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INTEGRATED RISK ASSESSMENT IN RAMP HANDLING OPERATIONS: RISK MAPPING FOR TURKISH AIRPORTS

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Ground operations are the least regulated section of the aviation sector and they have long relied on self-regulation and the pressure of airlines of which ground service providers are often a spin-off from state-owned international airlines (Pierobon, 2014). Ground handling is one of the most important airport functions influencing the entire transport process (Gonnord & Lawson, 2000; Wyld et al., 2005). The ground handling is related with the safety, accuracy, speed, efficiency, and elimination of risks (Ek & Akselsson, 2007). Peng et al. (2019) grouped the ground handling in terminal operations and ramp operations. Ek and Akselsson (2007) describe the ramp operations, so when an airplane arrives at the ramp, it is parked at apron and connected to ground power units and jetways, various types of cargo and mail are unloaded and loaded, fuel and water are tanked, and toilet services are performed. In addition, during winter, de-icing is carried out when needed. On departure, the airplane is pushed back from the apron, and the engines are started through communication between the pilot and a ramp operator. Therefore, ramp operations require the execution of complex tasks by employees, the operation of various expensive equipment and the interaction of equipment with staff.

These services are typically offered by a third-party ground handler, the airline itself or by the ramp handling business unit of an airport (Schmidberger et al., 2009). The ramp handling has a key role in ground handling, as the majority of accidents and incidents occurred when the aircraft are in apron and ramp personnel and equipment try to assist the arrived aircraft to depart on-time. An efficient ramp handling leads to the minimization of accidents and incidents and incurred delays. According to International Civil Aviation Organization (ICAO) (2019a) the direct costs related with aircraft damage on the apron and in maintenance facilities are upwards of $1.2 billion a year. In addition, the direct cost of air transport delays is $32.9 billion which incurs a loss of $3.3 billion to airlines (Abeyratne, 2020). Therefore, studies that focused to the optimization and safe operation of ground handling and in particular ramp operations, like the current one, are extremely useful.

In this situation, the role of employees is critical, and they should have proper knowledge and essential skills that contribute to a better service quality level (Hsu & Liu, 2013). Ramp personnel is the main element of ground handling operations as their mistakes cause major accidents or incidents and delays. Therefore, ramp employees' behaviours, actions, and interactions with equipment should be closely monitored and studied to find and prioritize risks that further impact their jobs, and this is the main objective of the current study. Methodologically, an integrated qualitative with quantitative risk assessment method is carried out, by considering the factors affecting the ramp personnel's errors and specific steps are followed. Initially, all risks (113) are categorized into four groups by using the academic literature, documents prepared by international organizations, and then by consulting expert opinions and prioritized using the 1-9 scale in Analytic Hierarchy Process (AHP) by experts in the field of ramp operations. With this method, the first 41 most important risks are determined. Then, a risk assessment matrix is created, considering the probability to occur and the impact of each factor. A risk index, a relation ratio a total risk index is created. Transferring the total risk index to the risk map, 'acceptable risks,' 'acceptable risks based on risk,' and 'unacceptable risks' are generated. Risk map is an effective methodology to manage risk factors with a strategic approach. Managers may use this map to identify their managerial priorities, share sources to manage risks and make decisions on risk handling options. Regarding the 'unacceptable risks,' 11 risk factors are identified as they have higher probabilities to occur and possible higher negative consequences. So, special emphasis should be placed on the handling of these specific risks. These 11 factors belong to the four groups of causes: a) ergonomics, b) organizational, c) ramp personnel, and d) sustainability-based risk factors: triple view. The participants/experts of the study (n=25) had a high experience and rich knowledge of the examined issue.

The study is applied to three Turkish Airports, Istanbul Airport (the biggest one in the country), Antalya Airport (the busiest one in seasonal traffic), and Eskisehir Hasan Polatkan Airport (regional airport), where in all cases there is an increased competition between ramp handlers and the study participants did not observe significant differences.

The proposed integrated risk assessment approach may apply to other departments of aviation such as pilots, traffic controllers, etc. in which the human factor has a significant role. Therefore, the study provides a way to assess risks that can be included in ramp operator's continuous improvement processes.

Background

In this part of the paper, the concepts of risk management and some general issues and some recent relevant studies are briefly presented.

Risk Management

Risk management is a systematic management approach that includes identifying, defining, measuring, and responding to all kinds of risks (Smith & Guy, 2002). In view of ramp handling and related services, the risks are appeared in the activities before the aircraft arrival and during the aircraft on the ground. (Effendi & Abbas, 2017). The ramp operation includes a high level of risk; thus, the implementation of risk management is required. Risk management is an integrated approach and contains a risk evaluation process, an optimal timetable creation, the availability of organizational and other resources for the management to handle risks, and the appropriate steps for implementation (Sadgrove, 2015). Risk management is an attempt to describe and eliminate the human range of risks coming from human, technology, the environment, organization, and so on (Socha et al., 2018).

