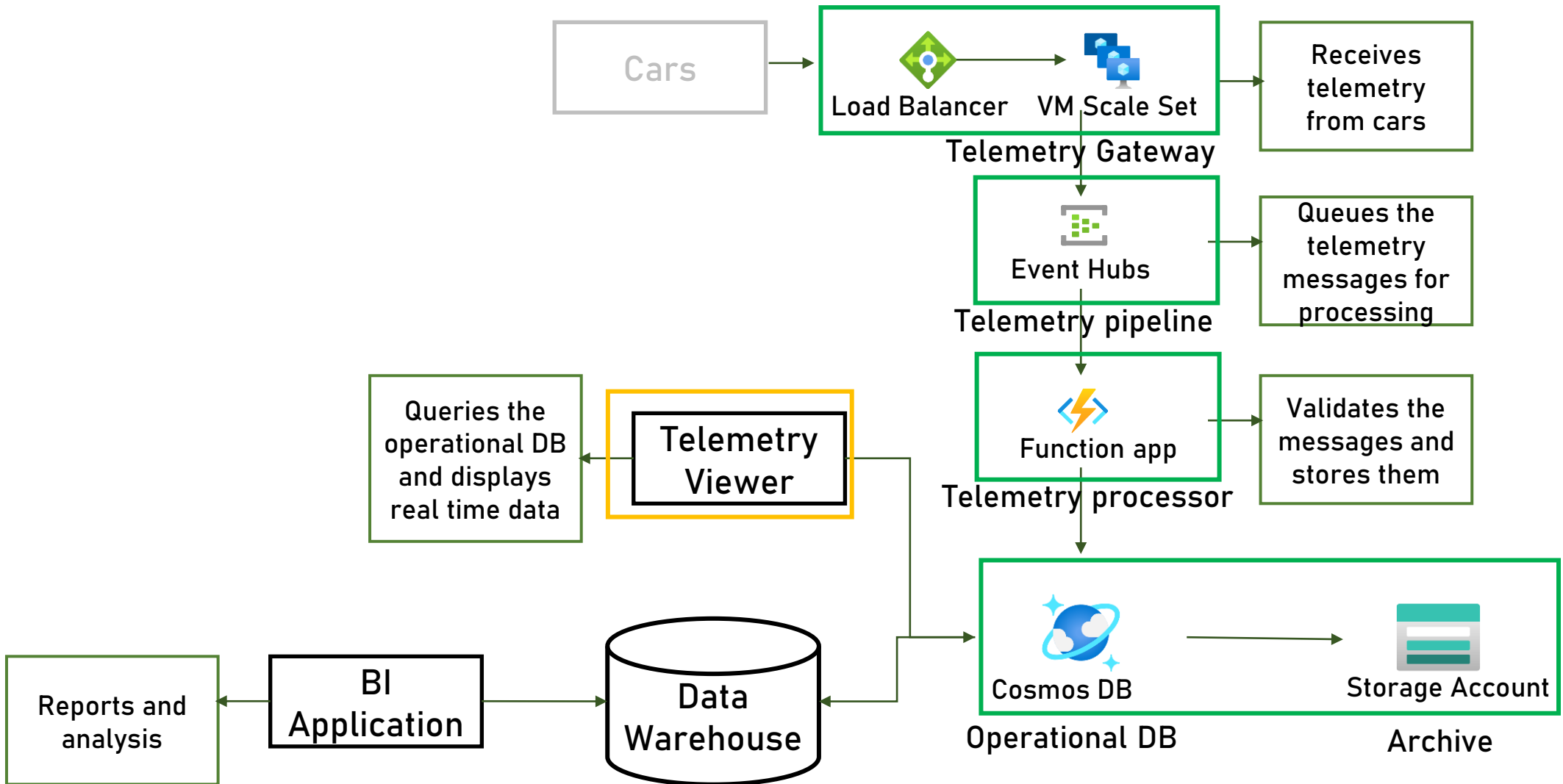
3 ✓

1 ✓

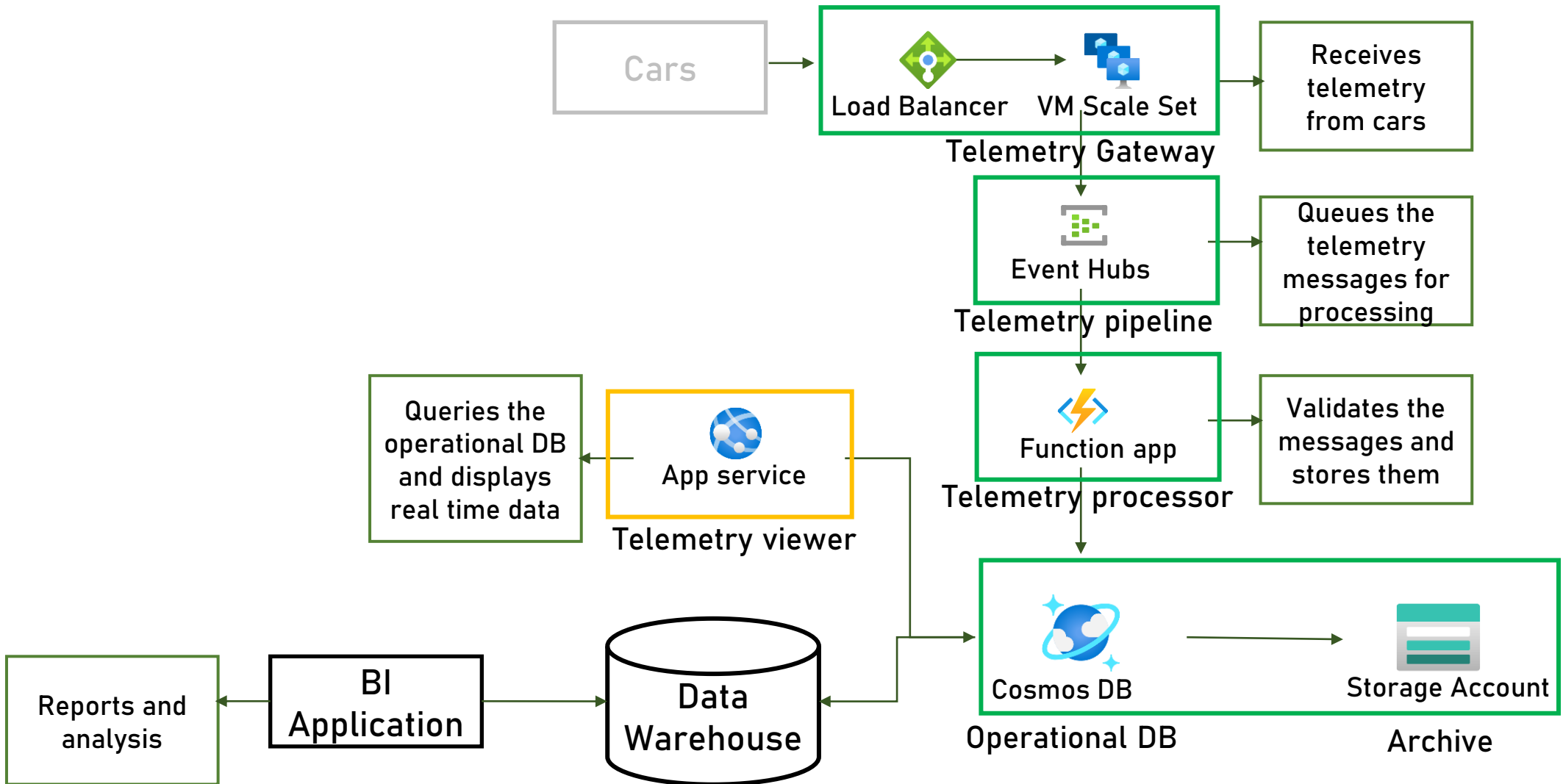
Schedule

This scale condition is executed when none of the other scale condition(s) match

