Extracting Contextual Information from Open Source Aviation Reporting Data

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Introduction

- ***Background: Aviation Safety Data Growing***
  - Accumulation of safety data
  - Need automatic analytics method

- ***Objective: Extract Information From Relevant Narratives***
  - Utilize artificial intelligence to summarize themes
  - Extract knowledge to detect emerging risks

Aviation Text Report Sample

MAIN HYD SYS UNLOADER VALVE PN HC5520, SN 235 WAS REMOVED FROM THE ACFT POST-INCIDENT AND WAS BENCH TESTED FOR FUNCTION. NORMAL VALVE PRESSURE RANGE UNLOADS AT 1,675 - 1,725 PSI AND LOADS AT 1,400 - 1,500 PSI. SUBJECT VALVE WAS FOUND TO UNLOAD PRESSURE AT APPROX 1,500 PSI AND RELOAD AT APPROX 1,250 PSI. THIS CONDITION RESULTED IN EXCESSIVE CYCLING OF THE VALVE, AND REPEATED HAMMERING OF THE HYD SYS RESULTING IN THE METAL FATIGUE AND CATASTROPHIC BURST OF THE RETARDANT TANK DOOR EMERGENCY HYD PRESSURE LINE. THE LINE FAILURE ALLOWED THE MAIN HYD SYS AND TANK EMERGENCY SYS TO LOSE PRESSURE AND FLUID WHICH LEAD TO THE FLIGHT CREW DECLARING AND IN-FLIGHT EMERGENCY FOR HYD SYS FAILURE.

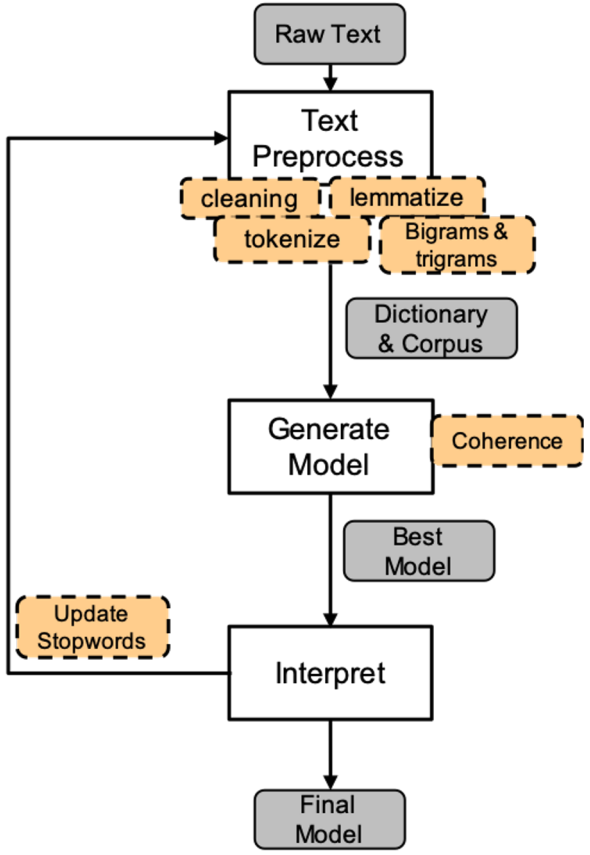
Project Outline

- ***Technical Applications***

  Use **Natural Language Processing (NLP)** approach to separate documents into different themes and detect trends over years to give explanations and suggestions. (Python: Gensim,SpaCy,NLTK package)

- ***3-Step Research Approach***

  1. Cleaning & Preprocessing Safety Narratives
  2. Training Topic Model
  3. Interpreting Result in Domain Knowledge & Sharing Actionable insights



