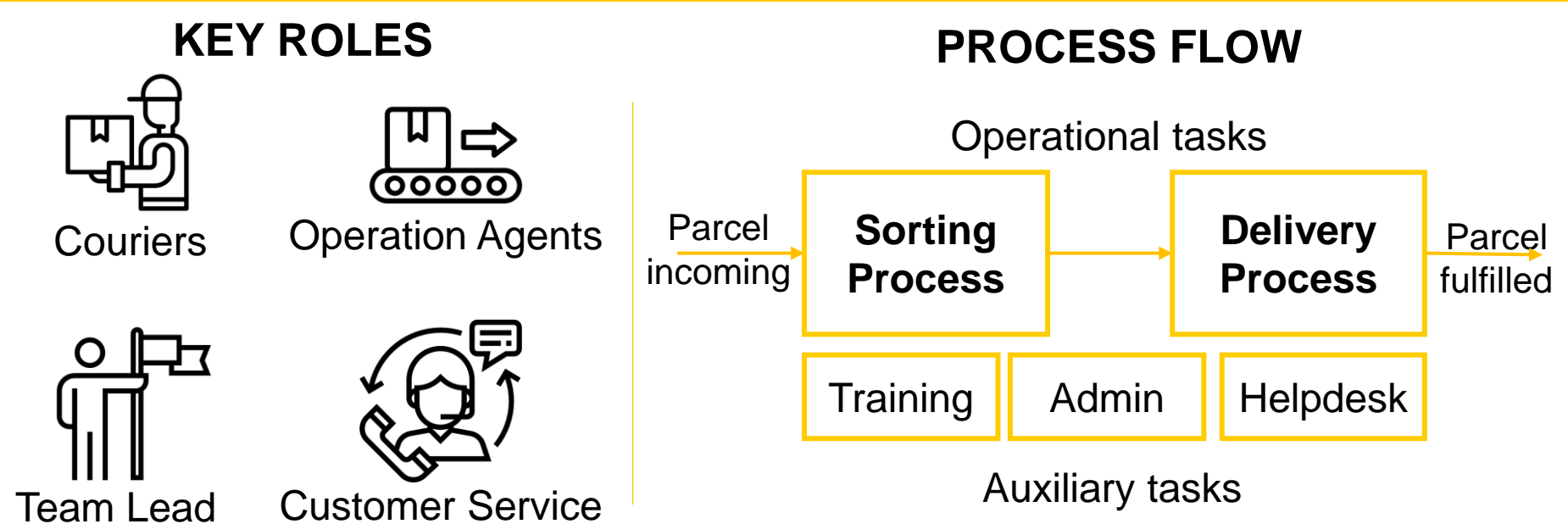


1. INTRODUCTION

DHL Express (DHLE) is the express arm of DHL, focusing on ensuring swift delivery with end-to-end tracking for critical delivery services.



2. PROBLEM DEFINITION

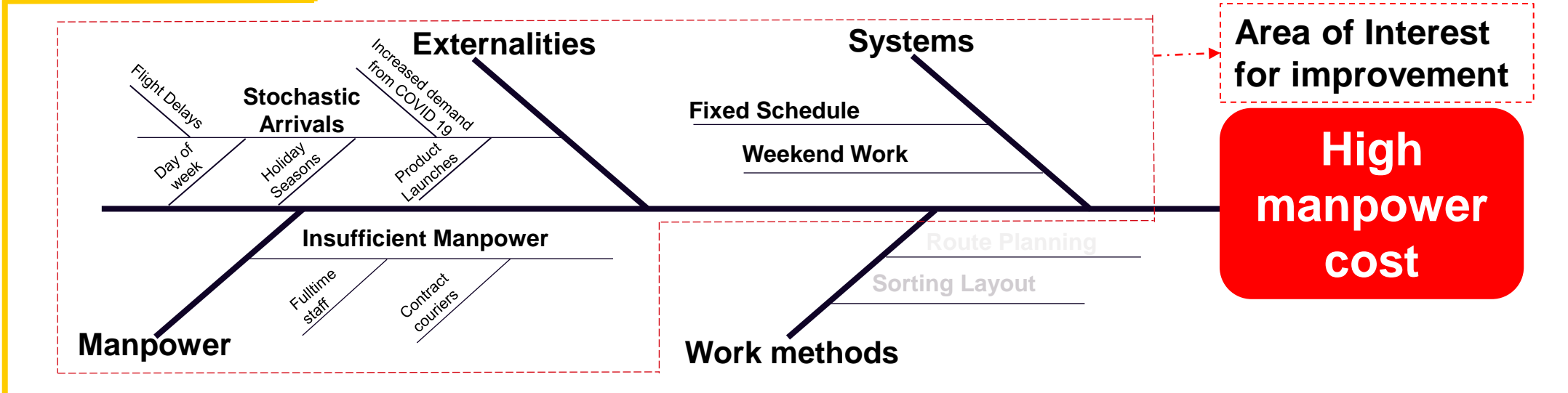
OBJECTIVE
 To improve DHLE's labour efficiency and lower manpower cost by

