Distribution of Traffic Intensity of Cargo Vehicles in Airport Area

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Abstract

The article studies the impact of irregular vehicles movements on accidents at airports. It is established that the operational determination of the distribution of traffic intensity of vehicles directly affects the regularity and efficiency of flights. Factors affecting the intensity of the movement of freight vehicles are determined, and calculations are made for its effective distribution. The Poisson distribution is utilized to improve the efficiency of traffic intensity of cargo vehicles in the airport area. Based on the Poisson distribution, the potential intensity of vehicles during a specific time interval is calculated using the total number of cargo vehicles serving the airports. The results of these calculations are displayed graphically.

Keywords: cargo, vehicle, airport, distribution, intensity, time.

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Aeroport ərazisində yükdaşıma vasitələrinin hərəkət intensivliyinin paylanması

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Xülasə

Məqalədə hava limanlarının ərazisində nəqliyyat vasitələrinin nizamsız hərəkətlərinin qəzalara təsiri araşdırılmışdır. Müəyyən edilmişdir ki, nəqliyyat vasitələrinin hərəkət intensivliyinin paylanmasının operativ təyin edilməsi ucuşların müntəzəmliyinə və effektivliyinə birbaşa təsir edir. Yükdaşıma vasitələrinin hərəkət intensivliyinə təsir edən amillər müəyyən edilmiş və onun effektiv paylanması üçün hesablamalar aparılmışdır. Yükdaşıma vasitələrinin hava limanının ərazisində hərəkət intensivliyinin effektivliyini artırmaq üçün Puasson paylanmasından istifadə edilmişdir. Puasson paylanması əsasında hava limanlarında xidmət göstərən yükdaşıma vasitələrinin ümumi sayına əsasən müəyyən vaxt intervalında nəqliyyat vasitələrinin mümkün intensivliyi hesablanmışdır. Hesablamanın nəticəsi qrafiklə göstərilmişdir.

Açar sözlər: yük, nəqliyyat vasitəsi, hava limanı, paylanma, intensivlik, vaxt.

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Распределение интенсивности движения транспортных средств в районе аэропорта

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Аннотация

В статье исследовано влияние нерегулярного движения транспортных средств на аварийность в аэропортах. Определено, что оперативное распределение интенсивности движения транспортных средств напрямую влияет на регулярность и эффективность полетов. Определены факторы, влияющие на интенсивность движения транспортных средств, и произведены расчеты их эффективного распределения. Распределение Пуассона использовалось для повышения эффективности интенсивности движения грузовых автомобилей в районе аэропорта. На основе распределения Пуассона рассчитывалась потенциальная интенсивность транспортных средств за конкретный интервал времени с использованием общего количества грузовых автомобилей, обслуживающих аэропорты. Результаты этих расчетов отображаются графически.

Ключевые слова: груз, транспортное средство, аэропорт, распределение, интенсивность, время.

Introduction

Cargo vehicle accidents in aerodromes can result in significant damage to infrastructure, equipment, and cargo. These incidents can also result in harm to personnel and passengers, as well as disruption to air traffic operations. Some common causes of cargo vehicle accidents in aerodromes include driver error, equipment malfunction, and poor maintenance practices. To mitigate the risks associated with these incidents, aerodrome operators and aviation regulatory authorities have implemented a number of safety measures. These measures include mandatory training programs for cargo vehicle operators, regular maintenance and inspection of cargo handling equipment, and strict safety protocols for cargo handling operations. Additionally, some aerodromes have adopted advanced technologies for reduce the risk of accidents. Despite these efforts, cargo vehicle accidents continue to occur in aerodromes. To further reduce the risk of these incidents, it is recommended that aerodrome operators regularly review and update their safety protocols, conduct regular risk assessments, and invest in new technologies that can improve cargo handling safety. In the event of a cargo vehicle accident in an aerodrome, it is important for the operator to respond quickly and effectively to minimize the damage and impact. This may involve conducting an investigation to determine the cause of the accident, implementing corrective actions to prevent similar incidents from occurring in the future, and communicating with stakeholders, including the aviation authorities and insurance providers, to ensure a timely and effective resolution. Overall, the prevention of cargo vehicle accidents in aerodromes is a critical aspect of aviation safety and requires the cooperation of all stakeholders, including aerodrome operators, aviation regulatory authorities, and cargo handling companies. Through the continued implementation of effective safety measures and the prompt resolution of incidents, the aviation industry can help to ensure the safe and efficient operation of aerodromes around the world.

