



CRM IPSW 2023 Air Canada - ULD Forecast

25 Août 2023

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Agenda

- 1 Background
- 2 Problem Statement
- 3 Methodology
- 4 Result
- 5 Conclusion and Recommendation



Background



ULD (Unit Load Device) are terms associated with transportation, particularly in the context of aviation and logistics.

ULD plays a crucial role in optimizing the efficiency of cargo transportation by standardizing loading procedures and maximizing the use of available space in the aircraft.



Problem Statement

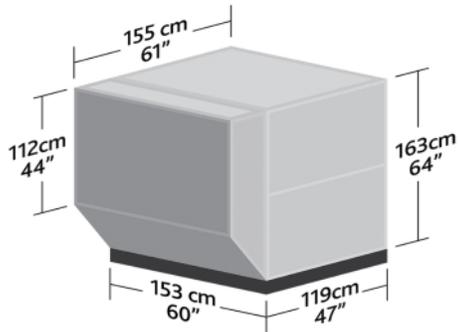
Types of ULD



LD2

Dimensions

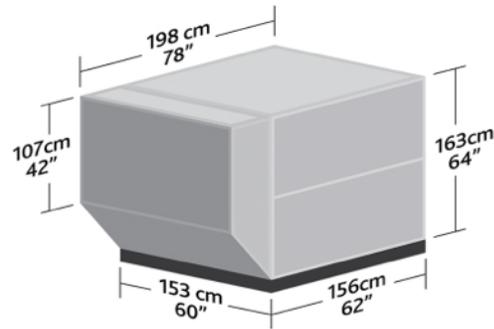
Longueur: 155 cm (61 po)
Largeur: 153 cm (60 po)
Hauteur: 163 cm (64 po)



LD3

Dimensions

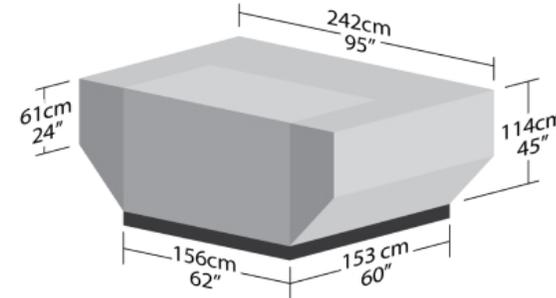
Longueur: 156 cm (62 po)
Largeur: 153 cm (60 po)
Hauteur: 163 cm (64 po)



LD3-45

Dimensions

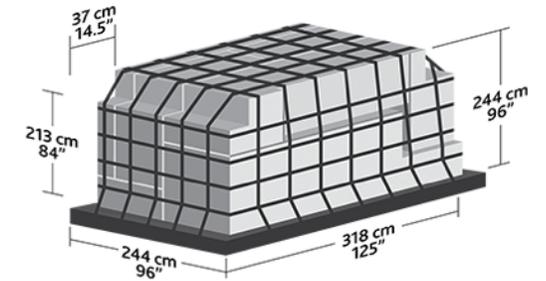
Longueur: 156 cm (62 po)
Largeur: 153 cm (60 po)
Hauteur: 114 cm (45 po)



LD7 (pont principal)

Dimensions

Longueur: 318 cm (125 po)
Largeur: 244 cm (96 po)
Hauteur: 244 cm (96 po)



Current State: Air Canada have a passenger forecast data which enable the company estimate the number of bags per flight.

Challenge: Air Canada lack a comprehensive forecast that encompasses all types of cargo.

Goal: Our aim is to create a forecast at the Unit Load Device (ULD) level by incorporating both baggage and cargo. 3 mostly used ULD types are PMC, AKE, AKH



Aircraft Types

- 8 aircraft types (789, 77W, 77L, 788, 76F, 320, 321, 333)
- Some ULDs are incompatible with some aircraft types
- ULDs have placement restrictions inside the aircraft

Boeing 777-300ER (77W) 777-200LR(77L)



Airbus A330-300 (333)



Boeing 767-300 Freighter (76F)



Boeing 787-9 (789) 787-8 (788)



Airbus A320-200 (320)

