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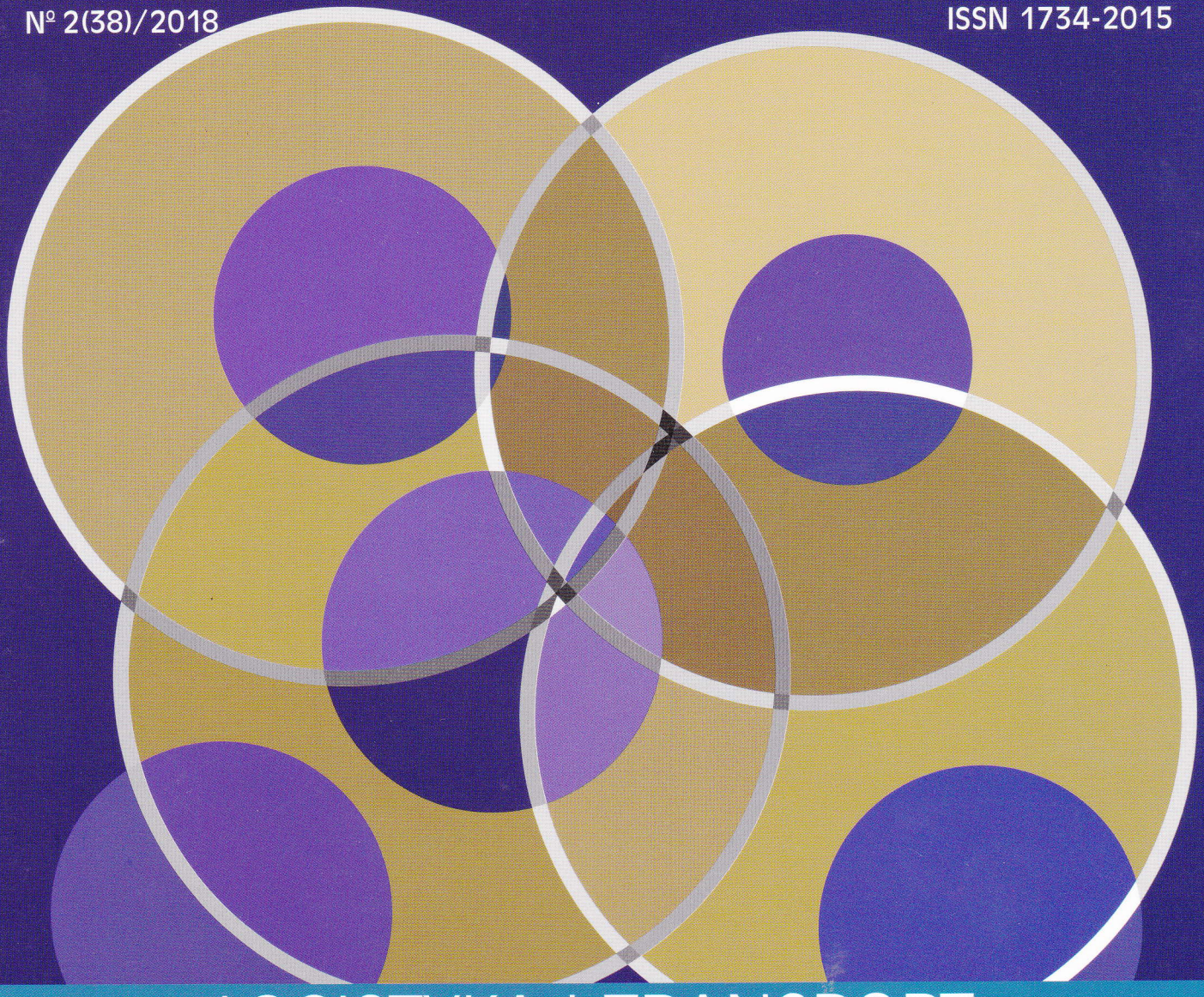

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Failure Mode and Effect Analysis of Air Cargo Freight Services Provider

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In the theoretical part, this article presents the basic conditions for the organization of air transport cargo divided into different types of cargo shipments. Then the analysis of the Polish market of air cargo shipments is presented, taking into account the type of companies, airlines and airports that support them. In the research part, an FMEA analysis of an entity providing air cargo transport organization services was made, presenting several disadvantages and possible remedial actions that contribute to the improvement of the quality of services.