There are following types of vehicles used in airports [1]:

1. Buses for the delivery of crew and passengers;
2. Aviation security vehicles;
3. Self-propelled snow cutter, water, catering service, tanker vehicles;
4. Vehicles for transportation of baggage and cargo to airplanes (from airplanes);
5. Public catering service vehicles.

One of the primary objectives in coordinating the interaction between aircraft and ground vehicles at airports is to ensure their safety and prevent collisions [2]. Such incidents between aircraft and ground vehicles can cause significant financial losses due to airport shut-downs, as was demonstrated by Nevak airport in the United States where a single hour of downtime costs a million US dollars. The occurrence of collisions on airport premises underscores the importance of this issue. For instance, on January 7, 2021, an A320 aircraft collided with ground transportation at Gdansk airport, causing damage to the aircraft's engine, leading to a prolonged repair process.

Ground vehicle accidents can be classified into three levels: Level 1 – Fatal accidents; Level 2 – Accidents resulting in personal injury; Level 3 – Accidents resulting in damage to the vehicle.

Accidents at airports involving air and ground vehicles as classified by the

International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) fall into the following categories: Ground Safety (GS), Operational Damage (OD), and Runway Safety (RS) [3].

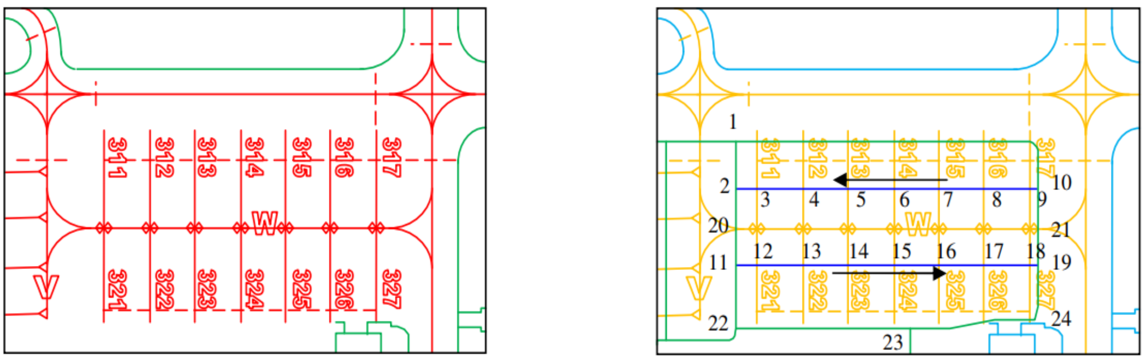
In 2015-2021, the accidents that occurred due to the movement of ground vehicles on the territory of the airport are shown in the table 1.

The increase in the intensity of flights at airports leads to an increase in the number of vehicles for transporting luggage and cargo. From this point of view, the correct assessment of the distribution of traffic intensity of cargo vehicles in the territory of the airport has a direct impact on the reduction of the number of accidents and on the regular performance of operations [4].

In order to determine the intensity of freight vehicles at airports, it is crucial to accurately determine their movement directions. The direction of movement of ground vehicles in the airport area is shown below [5, 6].

Table 1 – Accidents that occurred due to the movement of ground vehicles

Aircraft type	Ground vehicle type	Year	Airport	Vehicle damage
Airbus A320	Water transport vehicle	2021	Gdansk airport (Poland)	The plane and the tanker were damaged
Airbus A321	Fuel tanker	2020	Sheremetyevo airport (Moscow, Russia)	The plane and the tanker were damaged
Airbus A320	Pushback tractor	2017	Dublin Airport (Sweden)	The right engine of the aircraft was damaged
Airbus A320	Aviation security vehicles	2017	Alicante airport (Spain)	The right engine of the aircraft was damaged.
Boeing 767	Pushback tractor	2017	Bangkok Airport (Thailand)	The right engine of the aircraft was damaged
Airbus A330	Catering service vehicles	2016	Hong Kong airport (China)	The left engine of the aircraft was damaged.
Airbus A320	Aviation security vehicles	2015	King Abdulaziz Int ernational Airport (Jeddah, Saudi Arabia)	The right engine of the aircraft was damaged



a) b)

Figure 1 – Modelled fragment of the Aerodrome Ground Movement Chart (ICAO)

Figure 1a demonstrates the location of taxiways on which aircraft move between the runway and ramp area (stands), with numbers 311 to 317 and 321 to 327. Figure 1b illustrates the further path of movement of ground vehicles within the confines of the airfield.