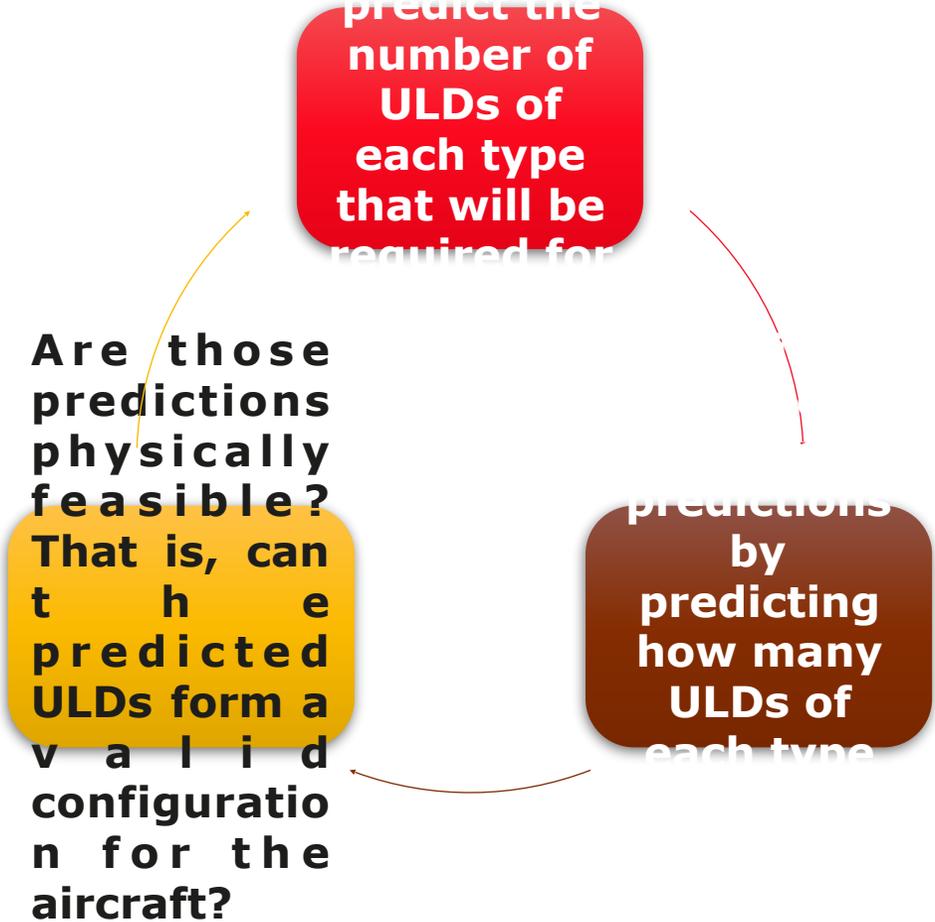


Cargo only

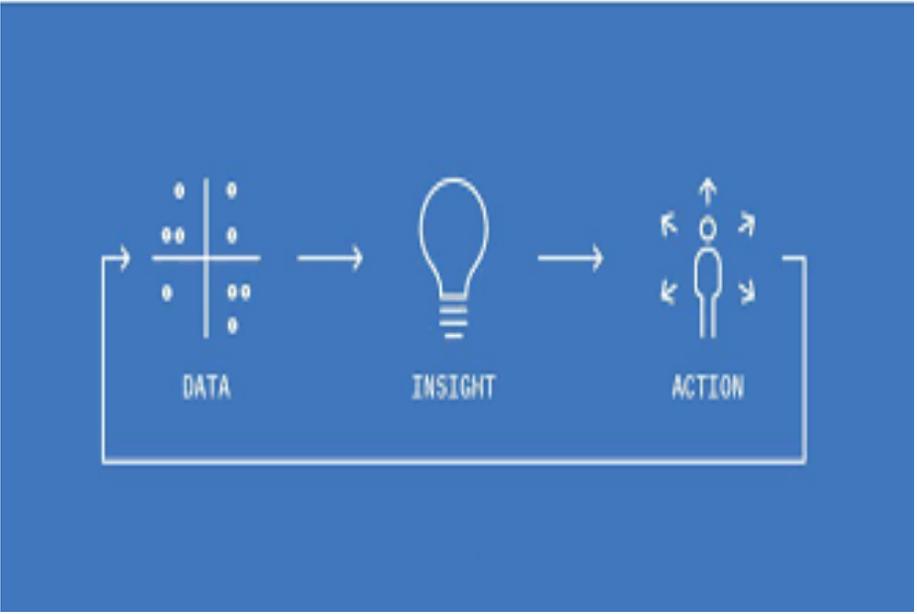
Baggages + Cargo



Research Questions



Data Insight



FLT_ORIG_LCL_DATE	LEG_SCH_DEP_LCL_DATE	CARR_CODE	FLT_NUM	LEG_ORIG
Min. :2022-01-01	Min. :2022-01-01	Length:4469794	Min. : 1	Length:4469794
1st Qu.:2022-06-19	1st Qu.:2022-06-19	Class :character	1st Qu.: 319	Class :character
Median :2022-11-04	Median :2022-11-04	Mode :character	Median : 860	Mode :character
Mean :2022-11-01	Mean :2022-11-01		Mean :2730	
3rd Qu.:2023-03-24	3rd Qu.:2023-03-24		3rd Qu.:7255	
Max. :2023-07-31	Max. :2023-08-01		Max. :8999	

LEG_DEST	LEG_ORIG_REGION	LEG_ORIG_CTRY_NAME	LEG_ORIG_CTRY_CODE	LEG_ORIG_CITY_NAME
Length:4469794	Length:4469794	Length:4469794	Length:4469794	Length:4469794
Class :character	Class :character	Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character	Mode :character	Mode :character

LEG_DEST_REGION	LEG_DEST_CTRY_NAME	LEG_DEST_CTRY_CODE	LEG_DEST_CITY_NAME	MULTI_LEG_IND
Length:4469794	Length:4469794	Length:4469794	Length:4469794	Length:4469794
Class :character	Class :character	Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character	Mode :character	Mode :character

