Runway Intersection Marking

BUILT WORLD ENTERPRISE

Michigan Technological University

Introduction

ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

Built World Enterprise (BWE)

BWE was established in 2019 to address civil and environmental engineering related challenges. The enterprise has had several teams work on ACRP projects and will continue to expand to address a variety of design challenges.

Airport Cooperative Research Program

The ACRP is a national university design competition that addresses a plethora of airport related challenges in four overarching categories. Teams are comprised of undergraduate and/or graduate students as well as a faculty advisor.

Design Challenge and Problem Statement:

The team addressed a challenge in the Runway Safety/Runway Incursions/Runway Excursions category. The specific problem and basis for the design solution is enhancing airport visual aids, improved lighting, marking, and signage for runways, taxiways and the airport apron.

Literature Review

FAA RIM Program

- The FAA RIM Program identifies nonstandard taxiway geometry as one of the main causes of runway incursions. The RIM database catalogs nonstandard geometry locations, hotspots, and incursions at airports across the US. They recommend reconstruction, improved lighting, improved signage, and changes to operational procedure to mitigate these risks.

Human Factors

- Pilot error is a main cause of incursions, which can be summarized under human factors.
- Effects experienced and inexperienced pilots alike
- Increasing situational awareness is the best way to mitigate this.

Colored Lanes in Bus Rapid Transit

- Cities across the US have begun to implement red lanes in their bus rapid transit systems as a way to decrease incursions into bus lanes by cars.
- NCYDOT was the first organization to follow through with this concept.
- The red lanes decreased incursions by 55.4%.
- They identified epoxy street paint as the best method to achieve red lanes, over other types of paint or mixing pigments into the cement or asphalt.

Runway Status Lights (RWSLs)

- RWSLs are a newer incursion mitigation strategy being implemented by the FAA. They are red LED lights imbedded in the centerline of taxiways and runways. They indicate to pilots if the runway they are approaching is currently in use. It is important to note they do NOT indicate ATC clearance.
- RWSLs are a more expensive strategy, due to their novelty. They are only operational at 20 US airports as of 2019.

Implementation Variations

See below

Design Method - Decision Matrix

Pavement Marking Pattern Decision Matrix

		Alternatives							
		Solid Markings		Striped (Red) Markings		Striped (Red &White) Markings		Do Nothing (Just Hold Short Marking)	
Category/Topic	Weight	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Friction	2	5	10	7	14	5	10	10	20
Salience: color contrast	1	6	6	8	8	10	10	0	0
Salience: orientation contrast	1	5	5	10	10	10	10	0	0
Salience: luminance	1	8	8	7	7	10	10	0	0
Maintenance	1	6	6	5	5	4	4	10	10
Pilot Interpretation: Best Case	1	6	6	8	8	10	10	4	4
Pilot Interpretation: Medium Case	1	8	8	6	6	6	6	5	5
Pilot Interpretation: Worst Case	-1	4	-4	5	-5	5	-5	7	-7
Pilot Interpretation: Base Case	-1	6	-6	5	-5	3	-3	8	-8
			39		48		52		24

The team used a decision matrix to analyze the design choices while removing biases. Three potential patterns for the runway intersection marking were proposed: solid markings, striped (red) markings, and striped (red & white) markings. Each element was assessed based on safety factors in the categories listed.

Safety Assessment

Hazards Consideration and Mitigation Strategies

- Foreign Object Debris (FOD): Occurs from paint chipping & entering runway surface. Refer to A/C 150.5340-30J.
- Pilot Misinterpretation: The team analyzed human factors to maximize pilot awareness in the design.
- Low Visibility: Reflectivity of the design is increased with white stripes, mitigating risk of low visibility at night.
- Reduced Friction: Glass beads are added to the paint to add friction.
- Safety Management System: AC 150/5200-37 is followed to implement new safety measures at airports.

Safety Risk Matrix

See below: the safety risk matrix lays out the potential hazards on a scale of severity and likelihood in order to appropriately assess the level of risk.

Runway Intersection Marking		Severity				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood	Almost Certain					
	Probable	FOD				
	Possible	Avoidance of Taxiway	Disregardance of Markings			
	Unlikely		Low Visibility	Minor Incursion		Reduced Friction
	Rare				Major Incursion	

Technical Design Aspects

Marking Geometry

- The runway intersection marking will start at the runway hold short line and continue to the runway edge marking.
- Stripe starts at a 30° angle from hold short line.
- Red and white stripes have a width of 15 feet.
- See right for detail drawing

Implementation Location

- The runway intersection marking will be classified as a nonstandard marking.
- Can be implemented at towered and non-towered airports within the United States.
- Located on the airfield at hot spot and FAA RIM problematic geometry locations to avoid confirmation and expectation bias among the user, increasing the effectiveness of the marking.

Paint Type

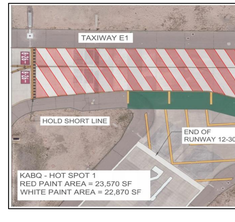
- The use of a waterborne paint that contains glass beads is recommended and fits FAA paint standards

Maintenance

- It is recommended to repaint the marking as other airfield markings are repainted.

