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# ANALYSIS OF TRENDS AND POSSIBILITIES OF REDUCING WASTE PRODUCTION ON BOARD OF AIRCRAFT AND INOVATIVE SYSTEMS FOR ITS ASSESSING

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**Abstract**

*A major trend in the 21st century is the protection of the environment from a global perspective, which is associated with reducing emissions and reducing waste production. Therefore, we try to apply the same trends in aviation. With the help of progressive technologies, we ensure the reduction of emissions. However, the issue of waste generated on board of aircraft during the flight is not comprehensively identified. This diploma thesis deals with the topic of reducing waste production on board. The main goal of this work is to analyze the current state of the problem and the subsequent creation of innovative solutions in the form of operating procedures for organizations operating in aviation. The laws and directives valid in the territory of the Slovak Republic in the application of relevant regulations and other EU legislation were used to prepare the work. Articles, studies and methodologies of foreign authors have contributed appropriately to the completion of the theoretical part of the thesis and to a better understanding of the issue. The first chapter presents the current situation and legislative requirements in the field of waste generated on board aircraft. The second chapter describes waste recovery processes and related processes such as landfilling, incineration and recycling. The possibilities of using alternative materials and the application of optimal recycling technologies are described in the third chapter. The practical part of the work was the creation of progressive procedures on board aircraft and in handling or catering companies. At the end of the work, the impact of the created procedures on the environmental, socioeconomic, and operational environment is described.*

**Keywords**

*environment, legislation, waste, recycling, operation procedures*

## 1. INTRODUCTION

One of the most actual issues in recent years is ecology and global warming. Many know that while this topic may not be relevant to us right now, our behavior today may affect future generations. For this reason, we are already trying to make effort to prevent environmental disasters, precisely mitigate the environmental impact of human activities.

Awareness of the waste problem is slowly increasing not only on the ground but also on board of the aircraft. In recent years, some airlines, airports and their contractors have begun to turn their attention to waste. In air transport, finances are the most important condition, often preventing companies from breaking away from traditional practices. Government restrictions and the growing awareness of the public are slowly but surely pushing airlines to take action to improve the environment not only by reducing emissions but also by reducing the production of waste on board aircraft.

This diploma thesis focuses on the problem not only with plastic, but also other types of waste. Specifically, it describes the ways in which procedures can be implemented to achieve a better and cleaner future. The aim of the thesis is to create a proposal for new operating procedures focused on separating waste on board and evaluating the impact of the use of alternative products. We will also mention the possibilities of waste utilization and disposal and look at ways of recovering waste that are more environmentally friendly. In the diploma thesis we will talk about the issue of waste on board of aircraft, and we will try to suggest the best way to reduce them. Based on the performed analyzes, we will determine the advantages and disadvantages of the established procedures and provide alternative approaches.

## 2. CURRENT LEGISLATIVE REQUIREMENT AND THE STATE OF THE PROBLEM

Each country, not just the Slovak Republic, has its own law on waste and its treatment. Act no. 79/2015 on waste, which regulates the competence of state administration bodies and municipalities, the rights, and obligations of persons in prevention waste management and liability and breach of liability in the field of waste management. This law contains definitions such as waste, by-product, biodegradable waste, hazardous waste. [2]

Waste management deals with activities that prevent the generation of waste and its harmful impact on the environment. These activities are waste collection, transport, sorting and disposal and supervision of individual activities. The order of priorities, i.e., what constitutes the best environmental choice under the legislation, is defined by the waste hierarchy: [2]

1. waste prevention,
2. preparation for re-use,
3. recycling (waste recovery operation by which waste is processed into products of the original or new purpose),
4. other recovery; and
5. disposal.