ACFT_TYPE	ACFT_CTG	ACFT_REG	FIN_NUM	MAX_ZERO_FUEL_WGT	ACT_ZERO_FUEL_WGT
Length:4469794	Length:4469794	Length:4469794	Min. :101.0	Min. : 17055	Min. : 12020
Class :character	Class :character	Class :character	1st Qu.:416.0	1st Qu.: 53283	1st Qu.: 47283
Mode :character	Mode :character	Mode :character	Median :530.0	Median : 65952	Median : 61945
			Mean :563.9	Mean :104142	Mean : 95910
			3rd Qu.:749.0	3rd Qu.:173000	3rd Qu.:160431
			Max. :948.0	Max. :237682	Max. :237682

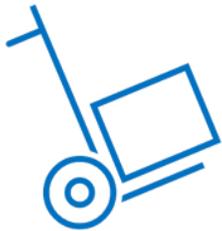
PAX_CAP	PAX_FLWN	PAX_WGT	BAG_WGT	BAG_CNT	POS_NUM
Min. : 0.0	Min. : 0.0	Min. : 0	Min. : 0	Min. : 0.0	Length:4469794
1st Qu.: 78.0	1st Qu.: 74.0	1st Qu.: 6445	1st Qu.: 856	1st Qu.: 57.0	Class :character
Median :169.0	Median :143.0	Median :12000	Median : 1853	Median : 113.0	Mode :character
