Abstract

To enhance the level of operations security is the most important objective of airport services responsible for adequate maintenance of the movement area. Terms and conditions included in the Annex 14 of the Convention on International Civil Aviation make all member states responsible for undertaking any necessary steps in order to remove any contamination from the maneuvering area in order to ensure adequate friction coefficient\(^1\) and rolling resistance. Moreover, the Annex 14 advocates the cleanliness of surfaces, free from stones and other objects that may damage the construction of airplane bodies and engines or reduce the aircraft’s effectiveness. It must be emphasized that the key objective of the airport management is prevention and removal of objects and contaminants that might impede intended operations. It is also necessary to measure the friction coefficient of surfaces and, in consequence, establish a set of methods in order to do so\(^2\). Furthermore, all the reports on friction coefficient measurements should be sent via SNOWTAM to all interested parties.

**Keywords:** security, movement area, airport operations, airport services, maintenance, air traffic controllers, friction coefficient, SNOWTAM, runway contamination, ground handling, safety management.

Definition of security

To ensure safety is the most crucial objective of all airport services. What is more, ATC (Air Traffic Control), FIS (Flight Information Service) and AIS (Aeronautical Information Service) all share the same key objective, which is the core of other goals. This also refers to services which, seemingly, have a small impact on safety matters of airport operations as well as smooth and regulated air traffic flow. The above statements concern the Airfield Maintenance Department in case of civilian and military airports.

Enhancing the level of security\(^3\) for aviation depends on the working schedule that airport services designate to the performance of this task and on access to financial resources. The greater of the time devoted to clearing the runway, the better its preparation, thus boosting the safety level for airport operations. However, the amount of time available

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\(^1\) Friction is a term used in aviation, and is defined further in the paper.


\(^3\) The term level of security is a general term and is used to present the state of airport operational security depending on conditions. In this paper, the level of security is a dimensionless quantity signifying the risk of unwanted events.
is limited, depending on the frequency of take-offs and landings operations. The airports with little air traffic (approximately ten operations per day) and adequate times between take-offs and/or landings enable the service department to perform a thorough (despite limited resources of machinery and tools) clearance of the movement area. Whereas, the airports with high air traffic with take-offs and landings occurring on average every few minutes face a different challenge. Here, airport services (ground handling) have limited opportunities to clear the runway or only enough time to perform a single run with a set of machinery. In such circumstances, the airport management expects the run to take as little time as possible while still clearing the whole width of the runway. In order to fulfil such expectations, an increase of the financial allocations for the purchase of a number of (in order to cover the whole width of the runway) efficient (performed in the least possible time) machinery and equipment is required. Taking into consideration this fact, every runway could be littered with unwanted particles. The runway, taxiway, apron, etc. must be cleared in order to ensure the safety of operations, leading to delays in the take-offs and landings of aircrafts until any obstacles are removed. Such activities obviously cause delays in air traffic, causing financial losses for carriers and maintain a high level of safety and security.

Increasing available financial resources also has an impact on enhancing the level of security of passengers, cargo, etc. A financial boost makes it possible to:

1. Increase employees’ competences level by commissioning specialized training, courses, etc.
2. Purchase movement area maintenance equipment.
3. Purchase and implementation of machinery and equipment maintenance systems.

It should be born in mind that airlines are not charity organizations but they are focused solely on carrying people and cargo from one place to another. The generation of profits from their operations determines their existence. Therefore, each company on the air transport market aims at achieving the highest possible profits. In order to raise the funds dedicated to the movement area maintenance, the airport authorities are forced to raise airport charges, which translates to higher air ticket prices. Such a practice can deter the airlines from using airports whose charges make it impossible to compete with others offering the same product (ground services) at a cheaper price, thereby gaining a competition advantage.

In order to achieve an acceptable standard of safety, one should consider the dependence between the level of security and cost of its maintenance. Firstly, a substantial boost to the basic security levels is possible even when limited funds are available. For example, an internal employee training will suffice to raise the situational awareness of possible dangers and risks which influence the safety of an aircraft. However, a high security level requires substantial funding, for instance, the purchase of any airport clearing machines raises costs. Secondly, any further advancement of safety and security by one level generates further costs. Therefore, a high level of security demands substantial financial resources. Thirdly, achieving total security is unattainable, only possible at the moment when aircrafts stop flying at all and it may occur that even after having spent substantial funds on security, its level will not have risen.

