Impact of Digitization and Web Technologies on Supply Chain Integration in Aviation MRO

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Affidavit

I hereby affirm that this Bachelor's Thesis represents my own written work and that I have used no sources and aids other than those indicated. All passages quoted from publications or paraphrased from these sources are properly cited and attributed.

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Abstract

The aim of the following bachelor thesis is to investigate the key drivers of inefficiencies in the Aviation Maintenance, Repair and Overhaul sector; in other words, to find out what factors and characteristics of the industry cause delays in operations of MRO service providers and significant rise in their expenses. The paper would also attempt to explore how digitization of the supply chain - with an aid of modern technologies (Cloud Computing, Big Data, 3d printing, Internet of Things and Blockchain) could help solve these inefficiencies.

The paper is structured as follows. The first part would introduce the problem and research questions, followed by the Section 2 in which the methodology employed for this research is explained. Literature review portion of the paper starts by defining the MRO industry and providing more details in regards to the classification of the industry, its supply chain structure, approaches to inventory management etc. This is followed by explanation of previously listed technological configurations and discussion of their potential use in supply chain management. The next section of the paper is dedicated to a case study of an MRO service provider located in Serbia, which provides a real life example of one MRO organization and aims to gain more insight into company's thoughts on digitization. Lastly, the findings of the study would be discussed by providing the final remarks and addressing limitations of the paper, as well as suggestions for the possible future research in the field.

Key words: aviation MRO, supply chain management, digitization, Cloud computing, Big Data, Blockchain, 3D printing, Internet of Things

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List of Abbreviations

AHM – Aircraft Health Management

AM – Additive Manufacturing

AOG – Aircraft On Ground

ARSA – Aeronautical Repair Station Association

CAA – Civil Aviation Authority

CRM – Customer Relationship Management

CSP – Cloud Service Provider

DSC – Digital Supply Chain

EAM – Enterprise Asset Management

EASA – European Aviation Safety Agency

ERP – Enterprise Resource Planning

FAA – Federal Aviation Administration

IATA – International Air Transport Association

IoT – Internet of Things

JIT – Just-In-Time

MRO – Maintenance, Repair & Overhaul

MRP – Material Resource Planning

OEM – Original Equipment Manufacturer

PKI – Public Key Infrastructure

PMA – Part Manufacturer Approval

RFID – Radio Frequency Identification

RLT – Replenishment Lead Time

SUP – Suspected Unapproved Part

TAT – Turnaround Time

1 Introduction

1.1 Background

Management consulting agency Oliver Wyman published, in collaboration with IATA, a 10-year forecast for the air transport market in 2017. According to the results, global commercial fleet is about to experience considerable growth over the upcoming decade: from 25,000 aircrafts in the previous year to approximately 35,000 by the end of 2027. Asia, particularly China and India, would account for roughly 40% of that figure (Oliver Wyman, 2017). As for the general aviation sector, FAA (Federal Aviation Sector) estimates that there would be a significant increase in the usage of corporate jets and air taxis (Ukler & Gok, 2015). The key drivers of this growth in demand for air travel are: rising consumer income, significant deregulation of global air transportation, newly added routes as well as increase in international trade which fuels air cargo industry (Oliver Wyman, 2017). Due to this development of air transport sector, aircraft manufacturing would blossom, as well as global rivalry in transportation market. It would be crucial for carriers to retain their competitive advantage by offering punctual and state-of-art services to their customers. For this reason, aircraft fleet represents the prime asset for every airline company (Kashyap, 2012), which in turn increases the importance of the MRO (Maintenance, Repair and Overhaul) sector. In fact, the aircraft maintenance industry is expected to grow on average 3.8% annually, reaching the 104.2 billion dollars market value by the end of 2027 (Oliver Wyman, 2017).

1.2 Problem Discussion

While large air carriers usually operate their own maintenance facilities, smaller and low-cost airlines typically outsource such activities to a third-party MRO service provider since they do not possess a sufficient amount of resources to carry out the maintenance on their own (Ayeni et al., 2010). However, MRO supply chains of today are still trapped in a so called ‘silo effect’, especially in the case of outsourcing, which implies that there is not enough collaboration or information sharing among different parts of the chain - the aircraft operators, MRO provider and suppliers (Buyukozkan & Gocer, 2018). This lack of integration might pose some difficulties: In order for all parties to gain benefit, fleet schedule of an airline and overhaul

9schedule of its MRO provider must be aligned which might not always be possible. Apart from coordination issues, outsourcing also requires transportation and handling which typically results in increased supply chain complexity (Boon, 2004). From MRO organization's perspective, in order to satisfy the client, work has to be completed as fast as possible while retaining the demanded level of service quality. However, due to the nature of the business, these MRO organizations typically face issues such as unpredictability of spare parts demand, fragmented supply base, excessive safety stocks etc. (Khandelwal, n.d.). On top of that, considering that this is technological field dependent of the engineering innovations, the MRO sector also experiences constant changes which could have an impact on their supplier network and the way daily operations are performed.