On track sections 10 to 2 and 11 to 19, only one-way traffic is allowed and on the remaining sectors, two-way traffic is allowed. At points 3 to 9, 12 to 18, 20, and 21, the path of movement of ground vehicles intersects with taxiways carrying moving aircraft.

Points 1, 2, 10, 11, 19, 22, 23, and 24 are three-way crossroads where ground vehicles intersect. Both aircraft (AC) and ground vehicles (GV) operate in the airport area.

The direction of movement of ground vehicles in the airport area is typically controlled by designated roads and taxiways. The vehicles move along these roads and taxiways in a specific direction, following the markings and signs that are in place to ensure the safe and efficient movement of aircraft and ground vehicles. In general, there are two main types of roads in the airport area: runways and taxiways.

Runways are used by aircraft for takeoff and landing, while taxiways are used by ground vehicles to move aircraft between the runway and the ramp (the area where aircraft are parked and serviced).

Ground vehicles, such as baggage carts, fuel trucks, and ground support equipment, are required to follow the signs and markings that indicate the designated direction of movement on taxiways and other roadways. These markings include painted arrows and signs with instructions for the vehicles.

Calculation of the intensity of movement of freight vehicles

The following factors impact the movement intensity of freight vehicles: Quantity of loads in loading warehouses; Quantity of loads on the aircraft; Distance traveled by the vehicle; Vehicle velocity; Quantity of aircraft; Timing of cargo unloading from the aircraft. In order to quantify the traffic intensity in the airport area, it is necessary to determine the number of freight vehicles that pass through point 11 or 10 in a specified time interval (15 minutes, 30 minutes, 1 hour) as depicted in Fig. 2.

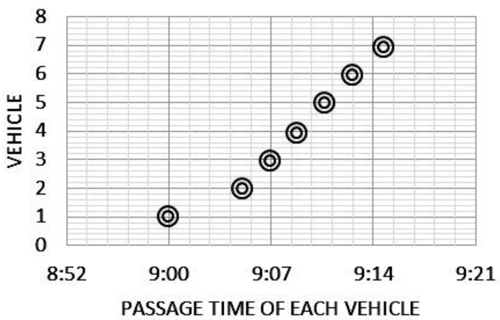


Figure 2 – Corresponding graphic

The quantity of vehicles passing the reference point at different times is presented in Table 2 and its corresponding graphic can be found in Figure 2. For the effective and efficient determination of movement intensity, processing and analysis of information from various sources in the time plane are of practical importance. In this regard, the characteristics of the acousto-optical effect can be used [7].

Vehicle intensity in an aerodrome refers to the level of ground vehicle traffic, such as aircrafts, tugs, baggage carts, and fuel trucks, that operate on the airport's taxiways, runways, and aprons. It is often expressed in terms of the number of ground movements, such as takeoffs and landings, per unit of time, such as aircraft movements per hour.

Table 2 – The quantity of vehicles passing the reference point

Vehicle	Passage time of each vehicle
1	9:00
2	9:05
3	9:07
4	9:09
5	9:11
6	9:13
7	9:15

High vehicle intensity in an aerodrome can lead to increased air traffic congestion and safety concerns, while low vehicle intensity suggests less utilization of the airport. Vehicle intensity is an important factor that must be considered in the planning and management of airport operations, as well as in the design of airport ground facilities and infrastructure. In order to determine the traffic intensity, it is necessary to tally the quantity of vehicles (or pedestrians) traversing a specified location over a well-defined period, such as an hour or a day. The resulting traffic intensity is expressed as the number of vehicles (or pedestrians) per unit of time. For example, if 1000 vehicles pass through a specific point in one hour, the traffic intensity is 1000 vehicles per hour. Here's the general formula to calculate traffic intensity:

$$intensity\ (flow) = \frac{number\ of\ vehicles}{time}$$

As demonstrated by the table, seven vehicles traversed the reference point within a 15-minute interval. Subsequently, we proceed to calculate the intensity of movement as follows:

$$intensity^{1}\ (flow) = \frac{7\ veh}{15\ min} \times \frac{60min}{1\ hr} = \\ = 28\ veh/hr$$

[1] Note: The accuracy of the traffic intensity calculation will depend on the method used to count the number of vehicles (or pedestrians) and the duration of the time interval.

