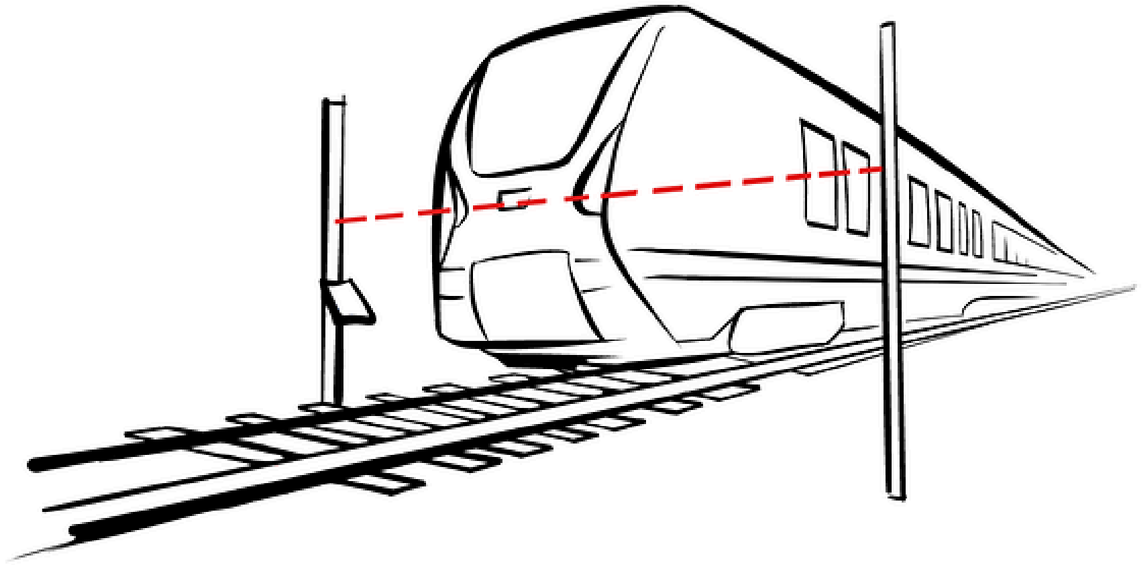
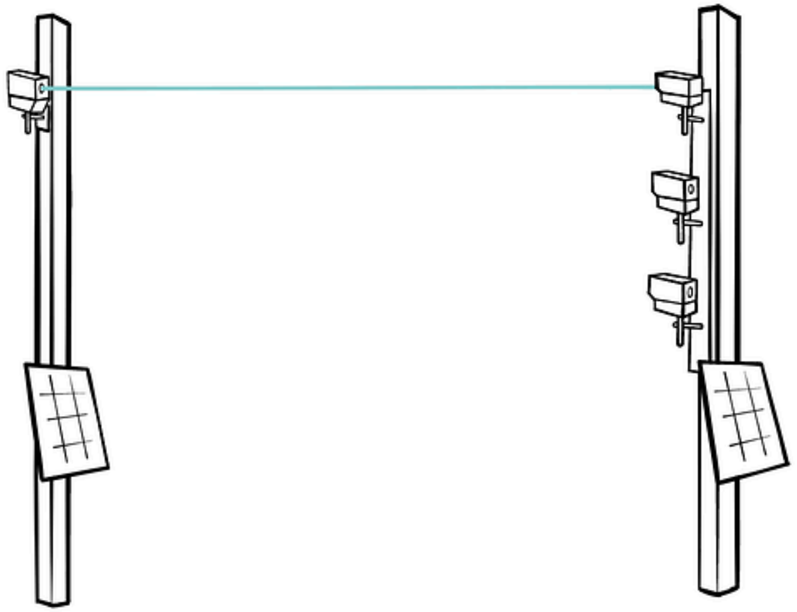
Real-Time Train Occupancy Monitoring System