- Adjusting work schedule of full-time couriers
- Reduction of contract couriers' hours
- Increase hiring of full-time couriers

through the combination of **forecasting** and **optimisation**.

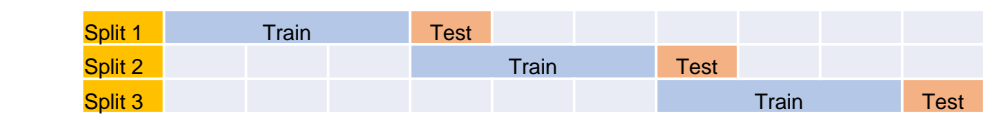
3. PRODUCT AND PROJECT MANAGEMENT

- Needs Analysis** - Interviews with stakeholders such as management and service center managers.
- Evaluation of Product Design** - Weighing solution design between Macro-enabled Excel and web application in the intranet
- Project Management** - Setting project timeline for management presentations, solution development, and user documentation.



4. FORECAST MODELLING

1. Cross Validation Scheme
 3-Fold Walk Forward Cross-Validation is used with a forward sample size of 28 days.



EVALUATION OF MODEL
2. Metrics for Model Evaluation
 Mean Absolute Error (MAE), where: forecasts = \hat{y}_i and the ground truth = y_i .

$$MAE = \frac{\sum_{i=1}^n |y_i - \hat{y}_i|}{n}$$

CANDIDATE FORECASTING MODELS

Holts Winter's Seasonal Model

- Traditional time series methods
- Able to pick out trends and seasonality from the stationary times series data

forecast: $F_{t+k} = L + kb_t + S_{t+k-s}$

Trend upwards from adoption of eCommerce due to COVID19

Seasonal Period of 7 (weekly)

Stacked Light Gradient Boosted Model

- Modern machine learning methods
- Uses 4 stacked models, 1 for each week
- Optimised with hyperparameter tuning

For normal days → **Blended Forecast = F_k** ← For special events (Public Holidays, Marketing events)

Stacked LGBM models perform better for days with special events while the Holt-Winter's Seasonal model performs better for all other days. Blended model adopted as final forecasting model.

5. OPTIMISATION MODELLING

OBJECTIVE FUNCTION

$$\min h \times \sum Fill_j + 4 \times h \times \sum \sum \sum Y_{ijk} + \sum \sum P_k O_{jk} + 115 \sum \sum C_{ik}$$

Fixed Cost Adjustments Total cost of normal hours Total overtime cost Total contracting cost

CONSTRAINTS

1. Business Practices

$$4 - 4 \times \sum Y_{ijk} - O_{jk} \leq M_{jk} a_{jk} \quad \forall j, k$$

$$4 \times \sum Y_{ijk} + O_{jk} \leq M_{jk} (1 - a_{jk}) \quad \forall j, k$$

either person j works at least 4 hours on day k, or does not work on that day at all

$$\sum (Y_{i,j,sun} + Y_{i,j,sun+7} + Y_{i,j,sun+14} + Y_{i,j,sun+21}) + O_{j,sun} + O_{j,sun+7} + O_{j,sun+14} + O_{j,sun+21} = 0$$

$\forall j = 1,3,5,7$ (rest days are on Sundays for odd indexed employees)

$$\sum (Y_{i,j,sat} + Y_{i,j,sat+7} + Y_{i,j,sat+14} + Y_{i,j,sat+21}) + O_{j,sat} + O_{j,sat+7} + O_{j,sat+14} + O_{j,sat+21} = 0$$

