Leveraging Graphic Neural Networks to Create Value for DHL

Josephine, Krishnasai, Bo, Jesse, Goyo

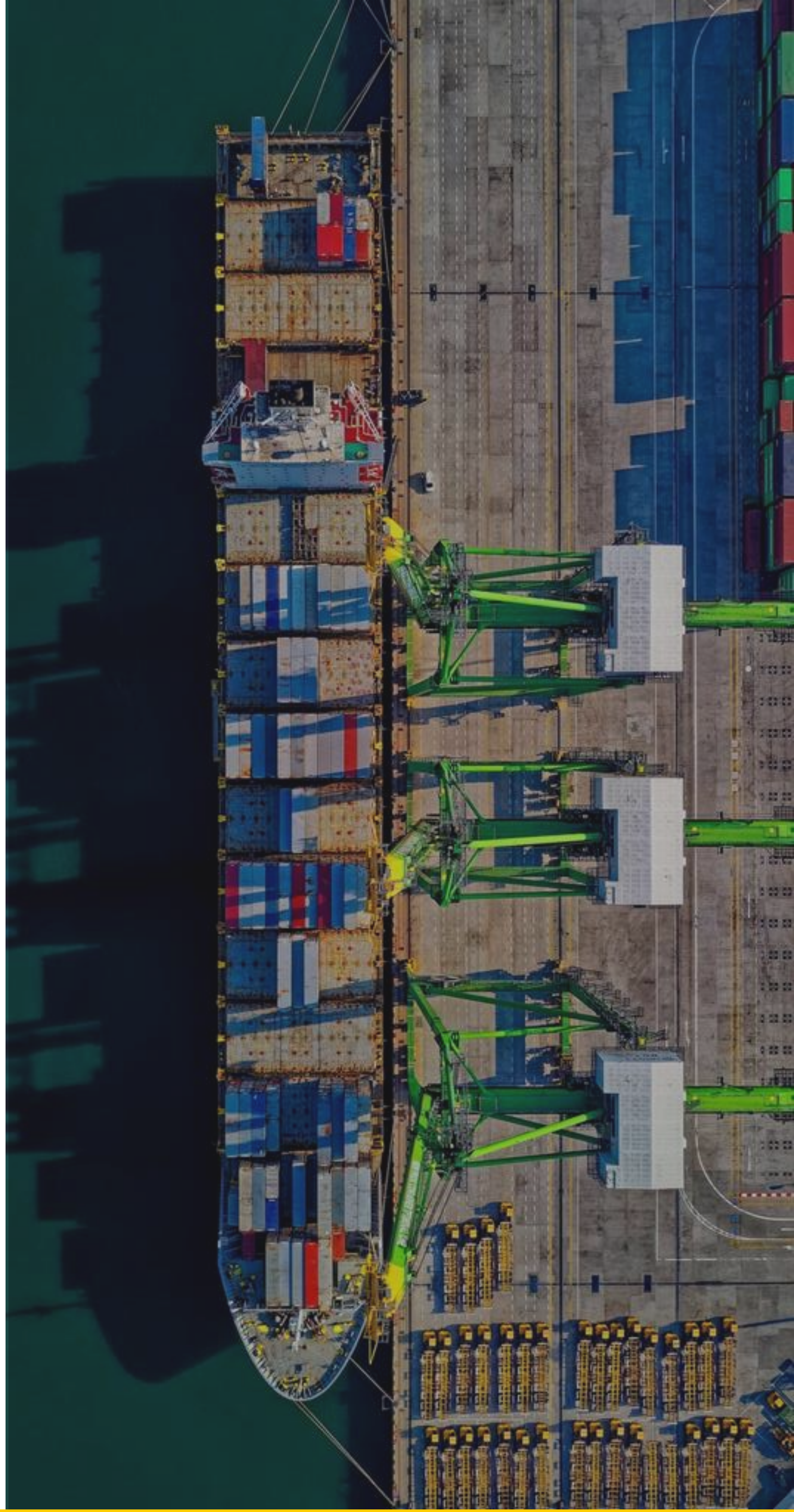
OVERVIEW

- Importance of Optimization
- Graph Neural Networks
- Neural Network Architecture
- Challenges and Mitigations
- Value Creation