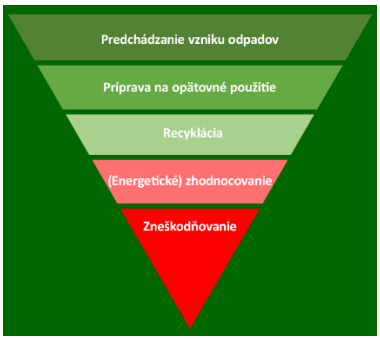


*Figure 1: Waste management hierarchy*

### *2.1. Directive on the reduction of the impact of certain plastic products*

The Directive of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment states that an endless increase in the generation of plastic waste and its negative impact on the environment needs to be addressed. A European strategy for plastics should achieve a circular economy that considers the recycling, reuse and processing of plastics and plastic products. This decision would help to use easily accessible and sustainable alternatives or innovative solutions focusing on more sustainable business models, reusable options and material substitution. [3]

### *2.2. PET bottles*

According to statistics, 1 billion plastic bottles are launched on the Slovak market every year. The Act no. 302/2019 states that the machines for collecting refundable bottles will be mandatory in all stores with a store area of 300 m2 and more. All other bottles purchased abroad and without the Z mark, as we well know, should be disposed of in yellow plastic containers. Until 30.6.2022, non-refundable bottles can still be found in stores. [4]

### *2.3. Glass*

Glass is a substance made of silica sand (70%), dolomite (14%), soda (14%) and clarifiers (2%). Glass is fully recyclable and can be reshaped and reused without compromising quality. Glass recycling is environmentally friendly, energy-efficient with low CO2 emissions. [7]

### *2.4. BRO – biodegradable waste*

Biodegradable waste (BRO) is all types of waste that are classified in group 20 according to the Waste Catalog defined in Waste Act No. 75/2015. These include biodegradable kitchen and restaurant waste, including edible oils and fats, which can also be identified as waste on board aircraft. [8]

Due to the specific conditions in the case of the production of such waste on board aircraft, we propose to ensure separate collection and management of biodegradable waste: [8]

a) by introducing special containers for separate collection

b) for catering partners by providing contractual partners for waste collection

(c) informing passengers of such a procedure, including public relations

Sustainable waste management refers to the collection, transport, recovery and disposal of various types of waste in a way that does not endanger the environment, human health and future generations. It covers all processes from production to final processing. In our case, from the food packaging production process, through on-board service to waste disposal. The aim is to reduce the use of natural resources in the production of products and instead to re-use materials that have already been involved in the production process. [9]

### *2.5. waste recovery*

Waste recovery means those activities that lead to the use of the physical, chemical and biological properties of the waste.

Not every incineration is an energy recovery of waste. Not all waste can be fuel. Plastics are considered to be almost pure fuel. They have a higher thermal capacity than solid fossil fuels, such as brown coal, which has a thermal value of 8-12 MJ / kg compared to PET with a thermal value of 22 MJ / kg. [10]

### *2.6. BIOgas*

During decompositions and syntheses performed by biochemical routes, a whole range of gaseous compounds is formed. Biogas is then used as a source for combined heat and power.

Recently, biodegradable waste accounts for almost half of mixed waste from aircraft decks. Although the sorting of bio-waste is more complicated, such procedures can be implemented on board aircraft relatively easily and at minimal investment and operating costs. [11]

### *2.7. Recycling*

After meeting the requirements of the STN ISO15270 standard, the district environmental authorities can be assigned activity code R3. Code R3 indicates material recovery using one of the following methods: [12]

(a) mechanical recycling

b) raw material (chemical) recycling

c) biological (organic) recycling

Mechanical recycling is the creation of a secondary raw material by processing plastic waste without significantly changing the chemical structure. Mechanical recycling takes place in several steps, which gradually prepare the recycled during the production process: [12]

collection → identification → sorting → crushing → washing → drying → sorting → agglomeration → extrusion or preparation of mixtures → granulation.

Raw material (chemical) recycling consists in the production of new raw materials by changing the chemical structure by cracking, gasification or depolymerization without energy recovery and incineration. [12]

The term biological recycling refers to a process where organic residues, water and carbon dioxide are the products of aerobic (composting) or anaerobic treatment (digestion) of biodegradable plastic waste in the presence of oxygen. [12]

### *2.8. Disposal*

Society and environmental requirements call for ever-improving incineration, cleaning, and waste management technologies. The requirements are: [13]

a) a smaller volume of waste deposited in landfills,

b) reduction or complete destruction of hazardous and noxious substances from waste and incineration plants,

c) stabilization and reduction of residual waste,

d) minimization of liquid and gaseous emissions during combustion,

e) maximizing the use of energy in the combustion process

In March 1989, the then Czech and Slovak Federal Republic signed the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. They are all disposal processes which do not result in recovery or reuse of waste and waste products. [14]