Risk is defined as ‘an estimation expressed of the expected probability and severity of danger, and it takes its point of reference as the worst case scenario’. To avoid falling into the trap of irrational expenditure, a safety and security level which will be ‘acceptable’ for all parties involved in air transportation operations needs to be determined. The

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4 Deliberations here ignore the dependences between the level of security and airport services’ working hours, as their reduction (lengthening) impact expenditure (loses).
‘acceptable’ obviously does not mean the consent of the airport management for accidents or air traffic disasters, as this would be against all the principles of life and health protection as well as safety and security management in air transportation. However, the acceptable risk of the incident occurrence and, based on it, the security level can be determined. The acceptable risk is presented in an alphanumeric formula which allows both its measurement and the level of reference. It can be noticed that the above definition of security risk combines it with both dangers and consequences, thus creating a matrix of dangers, consequences and security risk (Table 1).

Table 1. Risk estimation matrix.

<table>
<thead>
<tr>
<th>PROBABILITY OF OCCURRENCE</th>
<th>SEVERITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Catastrophic A</td>
</tr>
<tr>
<td>Extremely improbable 1</td>
<td>1A</td>
</tr>
<tr>
<td>Extremely remote 2</td>
<td>2A</td>
</tr>
<tr>
<td>Remote 3</td>
<td>3A</td>
</tr>
<tr>
<td>Reasonably probable 4</td>
<td>4A</td>
</tr>
<tr>
<td>Frequent 5</td>
<td>5A</td>
</tr>
</tbody>
</table>

Source: ICAO Doc.9859 ‘Safety Management Manual’

The parameters in Table 1 show the alpha-numeric matrix of risk estimation. Acceptable values are marked in green, acceptable values after the implementation of risk mitigating factors are marked in yellow, while unacceptable values are in red area. While analyzing the values in the table, certain interesting interdependences can be noticed. Firstly, in the case of highly improbable scenarios, including those of the highest severity of risk, all the values remain at acceptable levels. This is caused by the fact that if the event or situation is highly improbable, then it is unnecessary to prepare for its eventuality, especially if it was to trigger a substantial increase in costs. A covering of ice or snow at the airport in Lagos in Nigeria may serve as an example⁶. As the risk of the possibility of such conditions is virtually nil, the airport management does not need to provide airport services (ground handling) with snow ploughs or similar equipment, as it would be a waste of capital.

Secondly, in the case of a catastrophic severity of risk, unacceptable values occur with a remote probability of risk, for example, when the event results in a catastrophe, and its likelihood indicates its possibility, then the event involves unacceptable values. Therefore, it is clear that ensuring air transportation security remains a priority and only in extreme, highly unlikely cases may be overridden by economic concerns.

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⁶ The airport in Lagos is located in the equatorial zone, therefore does not record any snowfalls or ice on the runway.
Risks and their consequences in transport operations

It is widely accepted that the most sensitive air transport operations are the take offs and landings of an aircraft as far as security is concerned. This arises from the specificity of these operations. In case of a take-off, the engines in a multi-engine aircraft work at their highest revolutions in order to achieve good take off velocity and acceptable height as fast as possible. This causes the suction of massive amounts of air along with any contaminants (debris) on the runway itself. The suction of foreign bodies (debris) into the engine may lead to damage to the turbine and compressor blades which a consequence may lead to a disaster.

Being aware of the workings of the compressor blades of engine turbines, it can be imagined the destructive force of small stones or asphalt fragments. While working, engine blades undergo, among others, flexing and bending under aerodynamic forces, bending and flexing under centrifugal forces (the compressor spins up to a few tens of thousand times a minute), changing pressure due to vibration, high temperatures (800 – 1,200 degrees centigrade in the turbine blades, 300 – 600 centigrade in the compressor blades), rapid temperature changes in transient response, the impact of contaminated air, electrodynamic or gas corrosion at higher temperatures. Therefore, titanium which boasts extremely high mechanical resistance, is used to produce turbine and compressor blades. It is not always that such contaminants must involve the immediate destruction of the engine. In extreme cases, the damage made to the edge of the blades may distort airflow, which may lead to uncontrolled fuel combustion and thereby engine stalling. Chips or indentations are bound to distort mass balance, which, with revolutions from a few to few more tens of thousands a minute, will cause strong vibrations of the whole engine, a damage or even a destruction of the bearings supporting the shaft connecting the compressor with the turbine. Such circumstances frequently result in a disaster of the airplane.

Graph 1. Cause and effect interdependencies

Source: own work.