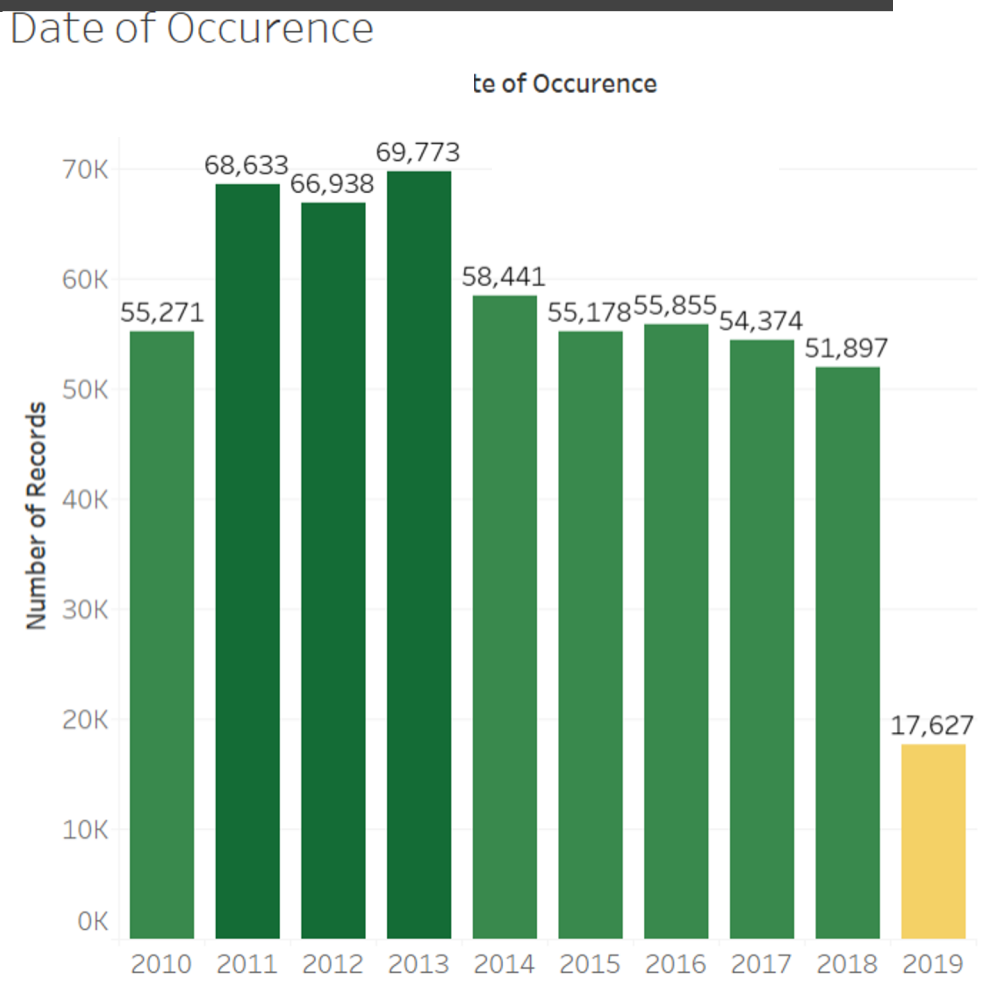
Flowchart

Dataset Overview

Service Difficulty Reports

SDR consist of **text report** of **maintenance incidents** collected by the FAA for the purpose of tracking repair problems with private, **commercial** and military aircraft and aircraft componentry

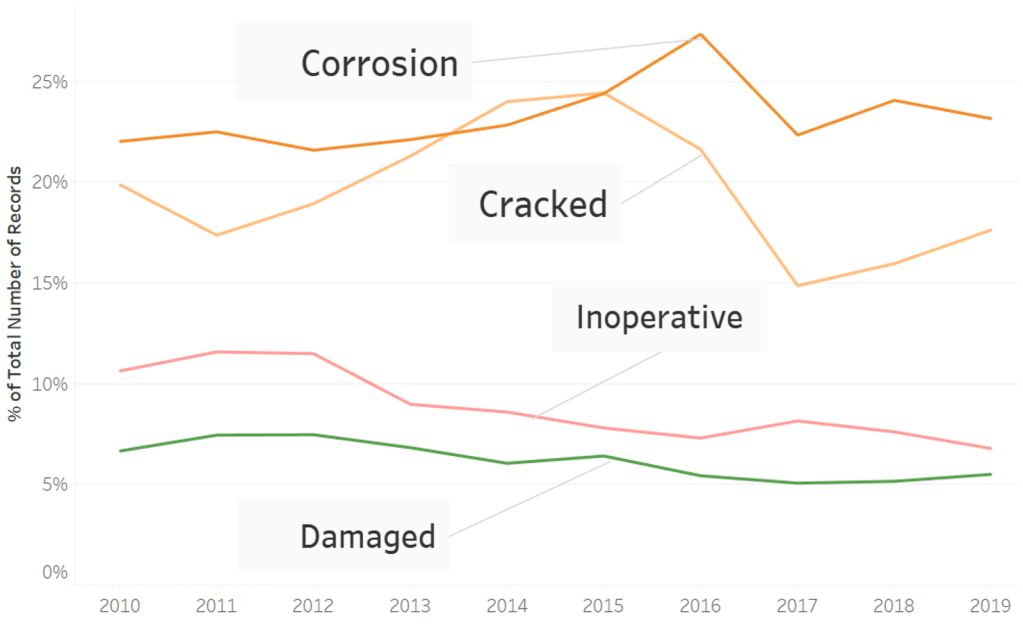
- Reliable
- Stable
- Sufficient data (>500K)
- Abundant features
- Commercial aircraft