1. INTRODUCTION

Cargo air transport is the transport of goods by air from one airport to airport within one country or to another. In a globalized economy, it is particularly important in intercontinental transport. The availability and quality of this type of transport is an enormous driving force for the country's development. The transported goods (neutral, dangerous or refrigerated under certain conditions) are located in passenger airplanes with cargo ports (from 2 to 16 tons) or dedicated transport aircraft (up to 100 t) in special air containers. Airline cargo takes place on regular routes or has the character of a chartered flight [9]. Air transport cargo is the fastest mode of transport, which allows a delivery to another continent within a dozen or so hours. It provides an attractive price in relation to courier services. The rate per kilo decreases depending on the total weight of the shipment being transported. The pay scale is higher due to the volume calculator 1 m^3= 167 kg. The most frequently mentioned disadvantage is the multiple reloading which can contribute to damage and/or loss of goods.

The scientific goal of this article is the analysis of competitiveness on the air transport services market in Poland and the FMEA analysis of the operator of such services.

2. TYPES OF AIR SHIPMENTS

All parcels handled by air freight are divided into two basic groups: ordinary and special consignments requiring handling services. They may also be decomposed according to stock management [5].

Normal shipments do not require a broader discussion, because they are standard shipments which do not require additional insurance or maintenance or express deadlines.

Special shipments include:

a) heavy cargo (HEA)
b) human remains (HUM)
c) live animal(s) (AVI)
d)..dangerous goods (DGR)
e) diplomatic mail (DIP)
f) perishables (PER)
g) valuable cargo (VAL)

Heavy cargo (HEA) is the one whose weight is over 125 kg, and requires the consent of the carrier and the destination port, and confirmation of the

possibility of handling the shipment of such weight and dimensions. The weight of shipments in bulk cannot exceed 600 kg and on pallets 4,800 kg. Such a shipment must be agreed upon with the handling agent no later than 24 hours before the planned date of shipment.

Human remains (HUM) transported by airplanes must be placed in a double casket (hermetically sealed metal and an external wooden coffin). Human ashes can be transported only in luggage holds in containers protected against opening or damage. Documents are required: death certificate, sanitary and epidemiological certificate, confirming that the deceased was neither infected with an infectious disease nor died on the territory covered by an infectious disease.

When transporting a live animal (AVI) the rules and conditions laid down in the provisions of the IATA Live Animals Regulations are applied. The basic conditions are: animals must be completely healthy, fed and watered, females must not be in advanced pregnancy, the packaging must be clean, tight, well closed, properly marked (sticker and instructions), a reservation must be made and confirmed throughout the route, veterinary certificate on health and rabies vaccination is required.

A distinction is made between nine classes of hazardous materials (DGR):

Class 1 – Explosives,

Class 2 – Gases,

Class 3 – Flammable Liquids,

Class 4 –Flammable Solids,

Class 5 – Oxidizing Substances,

Class 6 – Toxic & Infectious Substances,

Class 7 – Radioactive Material,

Class 8 – Corrosives,

Class 9 – Miscellaneous Dangerous Goods.

For each class there are special stickers in line with the type of threat posed by the material.

There are no special regulations for transporting diplomatic mail (DIP). The general rules for the handling of special consignments apply to them, so its value may not exceed USD 1,000 and the weight exceed 1 kg, the consignment note should contain the "Diplomatic Cargo" mark, the packaging should prevent access to the parcel to other entities except the recipient the ability to deliver and pick up the parcel directly to and from the plane, and to pick it up outside of check-in times). The carrier secures the shipment in the appropriate warehouse with limited access to it by unauthorized persons.

Perishable cargo (PER) are primarily:

- seedlings and flowers (PEF)
- fish and seafood (PES)
- meat (PEM)
- fresh fruit and vegetables (PEP)
- hatching eggs (HEG)
- vaccines, medical shipments, living human organs/blood (LHO)

Valuable cargo (VAL) are those which value exceeds USD 1,000 / kg, as well as platinum, legal banknotes, travellers' checks, securities, stocks, stamps, precious stones and jewellery containing precious stones and watches made of silver, gold or platinum. Such shipments are specially escorted to and from the aircraft and require special protection during transport or escorting.

In order to maximize the use of the loading area in transport and passenger planes, special ULD units (Unit Load Device) are used, which may be containers or pallets. Depending on whether the aircraft is narrow or wide, by implementation of ULD units it is possible to efficiently and economically pack the goods and use up the luggage area.

