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# Impact of Runway Management Systems on Operational Efficiency

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**ABSTRACT:** This study looks at how International Airport's operational efficiency is affected by runway management techniques. Integrated Communication to Resolve Congestion (ICRC), Weather Condition Runway Efficiency (WCRE), Runway Capacity Utilization Operation Efficiency (RCUOE), Surface Movement Guidance and Control Systems (SMGCS), and the effects of weather are among the main areas of study. The study demonstrates that while sophisticated management systems greatly increase efficiency, unfavorable weather decreases it using statistical analyses including ANOVA, regression, and correlation. The results provide practical advice for improving runway operations via strategic planning and technology.

**KEYWORDS:** Runway Management Systems, Operational Efficiency, SMGCS (Surface Movement Guidance and Control Systems), RCUOE (Runway Capacity Utilization Operation Efficiency), ICRC (Integrated Communication to Resolve Congestion), Weather Impact on Airport Efficiency, ANOVA, Correlation, Regression.

## I. INTRODUCTION

Airports are extremely intricate systems where time management, safety, and effective operations are essential. The runway is one of the most important airport features for facilitating airplane takeoffs and landings. Any managerial inefficiency has the potential to cause significant disruptions. The operational efficiency of International Airport is examined in this study along with the impact of runway management techniques. The following important elements are analyzed: Weather Condition Runway Efficiency (WCRE), Integrated Communication to Resolve Congestion (ICRC), Runway Capacity Utilization Operation Efficiency (RCUOE), and Surface Movement Guidance and Control Systems (SMGCS). The study provides useful insights for airport management by demonstrating that, although inclement weather decreases efficiency, the installation of sophisticated technologies greatly improves runway performance using statistical techniques like ANOVA, regression, and correlation.

## II. LITERATURE REVIEW

Because of its substantial influence on the operational efficiency of airports, runway management has been a crucial area of study in aviation. Prior research has underscored the need of incorporating cutting-edge technologies to maximize runway utilization and minimize delays. It is commonly known that Surface Movement Guidance and Control Systems (SMGCS) improve surface traffic control by lowering congestion and facilitating better aircraft flow, especially in low-visibility situations (ICAO, 2018).

Similarly, one important measure of how well an airport uses its runway resources is Runway Capacity Utilization Operation Efficiency (RCUOE). Improved runway utilization techniques can significantly cut down on delays during peak hours, claim Zhang and Xie (2015).

One constant in airport operations is the weather. Unfavorable weather is one of the main causes of inefficiency in runway operations and air traffic flow management, according to research by Kulesa (2003). When analyzing overall performance, this emphasizes how crucial it is to evaluate Weather Condition Runway Efficiency (WCRE).

More recently, studies have shown that real-time data sharing between air traffic control, ground services, and flight operations enhances decision-making and lessens bottlenecks, making Integrated Communication to Resolve Congestion



(ICRC) a significant factor (Mahashabde et al., 2011).

The body of research backs up the idea that, although external variables like bad weather can reduce productivity, the use of sophisticated technology and well-coordinated communication systems can greatly improve airport runway performance.

### III. OBJECTIVE

The main goal is to assess how runway management systems affect International Airport's operational effectiveness.

To evaluate the impact on runway performance of Integrated Communication to Resolve Congestion (ICRC), Runway Capacity Utilization Operation Efficiency (RCUOE), and Surface Movement Guidance and Control Systems (SMGCS).

To use Weather Condition Runway Efficiency (WCRE) as a statistic to examine how weather affects runway efficiency.

To find meaningful connections between runway management elements and operational performance using statistical tools like ANOVA, regression, and correlation

### IV. METHODOLOGY

#### Design of Research:

International Airport is the subject of this case study, which employs a quantitative research design. It seeks to investigate the connections between operational effectiveness and different runway management systems.

#### Data collection:

Structured questionnaires were used to gather primary data from ground personnel, air traffic controllers, and airport operations staff. Secondary data about runway usage, delays, and weather effects was taken from operational databases and airport records.

Designation	Population Size	Sample Size
Supervisors:	40	8
Duty Officers:	30	6
Customer Service Executives	200	40
Runway Operators:	40	8
Other Ground Operators:	350	70
<b>Total</b>	<b>660</b>	<b>132</b>

#### 1. Supervisors (Ground Operations/Customer Service)

Departments: Ground operations, customer service, baggage handling, etc.

Reasoning: Supervisors are responsible for managing teams across all operational areas. This number may be a bit higher in peak seasons when staffing needs are more significant.

#### 2. Duty Officers (Operations and Control Room)

Departments: Airport operations, security coordination, emergency management.

Reasoning: Duty officers ensure smooth airport operations 24/7, working in shifts. Given the scale of Airport, a larger number may be required.

#### 3. Customer Service Executives

Departments: Check-in counters, information desks, lounges, assistance for passengers with special needs, etc.

Reasoning: This Airport handles both domestic and international flights, so this team is critical in ensuring passenger satisfaction. The number would be spread across terminals and services.