Exploratory Data Analysis

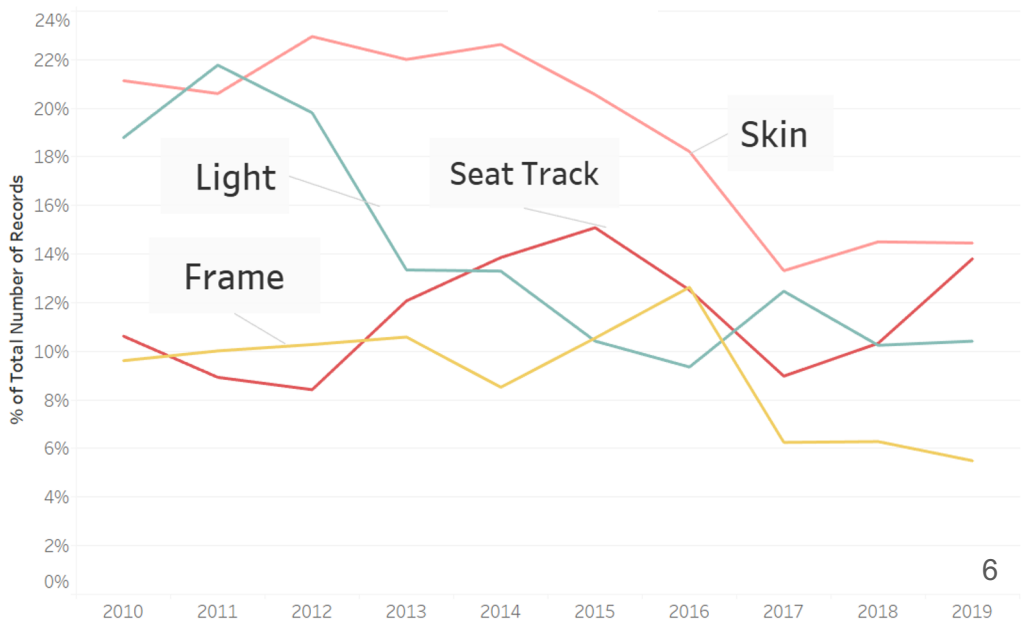
Common Detective Problem

- Corrosion
- Cracked
- Inoperative
- Damaged

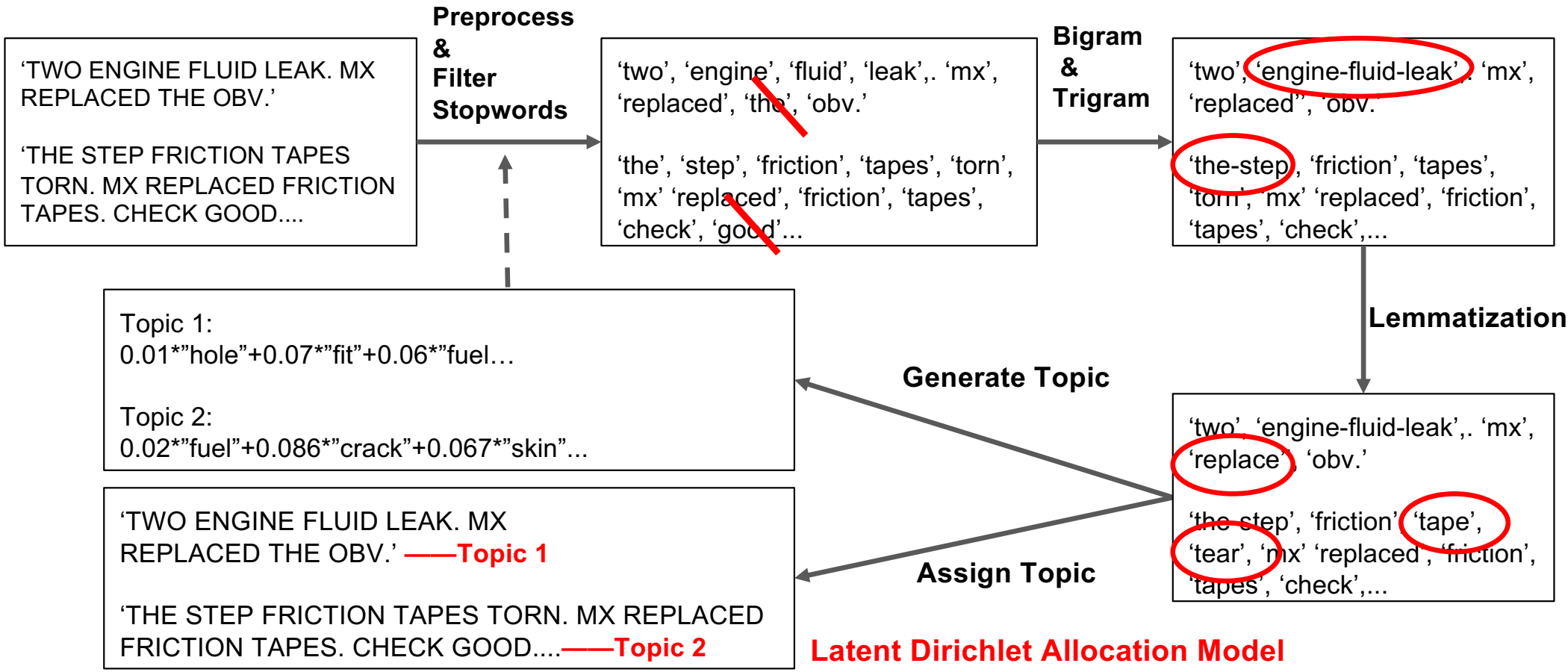


Common Location of the Defective Part

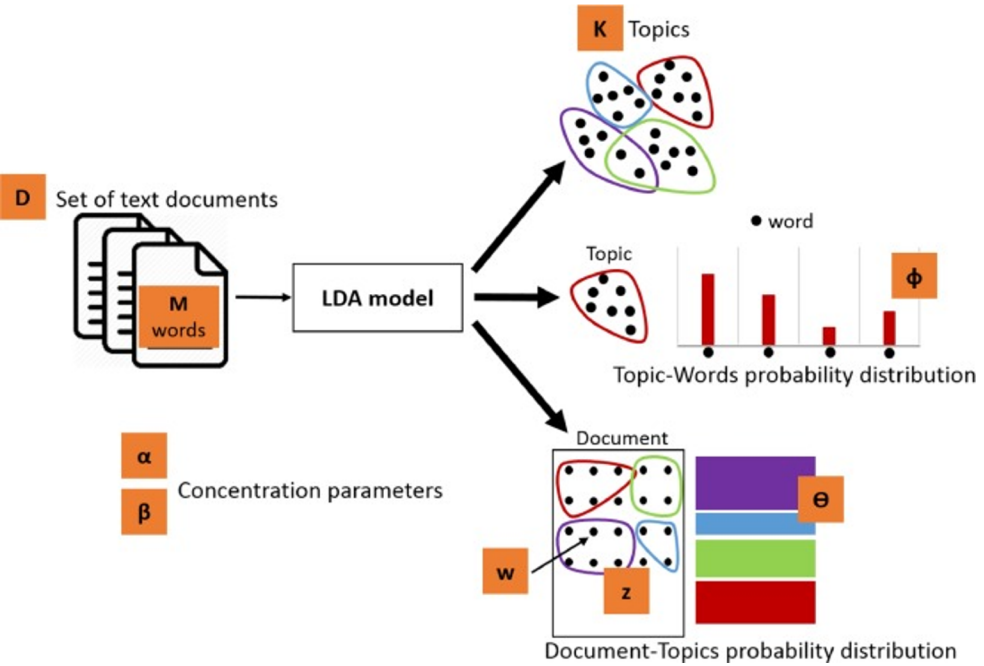
- Skin
- Seat Track
- Light
- Frame



Topic Modeling



Latent Dirichlet Allocation Model



Generative LDA as Bayesian Network
(Dirichlet Distribution: Prior for Multinomial Distribution)