Mean :195.7	Mean :165.9	Mean :13812	Mean : 2914	Mean : 156.7	
3rd Qu.:298.0	3rd Qu.:253.0	3rd Qu.:20830	3rd Qu.: 4272	3rd Qu.: 226.0	
Max. :450.0	Max. :450.0	Max. :40176	Max. :22270	Max. :1064.0	

Pros: Sufficient data
Cons: so many data

```
> dim(data1)
[1] 4469794      46
```



Data Information



- Identify the ULD per type per flight number

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- Determine whether the ULD contained Baggage or Cargo.

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- 18 months ULD data
- ~ 4.5 million observations
- 46 fields for a single ULD

Relevance

- Date (months)

- Flight number

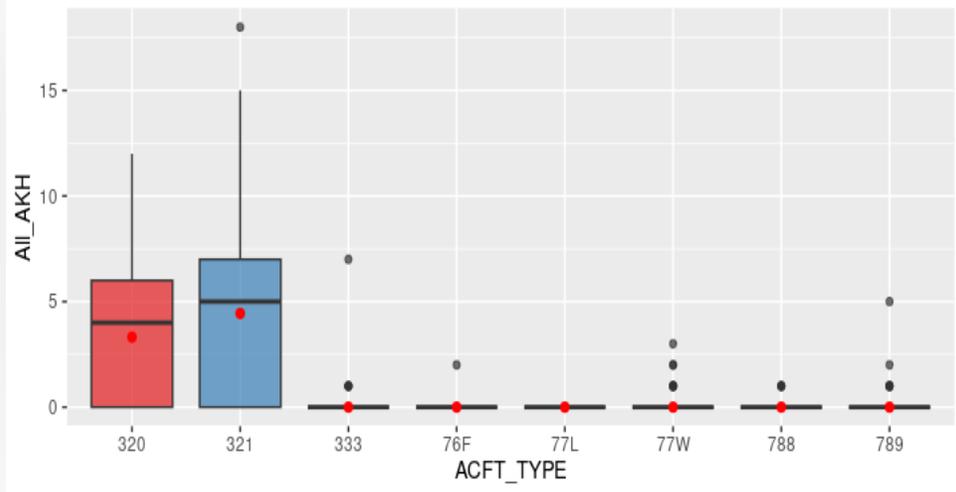
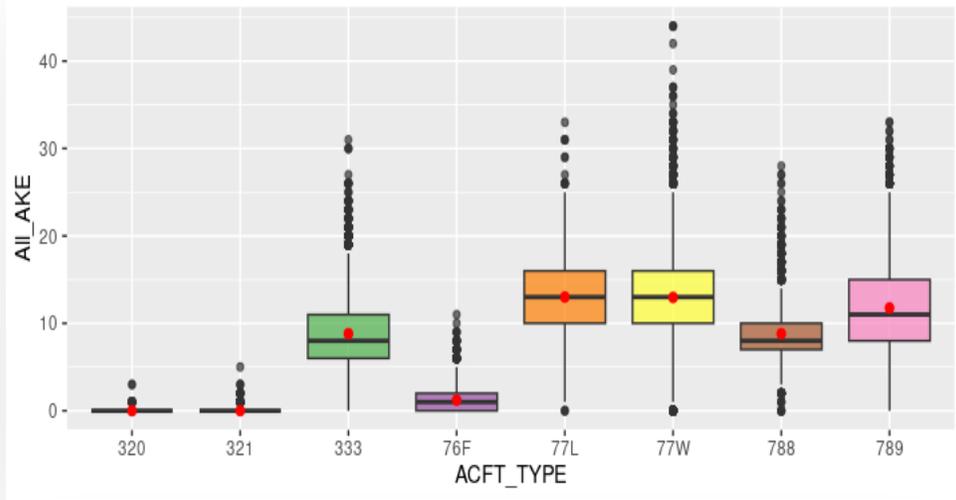
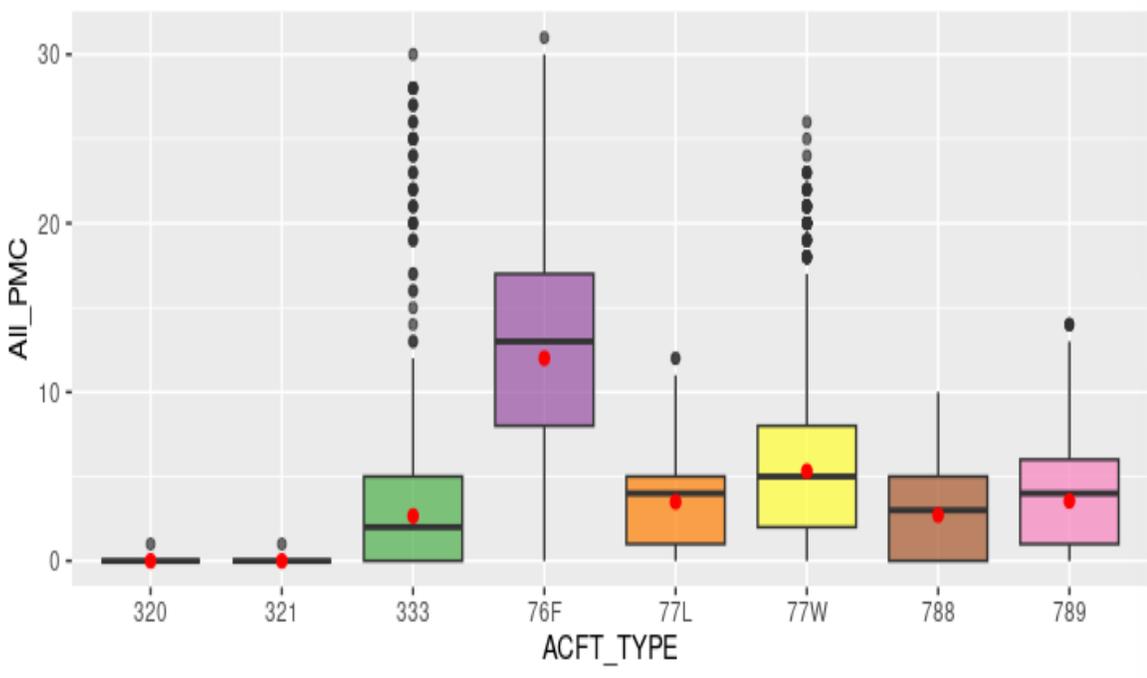
- ULD types