Risk has many facets and should be handled in many ways and methods (Tamasi & Demichela, 2011). Predicted likelihood and austerity of the consequences or consequences of threat may be named as risk (Chen et al., 2019). According to the Federal Aviation Administration (FAA) (2009), the following types of risks are existing: i) identified risk, ii) unidentified risk, iii) total risk, iv) acceptable risk, v) unacceptable risk, and vi) residual risk. All these risks require both specific and also different approaches to handle and different level of resources.

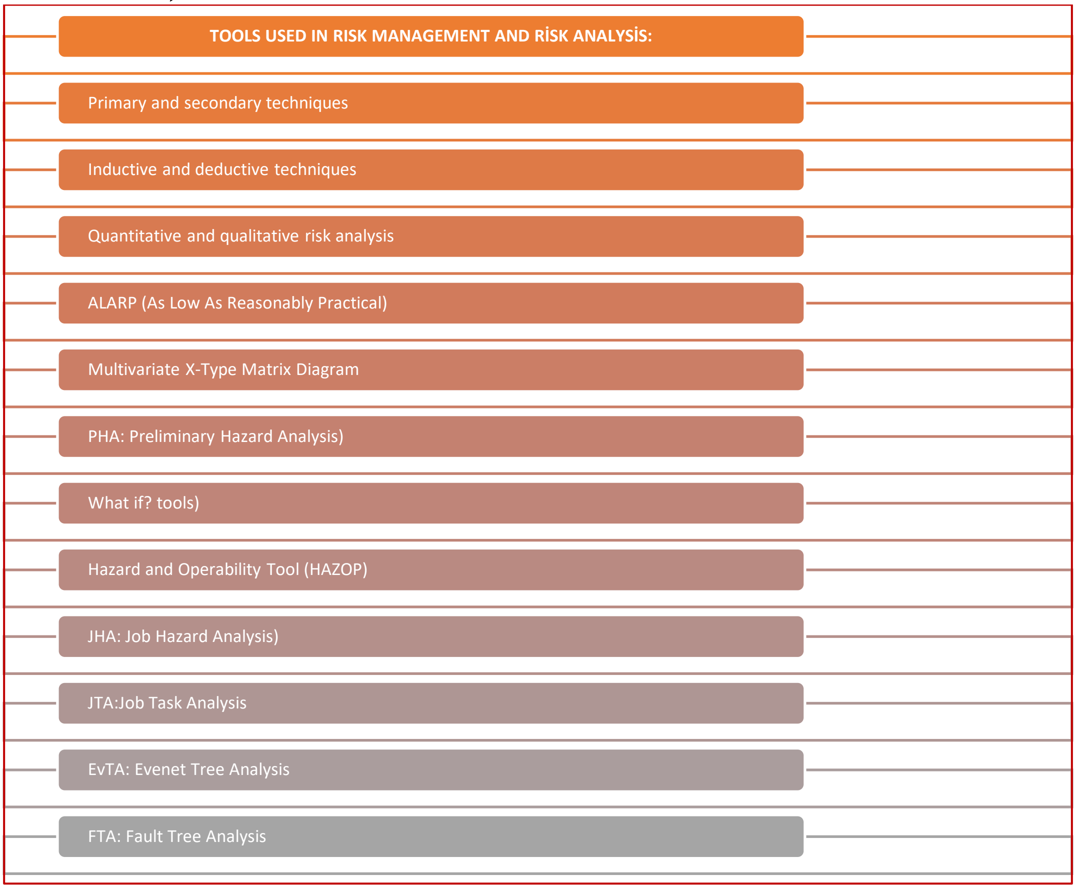
The risk assessment is required and this process should define the acceptability of a risk. This is usually accomplished by determining a Risk Tolerability Matrix that should be adopted across the entire organization (CAA, 2014). Assignment of sources to perform resolutions to lessen the risk includes the improvement of risk evaluation tools whose add to the identification of risk situations, ties between primary situations and outcomes, the likelihood of the existence, and alleviation actions (Cioaca et al., 2015). Thus, organizations have used well-organized methods and tools to recognize and to give priority to the various risks, particularly those with disastrous results (ACRP, 2012).

A safety risk assessment design and methods will provide a constant and well-organized procedure for the evaluation of safety risks. This should include a system that will define which safety risks are tolerable or unacceptable and to prioritize responses (ICAO Doc.9859, 2018). International Air Transport Association (IATA) (2020) pointed out the following risk assessment types: a) risk assessments of business, b) risk assessments of safety, c) risk assessment of security, and d) risk assessments of Pandemic health (focus on personnel's well-being).