JOHN MAURICE P. SISON

SOURCE: HTTPS://LIGHTGATE.DEUTSCHEBAHN.COM/LIGHTGATE-EN

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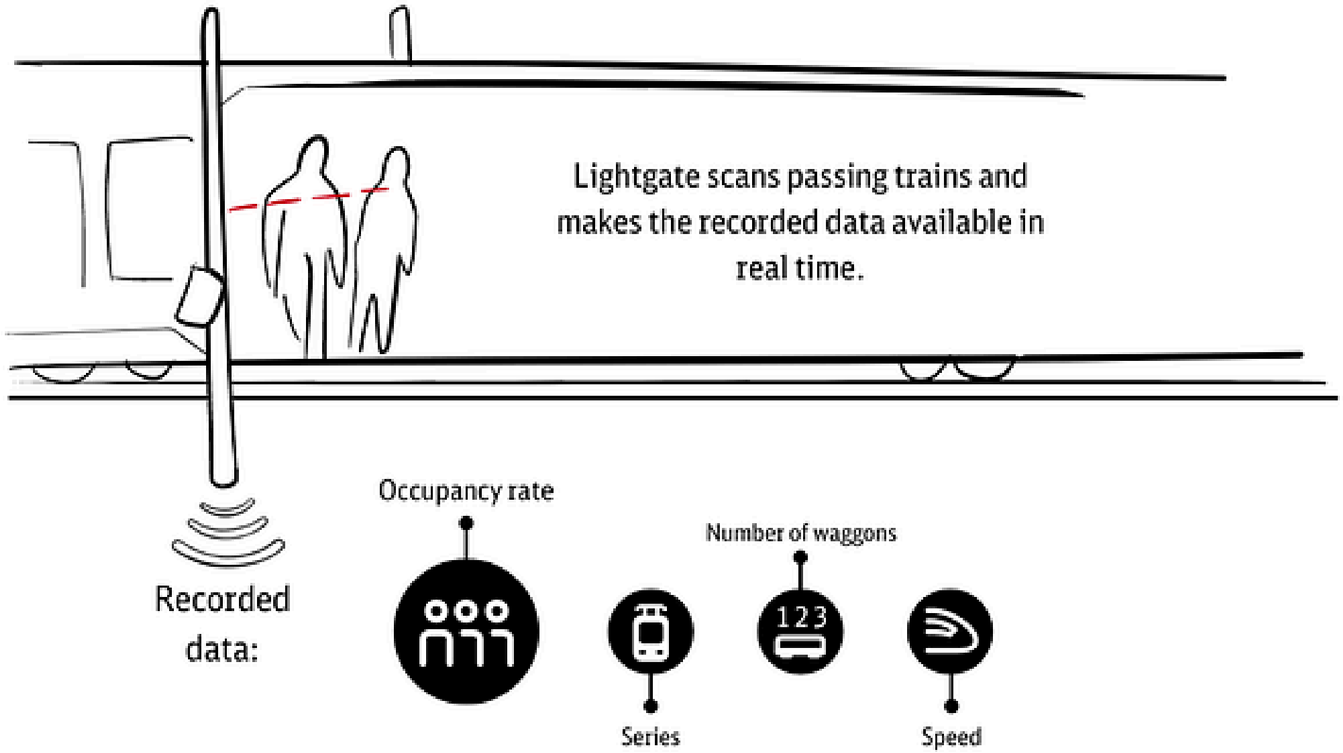

Our concept for the Real-Time Train Occupancy Monitoring System is inspired by the technology DB Lightgate company(Deutsche Bahn).

Their innovation scans passing trains using advanced optical sensors to capture real-time data on:

- Passenger occupancy rates
- Train classification
- Number of carriages
- Speed

This data is processed instantly and can be seamlessly integrated into customer systems, enabling informed decisions, efficient transport management, and enhanced passenger experience.