Environmental Implications

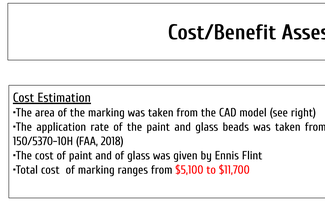
- There are no anticipated environmental impacts that may arise from implementation.

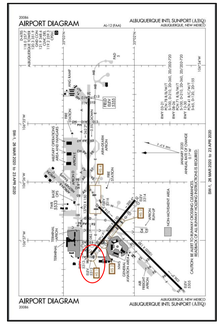


Left: Runway Intersection Marking Standard Detail

Below Left: KABQ HS 1 Runway Intersection Marking Implementation

Below Right: KABQ Airport Diagram with HS 1 circled





Cost/Benefit Assessment

Cost Estimation

- The area of the marking was taken from the CAD model (see right)
- The application rate of the paint and glass beads was taken from FAA AC 150/5370-10H (FAA, 2018)
- The cost of paint and of glass was given by Ennis Flint
- Total cost of marking ranges from $5,100 to $11,700

Type Of Paint		Type of Beads	Total Cost
Fast Dry	Type I & II	Type I	$5,119.40
	Type III.i	Type I	$6,616.40
	Type III.ii	Type IV	$10,423.25
High Build	Type I & II	Type I	$5,749.40
	Type III.i	Type I	$7,441.40
	Type III.ii	Type IV	$11,705.75

Benefit Estimation (FAA, 2015)

- The team focused on monetary damages to aircraft, but these are not the only costs caused by incursions
- The cost of repairing or replacing aircraft suffering "substantial damage," or being "destroyed" is collected by the NTSB each year
- For commercial passenger air carriers, the average cost in 2014 was $305,000,000 (in 2020$).
- For GA aircraft, the average cost in 2014 was $115,727 (in 2020$).
- Damages cost on average about 20% of an aircraft's value

Selected Professional Contacts

Dr. Kelly S. Steelman

- Dr. Steelman helped the team analyze the decision of marking recommendation.
- Salience properties was recommended by Steelman to be included in the team's decision matrix.
- Dr. Steelman also talked to the team about inattentional blindness

James Thomas

- Thomas is a Boeing 777 airline pilot and thought the runway intersection marking will improve safety
- Additionally, Thomas mentioned that the implementation of will not increase radio congestion and does not contain any language barriers for interpretation.

Austin Straubel International Airport Staff

- The staff raised concern about ice building and snow removal on pavement with additional pavement markings.
- They suggested using striped markings to decrease the area of the paint, increasing friction and decreasing maintenance.

Aaron Stewart, P.E.

- Stewart raised concern about FAA regulations and marking design standards when the runway intersection marking was proposed.
- Based on his feedback, the team decided to focus the runway intersection marking as a nonstandard pavement marking to fit FAA guidelines.

Conclusion

Meeting FAA Goals

- The goal of the runway intersection is to increase airport surface safety by reducing runway incursions through increased situational awareness.
- In the FAA Strategic Plan for 2019-2022 improved surface safety is a strategy mentioned to reduce aviation injuries and fatalities (FAA, 2019).

Commercial Potential

- The runway intersection marking is recommended to be implemented at hot spot or problematic geometry locations at both towered and non-towered airports as a permanent or temporary solution for mitigating runway incursions.
- The runway intersection marking is more affordable to implement than reconstruction or addition of RSWLs at an airport.

Design Implementation Process

- The runway intersection marking is anticipated to be classified as a nonstandard marking.
- It is expected that there will be virtual and physical testing of the marking prior to widespread implementation at airports across the United States.
- Education to users will have to be published to ensure effective implementation.

References

Federal Aviation Administration. (2007). *Advisory Circular: Introduction to Safety Management Systems (SMS) For Airport Operators. Advisory Circular: Introduction to Safety Management Systems (SMS) For Airport Operators.*

Federal Aviation Administration. (2010). *Advisory Circular: Airport Foreign Object Debris(FOD) Management. Advisory Circular: Airport Foreign Object Debris (FOD) Management.*

Federal Aviation Administration. (2019). *FAA Strategic Plan: FY 2019-2022.*

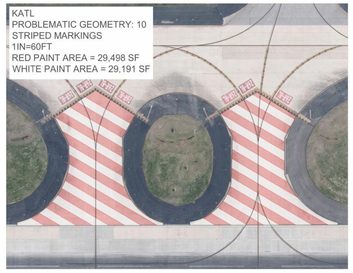
Team Members

Skylar Callis is a third-year student at Michigan Technological University pursuing a double bachelors in civil engineering and applied mathematics. They have been the secretary of the Built World Enterprise since its founding in Spring 2019.

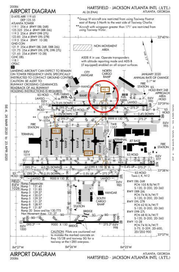
Lindsey Anderson is a second-year student at Michigan Technological University pursuing a bachelors degree in civil engineering with an international Spanish minor. They have been the part of Built World Enterprise since the Spring of 2019.

Kaitlyn Wehner is a second-year student at Michigan Technological University pursuing a bachelors in civil engineering. They have been apart of Built World Enterprise since its founding in Spring 2019 and the Public Outreach Coordinator since Fall 2019.

The team's advisor is Dr. Audra Morse.



KATL Runway intersection marking implementation at HS 1



KOPF Runway intersection marking implementation