$\forall j = 0,2,4,6$ (rest days are on Saturdays for even indexed employees)

$$O_{jk} \leq 12 b_{jk} \quad \forall j, k$$

If-then constraint, courier j must have full time work to do overtime work on day k

$$1 - \sum Y_{ijk} \leq 12(1 - b_{jk}) \forall j, k$$

2. MOM Regulations

$$\sum 4 \times Y_{ijk} + O_{jk} \leq 12 \forall j, k \quad (< 12 \text{ hours a day})$$

$$\sum_{k=1}^{I+7(x+1)} 4 \times Y_{ijk} \leq 44 \quad \forall j \text{ for } x = 0,1,2 \quad (< 44 \text{ hours a week})$$

$$\sum O_{jk} \leq 72 \forall j, k \quad (\text{Overtime } < 72 \text{ hours a month})$$

(Inclusive of additional constraints for partial weeks in each month)

3. Manpower hours needed based on forecasted volume and target productivity

$$\sum \sum (4 \times Y_{i,j,k} + O_{j,k} + 4 \times C_{i,k}) \times \text{productivity} \geq F_k + \alpha \times \epsilon_k \quad \forall k$$

- All forecasted shipment must be delivered, ϵ_k added to forecast for conservativeness
- ϵ_k empirically generated and scaled with α

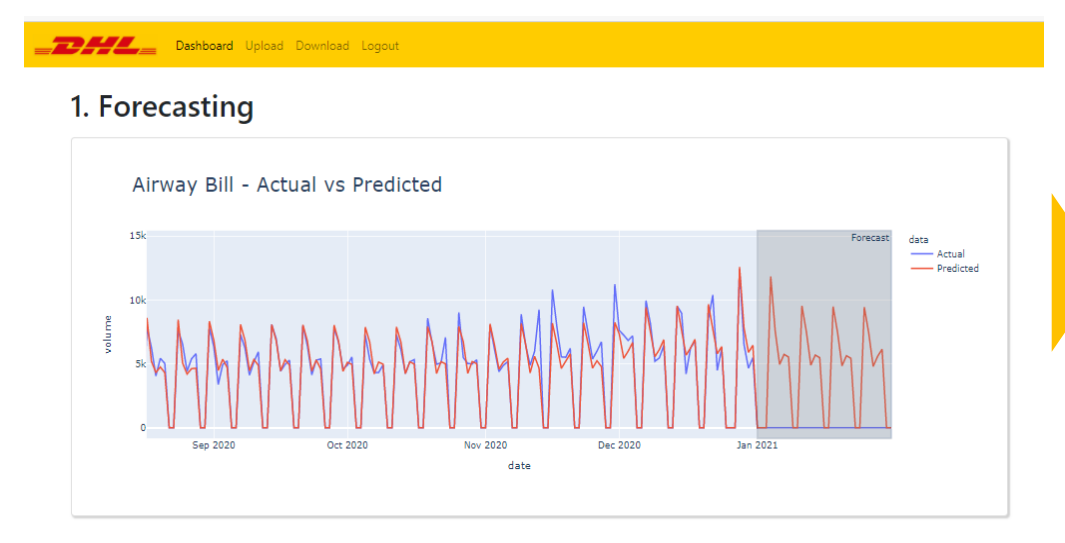
Conservativeness

ϵ_k derived from residuals of forecasts - adding only positive ϵ_k to forecasted shipment introduces conservativeness into our optimisation model.

$\epsilon_{b2b} + \epsilon_{b2c} = \epsilon_k \sim N(237, 1309)$

6. SOFTWARE SOLUTION

DHL HoursWatch
 A web application hosted locally in DHLE systems



1. Predictive Analytics – Shipment Forecast
 Users can compare the forecasted values against historical forecast visually.