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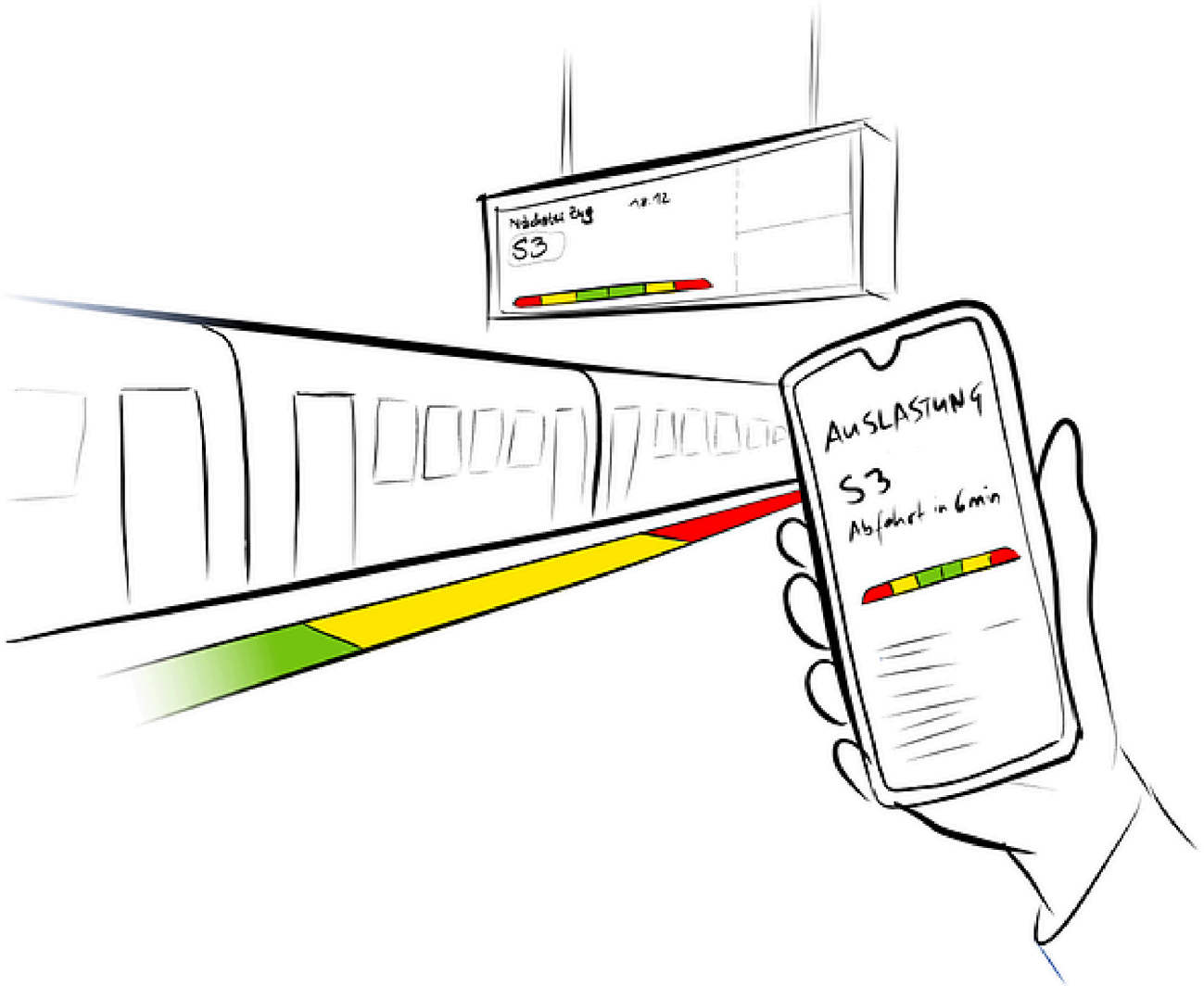
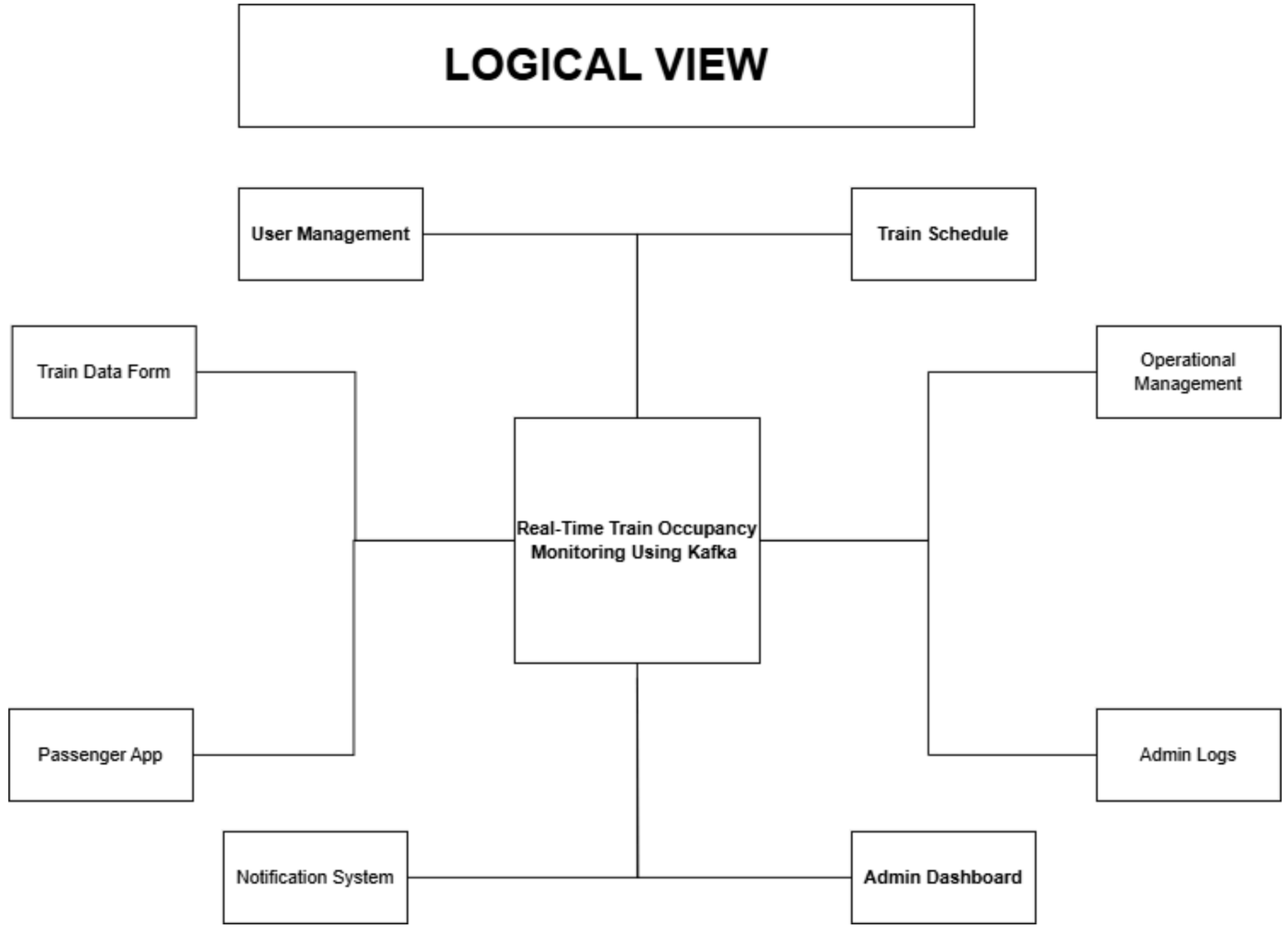


