

Application of STPA on Small Drone Operation: The Approach and First Results.

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Overview

- Background
- Research scope and assumptions
- Application of the STPA and results
- Comparison of four drones and statistical analysis
- Conclusions and next steps

Background



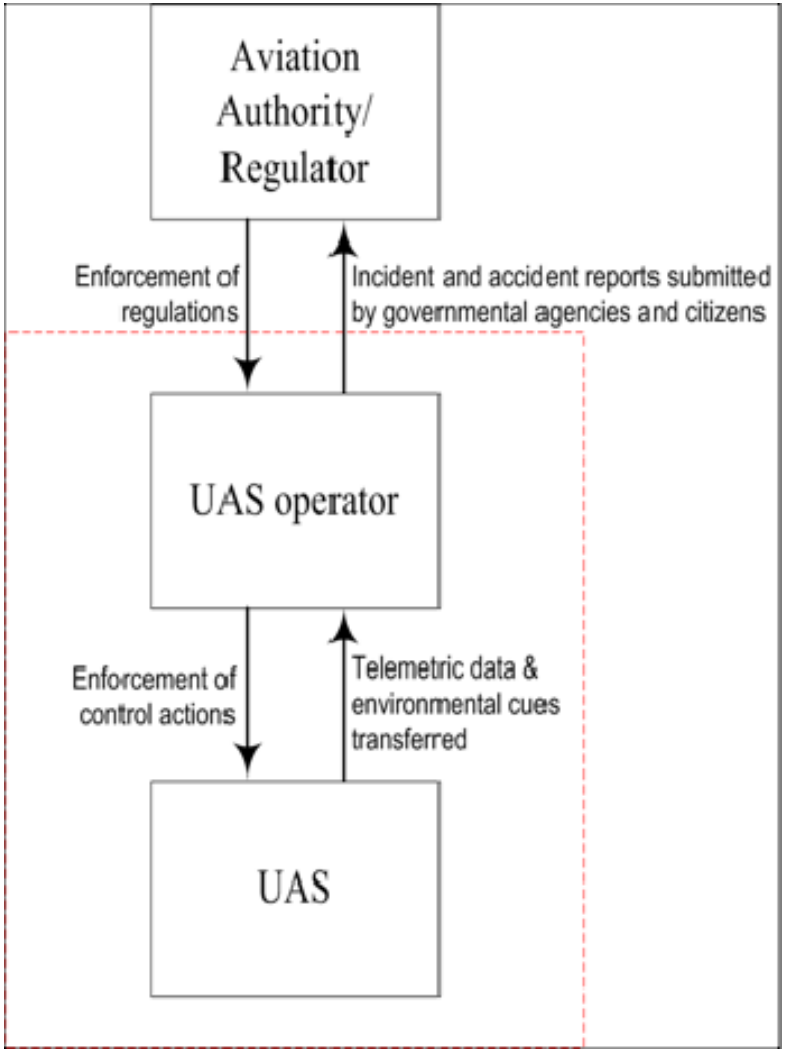
- Small drones are a new “toy” for everyone. Used for entertainment reasons.
- A great amount of drones is sold and used.
- No solid regulatory framework for drones’ manufacturing and operation.
- Operator is fully responsible for safe use of drone.
- Several reported accidents (incl. human injuries).

Research scope



- An analysis of the operator – drone system with STPA.
- Safety Requirements (SR) to be considered in certification and standardization.
- SR for: regulator, manufacturer, operator and automation
- Comparative analysis among four popular drone models with detailed user manuals.

HIGH LEVEL HIERARCHICAL CONTROL STRUCTURE



Assumptions



- Drones with weight less than 25 kg for the USA and 20 for the EU.
- The controller maintains visual contact with the drone.
- The drone is a rotary aircraft, hence is not subject to aerodynamic limitations.
- The display used for monitoring telemetry data might be integrated with the remote controller or not (e.g., smartphone).
- The loss of mission is not addressed due to non-direct implications on safety.