Full Time Courier Recommendations for January 2021

Estimated Overtime Cost: \$53,440
 Based on \$1427.54 per month

Estimated Overtime Hours: 2,517 Hours
 Deviated schedule below

Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	0	0	0	0	53	44	43
2	61	60	66	67	62	33	36
3	69	66	63	60	63	27	37
4	68	62	66	62	62	34	31
5	70	70	70	70	70	14	3

Full Time Courier Overtime

Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	0	0	0	0	1	1	1
2	162	162	141	128	163	0	2
3	12	85	126	127	99	2	0
4	114	167	98	135	131	2	2
5	120	132	129	129	136	0	0

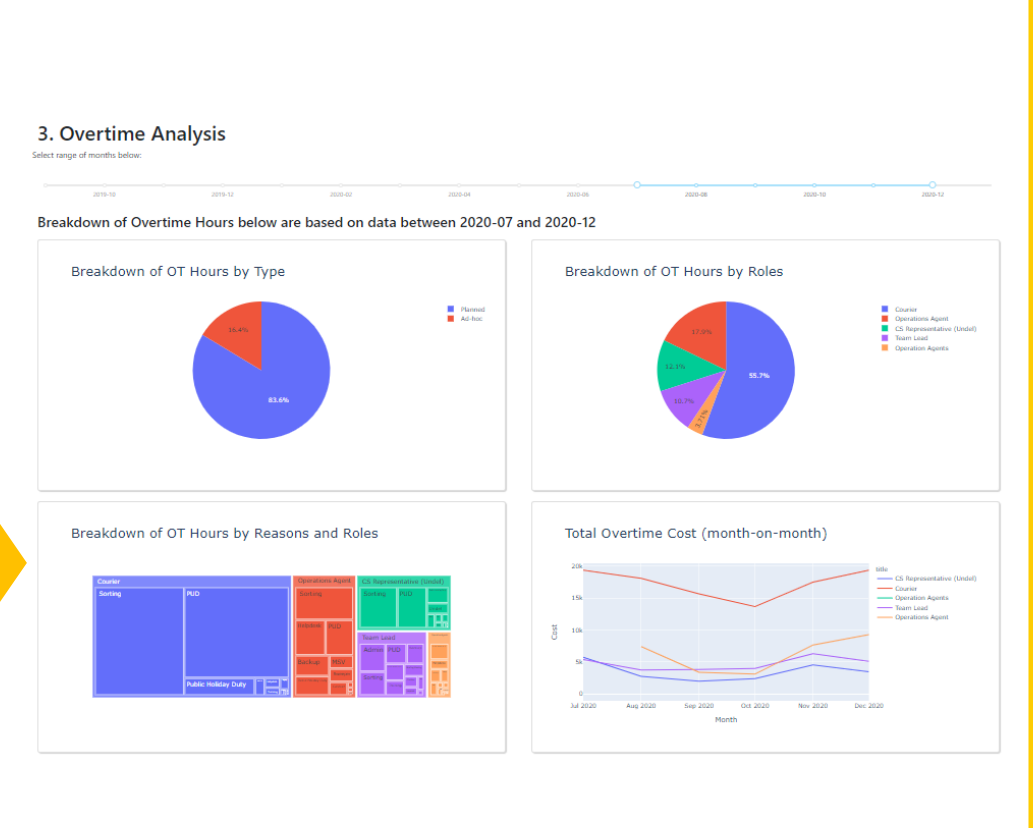
Overtime Cost Historical Trend

YTD Overtime Cost: \$416,656
 For 2020

Overtime Cost in Dec 2020: \$43,592
 -15% compared to average of last 6 months

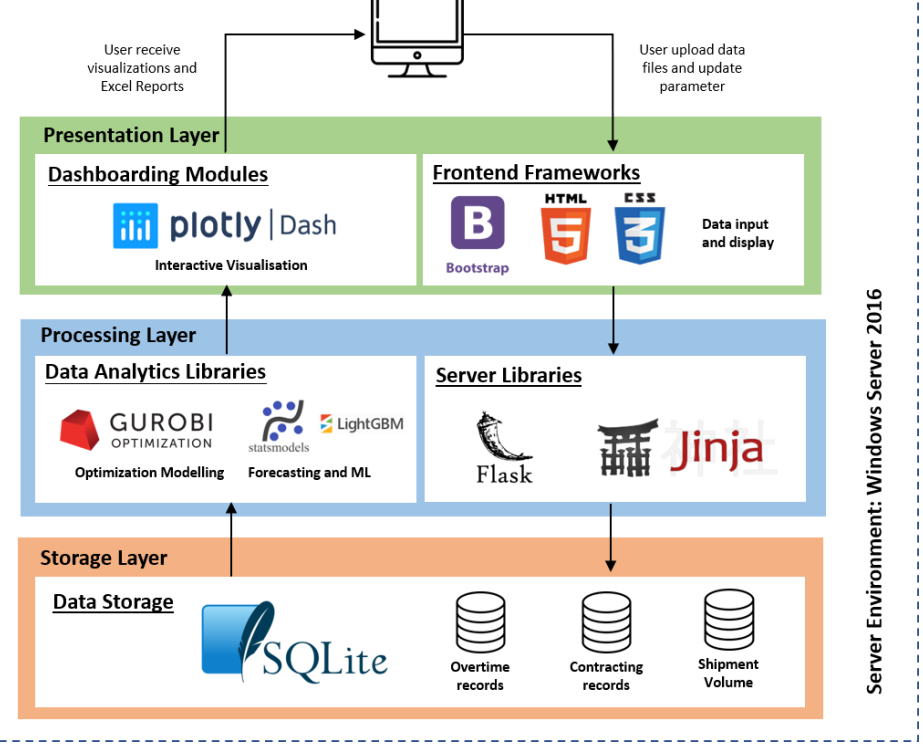
Overtime Cost (month-on-month)