### *2.9. Landfill*

A landfill is a place where solid waste is stored. Only authorized landfills are official and legal. Before building a landfill, it is important to assess safety, importance in the region, economic analysis and especially the impact on the environment. This assessment is governed by Act 24/2006 Coll. on environmental assessment environment. [13]

## 3. OPTIMIZING THE USE OF ALTERNATIVE MATERIALS AND RECYCLING TECHNOLOGIES

There are many alternatives for plastic products. So why do we still use a lot of plastic? In most cases, plastic cups are replaced by paper that is light, does not take up much space, does not burden the environment and is degradable. Plastic cutlery can be replaced with bamboo or wood. However, these are insufficiently strong at lower material thicknesses and often break and produce relatively dangerous sharp chips.

Table 1 shows data on the weight of some kitchen utensils also used on board aircraft. The items were weighed experimentally on a kitchen scale. The measured objects were not specifically from aircraft, but their size is close to those used on board aircraft.

The weight of these 6 items from column no. 2 together is 516g. If we take into account the flight on a Boeing 737-800 aircraft in the basic configuration of the cabin with 189 seats and for each passenger a dish with this weight would be prepared on board, the total weight will reach 97.52 kg if we do not count the crew and the journey from destinations back. In the case of fuel consumption and weight, 100 kg is a negligible weight, on the other hand, with increasing weight respect the MTOW and this may in certain cases limit the amount of fuel filled. It is for these reasons that materials such as glass, porcelain and metal are not used for all passengers.

One alternative is bamboo cutlery and paper cups. After calculating the weights, the result weight is 43.6 g per passenger and 8.24 kg for a full cabin for the same type of aircraft as in the previous case. In the case of bioplastic PLA cutlery and cups, the weight is 35 g per passenger and 6.52 kg per fully occupied aircraft. It only depends on the company's decision which alternative they choose.

*Table 1: Comparison of weights of kitchen utensils (https://markbal.sk/155-pribory)*

| item | material | weight | material | weight | material | weight |
|---|---|---|---|---|---|---|
| **little spoon** | steel | 19g | bambus | 2,3g | bioplastic PLA | 4g |
| **spoon** | steel | 19g | bambus | 3,4g | bioplastic PLA | 5,6g |
| **knife** | steel | 38g | bambus | 4g | bioplastic PLA | 4,6g |
| **fork** | steel | 19g | bambus | 3,9g | bioplastic PLA | 4,8g |
| **mug** | porcelain | 229g | paper | 15g | bioplastic PLA | 8g |
| **glass** | glass | 192g | paper | 15g | bioplastic PLA | 8g |
| **together** | | 516g | | 43,6g | | 35g |

Many studies indicate that more than half of aircraft cabin waste could be recycled. On-board recycling has already been introduced by some companies. Recycling can also reduce waste disposal costs. There are various obstacles to the recycling of waste on board: [1] [17]

- space and time pressure on the crew during the collection and separation of materials,
- a different understanding of what can be recycled
- lack of recycling facilities at airports,
- crew involvement and development of new procedures,
- involvement of cleaning staff and insufficient requirements in cleaning contracts.

### *3.1. Case study Air New Zealand*

In 2017, Air New Zealand worked with other partners on the "Project Green" waste management project. This project required changes in the airline's processes, in which flight crews played an important role in the proper storage and separation of materials. During 2017, the waste management project enabled the exchange and retraining of 40 products so that they could be reused the next flight if they had not been opened and used before. [18]

### *3.2. Airport Waste Management*

Vienna Airport is an example of how to dispose of waste properly and ecologically. Vienna Airport Eco-Model focuses on waste prevention, reduction and recycling. The less waste is produced, the less it must be separated and disposed of.

### *3.3. ReTrolley*

The European aircraft manufacturer has launched a new concept of boarding trolleys called ReTrolley. This is a trolley designed for efficient recycling directly on board. The innovative trolley allows the crew to collect and separate waste in one. It contains the containers for collecting liquids and space for stacking plastic cups and separate sections for recycling paper, plastics, and other municipal waste. [21]

## 4. DESIGNING PROGRESSIVE PROCEDURES ON BOARD OF AIRCRAFT AND AT HANDLING PROVIDERS

To implement, compare and evaluate new operating procedures involving on-board waste separation, it is necessary to identify the current operating procedures of the companies involved in this process.