Assumptions

- The remote controller used to direct the drone is also used to increase/ decrease speed. There is no separate and dedicated speed control.
- The lowest permitted flying altitude in the designated area is at least equal to the altitude of the highest physical obstacle.

STPA

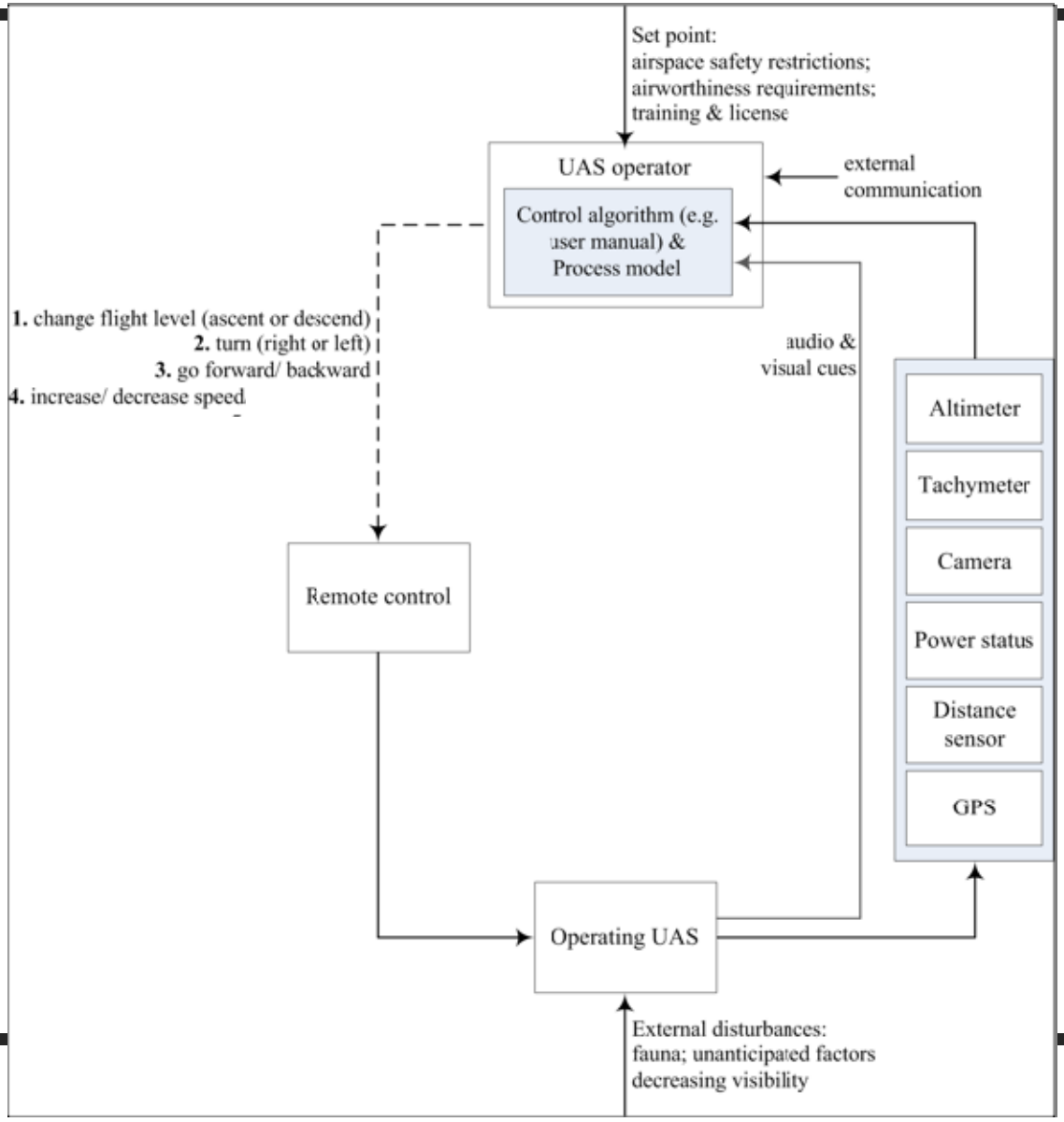
- **Accident definition**

  Injuries or property damage resulting from the operation of UAS.