Graph 1 shows an example of the interdependencies between the cause of risk and its effects. The reason for the risk to occur on the runway is an object, for instance, a substantial sized bolt or nut from another aircraft. One of the dangers of such a contamination is the plane’s tire deflecting the object during take-off, damaging the aircraft skin and rupturing the fuel tank. Self-combustion of the leaking fuel may lead to an explosion on the aircraft. The discussed case is similar to the disaster of Air France’s 4590 flight which occurred in 2000. The concorde, while accelerating on runway 26 at the Charles de Gaulle airport, hit, with the main wheels at high speed, a metal strip (an element having fallen from the engine of an airplane that had taken off previously), cutting the left tire and rupturing it. A large chunk of this tire debris, about 4.5 kg, struck the underside of the aircraft’s wing sending out a pressure shockwave that ruptured the number five fuel tank at its weakest point, just above the undercarriage. Leaking fuel gushing out from the bottom of the wing was most likely ignited by an electric arc in the landing gear bay or through contact with hot parts of the engine. A large plume of flame developed. At this point, the aircraft passed $V_1$, the critical engine failure recognition speed or take off decision speed. This resulted in the disaster and the death of 113 people (109 passengers the crew, and 4 victims on the ground). The probability of such a disastrous event is low (reasonably probable), however, its severity may be air crash, which is exemplified by the above case.

The most frequent security dangers on the movement area include:

- suction of a foreign body into the engine;
- destruction or damage to the construction of the aircraft;
- excessive braking distance;
- imbalance between individual wheels under braking;
- aquaplaning;
- excessive rolling resistance when taking off.

All the above dangers may lead to an aircraft disaster, which may include deaths of passengers, crew and people on the ground. Thus, maintenance of the movement area and information provided to all interested parties on its condition is of great importance.

**Operations of airport services**

In order to prevent collisions whose effects are undesirable from the point of view of the operations of airport security, airport services have to eliminate all possible risk. It is not possible to get rid of all causes of danger as most are of an uncontrollable nature for example, rain or a temperature drop cannot be prevented, nor the effects of these dangers.

In fact, this is the responsibility of other airport services (e.g. rescue services or airport fire department). Moreover, to prevent from undesired events appropriately, airport services should adopt the following procedure:

1. Identify the risk accurately.
2. Select appropriate machinery/devices in order to eliminate the risk.
3. Remove any contaminants.
4. Measure the friction coefficient.
5. Distribute SNOWTAM messages.

The accurate risk identification is a key operation, and results in rapid and effective actions performed by the maintenance department. Due to the nature of this service, the

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8 The speed beyond which the take off should no longer be aborted.
10 SNOWTAM is a special series NOTAM, notifying on the conditions on the movement area e.g. type of contamination, its coverage and depth, the friction coefficient, etc.
only risk that involves its responsibility is the contamination occurring on the movement area. Early identification of contaminants impacts the adequate selection of machinery or devices used for its removal. Contamination occurring on the movement area on the taxiway runway in particular includes:

- damp;
- wet;
- rime of frost, snow, ice;
- dust particles;
- ruts and ridges;
- foreign bodies from vehicles, an aircraft, etc.

Each of these contaminants negatively impacts the level of air operational security and may result in the above security risks. Airport services encounter the following problems in the field of risk identification:

1. Lack of or inadequate measurement tools – a maintenance department often may not have tools necessary to identify risk properly, which often leads to identification of risk based on the competencies of an individual personnel.
2. Identification based on personnel competences – often poses the risk of inaccurate identification, in the case of a lack of insufficient level of these competencies.
3. Inadequate time frame for identification – due to heavy air traffic, airport services do not have the time or ability to drive along the runway in order to spot contaminants.
4. Inaccurate meteorological information – meteorological services provide inaccurate data assessment, which may result in an inadequate risk assessment, for instance, instead of an above zero temperature forecast, freezing temperatures occur causing frozen standing water.

The appropriate contamination determination has a huge impact on the correct selection of machinery and/or devices used for its removal from the movement area. Despite accurate identification of contamination, the proper selection of machinery/devices also causes several problems for the airport services such as:

- Inappropriate assembly of machinery/devices, making it impossible for a task to be performed within a given time frame. If the manager responsible decides that multi-purpose machinery\(^\text{11}\), drill ploughs and airport hoovers access the runway, it may happen that the time required for the task to be completed is substantially longer than that available (it should be considered that the working speed of multi-purpose equipment is 50-60 kph, however, drill ploughs and airport hoovers work at 10-20 kph). Such a situation may interfere with air traffic flow, causing unnecessary delays.
- Inappropriate configuration of machinery/devices through badly equipped vehicles, e.g. brushes rather than ploughs. Poor configuration may extend the time required for assembly or make a task impossible.
- Lack of equipment due to poor service and maintenance planning schedule. Servicing, when planned inappropriately, may result in the necessary equipment being unavailable at the moment, it is needed to perform a removal task.
- Shortages of personnel to service the machinery or equipment. On the basis of available data, a manager should have a needed personnel to perform a task. If they fail to do so, it may lead, despite having the necessary tools and plan in place, to the personnel not being available.