The standard procedure is the sale of on-board refreshments such as baguettes, drinks, sweet and savory delicacies, alcohol, etc. Cabin crew go through the cabin with a snack cart and sell goods to passengers according to the offer. Free water is offered after the sale. Immediately afterwards, the waste from the on-board service is collected in empty trolleys with a plastic bag intended for waste. The cleaning company picks up garbage bags from bins and carts and throws them in one container after the flight. Currently, all generated waste is considered municipal, although some components could be recycled.

Content of trolleys:

- half trolley: 24 bottles of still water
- full trolley (BOB): cans of carbonated drinks 26x, cans of beer 10x, miniatures of alcoholic beverages 33x, snacks 26x, bottles of water and juices 30x

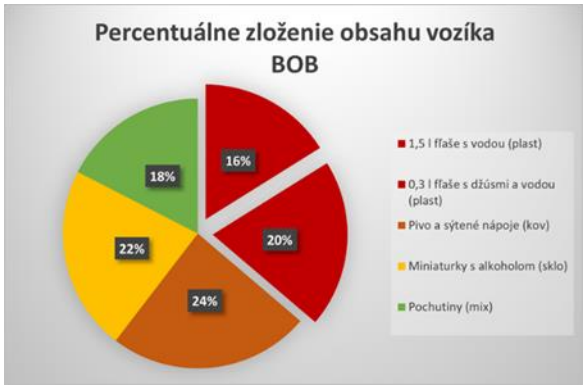


*Figure 2: percentage composition of the contents of the trolley BOB*

Of the total content of trolleys with snacks and drinks, 82% of the material can be recycled. The quantities of the individual trolleys vary depending on the operation. It can also be seen from the graph that 60% of the material in the form of plastic bottles and cans is refundable. The deposit for them is valid only if they are properly marked.

When separating, storage space for waste from different materials is important. There are designated waste areas in the galley, namely fixed waste bins. The trolleys are constructed as standard in two sizes, a long trolley and a half-size trolley. The responsibility for the trolleys lies with the airline and thus the crew during the flight, after the flight the trolleys are taken from the aircraft by the catering, which then exchanges and replenishes the items needed for the next flight and the trolleys return to the aircraft.

## 5. ENVIRONMENTAL, SOCIO-ECONOMIC AND OPERATIONAL EVALUATION OF THE INTRODUCTION OF NEW APPROACHES

### *5.1. Ecological impact*

Waste management contributes to climate change and air pollution and directly affects many ecosystems and species. Landfills are considered a last resort in the waste hierarchy, releasing methane, a harmful greenhouse gas associated with climate change. Currently, waste from the aircraft is treated as one component. Whether it is plastic, glass or paper, all types of waste are disposed of together in one container and then sent to the incinerator.

The introduction of new on-board separation procedures will reduce the environmental impact of waste. It is clear from the previous chapter that 82% of the waste sold on board can be recycled.

Energy saving by recycling materials: [22]

- plastic → 97%
- aluminum → 95%
- paper → 70%
- glass → 25%

### *5.2. Economic impact*

It is only possible to reduce the amount of waste by reducing the amount of goods offered on board. Since the interest in the offered dining service persists mainly on long flights, this option is impossible.

The question is whether the use of greener alternatives to these products pays off financially. In the following table we compared the prices of plastic, wooden and PLA plastic cutlery. We compared the price for 100 forks.

Table 2 shows that the cheapest fork is made of plastic at a price of € 0.94, wooden fork is up to € 2.40 more expensive and the most expensive is a PLA plastic fork for € 4.50. From these prices, it is clear why many companies prefer plastic cutlery.

*Table 2: Fork prices (https://www.h-print.sk/product-category/jednorazovy-riad/jednorazovy-pribor/plastove-pribory/page/2/)*

| _____ | material | pieces | price |
|---|---|---|---|
| fork | plastic | 100 pc | 0,94 € |
| | wood | 100 pc | 3,34 € |
| | PLA plastic | 100 pc | 4,50 € |

The airport charges airlines € 11 per service for removing and disposing of aircraft waste that arrived from an EU country. In addition, charges € 3 per 1 kg or € 0.66 for a plastic bag with a special sticker for waste from flights outside the EU.