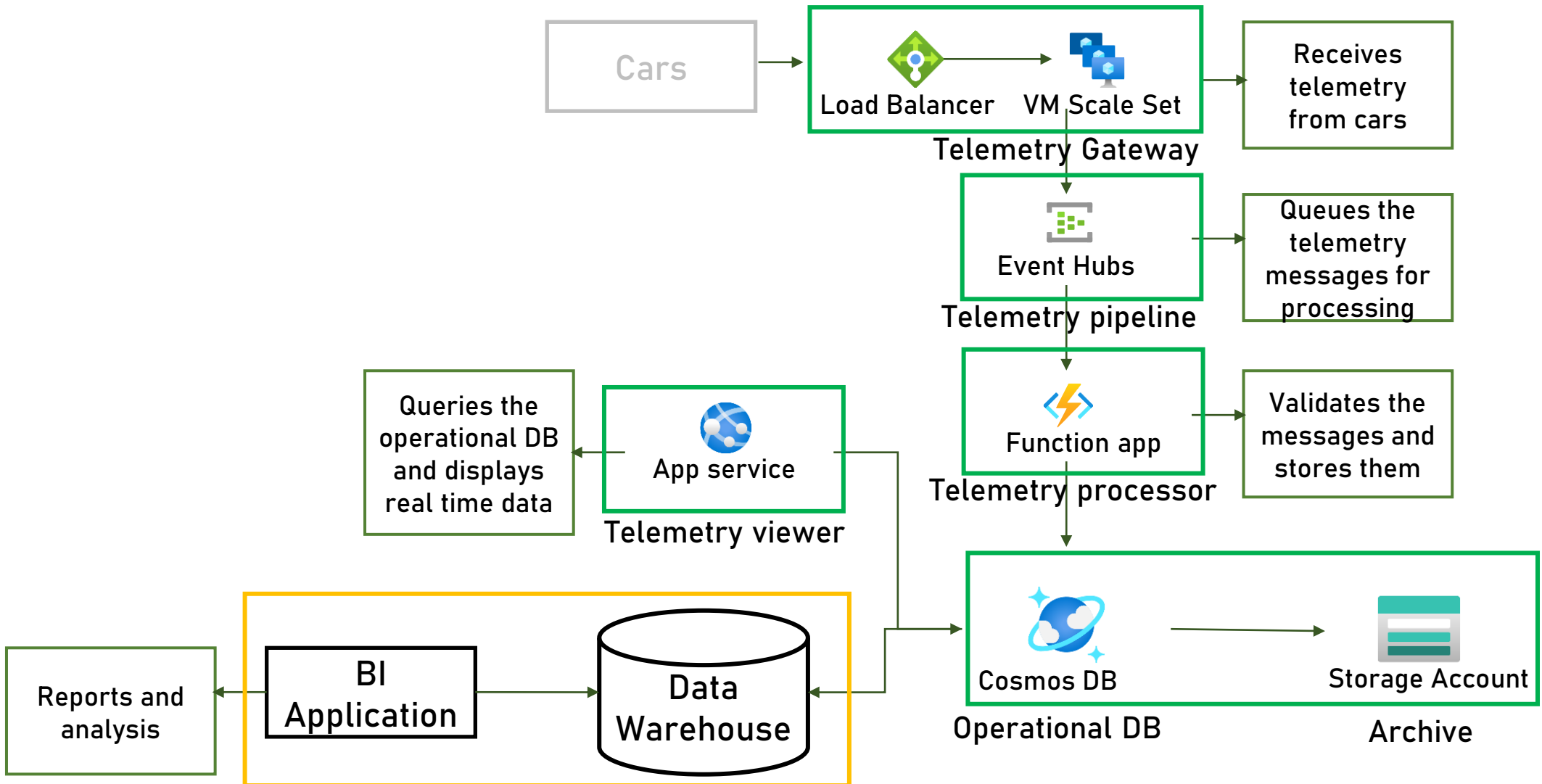
# Components



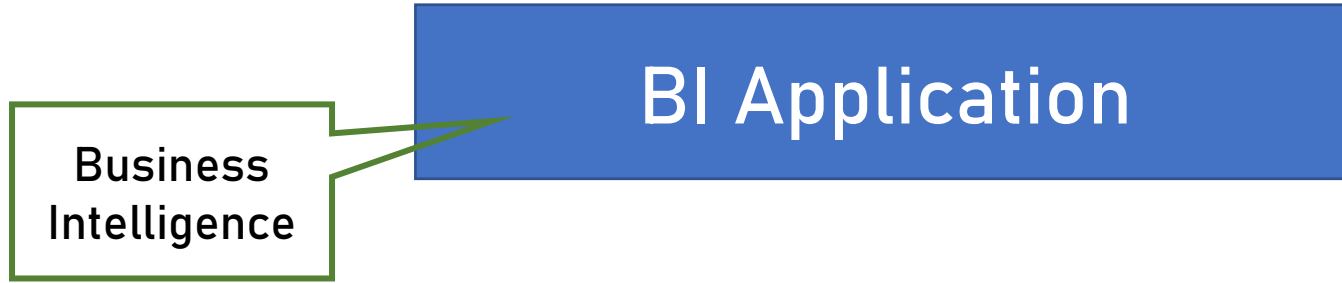
# Components



# Components







What it does:

- Analyzes telemetry data
- Displays custom reports about the data, trends, forecasts etc.
  - How many cars did break during the last month?
  - What is the total distance the cars drove?