2. Prescriptive Analytics – Optimised Schedule/Hiring
 Short term schedules and long-term recommendations for full time and contract couriers are shown monthly.



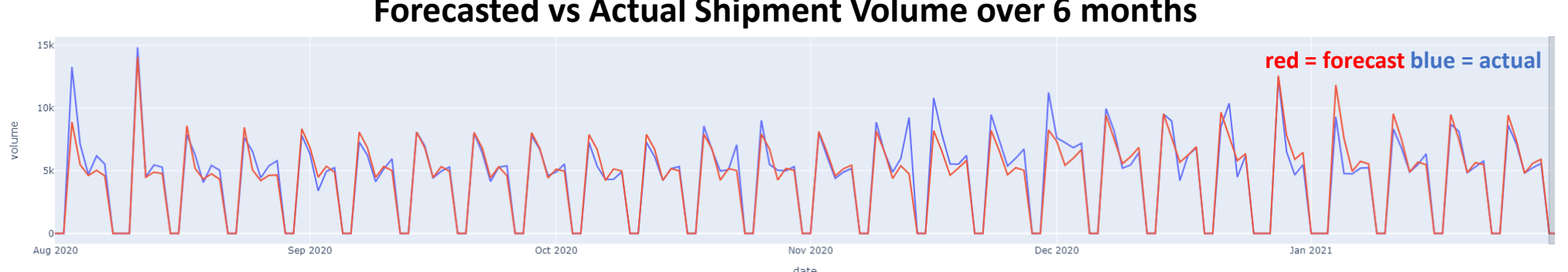
3. Descriptive Analytics
 Shows overtime analysis across all roles, type and reasons of overtime

7. ARCHITECTURE



Flask application hosted in DHLE's intranet, with statsmodel and LightGBM for forecast and Gurobi for optimisation

8. EVALUATION OF SOLUTION FORECAST PERFORMANCE



A forecast mean absolute error of 607 was achieved, which is a **57% improvement** to MAE of 1056 of the naïve forecasting method in the current process of DHLE.

OPTIMISATION PERFORMANCE

Month	Cost Savings	
	In Dollars (\$)	% of total manpower cost
Sep 2020	\$67,676	13.1%
Oct 2020	\$63,872	12.8%
Nov 2020	\$118,214	21.1%
Dec 2020	\$56,424	9.1%
Total	\$306,186	14.0%

The mixed integer optimisation model can potentially achieve a cost saving of **\$298,290** over 4 months which represents **14.0%** of the total manpower cost in that period.

9. RECOMMENDATIONS

- Service centre managers can consider utilising DHL HoursWatch as a forecasting tool before making the executive decision to adopt changes to scheduling.
- Managers manually reduce overtime hours to a desired level by swapping some overtime hours to contract hours to maintain good morale of the workforce.
- Hiring decisions in the long term may allow DHL to become self sufficient but sacrifices the flexibility to shed labour cost if shipment volume slows.

10. FUTURE WORK

- Develop the solution with a centralised repository of data integrated with internal database to gain more accurate and up-to-date data on employee salary and roles.
- Develop similar forecast and optimisation applications for different service centers to compare labor efficiency between service centers.
- Improve forecasting accuracy by using more advanced forecasting techniques