Nevertheless, recent developments in sophisticated technology such as: Cloud Computing, 3D printing, Big Data, Internet of Things or even blockchain might pose a solution for MRO supply chain inefficiencies in the future and improve the integration from the supplier all the way to the end customer which would essentially improve the service quality level and reduce the TAT (Turnaround Time) for an aircraft that is a subject to maintenance.

These issues have led to the following research questions:

1. What are the main drivers of inefficiencies in the aviation MRO industry?
2. How could digital solutions help correct these inefficiencies?

1.3 Aim and purpose of the paper

The use of information systems in supply chain management, particularly in aviation MRO, has been a practice for several years now (e.g. ERP systems), but new state-of-art web configurations that have emerged on the market relatively recently, mentioned in the paragraph above, have not been put to much use yet. Utilizing smart technology is still largely unexploited area and there is not much scholarly research conducted on this topic (Rai et al., 2006). Thus the aim of this research is to identify the specific issues within the aviation MRO supply chain as well as their source, and to examine how digitization could potentially be utilized in order to improve integration within aviation MRO and solve the identified problems.

2 Methodology

2.1 Approach

Considering the fact that the topic of total digitization in the aviation MRO field is still a relatively new phenomenon, the most appropriate approach to the presented research problem would be a qualitative study that seeks to explore research questions further and provide better understanding of the topic.

In general, according to Marshall and Rossman (2006), qualitative research methods are increasingly being used in social sciences and applied fields, such as management. This type of research is defined as interpretative and pragmatic, meaning that it largely relies on practical experience rather than theoretical aspect. Another important characteristic of a qualitative approach in studies is the fact that the course of the research is usually not predetermined, but rather emergent, which implies that it evolves along the way and may change its initially expected direction (Marshall and Rossman, 2006).

The paper begins with an overview of secondary research conducted by academics and industry experts on the topic of Aviation MRO and supply chain digitization, in order to gain more insight into the matter and as a preparatory step for the empirical part which focuses on primary data collected in a case study based on a third-party MRO service provider located in Serbia. Case study allows in-depth investigation of a topic from multiple perspectives, but it is set in a 'real-life' context. Its purpose is to provide deep understanding of professional practices, systems, organization's processes etc. (Simons, 2009). This approach is very flexible, that is, it is "neither time-dependent nor constrained by method" (Simons, 2009, p. 23). In other words, multiple different methods could be utilized to obtain data during the case study. Data collection techniques that are most frequently employed are: interviews, observation and document analysis. In-depth interviews are typically performed in an unstructured or open-ended manner. The main reason why interview is largely preferred instrument for data gathering is the fact that it can often unravel events or information that could not be seen through simple observation. In addition, interviews are flexible and they give researcher an opportunity to understand the topic from a different point of view (Simons, 2009).

An accompanying technique frequently used in conjunction with the interviews is observation of processes, interactions, surrounding etc. There are two types of observation: direct, where the researcher acts as a passive observer; or participant, where he/she takes an active role in a case study, for instance becomes a temporary employee (Yin, 2003). Observation gives an inclusive picture of the organization that is a subject to the study, but it also allows the researcher to assess how organizational culture, norms and communication may affect the problem being studied. What is more, it could also serve as a check for the validity of data collected during the interviews, therefore making an observation a solid foundation for further interpretations of the findings (Simons, 2009). Last component of the case study is document analysis. This could range from formal documentation which involves annual or audit reports, vision and mission statements, regulations etc. to informal documents such as memos, newsletters and so on. Although this approach is not as widely used as the previous two, it could still assist the researcher in gaining better understanding of the organization and its practices (Simons, 2009).

2.2 Research Procedure and Data Collection

Literature used for conducting the secondary research consists primarily of academic journals retrieved from Google Scholar, Science Direct and Emerald Insight databases, as well as books and several different industry reports published by leading global consulting agencies such as Capegemini, PWC and Deloitte. The literature review is followed by the empirical research, which is, as stated, based on a case study performed on a maintenance company “GAS Aviation” located in Serbia. It is not a study of the organization as a whole, but rather with a focus on specific issues in its supply chain, particularly the following: procurement of spare parts and other components, inventory and warehouse management, work orders management, AOG handling as well as relationships that the company maintains with its suppliers and customers.