Passenger Experience

The system delivers essential data to address passenger needs effectively. By providing real-time capacity information, passengers can choose the right connections and locate available seats tailored to their preferences. This boosts customer satisfaction and helps passengers reach their destinations more quickly, reliably, and comfortably. Moreover, active guidance for passengers aids in improving punctuality across the entire rail system.

4+1 View Model

LOGICAL VIEW



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DOCUMENTATION

KAFKA TOPICS

1. train-occupancy-levels → Collects real-time occupancy data.
2. train-notifications → Sends notifications for overcrowding, delays, or issues.
3. operational-scheduling → Optimizes train schedules.
4. passenger-real-time-info → Provides passengers information for seat availability.

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DOCUMENTATION

MICROSERVICES

Service	Role	Topics Published/Consumed
Service A (Data Input)	Accepts train data (manual input)	Publishes to **train-occupancy-levels**
Service B (Operational Management)	Decision making based on occupancy	Consumes **train-occupancy-levels**, Publishes to **operational-scheduling**
Service C (Notification System)	Sends alerts based on occupancy/delays	Consumes **train-occupancy-levels** , Publishes to train-notifications
Service D (Passenger Info Service)	Filters & formats data for passengers (user-friendly alerts)	Consumes **operational-scheduling**, Publishes to **passenger-real-time-info**
Service E (Passenger App)	Fetches & displays real-time train data	Consumes **passenger-real-time-info** and **train-notifications**
Service F (Logging & Analytics)	Logs system data for analysis	Consumes **all topics** for auditing