3. TRENDS ON THE POLISH AIR CARGO MARKET

The beginnings of commercial air transport took place in the 1950s and 1960s when aircrafts were used to transport goods. Earlier, after the Second World War, this type of freight transport existed but it was used sporadically. Technical progress, building ever larger flying machines allowed for the growth of this transport mode [6]. Thanks to large planes, it was possible to increase the transport mass of goods. Undoubtedly, air transport is considered to be a leader when it comes to the speed of delivery of goods.

In Poland, there are nine companies holding Air Carrier Certificate (AOC) in the A2 category, i.e. freight transport in liberalized market [8]. Table 1 presents the current list (for 2018-04-17) of Polish carriers possessing this license for the carriage of dangerous goods, and indicating their air shipping areas and types of aircraft used.

In addition to the aforementioned Polish airlines, many logistics companies handle the movement of goods as an operator [7]. One of the largest

Table 1. List of Polish holders of Air Operator Certificate (AOC) in the category A2 of carriage of goods

No	Name of the carrier	AOC number	Air shipping areas	Air transport		Types of aircraft
				cargo	dangerous goods	
1	LOT Polish Airlines	PL-001	EUR, AFI, MID/ASIA, World Wide	+	+	B787, B737, ERJ190, ERJ170, DHC-8
2	Enter Air	PL-003	EP, EUR, AFI, MID/ASIA, NAT, NAM, CAR, SAM	+	+	B737-800
3	Sprint Air	PL-007	EUR, AFI, MID/ASIA	+	+	SAAB 340A, ATR72
4	Travel Service Polska	PL-012	EUR, AFI, MID/ASIA, NAT, NAM, CAR, SAM	+	-	B737-800
5	SkyTaxi	PL-013	EP, EUR, AFI, MID/ASIA, NAM, CAR, SAM	+	+	SAAB 340A
6	Small Planet Airlines	PL-015	EUR, AFI, MID/ASIA, NAT	+	+	A320, A321
7	IBEX UL	PL-018	EP, EUR	+	+	BE-58, PA-34, C-172, C-182, C-T206H
8	SprintAir Cargo	PL-021	EUR, AFI, MID/ASIA	+	+	SAAB 340A
9	Royal-Star	PL-032	EUR	+	-	PA28, PA34, BE9L

Air shipping areas: EP (Poland), EUR (Europe), AFI (Africa), MID/ASIA (Middle East and Asia), NAT (North Atlantic), NAM (North America), CAR (Central America), SAM (South America)
Source: own elaboration based on [1]

companies in Poland dealing in comprehensive air transport logistics is Interfracht Co. It is a company that offers a very wide range of transport services not only for air but for intermodal transport as well. The most important services include: transport of live animals, express consignments, flammable materials, and hazardous materials. The company realizes orders for air freight based on the base of Airport-to-Airport, sea freight based on Seaport-to-Seaport and combined air and sea freight based on Door-to-Door, that is also directly. The main branch of the company's activity is unlimited transport by air. Maritime transport is limited to general cargo and container shipments. The Interfracht company is a company that independently performs orders and orders various tasks and forwarding services to cooperating companies. The scope of Interfracht's activity includes a comprehensive logistics and customs-forwarding service throughout the country. Interfracht Co. As a licensed Air Cargo agent, it represents the most reputable airlines involved in freight transport, and is among them: PLL LOT, Lufthansa, SAS, Air France, British Airways, Swiss Worldcargo, Aeroflot, Malaysia Airlines, Air Canada, Korean Air, Turkish Airlines, Cargolux, Finnair, Czech Airlines, Qatar, Airways, Eva Airways, Shanghai Airlines Cargo, Air China Cargo, LAN Cargo, Belavia, UPS Air Cargo Service, Aerosweet Airlines, Continental Airlines, SN Brussels Airlines. Other companies that also deal with the forwarding of goods by air or in intermodal transport are Cargo Transport or Euro-Pal-Ex. The number of manipulative and transport operations Polish operators have to organize is illustrated in Table 2, in which the number of cargo handled in kg at Polish airports in domestic and international traffic in 2016 and 2017 has been placed. As it can be seen from the table, 79.1% by the central airport in Poland, 14.3% by Katowice Pyrzowice International Airport is located in

southern part of Poland and 4.3% in Gdańsk at north. Also noteworthy are differences in the dynamics of changes in the transport potential of individual airports compared to the previous year. The increase in the volume of the cargo served was recorded at the airports in Gdansk (+ 22.3%) and Warsaw (+ 16.9%) and a slight decrease in Pyrzowice (-2.3%).