- ***Pros:***

1. **Relax assumptions** in other models like each word is generated from a single topic in Probabilistic Latent Semantic Analysis (PLSA)
2. LDA is best applied to documents where each document deals with **multiple topics**
3. Large volumes: LDA requires relatively less expensive computation

- ***Cons:***

1. Unlike Correlated Topic Model (CTM), LDA is incapable to model **relations among topics**

Source: Lee, S., Song, J. and Kim, Y., 2010. An empirical comparison of four text mining methods. *Journal of Computer Information Systems,*
Blei, D.M., Ng, A.Y. and Jordan, M.I., 2003. Latent dirichlet allocation. *Journal of machine Learning research*, 3(Jan), pp.993-1022.

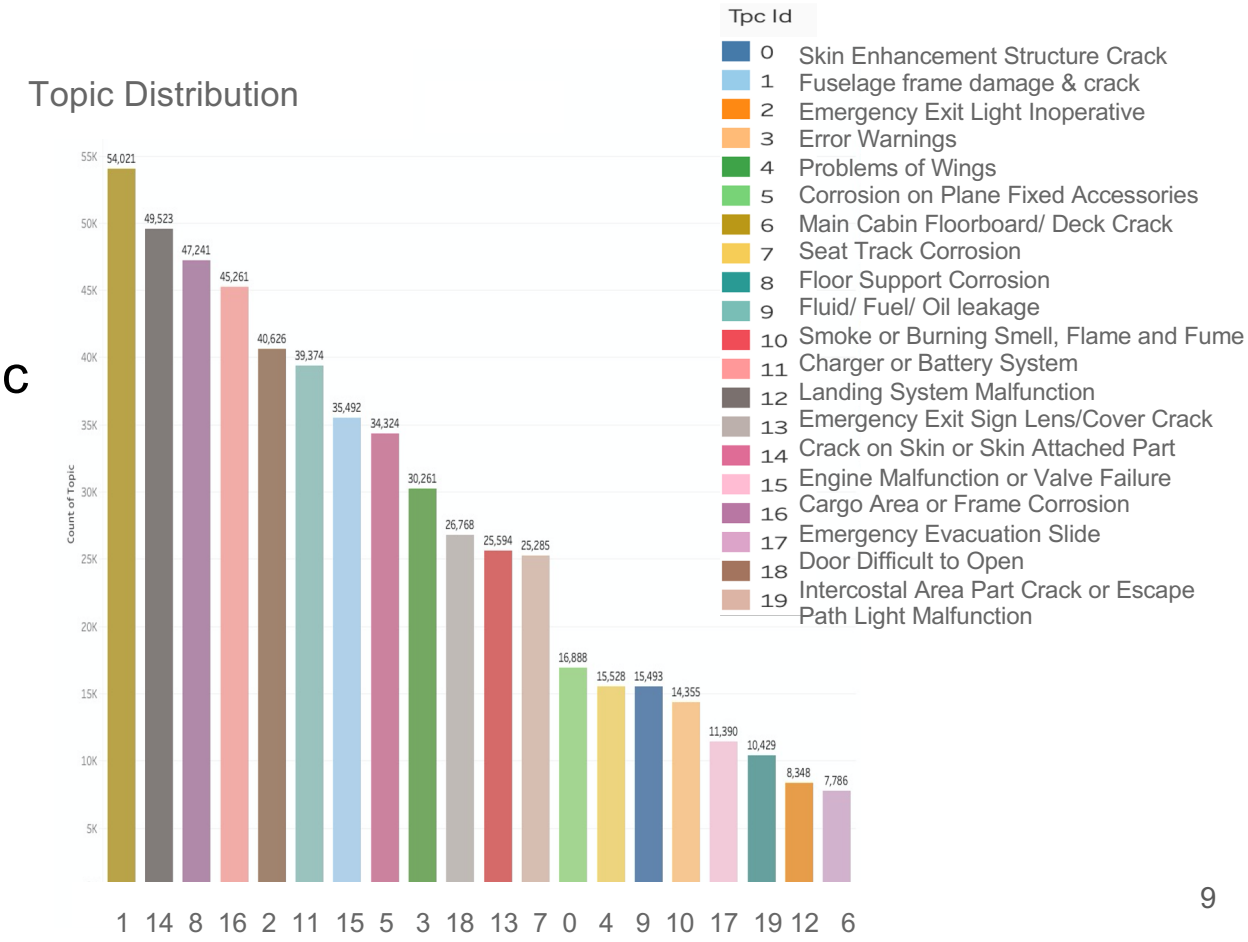
Topic Analysis

Overview

- 20 distinguished topics: Utilization of grid search and parameter optimization
- Detailed analysis of each topic with other attributes: Available in report