In aviation safety risk management, hazard analyzes are performed to identify hazards, hazard effects and hazard causal factors. These analyzes are used to determine the significance of hazards so that safety design measures can be established to identify system risk and thus eliminate or reduce the hazard. Hazard analyzes are performed to systematically examine the system, subsystem, facility, components, software, personnel, and the relationships between them. There are many different hazard analysis techniques in the system safety discipline. Each of these techniques has a different purpose, focus and methodology. The System Safety Analysis Handbook, published by the International System Safety Association (ISSS), lists more than 100 different techniques. It should be noted that this large number of methodologies creates some confusion as some techniques are not valid and some are simply modifications of other techniques. Therefore, it is important for the safety analyst to understand each technique and the unique characteristics of each technique. Basically, we may group techniques and methods in safety risk management and analysis as follows (Demirören & Kucuk Yilmaz, 2022). See Figure 1.

Figure 1

Tools Used in Risk Management and Risk Analysis (Demirören & Kucuk Yilmaz, 2022)



In airport cases, there are several steps to be followed to evaluate risks: recognizing significant airfield risks, identifying risk drivers, assessing risk controls effectiveness, judging risk materiality, and allocating risk ownership (ACRP, 2012).

A risk map (or risk heat map) is a tool for displaying data for specific risks possibly occurring as a result of operations. It presents chosen organization's risks in two-dimensional graphical description, defining both the significance and impacts of mentioned risks on one axis and the likelihood or frequency on the other. Risk map is important for understanding organization's risk environment, and to create this map the first step is to identify business related risks, then risks are evaluated by revealing the frequency and potential impacts and finally the third step is to prioritize the risks to efficiently manage them (Roy, 2018; Webb, 2020). In case of airline ground services, it is known that vulnerabilities and hazards may vary, so risk map needs to be revised regularly (Roy, 2018). Additionally, the management of the 'higher risks' is essential for the safety, and this leads to the sustainability of air transportation, at micro and macro-level.

Moreover, risk management tools are required to support the internal organizational processes for managing risks, to assess and present the results of risk assessments (Rose et al., 2020). These tools assist managers to act proactively and enabling “an analyst to examine a wide variety of accidents quickly, systematically, and probabilistically and assisting a risk manager in priority setting and policy decision making” (Shyur, 2008, p. 35). There are some interesting tools in the market such as the RAMP (Risk Assessment and Management tool for manual handling Proactively), FMEA (Failure Mode Effect Analysis), GAMP 5, etc. RAMP is risk management tool used in manual handling to reduce the musculoskeletal disorder, offered free and are based on need analyses (80 practitioners are participated) and literature studies (250 research publications) (Lind et al. 2019/2020). This model further improved adding new modules (RAMP’s Action module) and tested regarding its reliability, validity, and usability (Rose et al., 2020).

The role of human factors and ergonomics is important to risk management. Also, there is growing evidence of the association between psychological, organizational, and individual factors that influence the occurrence of incidents and accidents (Dianat et al., 2015). According to ILO estimations (2015) the musculoskeletal disorders constitute 40% of the global compensation costs of occupational and work-related injuries and diseases.

It is noteworthy, the important role of the educated and skilled human resources which can minimize the accidents (Sari et al., 2015). Aviation international organizations provide useful guidelines for the safe operation of ground/ramp handling. ICAO through Doc.10121 offers guidance for all stakeholders involved in the ground handling of aircraft that might impact the safety of operations (ICAO, 2019b).

Relevant Studies

According to Wang and Pham (2020), Vietnam Airlines (VNA) uses a model that includes cluster analysis, ANOVA, and Scheffe post hoc to evaluate service potentials, identify deficient service areas, improve the provided services at international airports and achieve a complementary corporate benchmark for evaluation ground handlers.

Sari et al. (2015) examined the risk factors in ramp operations in the Indonesian Halim Perdanakusuma Airport and found that the highest risks are noise, being struck, and being squeezed by Ground Support Equipment (GSE). Additionally, high-risk activities include fatigue, dust, being squeezed by hydraulic during preparation, being scratched by iron, improper body position when putting manual GSE, being struck down by things, falling down, and getting lavatory water splashed on.

Socha et al. (2018) argued that apart from risks, there are opportunities that provide a competitive advantage in ground handling services, and to assess them suggested specific steps. Sumathi et al. (2018) grouped the key locations where the accidents occur in ground handling and sub-group them in accordance with the reason behind them and/or resulting from their significance of them in terms of damage-relatedated scales. Uchronski (2019) analyzed aviation events arising in the field of ground handling of aircraft during the period of 2015-2017 and found that the psychophysical predispositions of airport employees and actual skills and abilities should be in line with the requirements of the performance-specific tasks, supported by the right organization of work.