Optimizing Routes in Real Time is Essential for Operational Efficiency

- Traffic Management
- Changing Weather
- Space Optimization
- Fuel Efficiency

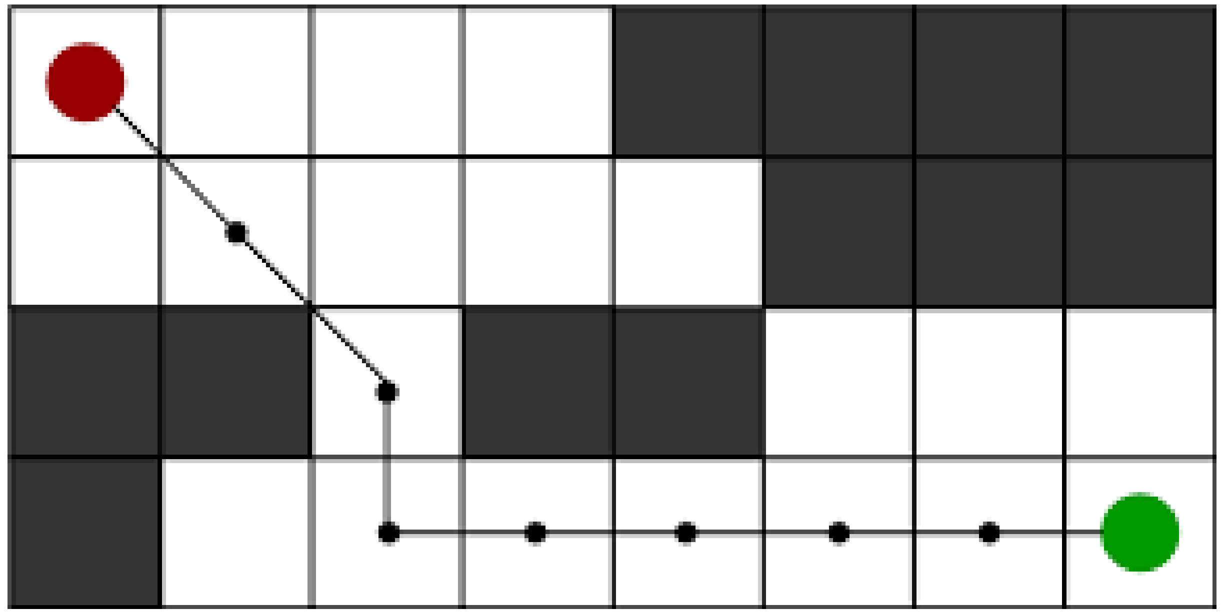
Moving Parts



The Right Path to **Effective Route Optimization**

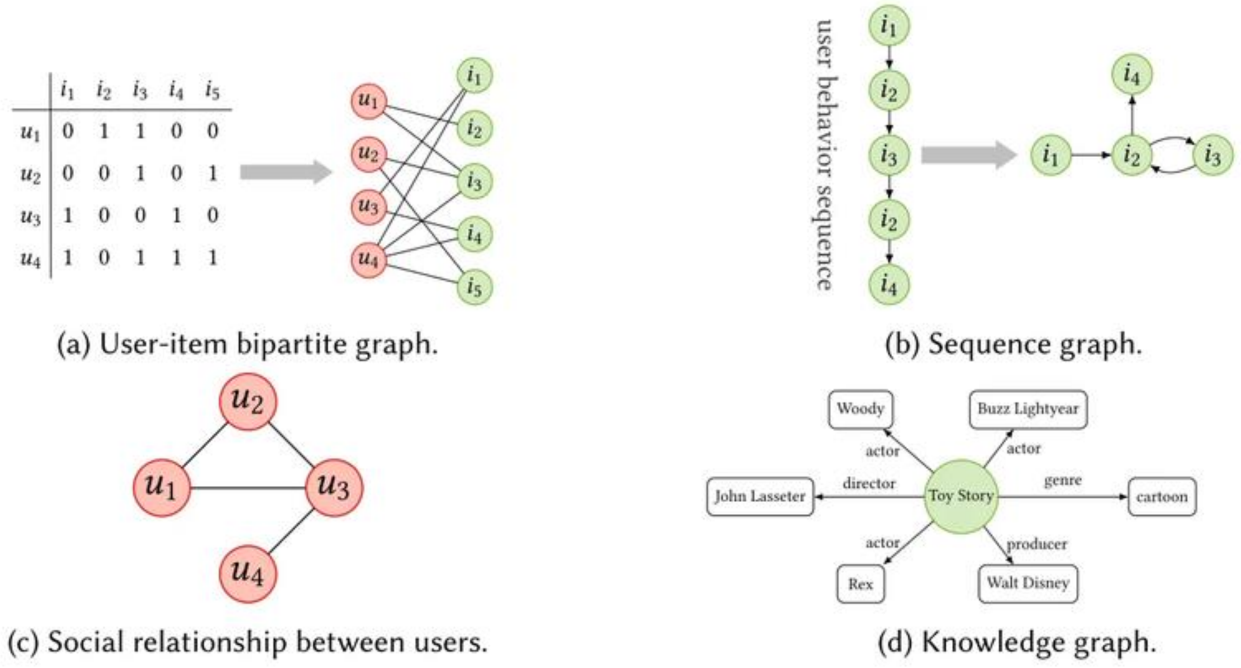