Key Findings

- 3 potentially emerging risks
- 2 improving events
- 2 insightful observations



Emerging Risk

- ***3 Topics Rising Significantly:***

1) **Topic 8: Floor Area Corrosion Damage**

Example: *AIRCRAFT IN BASE MAINTENANCE. DELAMINATION ON TOP LAYER FLOOR PANEL 261EG IN PASSENGER CABIN. REPLACED FLOOR PANEL PER SRM 53-02-00-300-009 AND IRM 9701 REV G.*

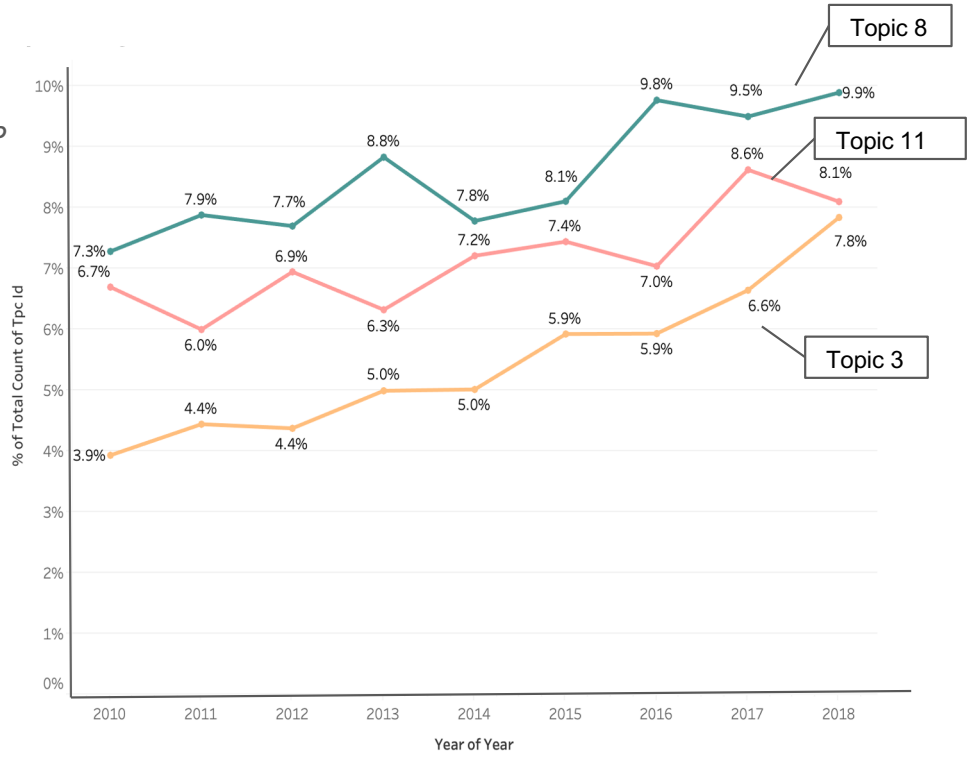
2) **Topic 11: Emergency Light Battery Inoperative**

Example: *FWD EMERGENCY FLASHLIGHT INOP. REMOVED AND REPLACED BATTERY PER MM.*

2) **Topic 3: Warning System Malfunction and False Activation**

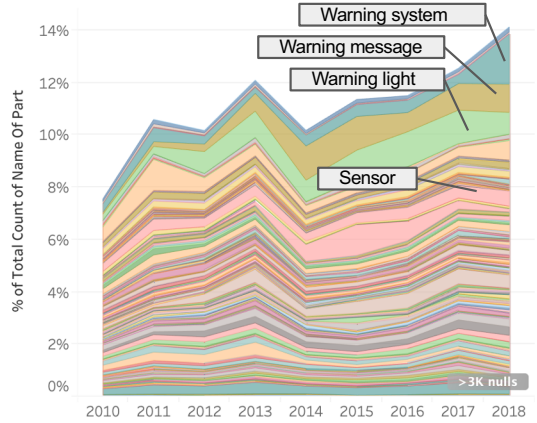
Example: *AFTER LANDING GEAR LEVER PLACED IN OFF POSITION, INDICATED RED LIGHTS. REMOVED AND REPLACED LANDING GEAR TRANSFER VALVE PER MM.*

Topic Yearly Trend

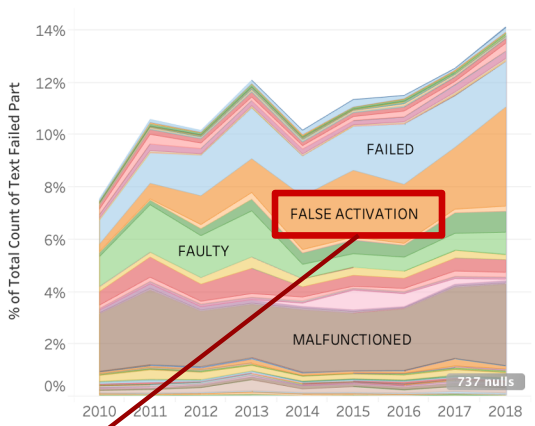


The Increase in False Warnings is Observed (Topic 3)

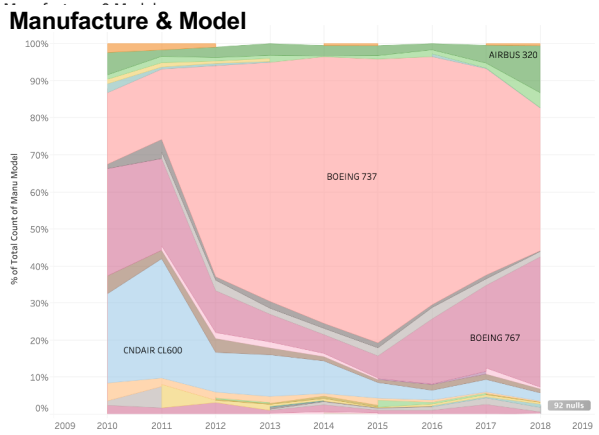
Defective or Malfunctioning part



Condition of failed part



Manufacture & Model



Two deadly crashes of the Boeing 737 MAX 8 initiated by a faulty reading from a single angle of attack sensor

Emergency Locator Transmitter generated 98% false alerts.