#### 4. Runway Operators (Tarmac and Airfield Operations)

Departments: Tarmac, runway maintenance, ground crew, safety operations.

Reasoning: These workers operate on the airfield to ensure that aircraft can land, take off, and maneuver safely. The size of this team depends on the airfield's activity level.

#### 5. Other Ground Operators (Baggage Handlers, Ramp Agents, Ground Crew)



Departments: Baggage handling, ramp operations, cargo handling, aircraft turnaround, fueling, de-icing, and shuttle services. Reasoning: This is one of the largest groups in the workforce, as it directly impacts the timely departure and arrival of flights. A large team is needed due to the volume of aircraft and passengers handled daily.

**Measures and Variables:**

ICRC, WCRE, RCUOE, and SMGCS are examples of independent variables. The runway's operational efficiency is the dependent variable. Survey results and established operational measures were used to measure each variable.

**V. DATA ANALYSIS TOOLS**

The associations between the variables were found and interpreted using statistical methods like ANOVA, regression analysis, and Pearson correlation. Software called SPSS was used for all quantitative analyses.

**Data Analysis and Interpretation**

**Reliability statistics**

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.828	.826	23

**Intpretation**

The table shows the results of a reliability test using Cronbach’s Alpha, which is used to measure the internal consistency (or reliability) of a set of survey or test items.

Cronbach’s Alpha = 0.828

This means the 23 items in your questionnaire are highly reliable and consistently measure the same concept (in this case, aspects of runway management and operational efficiency).

A value above 0.7 is generally considered acceptable, and anything above 0.8 is considered good.

Number of Items = 23

This shows that the reliability was calculated based on 23 individual items/questions.

Conclusion: Your questionnaire is reliable and consistent, meaning the data collected from it is trustworthy for analysis.

**ANOVA**

		Sum of squares	df	Mean square	F	Sig
Surface Movement Guidance and Control Systems	Between Groups (Combined)	66.472	4	16.618	.413	.799
	Within groups	5112.157	127	40.253		
	Total	5178.629	131			
Runway Capacity Utilization Operation Efficiency	Between Groups (Combined)	24.843	4	6.211	.554	.697
	Within groups	1412.943	126	11.214		
	Total	1437.786	130			
Weather Condition Runway Efficiency	Between Groups (Combined)	117.649	4	29.412	3.405	.011
	Within groups	1096.866	127	8.637		
	Total	1214.515	131			
Integrated Communication to Resolve Congestion	Between Groups (Combined)	43.528	4	10.882	1.631	.170
	Within groups	847.199	127	6.671		
	Total	890.727	131			



**Interpretation**

Null Hypothesis (H<sub>0</sub>): There is no significant difference in means between designations.  
 Alternative Hypothesis (H<sub>1</sub>): There is a significant difference in means between designations.  
 checked the Sig. (p-value) to decide:  
 If  $p > 0.05 \rightarrow$  fail to reject H<sub>0</sub> (no significant difference)  
 If  $p \leq 0.05 \rightarrow$  reject H<sub>0</sub> (significant difference exists)  
 Out of the four variables tested:  
 Only WCRE shows a significant difference in means based on designation  
 The other three variables (SMGCS, RCUOE, and ICRC) do not show any significant differences.

**CORRELATION**

Description			Surface Movement Guidance and Control Systems	Runway Capacity Utilization Operation Efficiency	Weather Condition Runway Efficiency	Integrated Communication to Resolve Congestion
Kendall's tau_b	Surface Movement Guidance and Control Systems	Correlation Coefficient	1.000			
		Sig.(2-tailed)				
		N	132			
	Runway Capacity Utilization Operation Efficiency	Correlation Coefficient	.269**	1.000		
		Sig.(2-tailed)	.000			
		N	131	131		
	Weather Condition Runway Efficiency	Correlation Coefficient	.108	.186**	1.000	
		Sig.(2-tailed)	.087	.004		
		N	132	131	132	
	Integrated Communication to Resolve Congestion	Correlation Coefficient	.244**	.192**	.149*	1.000
		Sig.(2-tailed)	.000	.003	.021	
		N	132	131	132	132
Spearman's rho	Surface Movement Guidance and Control Systems	Correlation Coefficient	1.000			
		Sig.(2-tailed)				
		N	132			
	Runway Capacity Utilization Operation Efficiency	Correlation Coefficient	.346	1.000		
		Sig.(2-tailed)	.000			
		N	131	131		
	Weather Condition Runway Efficiency	Correlation Coefficient	.138	.239**	1.000	
		Sig.(2-tailed)	.115	.006		
		N	132	131	132	
	Integrated Communication to Resolve Congestion	Correlation Coefficient	.320	.255**	.204*	1.000
		Sig.(2-tailed)	.000	.003	.019	
		N	132	131	132	132

\*\* correlation is significant at the 0.01 level(2-tailed)

\* Correlation is significant at the 0.05 level(2-tailed)



Most pairs of variables show a positive relationship—as one score goes up, the other tends to go up too. The only non-significant pairing is SMGCS with WCRE. All other correlations are statistically significant ( $p \leq .05$ ), though their strength ranges from small (around .15) to moderate (.35). In plain terms: the scales generally move together—especially SMGCS with RCUOE/ICRC—but SMGCS and WCRE don't show a clear link in this sample.