With the introduction of separation on board, the number of waste bags would increase, but we know that the so-called extended producer responsibility exists and therefore citizens do not pay for separated packaging.

### *5.3. Sociological impact*

Passenger feedback can tell companies what to focus on. The so-called review or feedback from passengers about food, services and the overall feeling of the flight can help the company make decisions in the future. Passengers could answer questions in the questionnaire such as:

a) Were you satisfied with the services on board the aircraft?

b) Was your food delicious? Would you change anything?

c) What dishes would you welcome on board and which ones would you rather exclude from the menu?

In response to the sorting of waste on board the aircraft, the questionnaire could include questions:

d) Do you separate waste in your household?

e) Do you separate waste at your job?

f) Would you welcome the introduction of separated waste on board the aircraft?

g) Do you agree with the introduction of the use of more environmentally friendly alternatives to kitchen utensils?

These questionnaires can be incorporated into the built-in entertainment system, accessible on the company's website, sent by e-mail when purchasing a ticket or in any other form. Improving the passenger experience will result in passengers receiving the food, drinks and products they prefer during the flight, leading to less waste and reduced costs.

### *5.4. Operational impact*

When introducing new procedures, it is necessary to motivate the employees who will execute these procedures in order to ensure the correct performance of these activities. Ways to engage and encourage the crew and cleaning staff can be as follows:

- to understand the barriers to recycling
- identification of triggers to encourage recycling
- precise instructions on which materials to collect
- to explain the contamination and its effects on recycling
- to accept the effects on the time needed to carry out these activities
- to get feedback from the crew
- to provide information on where the separated waste goes and how it is treated
- for financial and other rewards
- on exploiting competitiveness between crews
- to share knowledge with other companies

Airport organizations are often directly responsible for handling and disposing of cabin waste. Recycling facilities can vary considerably between airports, depending on the availability of local recycling and disposal facilities. The availability of separation facilities will affect the degree of effective separation on board during flight. Local regulators have a major influence on waste management, especially international waste, which is considered hazardous waste.

### *5.5. SWOT analysis*

The SWOT analysis serves as a tool for evaluating the current situation and describes the possibilities of development and possible strategy.

*Table 3: SWOT analysis*

| **strengths** | | | | **weaknesses** | | | |
|---|---|---|---|---|---|---|---|
| environmental protection | 5 | 0,4 | 2 | initial investment | 4 | 0,3 | 1,2 |
| advertisement | 4 | 0,2 | 0,8 | lack of time | 3 | 0,2 | 0,6 |
| employee bonus | 3 | 0,2 | 0,6 | lack of space | 3 | 0,2 | 0,6 |
| waste costs | 4 | 0,1 | 0,4 | cabin crew responsibility | 5 | 0,2 | 1 |
| refundable bottles | 4 | 0,1 | 0,4 | eco cutlery investment | 2 | 0,1 | 0,2 |
| **together** | | **1** | **4,2** | | | **1** | **3,6** |
| **opportunities** | | | | **threats** | | | |
| technologies | 2 | 0,1 | 0,2 | lack of interest of cabin crew | 5 | 0,3 | 1,5 |
| partnerships | 3 | 0,1 | 0,3 | increasing costs | 4 | 0,1 | 0,4 |
| implementing procedures to all bases | 3 | 0,2 | 0,6 | jeopardizing flight safety | 5 | 0,4 | 2 |
| implementing know-how | 5 | 0,3 | 1,5 | expensive flight tickets | 2 | 0,1 | 0,2 |
| EU grants | 4 | 0,3 | 1,2 | prioritizing waste separation | 2 | 0,1 | 0,2 |
| **together** | | **1** | **3,8** | | | **1** | **4,3** |

Strengths outweigh weaknesses, which is a good sign that moving ecologically is a good idea. The environmental value associated with advertising is of the utmost value, because if the public learns about the company's greener intentions, interest in their flights may increase.

Among the negative aspects, the initial investment prevails, which we cannot avoid, but in the long run the profits may be higher.

It is clear from Table 3 that threats have the highest value of 4.3, followed by strengths of 4.2, followed by opportunities of 3.8, and weaknesses of 3.6.