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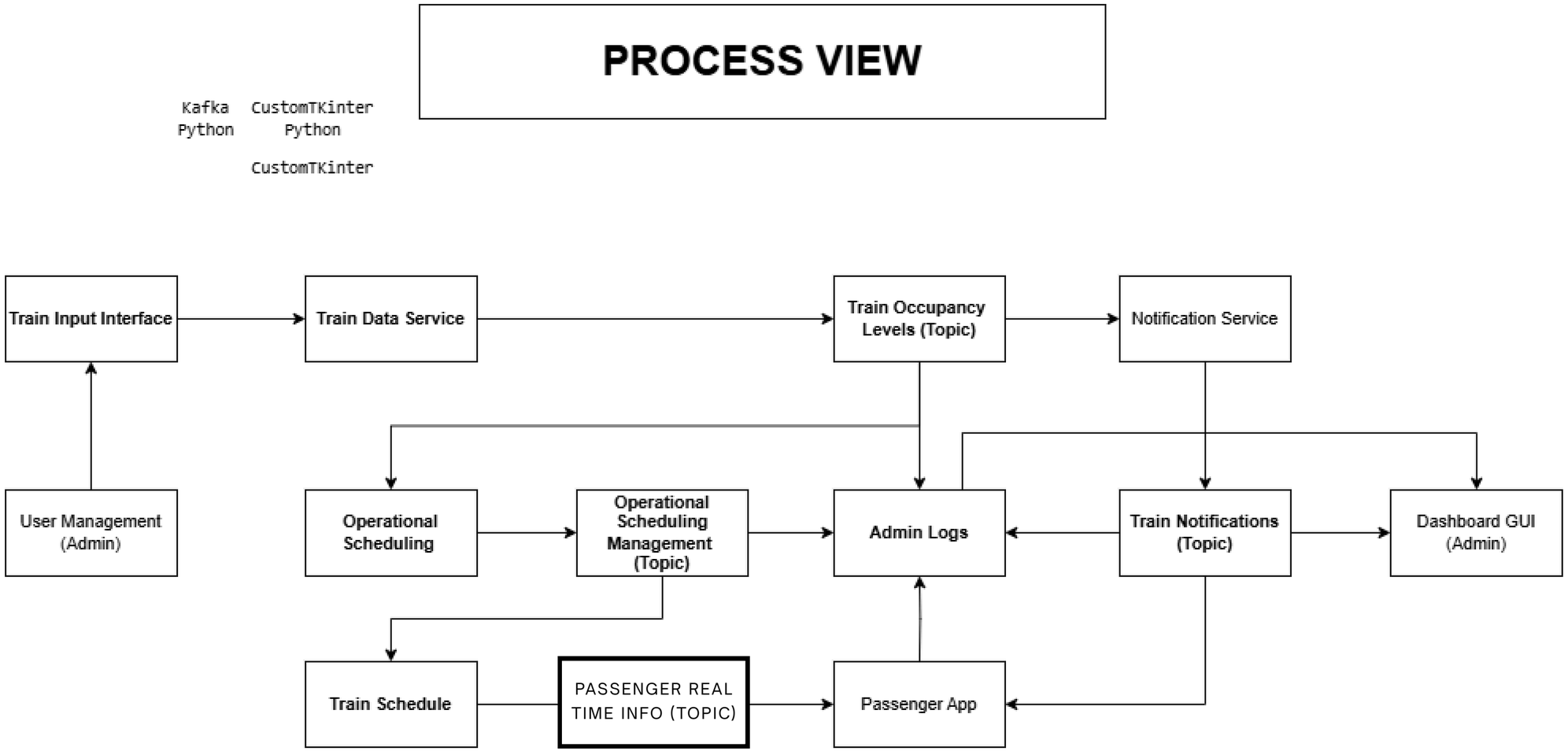
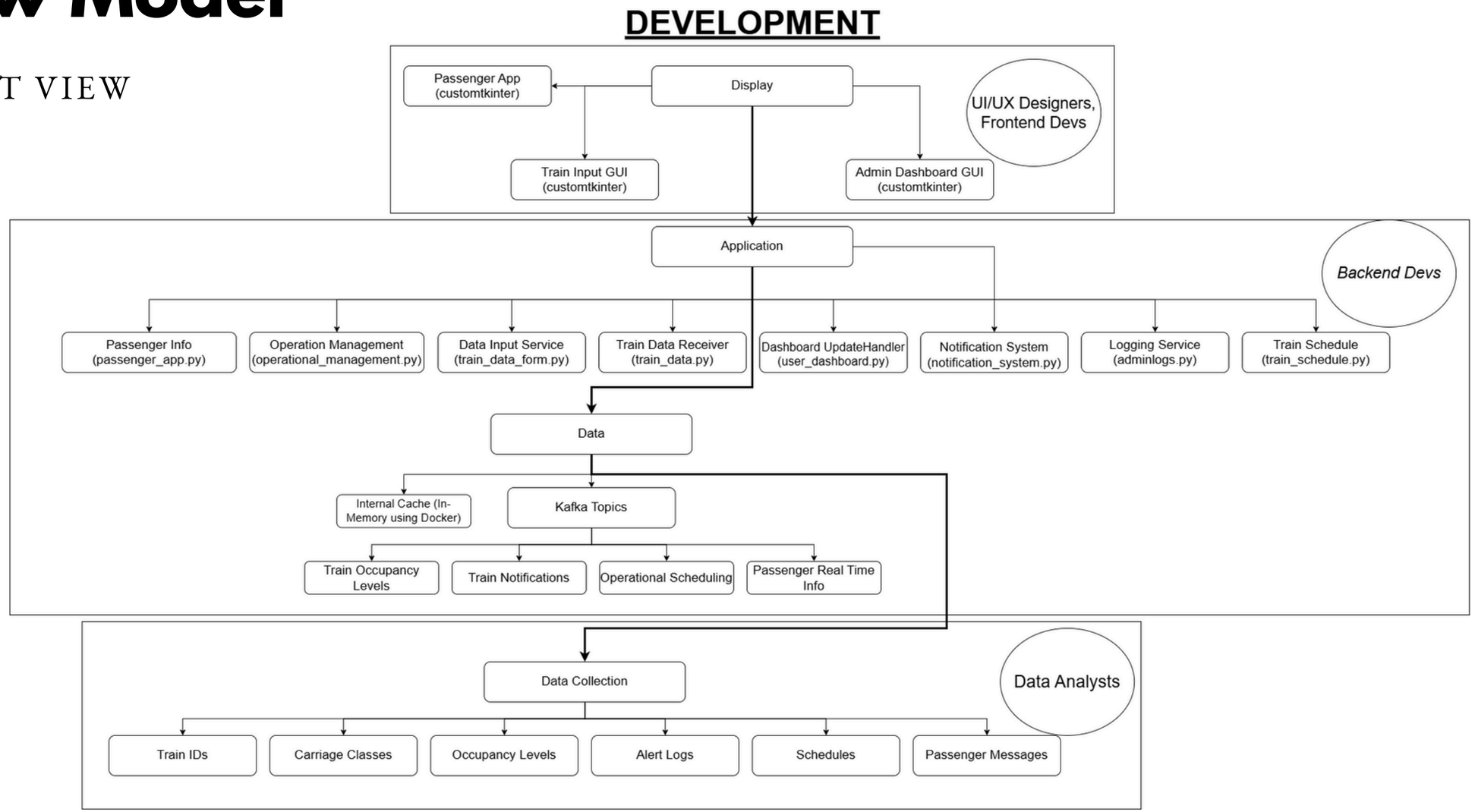
4+1 View Model