- Aircraft type

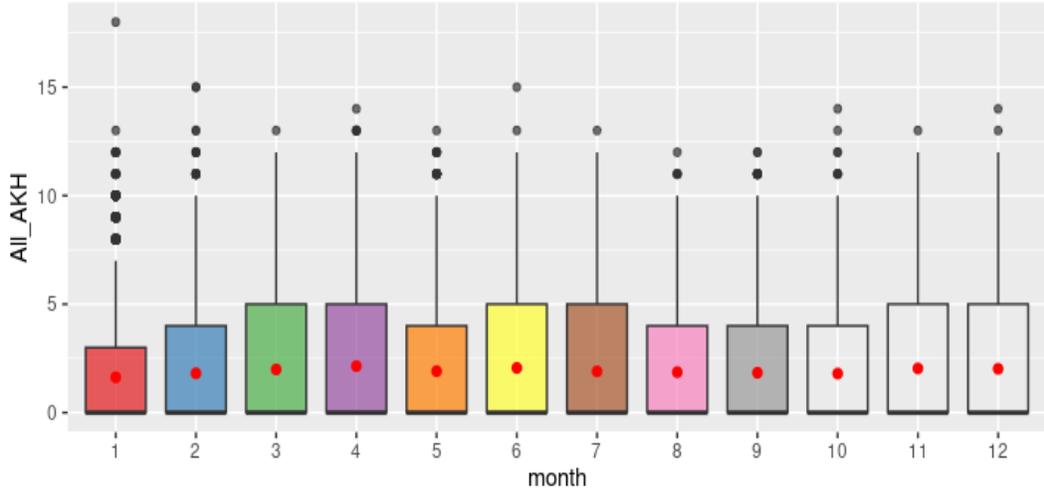
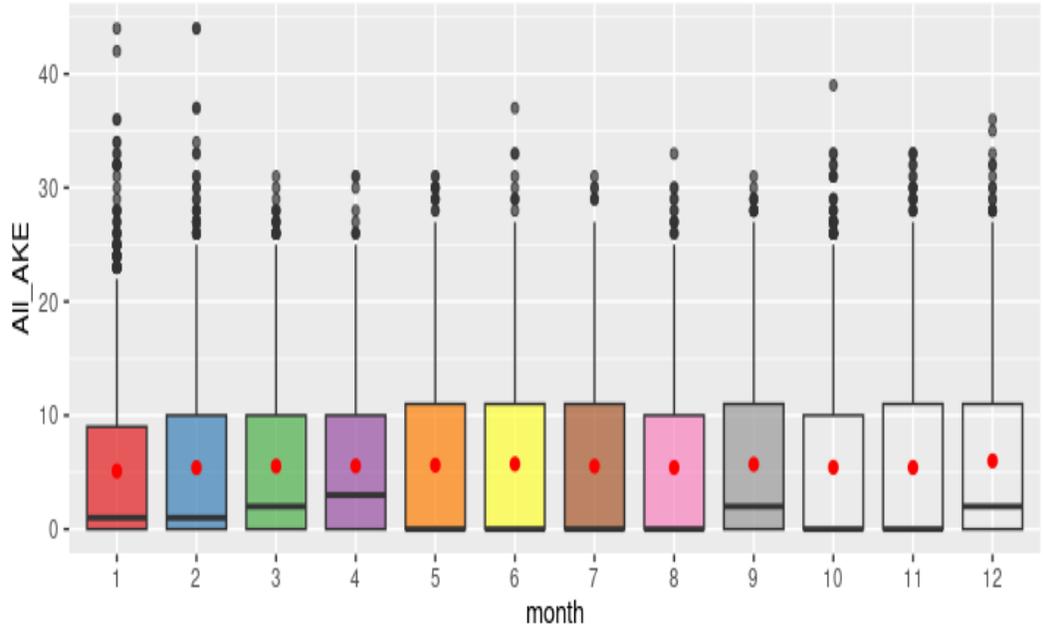
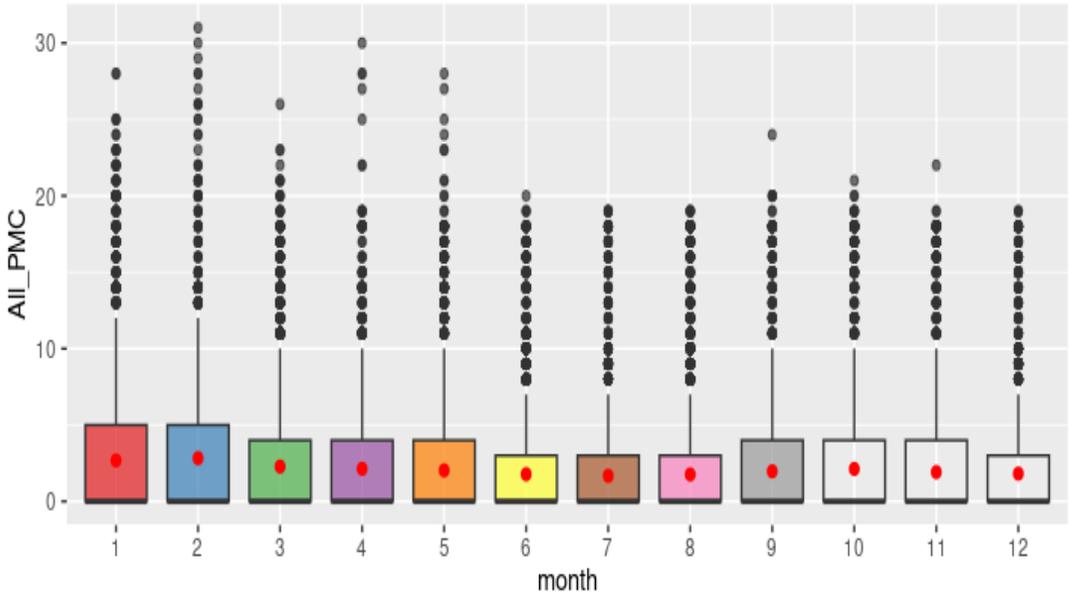
- Leg original to destination