Tarditional Methods

Rely on explicit graph-based computations to determine the shortest path.



Collaborative Filtering

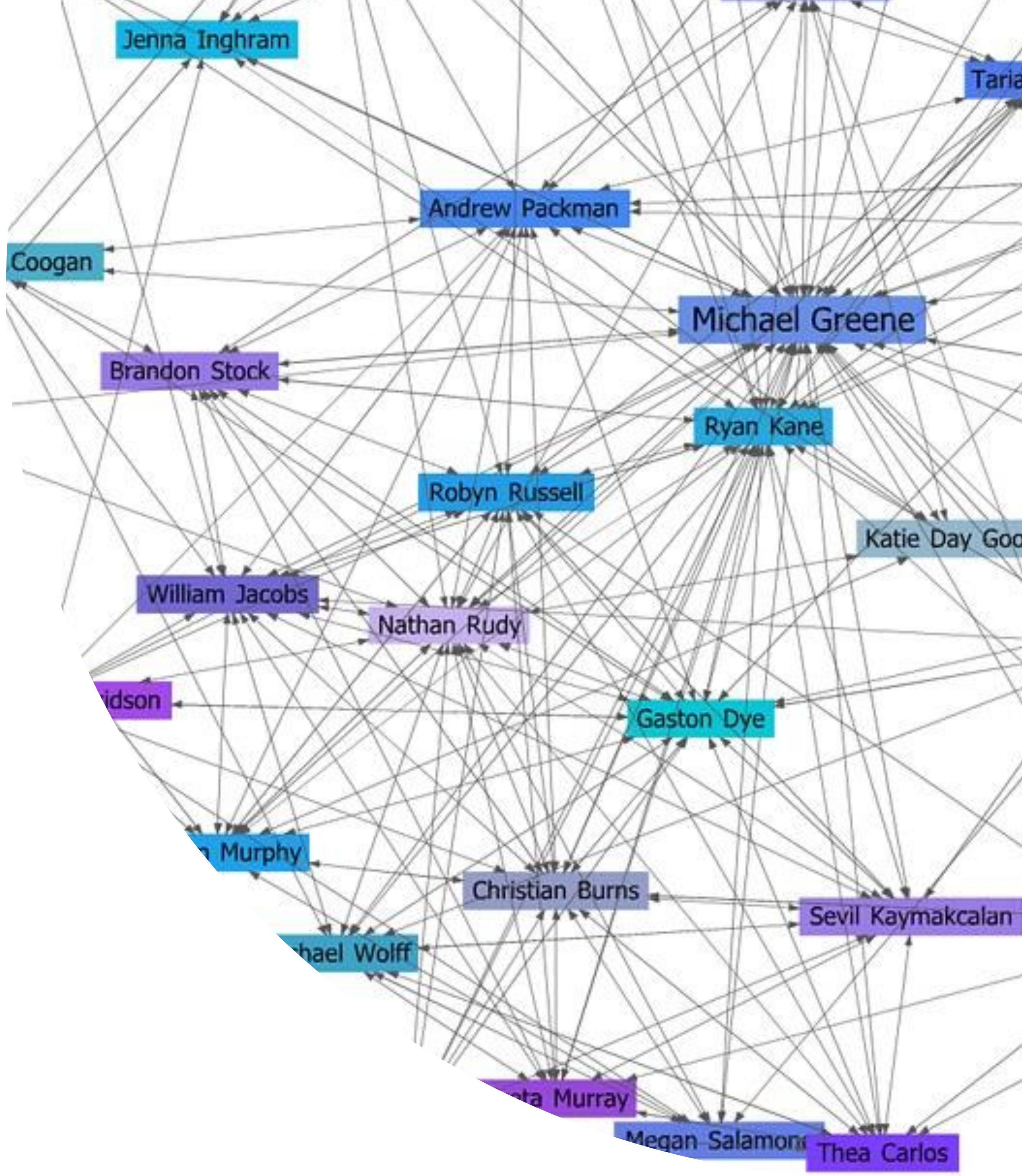
Used in recommendation systems. USes data that leverages historical route patterns to predict the most efficient paths.