## Application Type

- Doesn't matter
- BI Application is ALWAYS based on an existing tool

## BI Tools



# BI Tools

Figure 1. Magic Quadrant for Analytics and Business Intelligence Platforms



Source: Gartner (February 2019)

## BI Tools

- An important lesson:
  - Designing BI solution is NOT part of the architect's job
  - ALWAYS use BI expert for this task

## Security

- Pay attention to:
  - Public accessible databases
  - Unprotected access to App Service

## Security

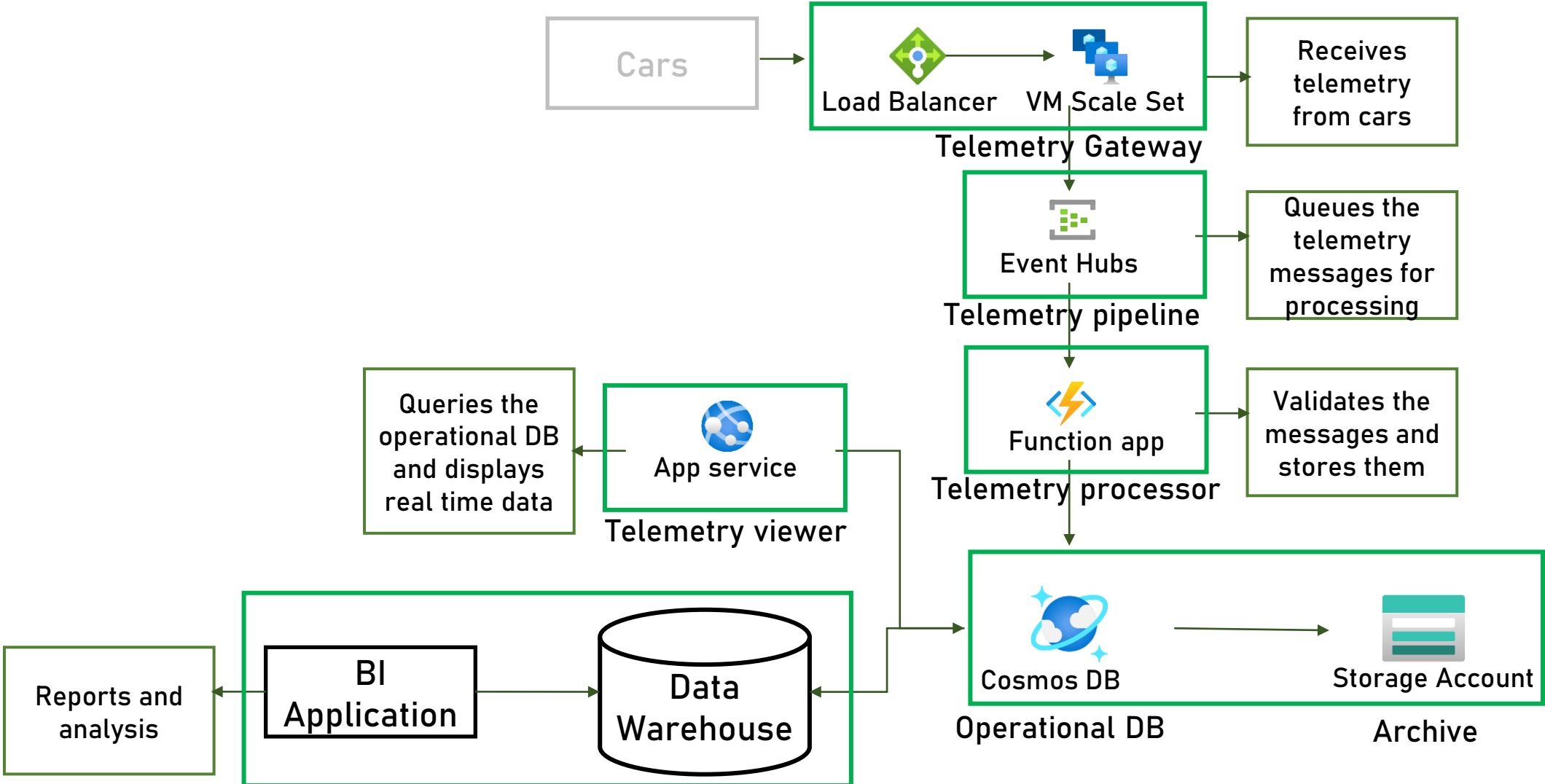
- To-Do:
  - Block access to databases from unauthorized IP addresses

## Security

- What about the App Service?
  - The client decided not to place WAF in front the App Service
    - Small service
    - Read-only operations
    - Save costs



# Architecture Diagram



## Cost

Estimated upfront cost

\$0.00

Estimated monthly cost

\$1,835.82

Download detailed cost estimation  
from the lecture's resources