Rizkiana (2017) used a descriptive quality method in ramp handling employees in Ahmad Yani Airport in Indonesia and grouped potential hazards. Peng et al. (2019) pointed out that the purchasing of equipment for ground handlers is a time-consuming and complex process but significantly contributes to safe airport operation.

According to ICAO (2019a), the most critical risk factors for ground damage occur in '*towing,*' '*ramp movements,*' '*ground service equipment and hangar movements,*' and the main cause of these is the lack of training.

Finally, in these types of studies, as in the current one, the methodology used is important and this must be easily applied to any process where it is necessary to identify, analyze and manage the risks (Socha et al., 2018).

Methodology

Quantitative Study

AHP method is used in the current study. The AHP is originally developed by Saaty (1980) for analyzing complex, unstructured and multi-criteria decisions and implements a pair-wise comparison based on the judgement of experts to determine priority scales (Loh et al., 2020; Saaty, 2008; Tran et al., 2020). The use of human judgments in decision making problems has significantly increased and AHP contributes on this direction, providing sufficient knowledge to the decision makers to make more effective decisions (Dağdeviren et al., 2004; Saaty, 2000). AHP is a convenient, effective and easy to use tool, ideal for solving many complicated decision-making problems taking into consideration multiple criteria, and for this reason it has been utilized in several areas (Albayrak & Erensal, 2004; Balci et al., 2018; Dağdeviren & Yüksel, 2008; Dağdeviren et al., 2009; Kahraman & Kaya, 2010; Kahraman et al., 2003; Karaman & Akman, 2018; Kulak & Kahraman, 2005; Wang et al., 2014;).

Initially, 113 risk factors are determined in the study, and these are prioritized using the importance scale 1-9 suggested by AHP. Saaty (1980) stated that the importance scales such as 1-5, 1-7, 1-15, and 1-20 are insufficient to obtain the appropriate solution (Dağdeviren et al., 2004; Saaty,1980). Significance scale values are shown by Dağdeviren et al. (2009) as 1-equally important; 3-moderatelly more important; 5- strongly more important; 7- very strongly more important; 9- extremely more important and 2-4-6-8- as intermediate values.

The study is applied to three Turkish Airports -IGA Istanbul Airport, Antalya Airport and Eskisehir Hasan Polatkan Airport- the first one serves approximately 50 million passengers on an annual basis, the largest in Turkey, and the second one is located on the Mediterranean coast, it is a major leisure

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destination in summer season, and the third-busiest airport. In 2019, Antalya Airport welcomed more than 35 million passengers (Tosun, 2019). In addition to training flights at the Hasan Polatkan Airport owned by Eskişehir Technical University, there are also VIP/CIP flights, air taxi, and ambulance flights, and scheduled/non-scheduled domestic passenger transport flights carried out. In 2019, a total of 87,788 passengers, both domestic and international, passed through the airport (HPH, 2021). Although these airports have different characteristics no important differences are observed by the study's experts.

Qualitative Study

A number of experts (n=25) to ground handling are used in the current study. All the experts had significant experience and knowledge of the examined subject and significantly contributed to the study's quality. More information about the participants/experts you can find bellow (in the 1st step of the proposed approach).

The Proposed Integrated Risk Assessment Approach with Quantitative Study

Based on integrated risk assessment approach with quantitative study, particular steps are proposed to prioritize risk factors those contribute to ramp personnel errors, as shown in Figure 2.

Step 1. Identify the Experts

In the first step of the proposed model, experts with significant professional experience and knowledge in the ramp operations are selected. The use of expert judgment is critical (Ouchi, 2004). In the current study, due to the lack of statistical data, the opinions, experiences, and knowledge of the experts in the ramp operation (n=25) is used to prioritize the 113 risk factors. These study participants are senior experts in ramp operations, managers, ramp agents working in ground handling operations in the Turkish airports, and academicians. Analytically, these are: 3 senior experts, 2 supervisors, 2 department managers, 7 ramp agents, 3 academicians, and 8 doctoral students in the field of aviation management. Brainstorming, group discussions and telephone interviews are held on-line. In the risk assessment process, expert opinions are important for scoring the severity and probability of risks, identifying the important risks, and evaluating the effects of prevention and mitigation measures (European Commission, 2010).