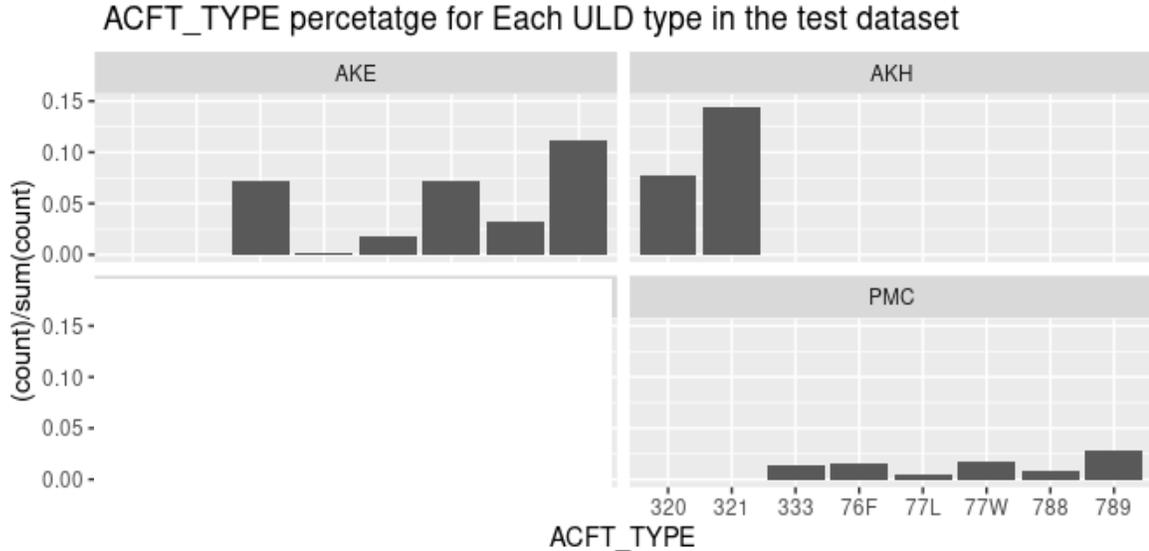
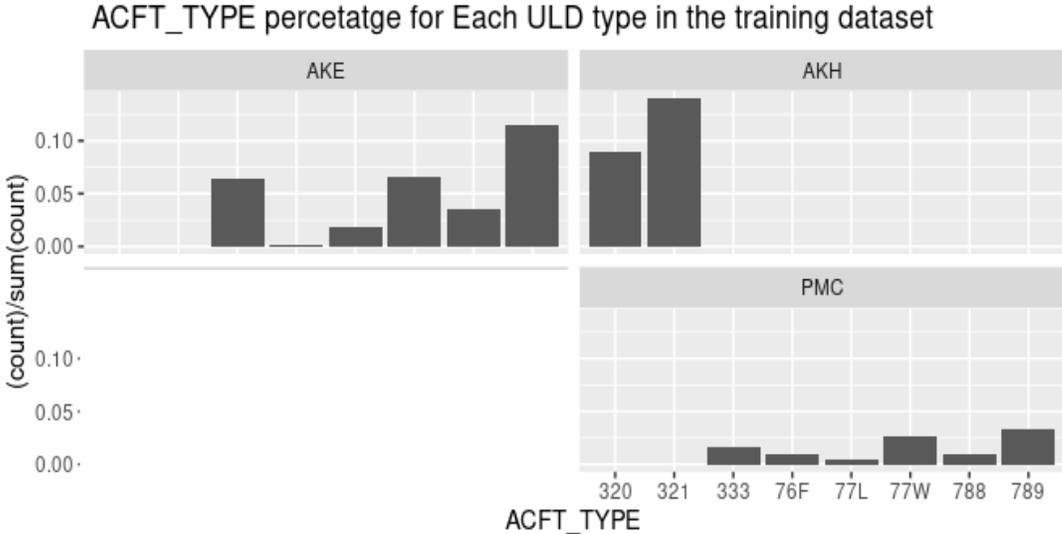
Variability of each ULD type number among Aircraft Types



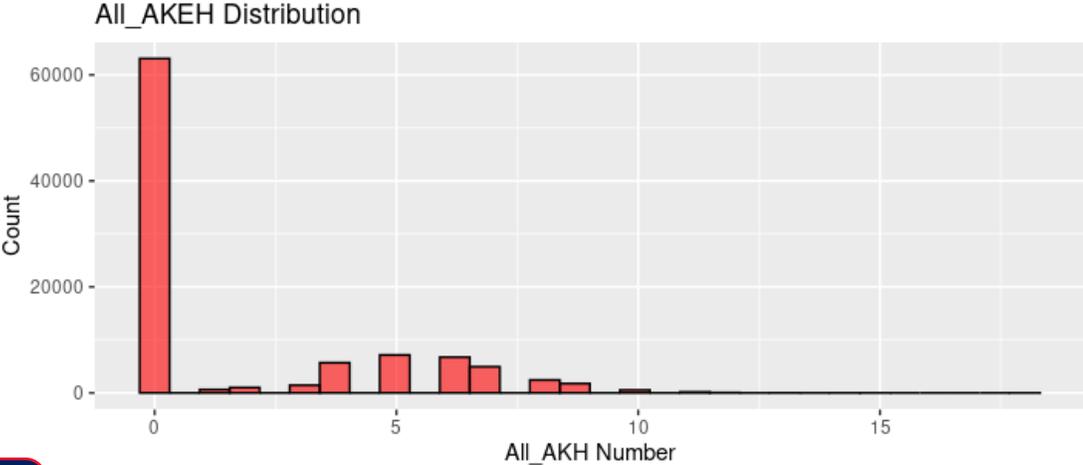
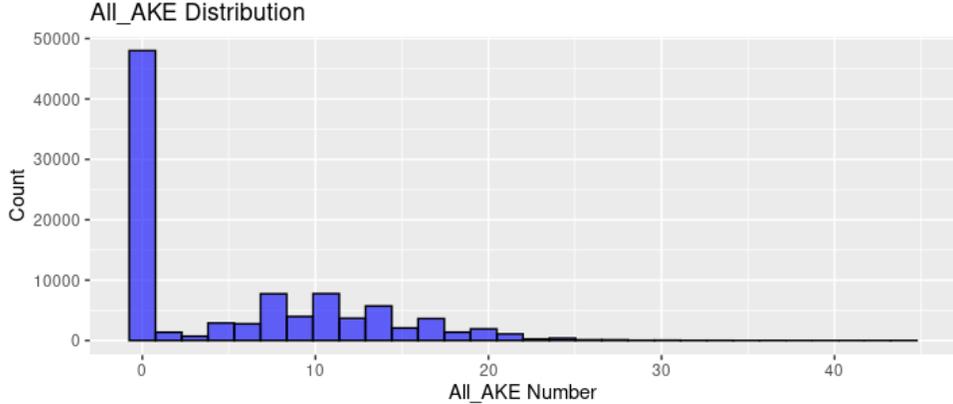
Variability of each ULD type number among months