In cases when none of the above factors occur, airport services are able to remove contaminants from the runway, the taxiway and the apron. It should be taken into account

\(^{11}\) Multi-purpose machinery consists of an attachable plough, brushes and a blower.
that during the removal of contamination airport services should follow the principles of the shortest and most effective implementation.

The limited transfer of aircraft wheel by friction coefficient measurement

The level of safety during roll out is strongly linked with the friction coefficient\(^{12}\). The value of the momentum which an aircraft wheel during braking can transfer is limited by the friction. The friction is analogical to the resistance force typical for the cooperation of a rubber tire with the surface considering all the conditions occurring during this interaction. Changes to these conditions may significantly influence the friction level, for example, when the wheel hits a covering of ice. The friction is determined by its coefficient, which is defined as the ratio of the friction force to the force of the tires on the aircraft on the paved surface or the net force of a tangent rate to normal force\(^{13}\). The coefficient of friction takes dimensionless quantities, higher values signify a high braking force of the aircrafts wheels, which impacts the shorter roll out and, in consequence, higher safety during landing. When considering the landing operation (an aircraft roll-out), it should be remembered that an average passenger aircraft weighs about 100 tones, and approach speeds of circa 250-300 kph per hour. In order to stop such a machine safely, it is required about 2000 meters of runway\(^{14}\) with a good friction coefficient, at 0.75 for a dry bitumen surface\(^{15}\). Reducing the value of the coefficient by only 0.05 is already regarded as a significant change of conditions\(^{16}\), which may influence the safety of the operation. With a low coefficient it is easy for the aircraft tire to slip, which will lengthen the braking path and, in an extreme situation with an uneven braking balance, it may also cause the aircraft to veer at the runway. Moreover, in modern turbo jet aircraft, the difference between the braking distance on a dry surface and on an iced surface in extreme conditions may reach up to 900 meters for an aircraft with poor braking parameters\(^{17}\). Considering that in poor weather conditions when the friction coefficient is low and the landing aircraft has poor braking parameters, the runway may be too short for the aircraft roll-out.

The correct preparation of the runway, the taxiway and the apron directly influences the flow of airport operations on the movement area. According to the ICAO doc. 4444 Air Traffic Management, the captain of the aircraft should not receive permission from air traffic control to take off until the preceding aircraft passes the end of the runway in use or turns, or until all preceding landing aircraft free the runway in use. This also refers to the aircraft intending to land, namely, the landing aircraft should not be issued the clearance to pass the threshold of the runway while on the final approach, until the preceding departing planes pass the end of the runway in use or turn, or until all the preceding aircraft free the runway in use\(^{18}\). Graph 2 is a graphic representation of the above situation. The aircraft may not receive permission to take off or land until aircraft A leaves the runway after landing, and aircraft B, which is preparing to depart, changes direction after it takes off and departing aircraft C passes the end of the runway.

\(^{12}\) Roll-out is the stage of an aircraft’s landing during which it travels along the runway while losing speed after the tires touch the runway. It is provided in meters and determines the distance covered by the landing aircraft from the moment of touching the surface to the aircraft stopping.

\(^{13}\) K. Parczewski, H. Wnęk, Wykorzystanie przyczepności podczas hamowania pojazdu, 2012.

\(^{14}\) For example the roll-out for a Tu-154 is 2100 m. http://pl.wikipedia.org/wiki/Tu-154.

\(^{15}\) Politechnika Wrocławska, Instytut Inżynierii Lądowej Zakład Dróg i Lotnisk, Projekt wstępny drogi klas \(G\) technicznej G, Wrocław, 2002.


\(^{17}\) ICAO Doc. 9137/Part II Pavement Surface Conditions 4\(^{th}\) edition, 2002.

\(^{18}\) ICAO Doc. 4444 Air traffic management 15th, 2015.
Therefore, the effectiveness of airport operations depends on the timeframe within which the aircraft leaves the runway. The quicker the aircraft manages to brake enough to leave the runway safely, the sooner the next aircraft can receive permission to take off or land. As a consequence, this will facilitate greater turnaround of air traffic. The greater effectiveness generates increased profits for the airlines due to the lack of delays and the economy of fuel usage, etc. What is more, taking entire responsibility for a decision of whether the surface’s condition will ensure the safety of airport operations, the management of airports must determine its own requirements for the daily measurements of the friction coefficient in winter conditions. Obviously, certain weather conditions require a particular attention and they include: temperature fluctuations around freezing or changeable conditions when for example warm, humid air comes into contact with very cold surfaces. Moreover, when meteorological reports forecast impending snowfall or black ice, then it is likely that the reports on the state of the surface will require to be updated hourly or even more regularly as well as every time a suspicion arises or it appears as a consequence of other reasons that there has been a significant change in the conditions on the runway.