If we represent the quantity of vehicles as 'n' and the duration of movement as 't', we obtain the following mathematical expression for the traffic intensity:

$$q = \frac{n}{t} \quad (1)$$

As we know, vehicle speed is defined as $\vartheta = d/t$ and traffic density is defined as $k = n/d$. Here, d-plane-destination distance, k (density) is the density of motion. Then

$$q = k \times \vartheta \quad (2)$$

The graph illustrating the dependence between the intensity (flow) and density of movement is shown in Figure 3.

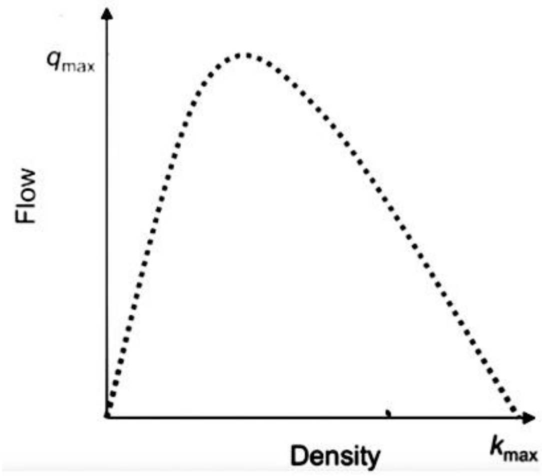


Figure 3 – Dependence between the intensity (flow) and density

A traffic intensity-density graph is a graph that displays the relationship between traffic intensity and traffic density. Traffic intensity refers to the average number of vehicles passing through a particular point on a road network over a specific time period, while traffic density refers to the number of vehicles per unit of road length at a particular point in time.

Typically, the x-axis of the graph represents traffic density, and the y-axis represents traffic intensity. As the traffic density increases, the traffic intensity also increases, reaching a peak and then decreasing as the density becomes too high and traffic congestion occurs. The shape of the graph can vary, but it typically resembles a bell curve, with the highest traffic intensity occurring at a moderate density and declining at very high and very low densities.

We use the Poisson distribution to determine the intensity of freight vehicles in the airport area:

$$P(n) = \frac{(\gamma t)^n \times e^{-\gamma t}}{n!} \qquad (3)$$

P(n) – probability of having n vehicles arrive in time t, t-duration of the time interval over which vehicles are counted, γ - average vehicle intensity(flow) or arrival rate in vehicles rate per unit time, e – base of the natural logarithm (e=2.718).

Example: 20 cargo vehicles serve the airport area within 1 hour. Let's find the probability of movement of 1,2,3,4 or more cargo vehicles within 60 seconds after the plane lands. Solution: γ=20veh/h=0.005 veh/s.

t= 60s; P(1)=0.2223; P(2)= 0.0333;

P(3)= 0.0033; P(4)=0.00025.

For four or more vehicles

P(n≥4)=1-P(n<4)=1-0.7408-0.2223- 0.0333-0.0033-0.00025= 0.00005

We can plot the Poisson distribution according to the calculation as follows (fig.4):

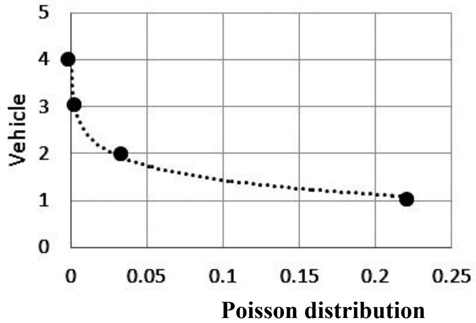


Figure 4 – Poisson distribution

Conclusion

As it can be seen, in modern times, the improper control of the movement of vehicles in the airport area causes accidents. It is possible to prevent accidents by pre-determining the distribution of traffic intensity of freight vehicles.

Conflict of Interests

The author declares there is no conflict of interest related to the publication of this article.

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