Step 2. Determine the Risk Factors Causing Ramp Personnel Error

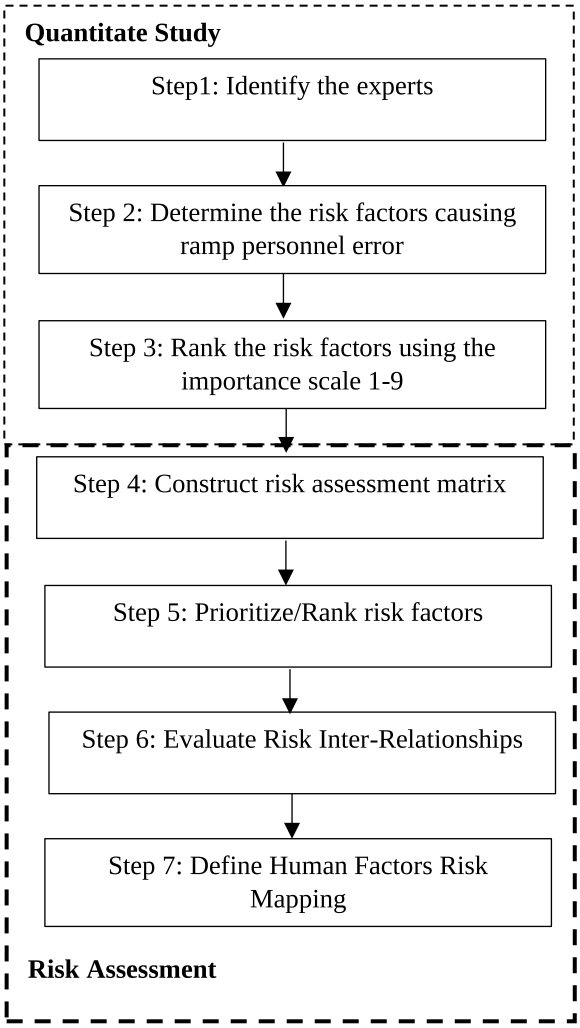
The second phase of the quantitative study includes the categorization process of the risk factors caused by ramp personnel errors. Thus, the 113 risks are classified into the four main groups related to: a) ramp personnel factors, b) organizational factors, c) ergonomics factors, and d) sustainability risk factors: triple viewpoint (environmental, economic, and social level; Yazgan et al., 2022). Factors taxonomy obtained from the comprehensive literature review (ACRP, 2017; Bendak & Rashid, 2020; CAA, 2002/2018; Cahill et al., 2021; Chang & Wang, 2010; Cioaca, 2011; Delice, 2016; Dupin et al., 2015; Kushnir, 1995; Leka et al., 2003; Rashid, 2010; Sandever, 2013; Vandel, 2004; Yazgan, 2018), taking experts opinions in airport operations and related previous studies (Yazgan et al. 2021/2022). These factors and groups further analysed in the next step.

Step 3: Rank the Risk Factors Using the Importance Scale 1-9

All the 113 factors are important for ground/ramp handling organizations. Experts are asked to evaluate the 113 risk factors by using the AHP's 1-9 scale. As a result of the evaluation, the most important 41 risk factors are ranked according to the mean of the values given by the experts for each factor (see Table 2). In this study, risk factors with a mean value of over 7.75 are considered as more crucial. Since there are no literature studies found related value determination, expert opinions are accepted as a mean resource for this value. Risk assessment method is applied to these high average risk factors in the next step.

Figure 2

Steps of the Proposed Integrated Risk Assessment Approach with Quantitative Study



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Step 4: Construct Risk Assessment Matrix

Risk analysis helps to estimate the probability to occur a risk and its impact. In the current study, the probability of these risks is defined as the frequency or probability of occurrence. Impact/severity is also defined as all possible consequences of an unsafe situation or object, considering the worst predictable situation. The probability categories are the following: extremely improbable, improbable, remote, occasional, and frequent; while impact categories are the following: catastrophic, hazardous, major, minor, and negligible. Categories for both issues are adopted from ICAO Safety Management Manual (SMM) (Doc 9859, 2018), a critical document for flight safety risk assessment.

Also, risk index is obtained by the process of the risk probability and impact/severity assessment The index is consisting by an alphanumeric indicator that indicates the combined results of the probability and impact/severity assessments. A risk assessment matrix is constructed using three different colours (green, yellow, and red) and is based on risk tolerability matrix of ICAO Doc 9859 (2018). This document suggests three different tolerability criteria as 'acceptable risks', 'acceptable risks based on risk mitigation' and 'unacceptable risks' under the existing circumstances (ICAO Doc.9859, 2018; Kucuk Yılmaz, 2019). The following Table 1 depicts the risk assessment matrix.

Table 1

Risk Assessment Matrix (ICAO Doc 9859, 2018)

Risk Probability	Risk Impact/Severity				
	Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent (5)	5A	5B	5C	5D	5E
Occasional (4)	4A	4B	4C	4D	4E
Remote (3)	3A	3B	3C	3D	3E
Improbable (2)	2A	2B	2C	2D	2E
Extremely improbable (1)	1A	1B	1C	1D	1E

Step 5: Prioritize/Rank Risk Factors

For ramp operation each risk identified in step 4 is sorted using by risk matrix. The probability/likelihood of a human risk factor and the impact/severity of the risk factor are significant for ranking. The risk matrix is used to assess the probability and impacts of the 41 risks. Priority of each risk is reached by the multiplication of probability and impact of risk and these values are achieved by experts' opinions (see Table 2).