It is worth to emphasize that such conditions may be accompanied by significant differences in the friction coefficient values of the surface and depending on the surface material or a part of the runway. Therefore, the friction coefficient measurements should be taken on the surface of the runway in use, not on the neighboring areas or taxiway nearby, which may have been constructed using totally different materials.

The determination of the coefficient of friction is conducted by its assessment or measurement. The choice of method is not accidental, which means that if the specialized measuring equipment is available, then it should be used. The assessment is performed whenever the airport lacks specialized equipment, which is often the case at the airport with low air traffic or military airports. The assessment is conducted by a trained employee on different sections of the runway, taxiway or apron. Based on braking trials, effectiveness is on a 6-point scale:

- 5 – good;
- 4 – average to good;
- 3 – average;
- 2 – average to poor;
1 – poor;  
9 – uncertain.

As the assessment of braking based on the employee’s experience is an inadequate method, it forces the aircraft pilot to maintain particular vigilance under braking.

Another method to determine the coefficient of friction is its measurement. This measurement provides a pilot with accurate values of the coefficient and, therefore, with the maximum braking force possible. This measurement can be performed by using a device with an additional wheel which measures the possibility of sliding while being in contact with the surface under measurement. This may be a separate assembly pulled by a vehicle or be the vehicle itself but with an additional wheel. The airports belonging to the ICAO, currently use several types of friction coefficient measurement devices. The operations, technical and construction solutions, as well as the operational parameters of these devices may vary substantially. Depending on its movement or braking system, the methods of friction coefficient measurement on airport surfaces can be divided into three main groups:

1. Devices measuring transverse friction coefficient, e.g. Mu-Meter. This is a group of continuous measuring devices where the measuring wheel is not impeded but rolls freely and is pushed from its main direction of travel by a particular angle, depending on the overall concept of construction. The friction coefficient is determined according to the classic definition of friction though comparison of a transverse force on the tire during a slant free roll against the direction of movement, with the static load on that wheel or wheels if there are two in the measuring system.

2. Devices measuring the coefficient of friction at a constant skid of the measuring wheel against the surface, e.g. Skiddometer or Runway Friction Tester. In this group, the measuring wheel moves against the surface with a particular sliding action, kinematically or hydrologically induced, with a zero slant from the direction of movement, measuring the peripheral friction coefficient (longitudinal) through the comparison of the friction force and static pressure (loading).

3. Devices measuring the coefficient of friction through deceleration under braking, e.g. Tapley Meter, Brakometer – Dynamometer. The decelometers are installed inside vehicles which fulfill certain criteria of ensuring the credibility and repeatability of results. The advantage of this particular solution is the simplicity of its measurement. However, the drawback is their usability only under certain conditions, on compacted snow, ice and very thin layers of loose snow. Deceleration measurements cannot be applied when the surface is covered by slush or melting snow or when the iced surface has a thin covering of water, as measurements under such conditions may be inaccurate. The other measuring devices may also give unreliable measurements when the surfaces are covered by a mixture of contaminants and when there are differences between air and surface temperatures. Another drawback of decelermers includes the fact that measuring vehicles must reach a certain measuring speed, which requires a certain distance. Therefore, the measurement sections needed are far greater than in the case of continuous measurement. As a consequence, such devices can be applied as regards only a spot check of the coefficient of friction on surfaces.

Comparing all the above groups, it can be observed that certain measurement conditions, namely skidding indicates that each individual device and measures assess the friction coefficient as though on a different scale, at a different level of numerical values. Graph 3 presents the differences in readings of particular types of measurement equipment.

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Graph 3. Correlation of readings of friction coefficient measuring devices


Having taken the measurements, there is a need to calculate the results and then refer to the common scale for the aircrafts crew and air traffic services to have an entire picture of the conditions on the runway. It is assumed that the following values of friction coefficient (goals or calculated) are equal to braking:

1. value 0.40 or above – GOOD;
2. value 0.39 to 0.36 – AVERAGE/GOOD;
3. value 0.35 to 0.30 – AVERAGE;
4. value 0.29 to 0.26 – AVERAGE/POOR;
5. value 0.25 and below – POOR.

The advantage of these devices is their accuracy, however the drawbacks include very high costs, both every device (vehicle) and the tires, which wear out quite quickly. The images below show such devices (Image 1).