- **Hazards**

  - **[H1]: Unsafe separation from terrain / objects on ground during controlled flight**
  - **[H2]: Uncontrolled flight over congested area**
  - **[H3]: Unsafe separation from other flying objects during controlled flight**

Control structure



Example of (Unsafe) Control Action

Control Action (CA)	Hazardous/Unsafe Control Actions (UCA)			
	Not Providing Causes Hazard	Providing Causes Hazard	Applied Too Early/ Too Late/ Wrong Order Causes Hazard	Stopped Too Soon or Applied Too Long Causes Hazard
[CA1] ascend	**[UCA1]** Operator does not provide ascend command when drone approaches lowest altitude of range area. [H-1]	**[UCA2]** Operator provides ascend command when drone close and beneath flying object. [H-3] **[UCA3]** Operator provides ascend command when drone approaches highest altitude of range area. [H-2, H-3]	**[UCA4]** Operator provides ascend command before drone passes beneath object flying over and close. [H-3] **[UCA5]** Operator provides ascend command after drone having crossed lowest altitude of range area. [H-1]	**[UCA6]** Operator applies ascend command too long when traffic above. [H-3]

STPA Results

- 7 CA.
- 34 UCA.
- 24 Causal factors.
- 67 Safety Requirements.
- One (1) Safety Requirement is only for the Aviation Authority.
- Total 66 requirements included in the analysis.

Comparison

- **Four drones:**
  - **No 1, France, 349 Euro.**
  - **No 2, China, 4330 Euro.**
  - **No 3, China, 900 Euro.**
  - **No 4, USA, 840 Euro.**