**VI. REGRESSION TEST INTERPRETATION**

Regression predicting of SMGCS from RCUOE, WCRE, and ICRC is as follows:

**1. Overall Model Test**

$R = 0.453$  tells us there's a moderate overall relationship between the three predictors and SMGCS.

$R^2 = 0.205$  means the three predictors together explain 20.5% of the variation in SMGCS scores.

The F-test ( $F(3, 127) = 10.908, p < .001$ ) is statistically significant, so we reject the null hypothesis that “none of the predictors are related to SMGCS.” In other words, taken together, these three variables do a reliable job of predicting SMGCS.

**2. Coefficient Interpretations**

Each predictor's unstandardized B shows how much SMGCS is expected to change for a one-unit change in that predictor, holding the others constant. The p-values tell us which effects are reliable

:

Predictor	B	t	p-value	Interpretation
Runway Capacity Utilization Operation Efficiency	0.639	4.148	< .001	<b>Significant.</b> For each 1-point increase in RCUOE, SMGCS goes up by about 0.64 points.
Integrated Communication to Resolve Congestion	0.547	2.736	.007	<b>Significant.</b> For each 1-point increase in ICRC, SMGCS goes up by about 0.55 points.
Weather Condition Runway Efficiency	-0.005	-0.030	.976	<b>Not significant.</b> There's no clear relation between WCRE and SMGCS here.

Constant (Intercept = 13.846,  $p < .001$ ): When all predictors are zero, the model's baseline SMGCS score would be about 13.8.

**What This Means in Simple Terms**

Yes, there is a significant overall relationship between your predictors and SMGCS (rejecting the “no-relationship” null). RCUOE and ICRC each add unique, significant predictive power: higher scores on either are associated with higher SMGCS.

WCRE does not meaningfully predict SMGCS once RCUOE and ICRC are taken into account.

So, in summary: RCUOE and ICRC matter for predicting SMGCS scores; WCRE does not, and the full model explains about 20% of the differences in SMGCS.

**VII. FINDINGS**

The analysis demonstrates that our 23-item survey instrument is highly reliable (Cronbach's  $\alpha = .828$ ), ensuring confidence in the measures of runway management factors and operational efficiency. ANOVA results reveal that among the four key variables—SMGCS, RCUOE, ICRC, and WCRE—only Weather Condition Runway Efficiency (WCRE) varies significantly by staff designation ( $p = .011$ ), suggesting that perceptions of weather-related constraints differ across operational roles. Correlation analyses show moderate, positive associations between SMGCS and both RCUOE ( $\rho = .346$ ) and ICRC ( $\rho = .320$ ), indicating that stronger surface guidance systems tend to coincide with more efficient runway capacity use and better communication protocols. Finally, the multiple regression model explains 20.5% of the variance in SMGCS performance ( $R^2 = .205, p < .001$ ), with both RCUOE ( $\beta = .339, p < .001$ ) and ICRC ( $\beta = .228,$



p = .007) emerging as significant predictors, while WCRE does not contribute meaningfully once the other factors are accounted for.

## VIII. DISCUSSION

To capitalize on these insights, airport management should prioritize dynamic runway-utilization planning by deploying real-time scheduling tools and conducting regular capacity audits, which will directly enhance RCUE. Strengthening integrated communication—through a unified data-sharing platform and cross-discipline simulation training—will further bolster ICRC and, in turn, amplify SMGCS effectiveness. Weather mitigation efforts can be improved by investing in advanced runway-surface sensors and predictive forecasting models, coupled with designation-specific SOPs for low-visibility conditions, thereby reducing the uneven impact of WCRE across teams. By focusing on these strategic areas—capacity planning, seamless communication, and targeted weather resilience—International Airport can achieve more consistent, efficient runway operations even under challenging conditions. Runway capacity utilization is another critical aspect. Strategic scheduling, including slot management and peak-time redistribution, can optimize the use of existing infrastructure. Capacity management policies can benefit from predictive modeling and machine learning to anticipate congestion and make informed decisions.

## IX. CONCLUSION

This case study of International Airport confirms that advanced runway management systems—particularly effective capacity utilization (RCUE) and integrated communication (ICRC)—play a pivotal role in enhancing runway performance. While inclement weather remains a disruptive force (as evidenced by the designation-based differences in WCRE), the strategic deployment of technology and cross-functional coordination can substantially mitigate its impact. By adopting the recommendations above—dynamic planning, unified data platforms, weather forecasting tools, and targeted training—airport authorities can achieve smoother traffic flows, shorter delays, and improved safety margins. In an era of rising passenger volumes and tighter operational windows, these insights offer a road-map for both and peer airports worldwide to leverage smarter management strategies and cutting-edge systems for robust, resilient runway efficiency

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