How is this approach **different from Traditional Route** Optimizaion

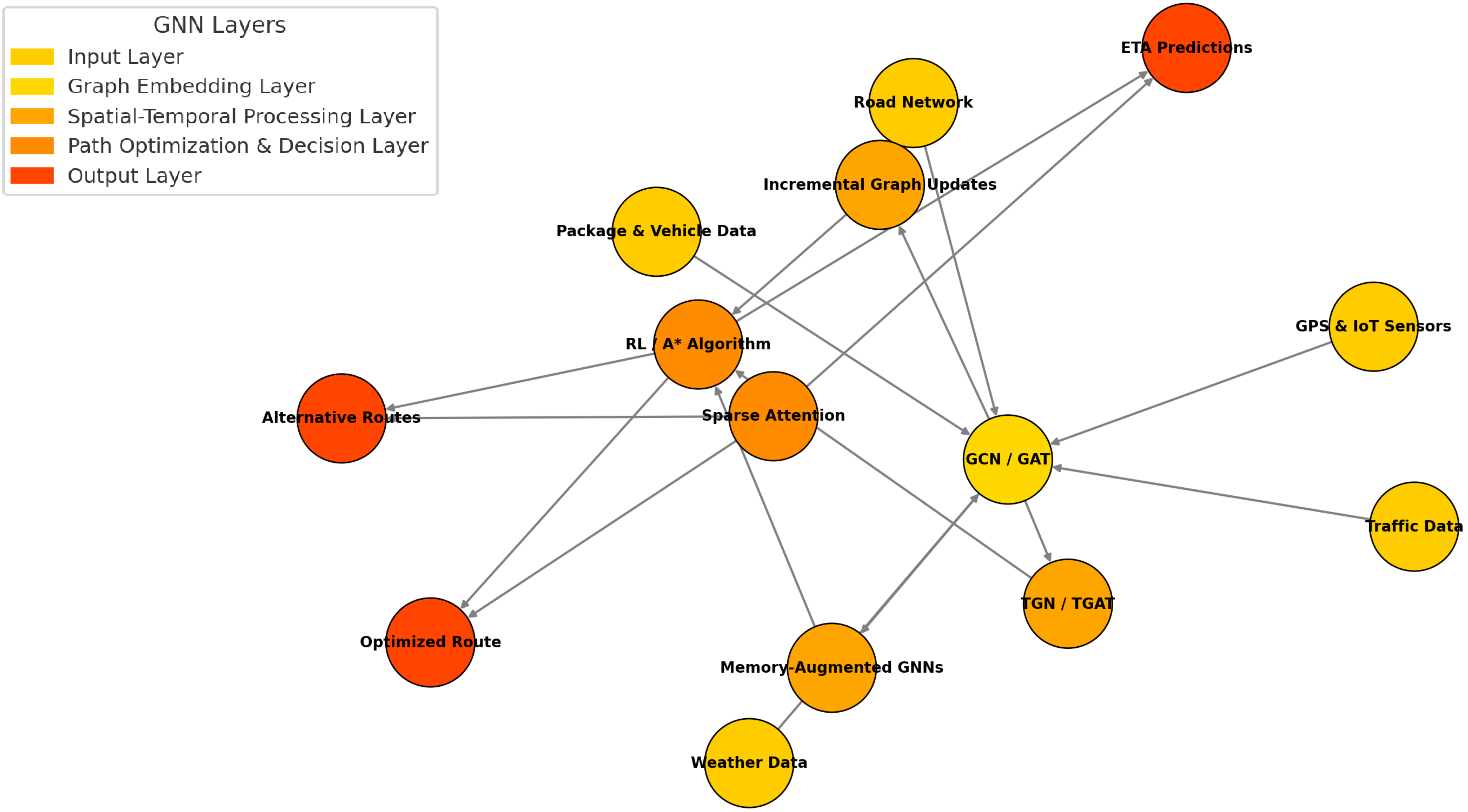
Feature	Traditional Methods (Graph-Based)	Collaborative Filtering (CF)
Approach	Computes shortest path explicitly	Predicts best routes based on past data
Learning Ability	Does not learn from history	Improves over time with more data
Personalization	One-size-fits-all routing	Tailored routes based on driver efficiency
Scalability	Struggles with large networks	Efficient for large-scale logistics
Real-Time Adaptability	Requires re-computation for every update	Dynamically adjusts based on live conditions
Constraint Handling	Requires manual constraint formulation (ILP)	Embeds constraints into learned models
Optimization Focus	Distance and cost minimization	Efficiency, driver behavior, and adaptability