Safety requirements

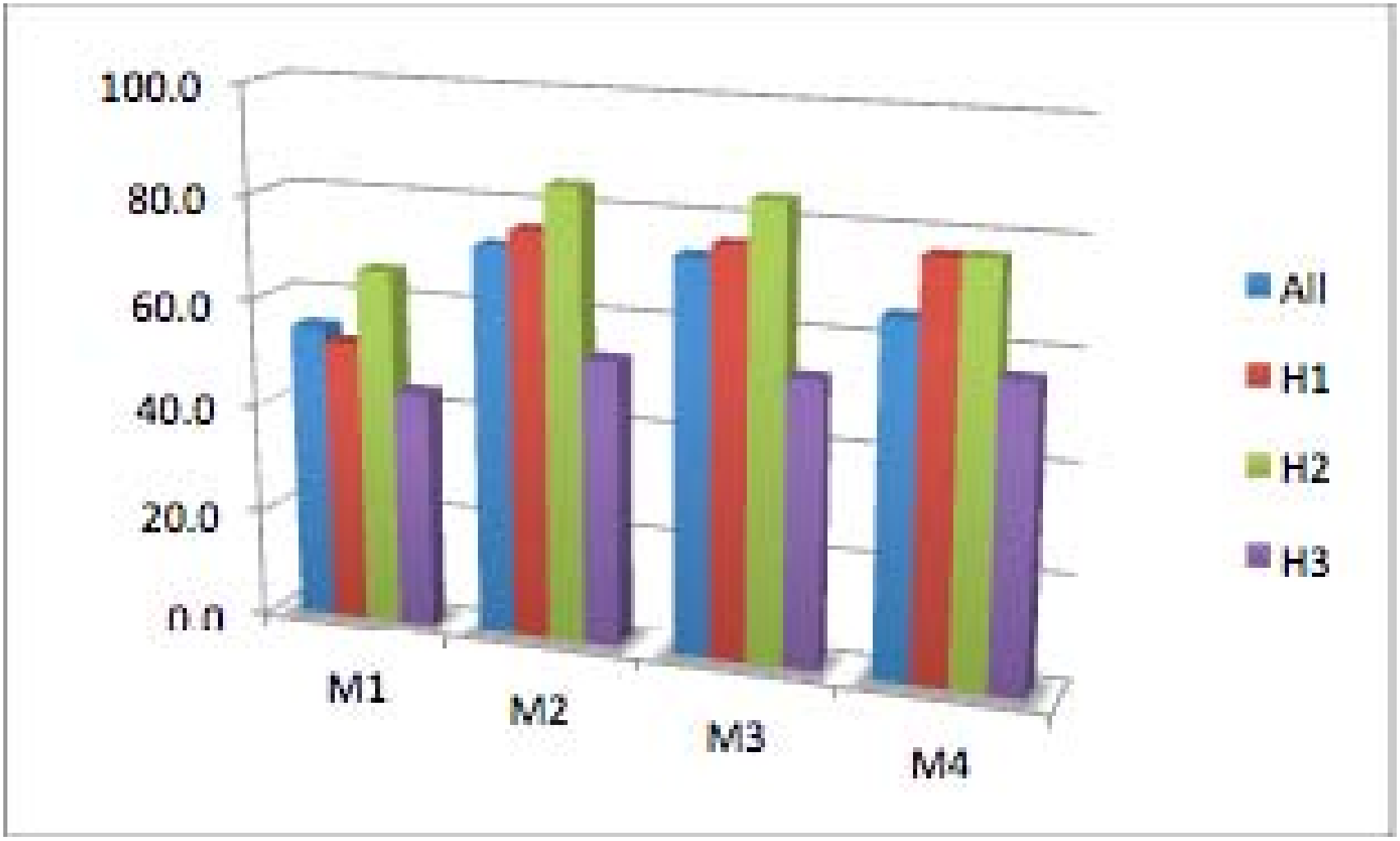


	Hazard [1]	Hazard [2]	Hazard [3]
SR for each Hazard	**27**	**39**	**34**

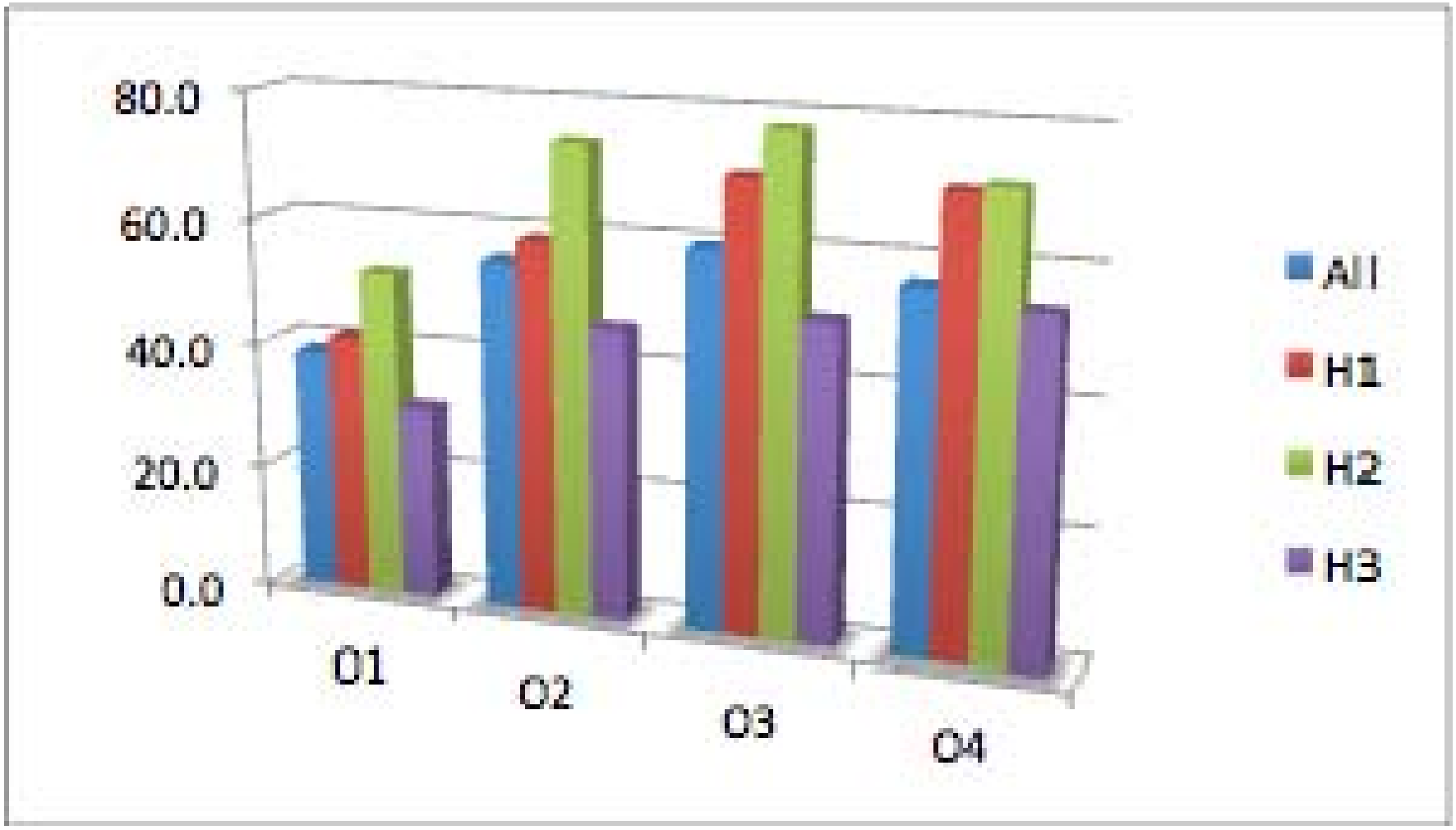
Frequencies

%	All	H1	H2	H3
M1	54.5	52.0	65.8	43.8
M2	72.7	76.0	84.2	53.1
M3	72.7	76.0	84.2	53.1
M4	65.2	76.0	76.3	56.3
O1	38.3	41.2	51.9	30.8
O2	55.3	58.8	74.1	46.2
O3	59.6	70.6	77.8	50.0
O4	56.3	70.6	71.4	53.8
A1	36.2	40.0	47.8	27.3
A2	63.8	73.3	82.6	36.4
A3	63.8	73.3	82.6	36.4
A4	48.9	60.0	65.2	27.3