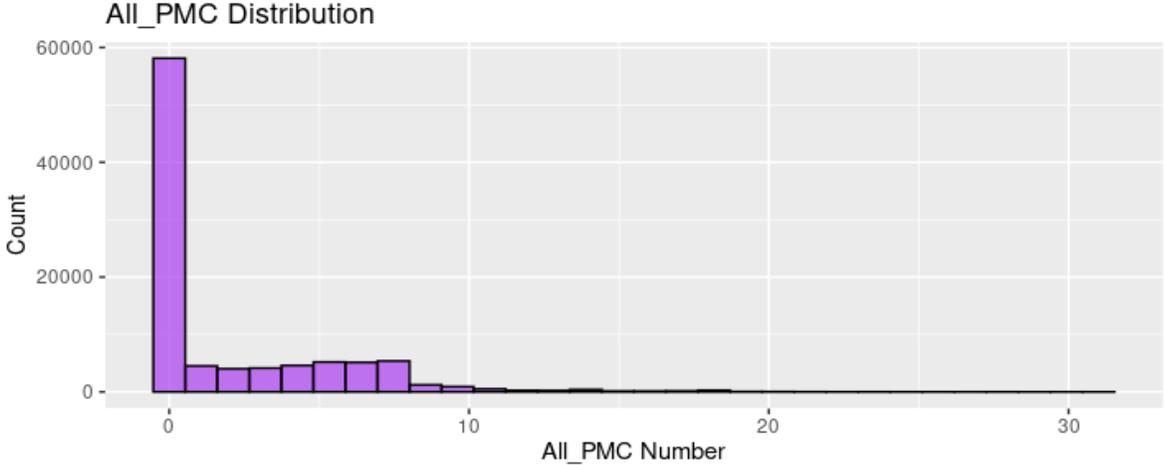
Percentage of each Aircraft type among ULD types in both training and test sets



ULD type number Distributions



Zero inflated distributions



Zero-Inflated Poisson (ZIP) Model

$$p(y_j|X_j, \Theta_j) : \mathbb{E}(y_j) = \gamma + \gamma_0(t_j) + \gamma_1(a_j) + \zeta_0(R_j)$$
$$y_j \sim ZIP(\mu_j, \pi_j),$$

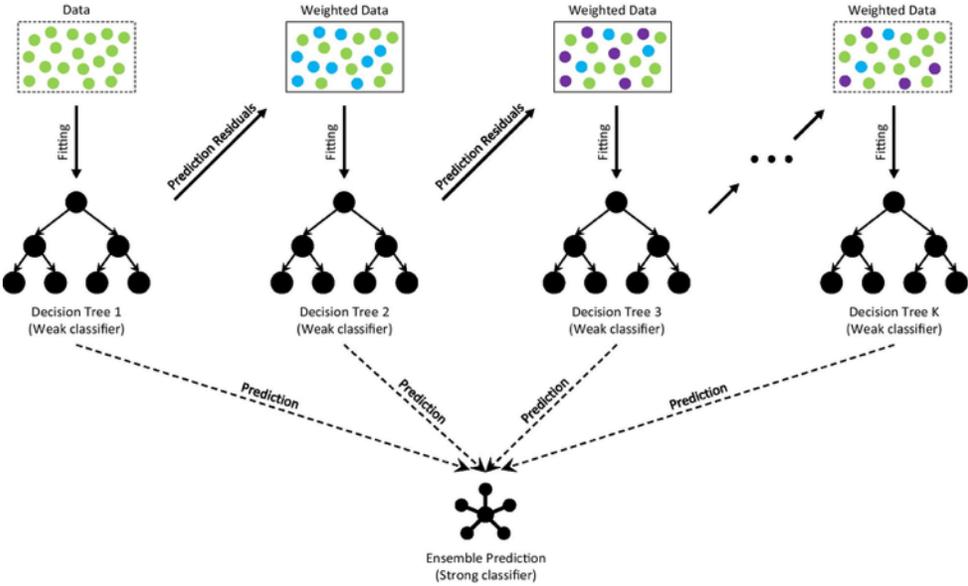
$$\zeta_0(R_j) \sim N(0, \sigma^2),$$
$$j = 1, 2, \dots, N$$

Different types of ULD number are fitted by different ZIP models by the R-glmmTMB

Symbol	Meaning
N	total observation numbers in year 2022
$p(\cdot)$	density function
y	ULD (PMC, AKE, AKH) number
t	Month (1 – 12)
a	Air craft type (789, 77W, 77L, 788, 76F, 320, 321, 333)
R	Leg route (original to destination, 856 levels)
$\gamma, \gamma_0, \gamma_1$	Fixed effect coefficients
ζ_0	Random effect coefficient
μ, π	Estimated parameters (mean and probability) in ZIP process
σ^2	Estimated parameter (variance) in Gaussian process



Extreme Gradient Boosting (XGBoost) Model



- Build a sequence of decision trees
- Optimize the predictions from the sequential decision trees



Loss Function

Mean Absolute Prediction Error (MAPE)

$$MAPE = \frac{\sum_i^M |y_i - \hat{y}_i|}{M},$$

where M is the total number of observations from the test set, y_i is the actual value and \hat{y}_i is the predicted value.