Table 2

Ranking the Risk Factors with Total Risk Index

	Risk Factors	Mean	Probability (P)	Impact (I)	Risk Index (PxI)	Relation Ratio (RR) (1:VL,2: L, 3:M, 4:H, 5: VH)*	Total risk index (PxIxR R)
1	Improper aircraft loading	8.67	3	B	3B	2	6B
2	Loosing situational	8.48	2	C	2C	4	8C
3	Incorrect fuel loading	8.48	3	C	3C	3	9C
4	Unauthorised (dangerous goods) items bulk loading (e.g.: hazardous, chemical	8.33	3	B	3B	3	9B
5	Over physical workload	8.33	4	B	4B	4	16B
6	Demotivation	8.29	4	D	4D	3	12D
7	Unsecured/unlocked loading (e.g. not applying 5 cm rule or not locking networks)	8.24	3	B	3B	3	9B
8	Incorrect manual load sheet drawings and calculations	8.19	3	C	3C	3	9C
9	Insufficient/inefficient	8.19	1	B	1B	3	3B
10	Malicious violation	8.10	1	B	1B	3	3B
11	Ineffective communication among departments/employees	8.10	4	D	4D	4	16D
12	Lack of technical knowledge/skills	8.10	3	D	3D	2	6D
13	Low visibility during	8.10	3	D	3D	2	6D
14	Insufficient rest periods and rest places: lack of quality environment during breaks	8.10	4	D	4D	4	16D
15	Equipment failure during	8.05	3	D	3D	2	6D
16	Unsafe de/anti-icing	8.05	3	C	3C	3	9C
17	Unsafe working environmental conditions	8.05	3	B	3B	3	9B
18	Misinterpretation of Loading Instruction Report (LIR)	8.00	2	A	2A	2	4A
19	Improper use of equipment	8.00	3	C	3C	3	9C
20	Postponed investment in safety issues	8.00	3	B	3B	4	12B
21	Ground to cockpit mis-communication (e.g. with marshalled and pilot while manoeuvring)	7.95	2	D	2D	2	4D
22	Physical fatigue	7.95	4	B	4B	4	16B
23	Musculoskeletal disorders due to working in awkward positions, handling heavy loads and working in confined spaces	7.95	4	B	4B	4	16B

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24	Leaving equipment in idle position in strong winds	7.90	3	B	3B	3	9B
25	Shortage of personnel	7.90	4	B	4B	4	16B
26	Improper performance management (e.g. reward	7.90	3	B	3B	3	9B
27	Exposed to hazardous/toxic substances/ de-icing chemicals	7.90	3	A	3A	3	9A
28	Stress	7.86	4	D	4D	3	12D
29	Insufficient information (e.g. inadequate flow of data management systems)	7.85	3	E	3E	4	12E
30	Time pressure	7.81	5	A	5A	5	25A
31	Distractions/interruptions during task performance due to environmental conditions	7.81	5	C	5C	4	20C
32	Lack of willingness to report	7.80	4	B	4B	4	16B
33	Not inspecting and implementing procedures of FODs	7.76	3	B	3B	3	9B
34	Lack of risk perception	7.76	3	D	3D	3	9D
35	Management failures (e.g. poor personnel management)	7.76	3	A	3A	4	12A
36	Overconfidence, nervous	7.76	3	B	3B	3	9B
37	Unprofessional managerial decision making	7.76	3	B	3B	3	9B
38	De-icing in lightning weather	7.76	3	B	3B	3	9B
39	Insufficient aircraft body	7.76	4	B	4B	4	16B
40	Lack off technology-system & equipment	7.76	4	B	4B	4	16B
41	High noise level	7.76	5	C	5C	4	20C

* According to the relationships, the scale is divided into five groups: VL: Very low, L: Low, M: Medium, H: High, VH: Very High)

Step 6: Evaluate Risk Inter-Relationship

The full understanding of risk requires the study of the individual risks plus their interactions. Ground handling organizations consider the relationships between risk factors to manage the risks. The total risk matrix created in the current study includes the relation ratio between the risk factors. Thus, instead of evaluating the significant risks for ramp operations in 2 dimensional - matrix, proposed the use of 3 dimensions' risk matrix. The equation for total risk index is given below:

Total Risk Index = Probability x Impact x Relation Ratio

With relation ratio, it can be considered the interaction of risks with each other and the resulting new probabilities and severity of impact. The study participants/experts also evaluated the risks and if some risks are combined and their severity impact increases, then new risks arose and these should be identified and efficiently managed. Total risk index is presented in Table 2. For example, '*distractions/interruptions during task performance due to* *environmental conditions'* has relation with other risk factors such as '*high noise level.*'