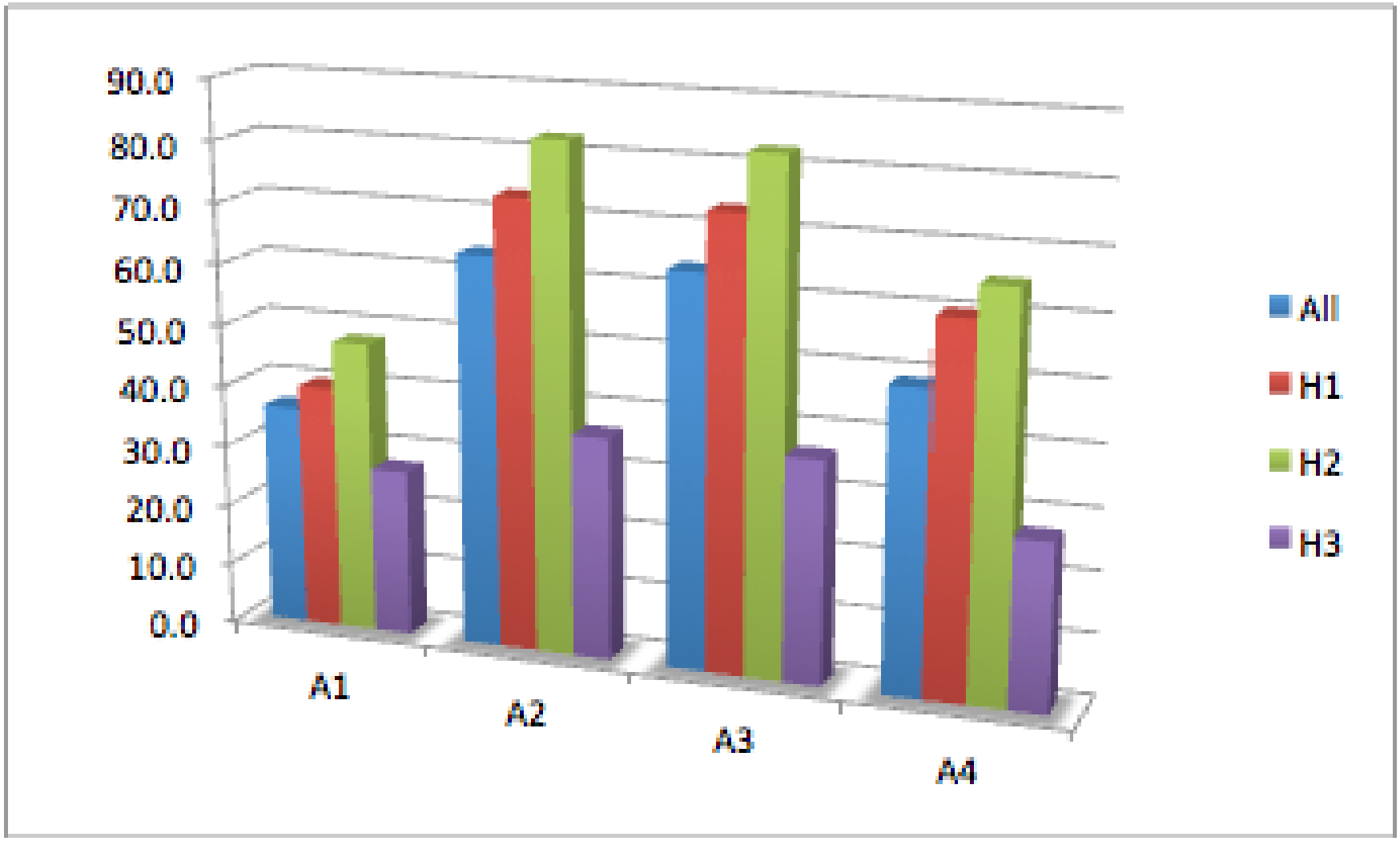
Manufacturer Frequency



Operator Frequency



Automation Frequency



Intraclass Correlations

	All SRs	[H-1]	[H-2]	[H-3]
Manufacturer	0.561	0.48	0.407	0.695
Operator	0.618	0.553	0.423	0.739
Automation	0.53	0.444	0.347	0.628

Intraclass Correlations per pair

	M1	M2	M3	M4
M1				
M2	0.498			
M3	0.498	0.925		
M4	0.286	0.617	0.59	
	O1	O2	O3	O4
O1				
O2	0.59			
O3	0.517	0.829		
O4	0.388	0.702	0.698	
	A1	A2	A3	A4
A1				
A2	0.333			
A3	0.333	1		
A4	0.32	0.624	0.624	

Spearman' s correlations for price

		Manufacturer	Operator	Automation
All SRs	Coefficient	0.949	0.400	0.949
	Significance	0.051	0.600	0.051
[H-1]	Coefficient	0.775	0.316	0.949
	Significance	0.225	0.684	0.051
[H-2]	Coefficient	0.949	0.632	0.949
	Significance	0.051	0.368	0.051
[H-3]	Coefficient	0.316	0.200	0.894
	Significance	0.684	0.800	0.106

Conclusions

- STPA drove to systematic identification of 67 SR.
- The framework can be used for drones' design, certification and safety benchmarking.
- The examined drones are compliant with 36.2% to 72.7% of the SRs.
- Similarities between drones:
  - Manufacturer from 0,286 to 0,925.
  - Operator from 0,388 to 0,829.
  - Automation from 0,32 to 1.
- Drones meeting the most of the SRs tend to have higher price .

Next steps

- **Compare the drones' regulatory framework of Aviation Authorities.**
- **Make comparisons among more drones.**
- **Compare the STPA results with other published hazard analyses (**e.g., Dalamagkidis, Valavanis, & Piegl, 2012).

Questions?