When analyzing the quality of air transport services, the most important determinants specific to this type of transport should be considered:

- the fastest and most expensive mode of transport,
- large and very long transport distances,
- transport mainly of high-quality general cargo and urgent items,
- relatively low load capacity of means of transport,
- the need to transport and deliver parcels to the airport, resulting in longer delivery times,
- division of the transport services market into regular and charter flights.

Competition on this market has been forcing constant improvement in the quality of services provided, as well as the search for better and better technical solutions, lowering costs, negotiating prices, hence the qualitative analysis of services seems to be desirable.

4. FMEA ANALYSIS OF AIR CARGO SERVICES

The research part was developed partly based on [4] and data from subject of analysis which is one of the key Polish companies providing air transport services in the world. The aim of the research was the FMEA analysis supporting the process of preventing the effects of defects that may occur in the planning phase and in the implementation phase of transport services. Preparing a list of preventive factors for the occurrence of non-compliance has an impact on improving the quality of services, and thus the competitiveness of a company in the field of air freight transport [11, 12].

Table 2. Volume of freight on board (kg) reported by airports in 2016 and 2017

Airport name	Year	
	2017	2016
Warsaw Chopin Airport	84,389,442	72,186,365
Katowice International Airport	15,233,859	15,586,274
Gdansk Lech Walesa Airport	5,118,050	4,186,389
Rzeszow-Jasionka Airport	392,779	731,770
Poznan-Lawica Airport	466,397	212,291
Wroclaw-Starachowice Airport	944,055	2,318,334
Szczecin-Goleniow Airport	129,639	278,775
Bydgoszcz-Szwederowo Airport	23,545	-
Lublin Airport	14	1,007
Cracow-Balice International Airport	108	3,487
Total	106,697,888	95,504,692

Source own elaboration based on [2]:

The FMEA method (Failure Mode and Effect Analysis) is also known under other names: FMECA (Failure Mode and Criticality Analysis) and AMDEC (Analys des Modes de Defaillace et LeursEffets) was used in the USA since 1960s. Its aim is to consistently and systematically identify potential defects of the product/process, and then eliminate or minimize the risks associated with them.

The FMEA analysis began with the preparation of a flow diagram of the air freight transport organization process. It is a traditional quality management tool. It is characterized by the presentation of a process in the form of algorithm or block diagram. Then the analysis of potential process defects was carried out

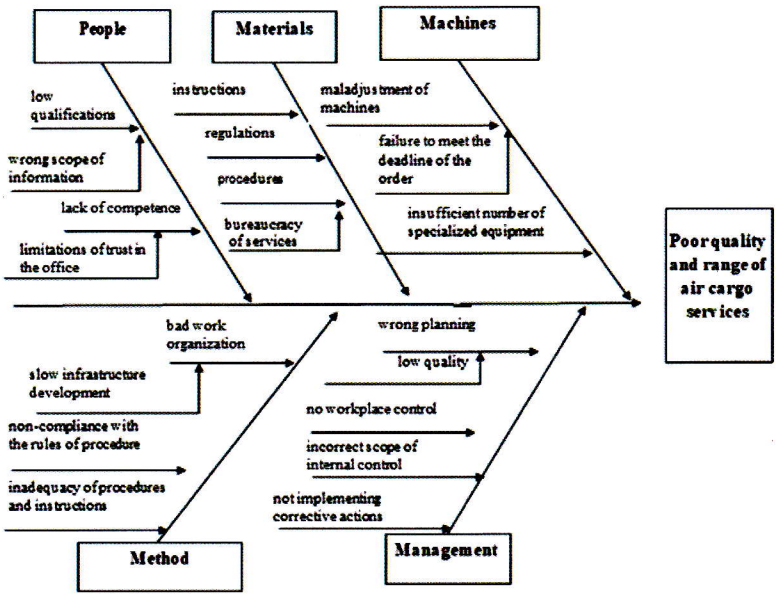

Fig. 1. Ishikawa diagram

using the Ishikawa diagram, shown in Figure 1.