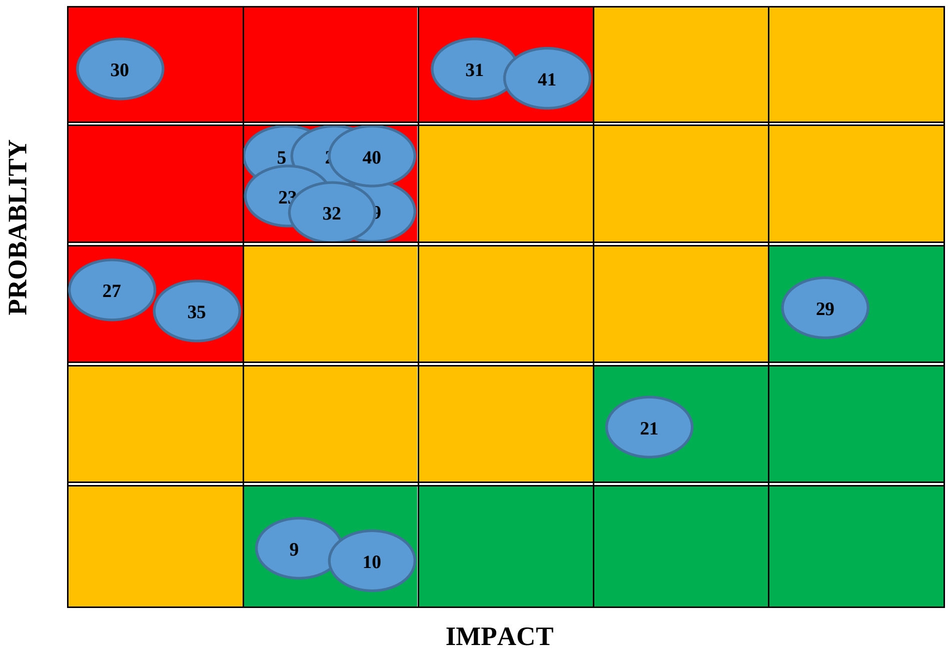
Step 7: Define Human Factors Risk Mapping

Maps are important tools, showing information about risks in a particular area, and supporting the risk assessment process and risk management. Furthermore, the process of priorities for risk reduction has used these maps (European Commission, 2010; Kucuk Yılmaz, 2019). Organizations can gain a comprehensive view of risks by comparing these risks with help of the matrix of impact and probability (Treasury Board of Canada Secretariat, TBC, 2018). Risk maps categorize and assess risks are useful the effectiveness and efficiency of risk management (Kucuk Yilmaz, 2008).

In this step, risks are ranked from highest to lowest at the risk map according to the total risk index (see Figure 3). Once all risks have been identified and entered onto the risk map, the management team must concentrate on devising an action plan to counteract all the risks appeared in the red box. Unacceptable risks' and 'acceptable risks' with risk numbers are plotted on the risk map illustrated in Figure 2. In this study, there are many factors at level of '**acceptable risks based on risk mitigation,'** and these cannot be shown on this risk map.

Figure 3

Risk Map for Prioritized Risk Factors (Neil, 2013)



Findings

Methodologically, a holistic approach is applied by using an integrated risk assessment method, defining, classifying, and weighting the possible risks in ramp operations with the help of risk matrix. Initially, 113 risk are used, then grouped into 4 categories. Based on high experience and rich knowledge of 25 experts in the ramp operations, 41 most important risks are determined. Weighting these risk factors on the basis of probability and severity, a risk index is generated and considering the relations between risks, a total risk index is created. Transferring the total risk index to risk map 'acceptable risks', 'acceptable risks based on risk mitigation' and 'unacceptable risks' are generated (see Figure 2). The last one is more important, as they have higher negative impact and should emphasized by management as they can cause significant problems. Eleven (11) risks are located in this group. These 11 prioritized risks (unacceptable risks) are representing risk map of ramp operations organizations as follows: time pressure, lack of willingness to report, management failures (e.g. poor personnel management), insufficient aircraft body check, exposed to hazardous/toxic substances/ de-icing chemicals, lack off technology-system & equipment, high noise level, distractions/interruptions during task performance due to environmental conditions, musculoskeletal disorders due to working in awkward positions, handling heavy loads and working in confined spaces, physical fatigue, over physical workload. In particular, (4) four of the risky activities out of (11) eleven are related to ergonomics factors, 3 of them to organizational issues, 2 of them to personnel issues and 2 of them to sustainable factors. **Ergonomics factors** are the *'over physical workload,' 'physical fatigue,' 'musculoskeletal disorders due to working in awkward positions,' and 'distractions/interruptions during task performance due to environmental conditions.'* **Organizational factors** are *'lack of technology-system & equipment,' 'management failures (e.g., poor personnel management),' and 'time pressure.'* **Personnel factors** are *'lack of willingness to report,' and 'insufficient aircraft body check.'* **Sustainability factors** are *'exposed to hazardous/toxic substances/de-icing chemicals,' and 'high noise level.'*