Result

XGBoost VS ZIP models by MAPE over all flights

Model	ULD Type		
	AKE	PMC	AKH
XGBoost	1,40 (1,48)	1.15 (1.20)	1.08 (1.21)
Zero-inflated Poisson	1.19 (1,38)	0,95 (1,15)	1,98 (2.39)



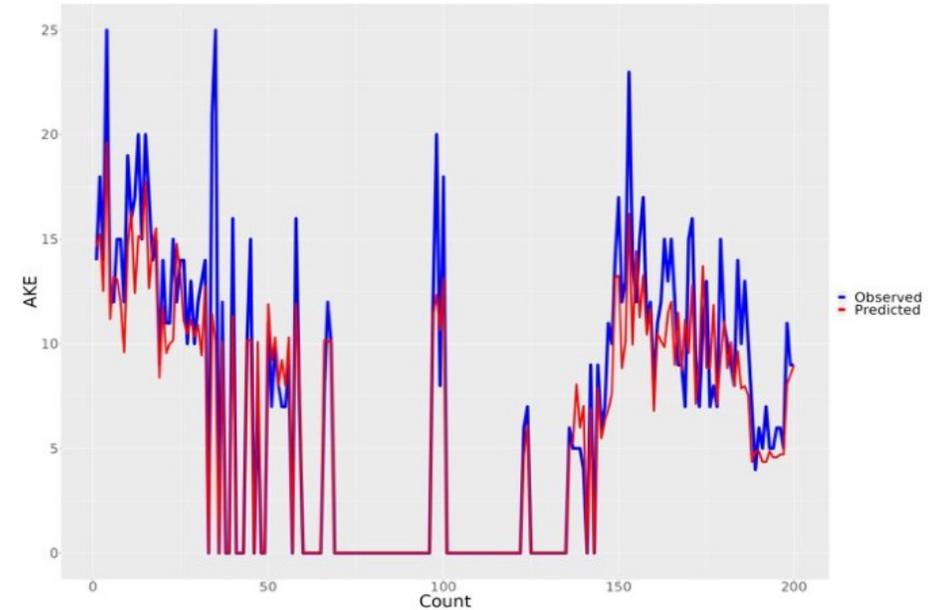
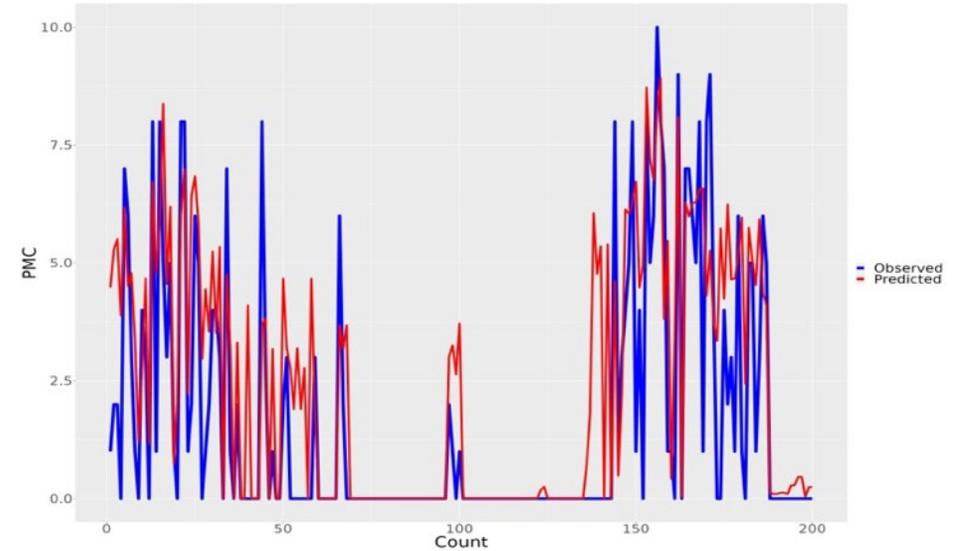
MAPE per Aircraft type

Aircraft type	AKE		PMC		AKH	
	XGB	ZIP	XGB	ZIP	XGB	ZIP
788	2,19	1,91	1,73	1,40	0,05	0,24
77W	3,17	3,02	2,42	2,12	0,03	0,18
789	2,68	2,36	2,02	1,70	0,04	0,10
77L	2,65	2,57	1,72	1,54	0,05	0,30
321	0,14	0,00	0,06	0,00	2,23	4,28
333	2,35	1,95	1,95	1,45	0,04	0,12
320	0,14	0,00	0,08	0,00	2,12	3,34
76F	1,36	1,09	4,19	4,29	0,03	0,28



Summary

- The model predicts the ULD usage with reasonable accuracy.
- These approaches have proven highly effective not only for passenger segments but also for forecasting the appropriate ULD types utilized.



Recommendation and future work



Considering additional data features



Improving the predictor



Consider more complex ULD configurations

Questions





Merci
Thank You