PROCESS VIEW



4+1 View Model

DEVELOPMENT VIEW



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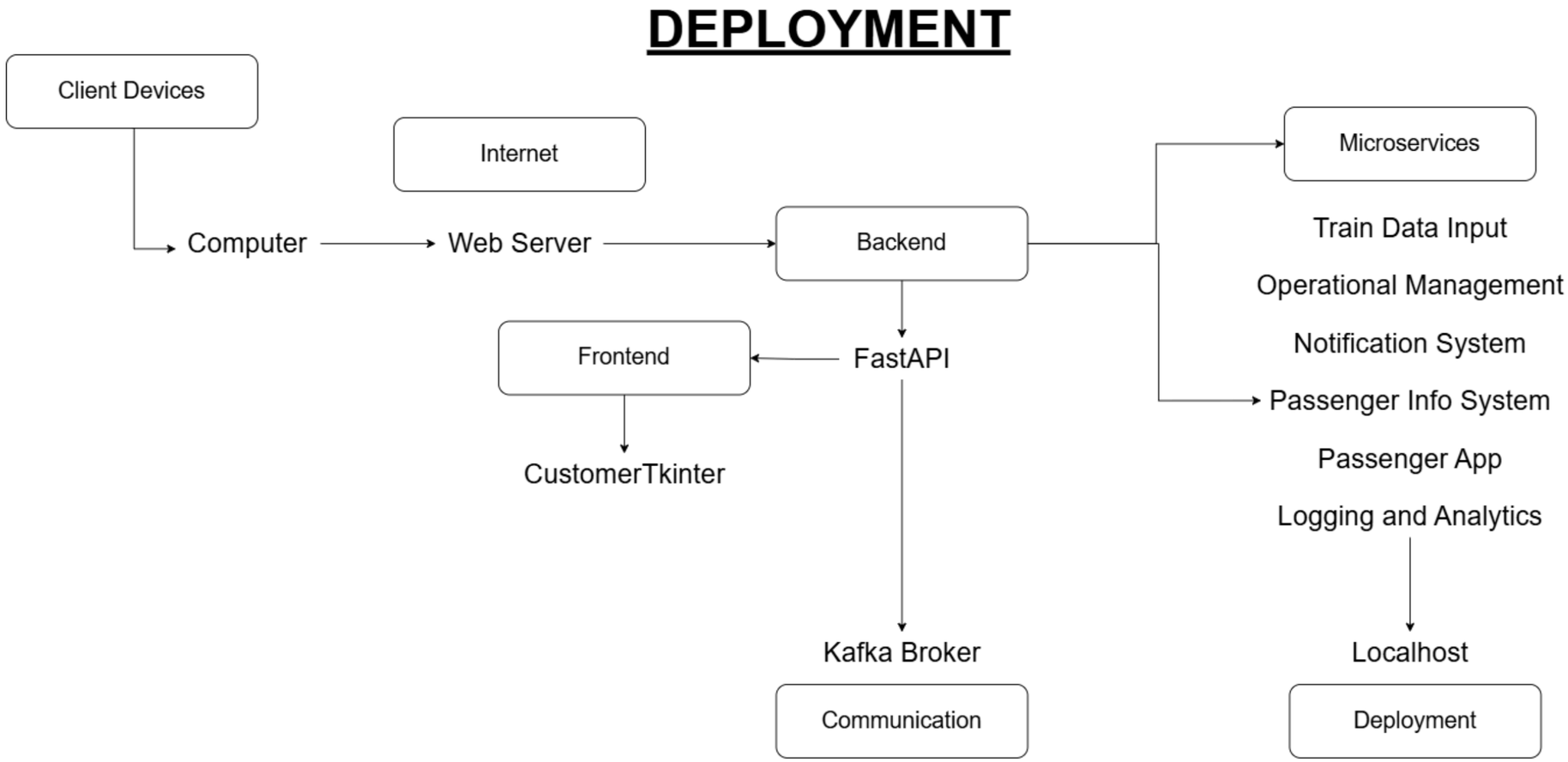
4+1 View Model