The first step in the case study would be a documentation analysis. Some of the archival records (such as work orders etc.) would be reviewed alongside the company’s exposition - a file with comprehensive descriptions of business operations and practices, which is required by EASA since “GAS Aviation” is a holder of the EASA.145.0713 certificate. The purpose of the documents review is better preparation for the interviews.

Interviews would be conducted with the following employees:

Zeljko Ivosevic – general manager

Nikola Lukic – quality manager

Marija Matovic – logistics manager

Stefan Dabic – mechanics

The questions would vary depending on the interviewee and his/her job position. All the interviews would be executed in an open-ended and semi-structured manner, meaning that some of the questions would be prepared in advance - prior to the interview session; however, new questions would naturally arise as the interview progresses further in order to gain better understanding of the topic that is a subject of discussion. Three interviews would be executed in person, while the two remaining ones would be performed via Skype. Questions covered during the interview could be found in the appendix at the end of the research paper.

Apart from interviews, participant observation would also assist in getting to know the physical environment in which the company operates: hangar, office space and warehouse setting, as well as employee behavior and interrelationships, communication between different departments of the company and the overall company culture which may affect the daily activities that are the essential part of the organization.

2.3 Data analysis

The process of qualitative data analysis is significantly different and less straightforward in comparison to analyzing the quantitative data. According to Miles and Huberman (1994) there are essentially three different steps that comprise the proper analysis of qualitative data: data reduction, data display and conclusion drawing/verification (as cited in Walliman, 2004., p. 189). Data gathered using the qualitative data collection techniques is usually unorganized, redundant and difficult to work with in its 'raw' form which is why it is necessary to filter through the collected information and segregate the parts which are relevant for answering the research questions. The following step is compiling the corresponding data from various sources into groups based on their content. By classifying data in this manner, researcher has the ability to detect patterns, themes and gather more insight. If possible, data could even be showcased using a diagram or a graph to help the researcher illustrate the point and draw justifiable conclusions (Walliman, 2004).

2.4 Limitations of the method

As it is the case with any research methodology, qualitative research, particularly case study, has its limitations worth criticizing. Although interviews tend to be focused and insightful, there are several issues associated with this data collection approach: bias that may arise due to inadequately constructed questions, response bias, reflexivity – "interviewee gives what interviewer wants to hear" (Yin, 2003, p. 86), inaccurate or inadequate formulation of the answer etc. Furthermore, the biggest problem when being involved in participant observation process is that the researcher may become a part of the organization that is a subject of the study, which may result in biased opinions and findings. Nevertheless, it provides him/her with a unique opportunity to see things from another perspective, observe events and gather information that normally cannot be accessed through the direct observation investigation (Yin, 2003).

3 Literature Review

3.1 Defining Aviation MRO

Aviation MRO (Maintenance, Repair and Overhaul) sector could be defined as a service industry responsible for performing the following activities: scheduled checks that involve inspection and determination of the aircraft's condition, as well as modifications and overhaul of separate components such as: landing gears, braking systems, wheels, hydromechanical components, electronic components etc. (Ayeni et al., 2011).

The key difference between general machinery and aircraft maintenance is the fact that the latter is obligatory, but also highly regulated and controlled by aviation authorities such as FAA, EASA, CAA etc. "The concept of 'break-fix' which is common is general plant and machinery maintenance, is not applicable to aircraft." (Sahay, 2012, p. 5). For obvious reasons, in the aviation sector maintenance activities are more of preventative nature. Regulatory compliance is in the foundation of the aircraft maintenance, which implies that it ought to be performed in the same manner no matter where the MRO provider is located (Sahay, 2012).

In case of the airline-owned MRO services, the key customer is naturally the airline itself. Other maintenance companies typically work with low cost and small air transport providers, as well as different leasing companies. Occasionally, however, big airlines that typically have their own maintenance facilities would still collaborate with an independent MRO organization to take advantage of a location, since they cannot afford to have their own employees set at every hub or airport where they operate; or in case they are searching for special services that would be too expensive to perform on their own (Sahay, 2012). Another area that is a subject to maintenance, and represents a niche market in these services, is general aviation sector. GA includes aircrafts used for business traveling, recreational flying, instructional flying, as well as aerial work, such as: agricultural aviation, patrol, rescue, photography, surveying etc. (ICAO, 2009).

There are two basic maintenance levels performed on aircrafts, regardless of their type and size:

CHECKS	APPROXIMATE FEREQUENCY	ESTIMATED DURATION
Pre-flight/Gate	Every departure	40-60 minutes
Turnaround	3-5 days	Overnight (up to 90 minutes)
A check	Roughly 125 flight hours (two to three weeks)	Overnight
B check	750 flight hours (three to four months)	Overnight
C check	3.000 flight hours (every 15 months)	3-5 days
D check	20.000 flight hours (six to eight years)	1 month

Figure 1: Types of maintenance activities (based on Wensveen, 2007)

1. <u>LINE maintenance</u>

"This function involves the routine maintenance of the aircraft." (Ayeni et al., 2011, p. 2110). In other words, it is performed while the aircraft is still operating on the assigned fight schedule. Within this category, airlines differentiate between 'gate', 'turnaround', A and B maintenance.