Image 1. Examples of friction coefficient measuring devices

a - towed by a car,  b - installed in the car,  c - decelometer

Source: manufacturers’ websites.
The challenges that await airport services while measuring the friction coefficient include:

1. A lack of spare parts (in particular tires that measure the friction coefficient), forcing the airport services to estimate the braking rather than measure the friction coefficient.
2. Uneven surface on the runway, meaning that the measured coefficient at one spot on the runway is substantially different from another spot a few meters away. This variability of the coefficient may lead to a pilot's erroneous conviction of the real braking on the runway.
3. Wrong or inaccurate braking estimation. Employees responsible for the braking estimation should have received adequate training on the ways and procedures of the braking tests, however, a person with a several year experience can be trusted.

SNOWTAM form

SNOWTAM, a message distributed via AFTN, a worldwide system of fixed telecommunication network, the Internet, etc. include vital information to safety and smooth air traffic flow, distributed to all interested parties. It is a special series of NOTAM\(^{20}\), issued to alert pilots of any potential hazards on the runway, passed via air traffic services to the aircraft crew. The following runway condition related changes are considered as being significant:

1. A change in the coefficient of friction of about 0.05;
2. Changes in the depth of deposit greater than the following: 20 mm for dry snow, 10 mm for wet snow, 3 mm for slush;
3. A change in the available length or width of a runway of 10 per cent or more;
4. Any change in the type of deposit or extent of coverage which requires reclassification in Items F or T of the SNOWTAM;
5. When critical snow banks exist on one or both sides of the runway, any change in the height or distance from centre line;
6. Any change in the conspicuity of runway lighting caused by obscuring of the lights;
7. Any other conditions known to be significant according to experience or local circumstances\(^{21}\).

Each of the above points present all parameters which influence the aircraft roll-out, and should be distributed using a special SNOWTAM form (message) to aircraft crew commencing a flight and/or distributed to the aircraft crew which is airborne via Aeronautical Information Services or air traffic control. An example of such messages is shown below:

| A) LSZH | B) 11070620 |
| C) 10 | D) 2200 | E) 40L |
| G) 20/10/20 | H) 30/35/30 MUM | J) 30.5 L |
| L) TOTAL | M) 0900 | P) YES 12 |
| C) 14 | D) 3000 |
| G) 05/05/05 | H) 32/35/9 MUM |
| S) 11070920 |
| T) FIRST 300 M RWY 10 COVERED BY 50 MM SNOW, RWY 14 SANDED, RWY CONTAMINATION 100% ALL RWYS |

\(^{20}\) NOTAM (NOtive To Air Man) - a message distributed via telecommunication networks, which includes information at a particular time crucial to the air traffic operations staff.

The above example includes all crucial information on the condition of the movement area. As SNOWTAM messages are written in code, below there is the description of the individual items of the message, along with the explanation of the code itself. Knowledge of the form and accurate interpretation of individual items by airport services ensure an appropriate safety level of air traffic operations by the following items:

— **Item A** refers to the airport location indicator. It uses a 4-letter ICAO code, an indicator for a particular airport, which should be in accordance with the ICAO 7910 Location Indicators. The document includes all the location indicators for individual airports. It consists of four letters, with the first signifying the region of the world belonging to a particular Flight Information Region (FIR), according to which, the letter E indicates the northern part of Europe, the second letter comes from the first letter of a particular country (most often), the third and fourth letters signify a particular location, e.g. DE for Dublin, WA for Warsaw. In the example shown above, **LSZH** indicated the airport in Zurich (L - southern region of Europe, S - Switzerland, ZH - Zurich).

— **Item B** refers to the date and time of observation at an airport. It consists of 8 digits, signifying the month, date, hour and minute. It should be born in mind that aviation utilizes UTC as its universal time. Unlike NOTAMs of other series, SNOWTAM does not provide a year, as its maximum validity lasts just 24 hours. The example above, **11070620**, indicates 06:20 UTC time of the 7th November.

— **Item C** refers to runway designators, information on the runway threshold which is the reference point for observations. As any runway has two thresholds, the one with the lower designator should be used. It must be emphasized that the runway which is currently in use is not relevant. This means that the airport monitoring services or aeronautical information services must consider this fact when passing on information from SNOWTAM to aircraft crew. For example, if the runway with a higher designator is in use, then the services must report the conditions on this runway starting from the threshold of the higher designator (like the runway in use), despite the fact that the airport services passed the information in the reverse order, starting from the threshold of the lower figure.