Why Graph Neural Networks are **better for DHL?**



- Learn from data and continuously improves
- Personalized routing and optimization
- Scalable for large logistics networks and complexity
- Real-time adaptability

Visual Overview of DHL’s Graph Nural Network



Neural Network Architecture:
Graph Neural Networks (GNN) for Route Optimization

Delivery locations, intersections, distribution centers.

OUTPUT

Tell Franklin where to go!

Edges = roads, highways, traffic paths.

GNNs excel at learning spatial relationships and dynamic route dependencies

Real-time processing and scalability is challenign in large-scale Logistics Networks

Mitigation

Hierarchical Graph Partitioning

Global Graph
Central GNN updates global routing policies

Regional Aggregation
City models communicate with regional dispatchers

Local Graphs
City level with independent graph model on edge devices

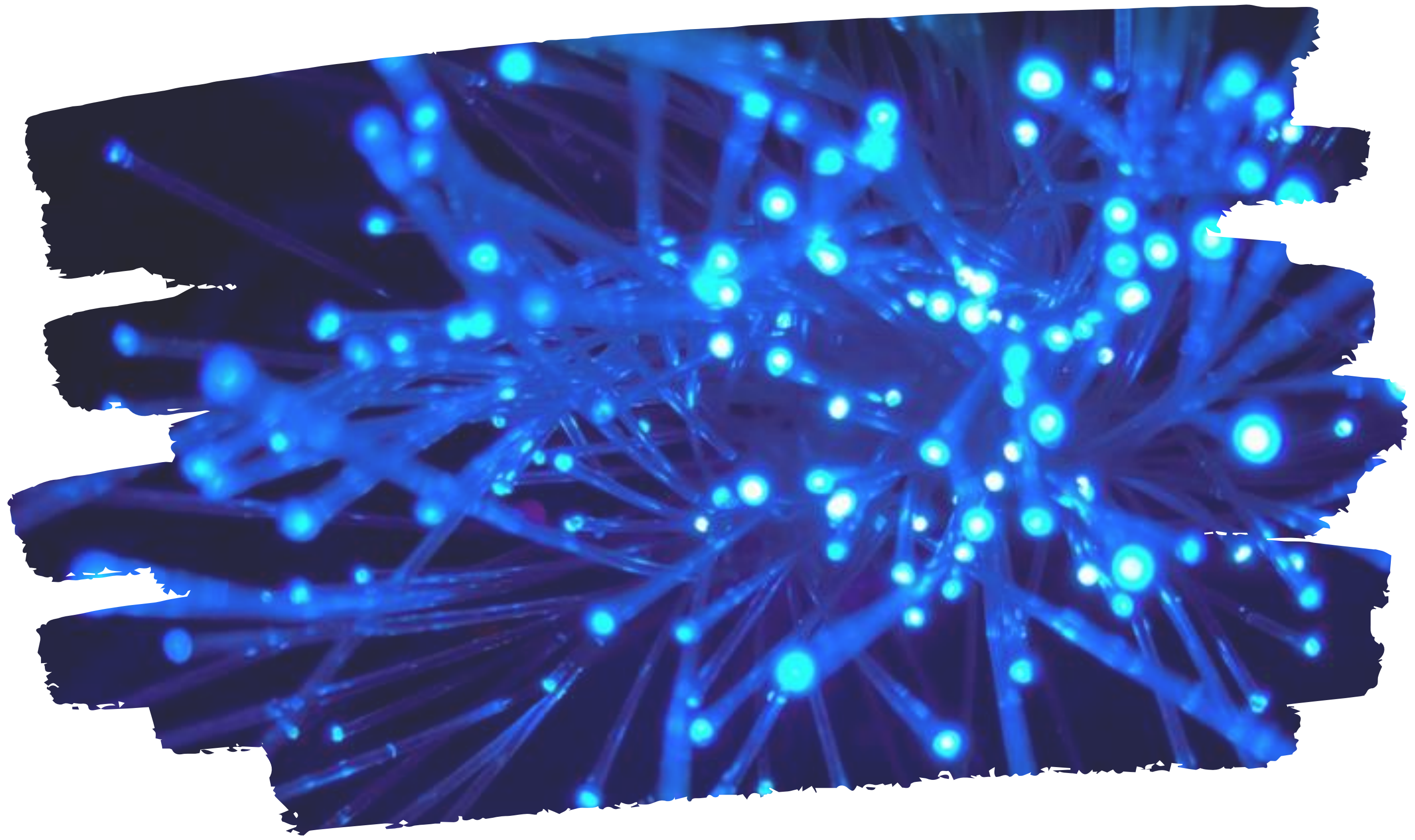
Edge AI Deployment | **Dynamic Subgraph Extraction**