Further research methodology - the assessment of risk by means of determining the level of Risk Priority Number (RPN) process implementation for cargo air transport services. The product represents the level of probability of risk associated with the occurrence of a defect - incompatibility. It can take values in the range of 1 –1000 [3].

$$RPN = S \times O \times D$$

where:
S - severity,
O - probability of occurrence,
D - probability of detection.

The FMEA method allows realizing the qualitative assumption of continuous improvement in practice [13]. The evaluation criteria S, O, D for the analysed service are presented in the table 3.

Failure Mode and Effect Analysis in the process of organizing air cargo transport are shown in Table 4.

Table 3 Criteria for estimating S, O, D for the analysed air cargo transport service

Severity for the customer S	Probability of occurrence O	Probability of detection D
1 - meaningless	1 - random	1 – very high
2-3 - low	2-3 - low	2-3 - high
4-6 - moderate	4-6 - moderate	6-8 - moderate
7-8 - high	7-8 - high	9 - low
9-10 – very high	9-10 – very high	10 - random

Table 4 Failure Mode and Effect Analysis in the process of organizing air cargo transport

Failure no	Potential defect	Potential consequences of the defect	Potential reasons for the defect	Preventive actions	S	O	D	RPN	Actions to improve failures	S	O	D	RPN
I	Delays in service time	Contractual penalties	Failure to comply with procedures, excessive bureaucracy	Training, strengthening the control system, verification of the document flow system	9	6	3	162	Training, control exacerbations, introducing changes to the document flow system	6	3	3	36
II	Low quality level	Lowering the demand for services	Non-compliance with procedures	Training, strengthening of control	9	6	3	162	Training, workplace control	8	4	1	32
III	Packaging and specialized equipment	Delays	Lack of proper packaging	Increasing the range of packaging, specialized containers and specialized transport equipment	8	7	1	56	Purchase of appropriate equipment and a wide range of packaging, including containers for transporting non-standard consignments	8	6	1	48
IV	Lack of storage facilities	Cargo limitations	Insufficient infrastructure	Expansion of infrastructure	8	7	1	56	Expansion of cargo infrastructure at domestic airports	6	9	1	54
V	Incompetence of employees	Poor quality of service	Lack of training	Improvement training, increasing qualifications	8	6	7	336	Developing a system of improvement training for employees	4	6	7	168
VI	Poor marketing and information	Limited market	Lack of training	Hiring specialists, training	7	6	7	294	Purchase of appropriate programs, exchange of experiences during workshops and apprenticeships, increase of recruitment requirements for new employees	6	7	7	294

The summary of the activities before and after the FMEA analysis is presented in Table 5.

Table 5. A comparison of the RPN level indicator before and after the FMEA analysis

Failure number	Total RPN – failure causes		Sorted by highest RPN	Accumulated percentage [%]	
	before	after		before	after
I	162	36	V	31.5	26.6
II	162	32	VI	27.6	46.5
III	56	48	I	15.2	5.7
IV	56	54	II	15.2	5.1
V	336	168	III	5.3	7.6
VI	294	294	IV	5.3	8.5

Fig. 2 presents Pareto-Lorentz diagram of cumulative percentage share of defect causes for cargo air transport services before and after FMEA analysis.

Fig. 3 presents column chart showing the comparison of risk level indicators before and after the FMEA analysis.

After applying training, workshops, professional development and strengthening internal control, the situation related to incompetence and low qualifications of employees, failure No 5 will change significantly and the risk of defect becoming larger or smaller is reduced. In the case of failures No 4 and 6, inadequate infrastructure and poor marketing and computerization, the level of risk persists. Preventive actions require time and in the

case of infrastructure expansion of major capital expenditures, and therefore increase funds for the development and modernization of airports, especially cargo facilities. Both of these factors are of great importance for the development of cargo. Failures 1, 2, 3 indicate that after the corrective actions the risk level will not decrease or increase. Defect 1 this untimely time often caused by excessive bureaucracy, a change in the document flow system is not a guarantee of lowering the risk factor for this defect again. Failure 2 concerns low quality services that the company intends to improve through a quality control system. However,