- False activation could be the drive behind the increase of the topic
- Boeing 767 shows an increased trend in false activation warning issue
- More work needs to be done for evidence but warning system maintenance issue should draw more attention

Source: https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/info/all_infos/media/2018/InFO18007.pdf

Enhancement

- ***2 Improving Issues:***

1) The Fuselage Material Improved

Topic 1: Fuselage frame damage & crack

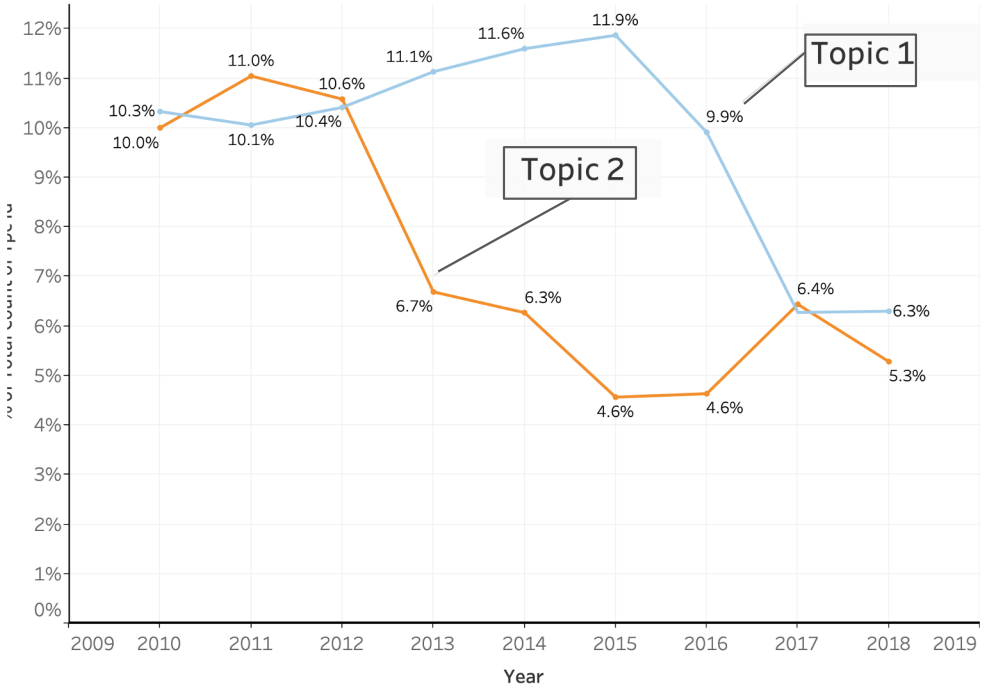
Example: *DURING SCHEDULED 12Y CHECK, FOUND FUSELAGE FRAME CRACKED AT BS 440, STR 8R. REPAIRED FRAME PER EA.*

2) Efficient Lighting Systems are Applied

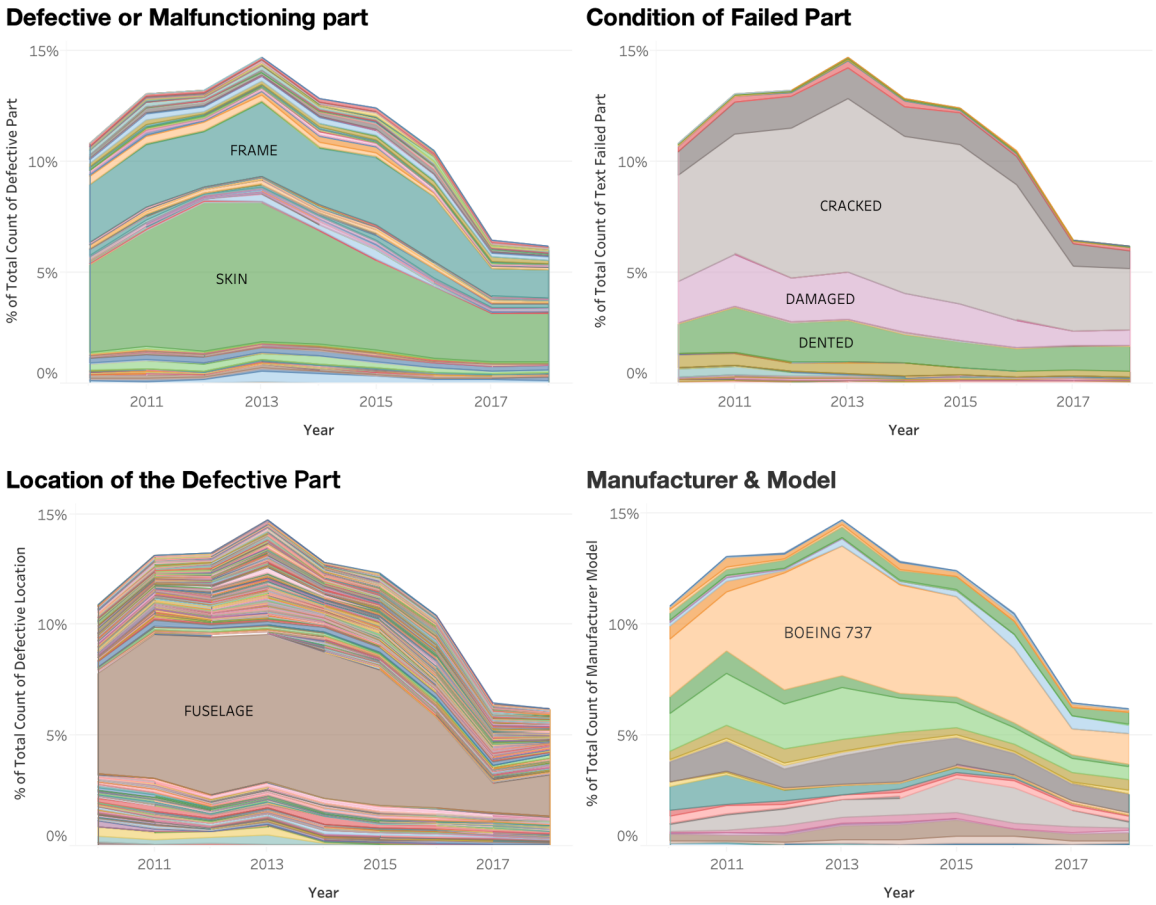
Topic 2: Emergency exit light lamp inoperative