— **Item D** refers to cleared runway length, which is expressed in meters. Although, in accordance with the ICAO Annex 15, the measurement unit is not added, which also applies to any field which includes any unit of measurement (mm, cm or meters). This field is optional, filled only when the length of the cleared runway shows a reduction from that published (if the published length of the runway stands at 3,000 meters, which matches that published, then this field is ignored.

— **Item E** refers to cleared runway width. As with field D, the width is expressed in meters and is optional. It is ignored if the cleared width is in correlation with that published.

— **Item F** refers to the deposits over total runway length. As runways are of substantial length (usually over 2500 meters) deposits may vary at its beginning and end. Therefore, each runway is divided into three equal parts and the type of deposit is reported for every individual part, starting from the threshold having the lower runway.

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22 **FIR** – Flight Information Region – is a specified region of airspace in which a flight information service and an alerting service (ALRS) are provided.
designation number. The types of deposit on the runway and their codes are as follows (Table 2).

Table 2. Types of deposit and corresponding codes entered in Items F,N,R in SNOWTAM.

<table>
<thead>
<tr>
<th>Code</th>
<th>Type of deposit</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIL</td>
<td>CLEAR AND DRY</td>
</tr>
<tr>
<td>1</td>
<td>DAMP</td>
</tr>
<tr>
<td>2</td>
<td>WET</td>
</tr>
<tr>
<td>3</td>
<td>RIME OF FROST</td>
</tr>
<tr>
<td>4</td>
<td>DRY SNOW</td>
</tr>
<tr>
<td>5</td>
<td>WET SNOW</td>
</tr>
<tr>
<td>6</td>
<td>SLUSH</td>
</tr>
<tr>
<td>7</td>
<td>ICE</td>
</tr>
<tr>
<td>8</td>
<td>COMPACTED SNOW</td>
</tr>
<tr>
<td>9</td>
<td>FROZEN RUTS AND Ridges</td>
</tr>
</tbody>
</table>


Sometimes, there can be more than one type of deposit on a particular part of the runway. Then a combination of numbers which determines all types of contamination is applied, for instance, 47/47/7 which means that in the first and second sections of the runway, starting from the threshold having the lower runway designation number, are covered by dry snow and, underneath, a layer of ice, with the third section having only a layer of ice. It should followed the principle that contamination is reported from the top layer downwards. What should be done in the case when there is contamination on one section, but covering only a small part of the runway? Then, the percentage of the deposit on each third of the length should be entered in the item T.

**Item G** refers to the depth of contaminant for each third of the runway length. The measurement must be taken with the precision of 20 millimeters for dry snow, 10 millimeters for wet snow and 3 millimeters for slush. If the deposit of contamination consists of more than one layer (e.g. dry snow on compacted snow) then, following the stipulations above, the total depth of the deposit should be given. Sometimes the depth of the layer may be insignificant or unmeasurable (e.g. a layer of ice or a damp surface). In such a case, XX/XX/XX should be entered in item G (referring to each section of the runway).

**Item H** refers to measured or calculated friction coefficient and, in the case of a lack of friction measuring device, estimation of braking. How can it be known whether the value entered in the item (for each third of the runway) refers to the friction coefficient or the estimation of braking? The friction coefficient is expressed in two digits (the coefficient is multiplied by 100) and the abbreviation of the measuring device is provided, however, estimation of braking is expressed in one digit.

**Item J** refers to the critical snow banks along the runway. If present, insert height (in cm), distance from the edge of the runway (in m) and the side where they occur, starting from the threshold having the lower runway designation number. If it is left – insert L, R for right, if on both sides, LR.
**Item K** refers to runway lights. If visible, the item is ignored, if obscured, insert YES. As in the case of the item above, add L, R or LR to indicate on which side of the runway the lights are obscured, left, right or both.

In the case of intense and extended snowfall or strong wind drifting the previously removed snow, airport services need to work constantly to remove it. Then, all the interested parties should be informed of the airport conditions, which length of the runway is to be cleared and the time frame necessary. In order to inform others on the length of runway scheduled for clearance, the length (in meters) of the runway section should be inserted in the **Item L**. If the runway is scheduled for complete clearance then ‘TOTAL’ should be inserted. However, the expected time of completion, in hours and minutes is inserted in the **Item M**.

**Item N** refers to the condition of the taxiway, applying the same indicators as in the item F. Should no appropriate taxiway for a particular runway is available, then ‘NO’ should be inserted. In the case that different runways are experiencing different conditions, then the conditions for other taxiways e.g. N)A/45, B/4, C/45 \(^{23}\) need to be inserted in item T.

**Item P** refers to taxiway snow banks, and is entered only when above 60cm. In such cases, ‘YES’ should be inserted, with the distance between them in meters.