DEPLOYMENT VIEW



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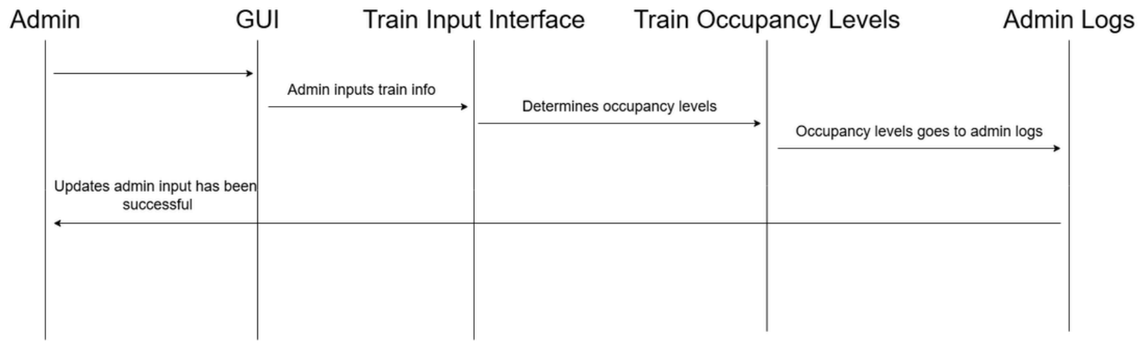
4+1 View Model

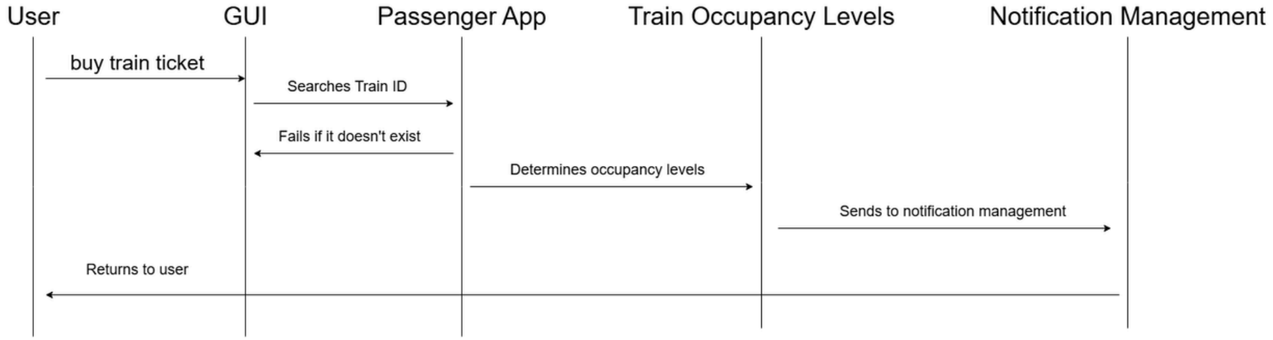
USE CASES

USE CASES

Admin Inputs Train Occupancy Data



Passenger Monitors Train Occupancy



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DOCUMENTATION

TRAIN DATA FORM

Field	Type	Description
train_id	string	Unique identifier for the train.
train_class	string	Class of the train (e.g., "Express", "Economy").
carriages	integer	The number of carriages in the train.
occupancy_level	float	The current occupancy level of the train (0 to 1).
speed	float	The current speed of the train in km/h.

carriage details	list	The list of carriages
max seats	int	Maximum number of seats
occupied seats	int	Maximum number of occupied seats

DOCUMENTATION

TRAIN CLASSIFICATION

Class	Description	Priority	Expected Speed
Express	Premium Express - Faster	High	200–300+ km/h
Economy	Standard Passenger - Average	Average	100–180 km/h

🚄 DOCUMENTATION

DECISION MAKING - OPERATIONAL ACTIONS

Criteria	Condition	Action	Reason	Action Message
🚨 Overcrowded	occupancy_level >= 100% and speed >= 200	ADD_TRIP	Critical demand, train is fast	"A new train will be added shortly due to high demand."
🚨 High but slower train	occupancy_level >= 100% and speed < 200	ADD_CARRIAGES	Overcrowded but not fast enough to duplicate	"Additional carriages are being added to the train for better capacity."
⚠️ High demand	85% <= occupancy_level < 100%	ADD_CARRIAGES	High load, better add wagons	"Additional carriages are being added to the train for better capacity."
✅ Stable usage	60% <= occupancy_level < 90%	MAINTAIN_SCHEDULE	Balanced load	"The train is operating on its regular schedule, no changes."
🌀 Underused	50% <= occupancy_level < 70%	MERGE_ROUTE	Moderate underutilization	"Two similar routes are being combined to optimize schedules."

🚄 DOCUMENTATION

DECISION MAKING - OPERATIONAL ACTIONS -CONTD.