Overconfidence, nervous personality, unprofessional managerial decision making, de-icing in lightning weather, insufficient aircraft body check, not inspecting and implementing procedures of FODs, lack of risk perception etc. are the considerable (orange color) risks. The other risks are determined as acceptable (yellow color) risks based on risk elimination. Risks in yellow color are managed and considered since they may turn in red. However, in the green category risks are managed routinely. Yellow colored risks are not considered important as orange and red colored risks are (Kucuk Yılmaz, 2019). The 11 risk factors colored in red in this map should be continuously taken into account by managers with timely and correct allocation of sources.

According to risk index, results indicate that 16 risks of 41 are highly interrelated with each other. To manage risk, these interrelations must be evaluated by managers beside probability and severity of related risks.

Discussion and Conclusion

Risk mapping critical tool in the risk management system. To manage aviation risk with based ramp handling, the methodology is a truly sound and good choice. Ramp handling is very complicated and difficult to manage. This study is presented an effective tool to manage ramp handling-based operations in airport management and also other related operations. This result, which has a systems engineering approach, also includes suggestions for the solution of the safe operation of complex administrative and operational systems in systems engineering today, thanks to the integrated risk assessment applied.

In this study, a new mapping model for ground handling operations is offered. This new mapping model includes two approaches: a new taxonomy method for human risk factors in Ground Handling Companies, and a three dimensions-based approach to risk assessment of risk factors. This approach is based on three dimensions of risk assessment probability, severity, and interrelations. Interrelations change in every result because two dimensions do not valuable in today's global aviation sector. So, interactions among risks are essential for sustainable risk management.

Management and academicians should develop those tools, processes, policies, and strategies that identify, prioritize, monitor and handle especially those risks with the higher negative impacts and higher probability to occur. The implementation of an efficient safety culture, which includes the appropriate leadership and the availability of adequate resources should be the main objective of top management, as this proactively contributes to the identification and minimization of risks. The current study emphasizes on risks that occur in the ramp operations, an airport area where a large number of professionals and equipment operate and a small mistake caused by one of the sub-processes can greatly impact the holistic system, to the extent of both life loss and materialistic loss (Sumathi et al., 2018), and creating significant delays and bad reputation for the airport and country. Therefore, studies that focus on the risks in the ramp operations like the current one is extremely useful and strongly recommended.

The results of the study recommend the following issues for ramp handling organizations: a) employees must not exceed too much the allowed working hours, b) the workload and work tasks should be aligned with the employees' abilities, c) the required equipment should be offered to employees, d) no expose employees to the time pressure, e) avoid managerial mistakes, and f) management should ensure the health and safety of employees. Furthermore, it has been seen in this study that considering the opinions of employees regarding work issues and reviewing the reward and punishment (in very few cases) mechanisms are key issues that positively affect the ground operations. The provision of training on human factors that influence the ground operation and to monitor the implementation of this training is important.

Human factors can cause many accidents and incidents such as risk occurrence (i.e., adverse events), poor hazard reporting culture, and poor safety culture (Britton, 2018) in aviation approximately as 80% (Aeronautics Guide, 2017). For this reason, human factors is an essential issue (Alexis & Scheid, 2013). Management is responsible to ensure employees' experience and human error reduction (Watson, 1985).

The study reveals qualities that have the potential to be applied to other airports and contributes to both academic and industry applications, providing useful insights. In business level, all hierarchical levels are benefited from the current study, especially the middle-level management, as can apply the proposed methodology to their cases and have 'better and safer' operational decisions and operations. By improving risk management and focusing on human factors and those risks that have a higher probability to affect the ground handling operation, ramp handling organizations achieve their corporate goals. In the academic level, the used methodology provides useful insights and apply to other cases.

Future studies may focus on ergonomic risk assessments, especially physical workload and musculoskeletal disorders, which are among the most important risks and use the Rapid Entire Body Assessment (REBA), Rapid Upper Body Assessment (RUBA), techniques that are close related to ramp operations. Also, comparison studies between airports ramp operations from different countries and different owners' status (i.e., private 3^{rd} company vs airport company) can take place, as individual airports have different characteristics and this should be considered (Wang & Pham, 2020).

The involvement of more front-line employees is the main limitation of the current study and new studies on this direction in different operational fields are suggested. Various results will be obtained in the risk taxonomy of this study in another organization and location. The research sample is limited to three airports in Turkey and ramp operations. This research can be extended to apply to different operational areas in the aviation sector.

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