Static GNNs **Fail to Adapt** to **Real-Time Route Changes**

Challenge → Need for Static Graph Sturtcures → DHL needs real-time changing structure → Traffic, congestion, weather, accidents → **Delays and Costs**

Connect to live data to build a Dynamic GNN

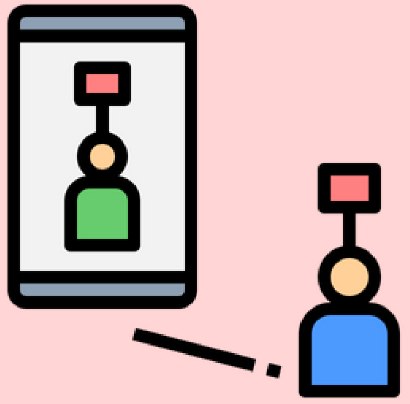
- Real-time disruption detection and instant rerouting
- Leverage incremental graph updates instead of the entire network
- Use past disruptions to anticipate future ones



Poor Data Availability in Emerging Markets and Remote Areas

Challenge: Sparse Road Network

Lack of historical traffic or infrastructure details



Poor GNN POerformance

Synthetic Data Augmentation

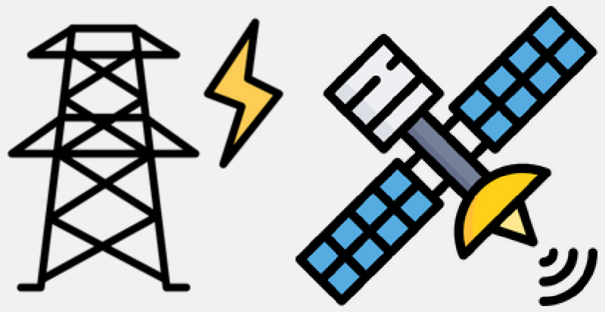
- Training: similar routes
- Generative models (GANs): predicting missing roads

Federated Learning for Localized Adaptation

- Localized regional GNN
- Decentralized training

Proxy Sensor Inputs

- Cell tower signals,
- Weather station reports
- Satellite imagery



GNN-Enhanced Route Optimization Creates Value for DHL

Major Business Impacts

Reduced latency,
Faster decisions , more on-time deliveries

Cross-regional scale-up
Dynamic roads adaptability

Resilient from
delays and disruptions

Operational Efficiency

Costs Decrease by 10-30%

Customer Satisfaction

Faster, reliable ETAs improve service quality

Q&A

Appendix

Neural Network Architecture:
Graph Neural Networks (GNN) for Route Optimization

Layer	Components	Function
1. Input Layer	Road Network (nodes: locations, edges: roads), Traffic (live + historical), Weather (storms, floods), Package & Vehicle Data (load, priority), GPS & IoT Sensors (real-time tracking)	Collects real-time and historical logistics data.
2. Graph Embedding Layer	GCN / GAT	Converts road and traffic data into structured representations.
3. Spatial-Temporal Processing Layer	TGN / TGAT (time-based updates) • Memory-Augmented GNNs (learns disruptions) • Incremental Graph Updates (updates only affected roads)	Adapts dynamically to traffic/weather disruptions.
4. Path Optimization & Decision Layer	RL / A* (route decision-making) • Sparse Attention (prioritizes key roads)	Selects the most efficient delivery routes.
5. Output Layer	Optimized Route • ETA Predictions • Alternative Routes	Provides real-time AI-driven routing.

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