Threats have the highest value because nothing is taken lightly in air transport and any change must be approved, either by the national transport authorities or even by higher aviation

organizations. It all costs time and money and these facts cannot be changed because safety always comes first.

Opportunities come with time and evolve, so the value we have calculated may change and may not be a decisive factor in adopting a new strategy.

### *5.6. PESTE analysis*

PESTE analysis is used to map the external factors affecting the operation of the company.

*Table 4: PESTE analysis*

| | | | | |
|---|---|---|---|---|
| Political | war | 0,4 | 5 | 2 |
| | pandemic | 0,3 | 3 | 0,9 |
| | political stability | 0,3 | 4 | 1,2 |
| Economic | inflation | 0,4 | 3 | 1,2 |
| | unemployment | 0,2 | 3 | 0,6 |
| | economic growth | 0,4 | 4 | 1,6 |
| Sociological | demography | 0,3 | 5 | 1,5 |
| | ethics and religion | 0,2 | 4 | 0,8 |
| | state precocity | 0,5 | 4 | 2 |
| Technological | technological innovations | 0,4 | 5 | 2 |
| | internet connections | 0,2 | 3 | 0,6 |
| | cybersecurity | 0,4 | 4 | 0,8 |
| Environmental | sustainability | 0,3 | 4 | 1,2 |
| | recycling | 0,3 | 4 | 1,2 |
| | pollution | 0,4 | 4 | 1,6 |

War as a political factor affects both the whole world and the aviation. An example is the current war in Ukraine, which has restricted airspace, airports, and destinations to which it is forbidden to fly. This causes flight cancellations or flight length extensions and therefore higher costs for the company.

The speed of economic growth of the state affects the construction of airports and infrastructure, on which the handling of aircraft depends, the time and quality of service. This means that if there are no separate waste containers at the airport, the airline unnecessarily separates the waste on board.

From a sociological point of view, the state's maturity weighs on society's perceptions of climate change, pollution, and environmental protection in general. If the state's maturity is low, the implementation of separation procedures will be even more difficult to implement.

Technological innovations determine the company's development in the future. Financial support for the development of new technologies helps the company to advance and compete in the market.

Environmental factors have about the same value because when it comes to the environment, all activities to protect it should have the same priority.

## 6. SUMMARY AND RECOMMENDATIONS

By analyzing the composition of the sales trolley, it is evident that plastic, glass, metal or paper waste is generated on board and other municipal waste generated by food residues and multi-component packaging.

Through a detailed analysis of operating procedures, we have identified that not only airlines, but also airport, catering and handling (and cleaning) companies are involved in reducing waste production in aviation. Their common goal should be to ensure that the operation is more environmentally friendly. If the airline adopts this strategy, it is important that it involves the other companies mentioned in this process, without which it is not possible to make successful progress in this environmental area. The airline itself must assess whether it has sufficient resources for this process, as the implementation of such a process requires significant investment.

External companies can also be included in the strategy, which will contribute to waste reduction and recycling with their knowledge. For example, by working with 3D printing specialists, recycled plastic can be used to make models of airplanes or other goods from which the airline will make profits. Using online questionnaires, the company can evaluate the interest of passengers, their observations, and ideas for waste separation. Later, with the help of modern innovative technologies (e.g. the use of AI), the company can simplify the separation or identification of waste.

Initially, we recommend to the airline to move to a new strategy by small but predefined steps. In the first step, only the backup of plastic bottles and metal cans can be introduced. These would be stored back in the trolleys. In this way, after some time, the company would find out whether the profits from the bottle advances are returning and could proceed with the introduction of further waste separation procedures.

## 7. CONCLUSION

The issue of sustainability in food waste management cannot be ignored indefinitely.

Nowadays, operating procedures do not consider waste and its impact on the environment. The aim of the diploma thesis was to evaluate the current operating procedures and create an annex including the separation of waste on board. We have found that up to 82% of the total products in the service trolley are recyclable. This is a high percentage of waste that ends up in landfills unnecessarily. In addition, the treatment of unsorted waste consumes a large amount of energy that could be used for other activities. By separating and using waste as a secondary product, we can reduce the extraction of minerals, reduce emissions, and reduce the amount of waste.

Through analyzes, we have found that even though the aviation is highly controlled for safety reasons, at least in small steps the company can gradually improve its efforts to fully achieve waste-free operation.

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