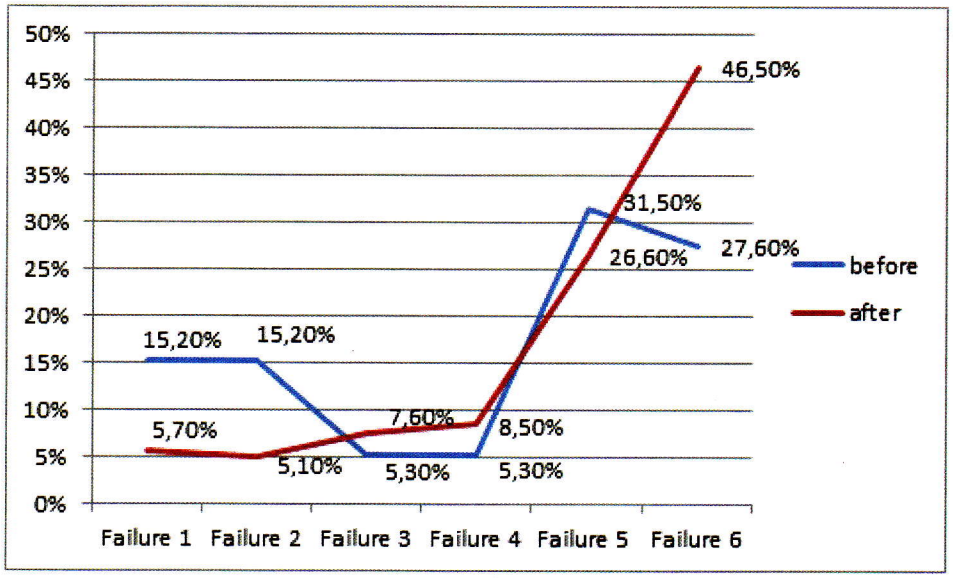

Fig. 2. Pareto-Lorentz diagram of cumulative percentage share of defect causes for cargo air transport services before and after FMEA analysis,

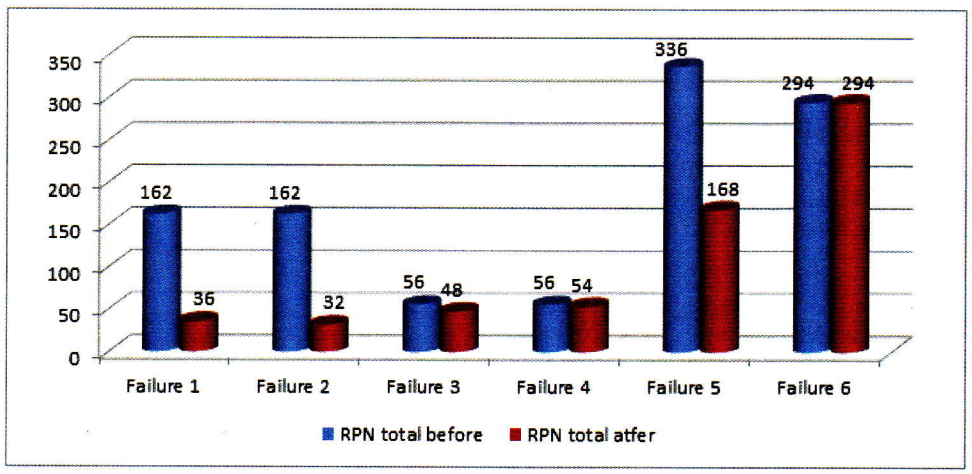

Fig 3. Comparison of the level of RPN risk indicators

these preventive measures are also not a guarantee of reducing the risk of a defect again. The system of increased control itself is insufficient to reduce the risk indicator of a defect and even its severity. Failure 3 relates to equipment inadequate to customer orders (insufficient number of appropriate packaging, containers for specialized transport and the right quantity and quality of equipment to provide internal and external transport in the case of combined transport.) The risk of this failure is high.

5. CONCLUSIONS

In the FMEA analysis of the processes of organizing air cargo type of transport, a few significant flaws have been identified and among them quite significant ones- people i.e. management, control, service staff, etc. It is mainly people who care about the quality of services they provide, and it is thanks to people that the company's image is created. The audit analysis and FMEA analysis show that at every level the improvement tasks should include improvement training, enable workshop meetings and internships in other companies dealing with a given problem, and raise the recruitment criteria. A very important element in corrective actions is raising the quality of public information, advertising and marketing as well as opening new connections, especially on transatlantic and intercontinental routes.

The benefits of the FMEA [10] method are undoubtedly:

- a better product (good or service), by eliminating the problem before it occurs,
- higher level of quality,
- increase the process capacity by reducing re-work,
- reducing the level of waste or complaints,
- increase in customer satisfaction,
- elimination of wrong conditions,
- increased profitability and greater safety for everyone.

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