🧊 Low demand	25% <= occupancy_level < 40%	REDUCE_FREQUENCY	Low usage, fewer trips needed	"The train frequency is reduced due to lower demand.”
🛑 Critically low	occupancy_level < 25%	CANCEL_TRIP	Very low demand	"The scheduled train has been cancelled due to very low demand.”
🐢 Slow business train	train_class in ['A','B'] and speed < 80	ROUTE_REVIEW	Business train not meeting standards	"The train's route or speed is under review for better performance.”
⚡ Speedy economy train	train_class in ['C','D'] and speed > 110	ROUTE_REVIEW	Possible safety/efficiency issue	"The train's route or speed is under review for better performance.”
🏗️ Too many wagons & underused	carriages > 12 and occupancy_level < 30%	CANCEL_TRIP	Long train not justified by ridership	"The scheduled train has been cancelled due to very low demand.”
🔎 Invalid input check (optional)	occupancy_level > 150% or carriages <= 0	INVALID	Data integrity issue	"Data integrity issue”

DOCUMENTATION

OPERATIONAL ACTIONS - MESSAGE

Action Code	Description
ADD_TRIP	Schedule another train during peak hours
ADD_WAGONS	Increase number of wagons to meet demand
REMOVE_WAGONS	Decrease wagons due to underutilization
REDUCE_FREQUENCY	Limit trips to off-peak hours
ROUTE_REVIEW	Flag for route/speed reassessment
CANCEL_TRIP	Suggest cancellation if demand is extremely low
MAINTAIN_SCHEDULE	Keep current schedule, no change
MERGE_ROUTE	Suggest route merge for optimization
INVALID	Data integrity issue

📩 SAMPLE OUTPUT - ADD_TRIP

TRAIN DATA


```
{
  "train_id": "TR_ADD_TRIP",
  "train_class": "Express",
  "speed": 210.0,
  "carriages": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 95 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 96 }
  ]
}
```

📩 SAMPLE OUTPUT - ADD_CARRIAGES

TRAIN DATA


```
{
  "train_id": "T002",
  "train_class": "Express",
  "carriages": 4,
  "carriage_details": [
    {"carriage_number": 1, "max_seats": 40, "occupied_seats": 38},
    {"carriage_number": 2, "max_seats": 40, "occupied_seats": 39},
    {"carriage_number": 3, "max_seats": 40, "occupied_seats": 40},
    {"carriage_number": 4, "max_seats": 40, "occupied_seats": 36}
  ],
  "speed": 150.0
}
```

📩 SAMPLE OUTPUT - MAINTAIN_SCHEDULE

TRAIN DATA


```
{
  "train_id": "TR_MAINTAIN",
  "train_class": "Economy",
  "speed": 90.0,
  "carriages": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 60 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 80 }
  ]
}
```

📩 SAMPLE OUTPUT - MERGE ROUTE

TRAIN DATA


```
{
  "train_id": "TR_MERGE",
  "train_class": "Economy",
  "speed": 80.0,
  "carriages": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 50 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 65 }
  ]
}
```

📩 SAMPLE OUTPUT - REDUCE_FREQUENCY

TRAIN DATA


```
{
  "train_id": "TR_REDUCE",
  "train_class": "Economy",
  "speed": 70.0,
  "carriages": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 30 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 25 }
  ]
}
```

📩 SAMPLE OUTPUT - CANCEL_TRIP

TRAIN DATA


```
{
  "train_id": "TR_CANCEL",
  "train_class": "Economy",
  "speed": 60.0,
  "carriages": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 10 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 15 }
  ]
}
```

📩 SAMPLE OUTPUT - ROUTE REVIEW

TRAIN DATA - (>150% occupancy or carriages <= 0)


```
{
  "train_id": "TR_INVALID_OCCUPANCY",
  "train_class": "Economy",
  "speed": 80.0,
  "carriages": 2,
  "carriage_details": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 200 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 120 }
  ]
}

{
  "train_id": "TR_INVALID_CARRIAGE_COUNT",
  "train_class": "Express",
  "speed": 150.0,
  "carriages": 0,
  "carriage_details": []
}
```

📩 SAMPLE OUTPUT - INVALID

TRAIN DATA - Express but too slow OR Economy but too fast


```
{
  "train_id": "TR_REVIEW_EXPRESS",
  "train_class": "Express",
  "speed": 70.0,
  "carriages": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 70 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 75 }
  ]
}
```

```
{
  "train_id": "TR_REVIEW_ECONOMY",
  "train_class": "Economy",
  "speed": 120.0,
  "carriages": [
    { "carriage_number": 1, "max_seats": 100, "occupied_seats": 70 },
    { "carriage_number": 2, "max_seats": 100, "occupied_seats": 75 }
  ]
}
```

THANK YOU

REAL-TIME TRAIN OCCUPANCY MONITORING SYSTEM

BY:

JOHN MAURICE P. SISON