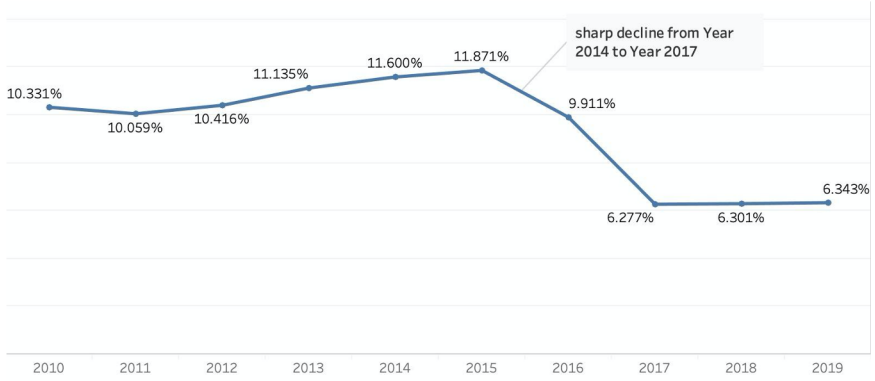
Example: *DURING SCHEDULED MV2 CHECK, FOUND EMERGENCY EXIT LIGHT INOP AT ROW 10. RELAMPED PER MM."*

Topic Yearly Trend



The Fuselage Material Improved (Topic 1)





- **Advanced composite materials** such as carbon fiber reinforced plastic are mixed in to the fuselage.
- The stitched composites were **30 percent stronger, withstanding greater forces** before breaking apart.

Source: BBC News, Massachusetts Institute of Technology

Insightful Observation

Topic 18: Door Difficult to Open or Part Damage

Topic 17: Door Emergency Evacuation Slide out of Position

- **Finding**

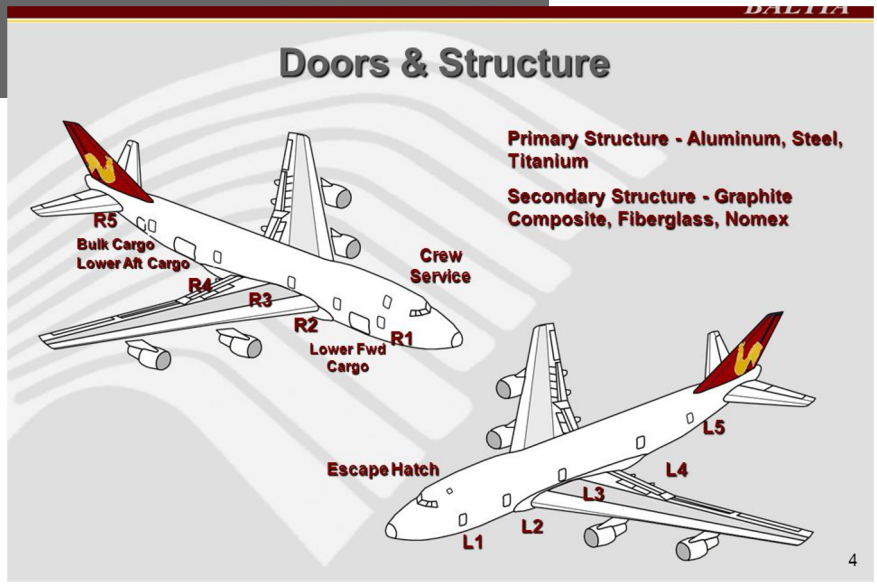
L1 door of the aircraft showing more defective than any other doors according to the data