**Item R** refers to apron conditions. To describe the conditions, indicators identical to items F and N are used. In the case of varied conditions on individual aprons, conditions for other aprons (identical to taxiways) need to be inserted in item T.

**Item S** refers to the next planned date and time of observation/measurement, and it follows the indicators in the item B. This item is applicable when airport services expect any change to the conditions on the maneuver field (runway, taxiway and apron), usually as a result of changing weather conditions (e.g. a temperature drop at night, causing standing water to freeze) and as a result of the removal of deposits conducted by airport services.

**Item T** covers any extra, significant information on conditions at the airport and to details (if the need arises) provided in the above items. It must include information on the level of runway contamination and, in justified cases, on taxiways and aprons. The level of contamination informs interested parties of the percentage of the maneuver field covered by contamination provided in items F, N and R. If the runway is covered by a range of contaminants, in each third of the length (item F), the percent of contamination for each section is inserted. However, if the full length of the runway is uniformly contaminated, the percent of contamination for the whole runway will suffice. The procedure is similar with taxiways and aprons. The provided value of contamination is rounded according to Table 3.

<table>
<thead>
<tr>
<th>No</th>
<th>Value inserted in item T</th>
<th>True contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Runway contamination (^{24}) – 10 %</td>
<td>up to 10 % runway</td>
</tr>
<tr>
<td>2.</td>
<td>Runway contamination – 25 %</td>
<td>11 – 25 % runway</td>
</tr>
<tr>
<td>3.</td>
<td>Runway contamination – 50 %</td>
<td>26 – 50 % runway</td>
</tr>
<tr>
<td>4.</td>
<td>Runway contamination – 100 %</td>
<td>51 – 100 % runway</td>
</tr>
</tbody>
</table>


\(^{23}\) It signifies that the taxiways ALPHA and CHARLIE are covered by dry and wet snow whereas BRAVO is only covered in dry snow.

\(^{24}\) Runway contamination – RWY Cont.
The intervals are selected due to the precise determination of the true contamination levels. Due to this, airport services are able to determine with a higher probability to which interval a runway contaminant should be classified. It may be wondered why the intervals are not equally divided, for example every 25%? An interval of 10% is of significance to an aircraft crew as such limited contamination has little bearing on the length of the aircraft roll-out. Therefore, a pilot can safely apply brakes and stop before the end of the runway. However, an interval of 75% would refer to the runway contamination in such a high percentage that a pilot would have to apply brakes with extreme caution or could not do it at all with a 100% coverage. Another piece of information inserted in this item is the length of uncleared runway. This is of operational significance as it impacts directly on the safety of air traffic operations, despite the fact that the length of uncleared runway is clearly understood from the item D, it should be added.

When the runway has been sanded or gritted, or de-icing (urea, potassium formate based liquids) conducted, such information should also be added to this item. Details regarding the condition of the runway edge is sometimes provided, as gusts caused by aircraft taking off can blow contaminants from the centre to the edge. Additionally, gases coming from the engines reach extremely high temperatures, which may also affect the central section more than the edge.

It is the final item in the SNOWTAM message. When an airport has more than one runway items from C to P should be repeated to ensure these runways are covered. The correct completion of all items facilitates a complete picture of airport conditions. It is not possible to read a SNOWTAM message without an in-depth knowledge of its codes. Moreover, any inappropriate arrangement of messages may be challenging for inexperienced employees. A lack of units of measurement also contributes to errors during decoding the arrangement of the message. Inaccurate readings may have severe consequences for air traffic safety.

**Conclusion**

The operations of airport services in the maintenance of the movement area play a crucial role in ensuring air traffic safety operations performed on the area. Each task implemented by the services has a direct impact on air traffic delays and the safety of the aircraft crew, passengers and cargo carried. Inadequate contamination removal, inaccurate friction coefficient measurement or lack of information on the conditions on the runway may contribute, directly or indirectly, to air traffic delays or even to an aircraft disaster. Therefore, a complete performance of the tasks by airport services is of crucial significance.

The operations presented in the paper belong to the most published ones contributing directly to the safety of air traffic operations. The responsibilities of airport services also include a number of indirect tasks which do not have an immediate influence on the safety of air traffic, however, are indispensable for the performance of the presented tasks. They include the maintenance of equipment and devices used to care about the movement area. Appropriate maintenance, for example, servicing, repairs and overhauls allow the operations presented in this paper to be performed.
Mechowski T., Sprawozdanie z realizacji pracy TD-71 pt.: Analiza i weryfikacja wymagań i procedur pomiarowych oceny właściwości przeciwpowłogowych nawierzchni dróg publicznych i autostrad płatnych, Warszawa, 2005;