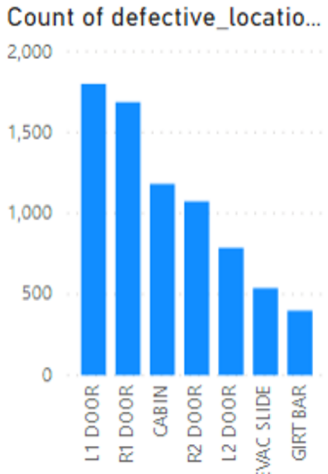
- **In reality**

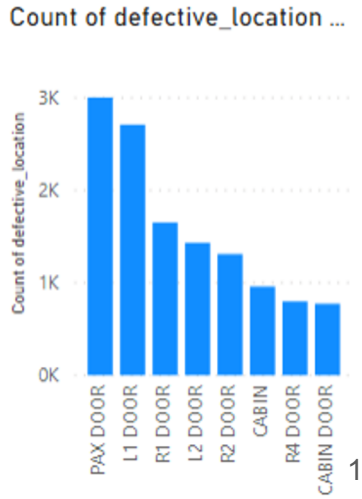
L1 and L2 doors are usually used for getting passenger on board, R1 and R4/5 doors are usually for loading supply

- **Suggestions**

Doors that are used more often and with more load seemingly more likely to be defective; More frequent inspection and maintenance could be scheduled for such doors; Boeing has been observed with more frequent related issue reported with evacuation slides







Conclusion & Future Work

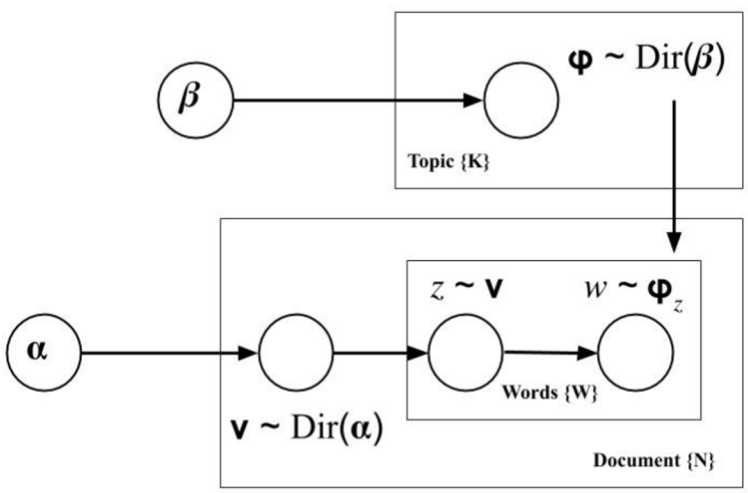
- ***Conclusion:***
  - Summarize documents by reasonable themes with **topic analysis** and identify some trend and observations by the occurrence of each theme
  - **Extracting phrases** out of the report to find some rare but serious issues
  - Combining analyze text analysis result, current attributes and external information
  - Extensively usage: **road accident reports**, **medical records** and **product reviews**

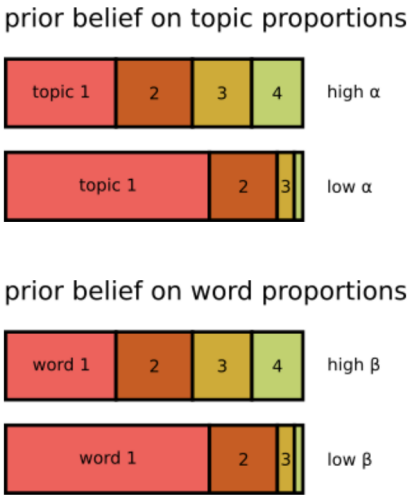
- ***Future work:***
  - Mixed topics due to the LDA model is sensitive to the numbers of topic we assigned
  - Further **parameter tuning** or Creating **Sub-LDA model** for specific topics

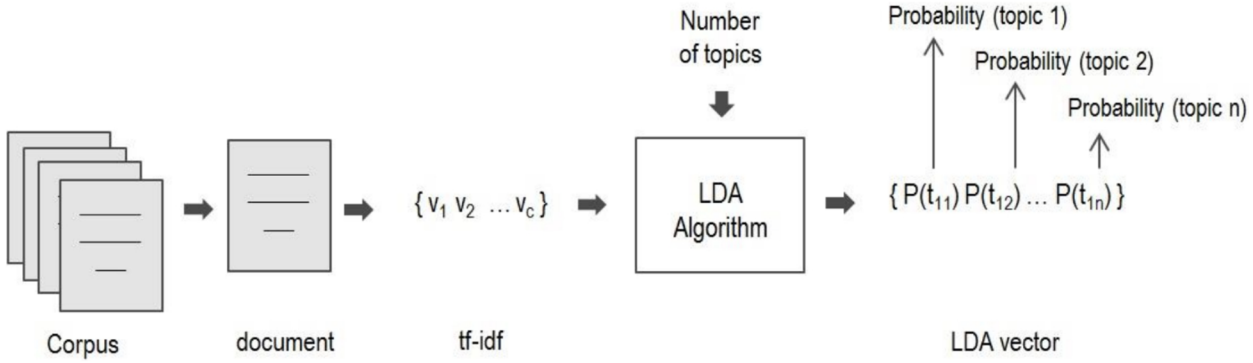
Thank you

Q & A

Appendix


β
φ ~ Dir(β)
Topic {K}
α
z ~ v
w ~ φ z
Words {W}
v ~ Dir(α)
Document {N}


prior belief on topic proportions
topic 1
2
3
4
high α
topic 1
2
3
low α
prior belief on word proportions
word 1
2
3
4
high β
word 1
2
3
low β


Number of topics
Probability (topic 1)
Probability (topic 2)
Probability (topic n)
{ v1 v2 ... vc }
LDA Algorithm
{ P(t11) P(t12) ... P(t1n) }
Corpus
document
tf-idf
LDA vector