- *Gate:* simple visual checkup as well as brief inspection of the vehicle to ensure that there are no external damages or leakage that could be potentially fatal (Hessburg, 2001 in Boon, 200 (ups, 2015)4).
- *Turnaround:* it is generally conducted at the end destination of an aircraft's schedule; it includes basic servicing and minor repairs if necessary (Boon, 2014). "Workers conduct a 1-11/2 hour inspection to ensure that the plane is operating in accord with the original equipment manufacturer's (OEM's) minimum equipment list (MEL)." (Wensveen, 2010; p. 229)
- *A-check:* It includes the examination of the general condition of an aircraft which involves the inspection of electronics (avionics), power plant and the main body (fuselage). It is usually limited to visual examination. (Wensveen, 2010).

- *B-check:* It incorporates A-check procedures as well as more detailed inspection of the airframe and some preventive maintenance: engine oil analysis, removal and inspection of oil filters, lubrication of parts as required by the manual etc. (Wensveen, 2010).

2. BASE maintenance

In order to conduct base maintenance, an aircraft has to be temporarily withdrawn from its schedule and transported to hangar within MRO facilities for a detailed checkup (Boon, 2014). Base maintenance is considered 'heavy' maintenance and therefore requires excessive downtime for an aircraft (Wensveen, 2010).

- *C-check:* "Components are repaired, flight controls are calibrated, and major internal mechanisms are tested" (Wensveen, 2010; p. 230). Apart from the previously indicated tasks, during the C-check, workers are obliged to perform corrosion prevention, compressor washes, intense lubrication etc. which would approximately take up to 5 days, depending on the size of the aircraft (Wensveen, 2010).
- *D-check:* This is the most rigorous form of maintenance which essentially implies reassembling an entire aircraft after it has been deconstructed for maintenance purposes. All elements of the aircraft's interior, such as seats, lavatories, cockpit etc. are removed in order to facilitate the detailed inspection of the structural components, as well as fuel systems and flight controls. Due to the intensity of the procedure, an aircraft would typically remain unoperational for a month or even longer if there are any additional repairs that ought to be performed (Wensveen, 2010).

As technology keeps advancing and aircraft types become more diverse and sophisticated, there is a growing need for specialization in the MRO. Hence, MRO organizations could be classified into the following categories: heavy-maintenance, line maintenance (routine checks), engine overhaul, component overhaul, avionics, conversions (Ayeni et al., 2011).

As far as the organizational structure is considered, all MRO organizations belong to one of the two categories:

1. Independent/third-party MRO providers
2. Airline-operated-and-owned

Typically, bigger carriers that have been present in the industry for a considerable amount of time and hold a large portion of the market share, would have their own MRO facilities set at important locations (Ayeni et al., 2011). Examples would include carriers such as American Airlines or Lufthansa. This allows them to have better control over maintenance activities and safety of their fleet, while ensuring even flow of processes throughout the supply chain (Boon, 2004).
On the other hand, smaller companies and low-cost carriers would generally outsource such services due to the fact that establishment of MRO branch requires a great deal of expertise and capital (Ayeni et al., 2011). With an increase in competition in the air transport sector, companies were forced to lower their prices and focus on building a strategy for the purpose of increasing their market share. With that in mind, majority of airlines, especially the new ones in the market, could not afford to spend too much capital nor effort in the maintenance department, while neglecting their core activities. Outsourcing became a perfect solution for that problem (Sahay, 2012). Furthermore, third party MRO providers are able to achieve economies of scale for a considerable amount of their tools and facilities because they have a tendency to combine work contracted from a variety of different clients across the market, which in turn results in lower competitive prices. This implies that it is, indeed, more affordable for airlines to outsource maintenance activities since it would lead to cost reduction in the long run (Boon, 2004). OEMs (Original Equipment Manufacturers) share the same advantage. In the last few years, OEMs have entered the MRO market. “OEMs are offering packages the extend beyond the warranty of purchased products to include complete service package that deals with the maintenance, servicing, and spare-part replacement over a fixed time period.” (Ayeni et al., 2011, p. 2111) However, majority of these OEMs still do not provide the repair services for the entire aircraft, rather for separate components, such as

engine, e.g. General Electric, Pratt & Whitney, Rolls Royce etc. (Goh, 2003 in Boon, 2004).

3.2 Supply Chain in Aviation MRO

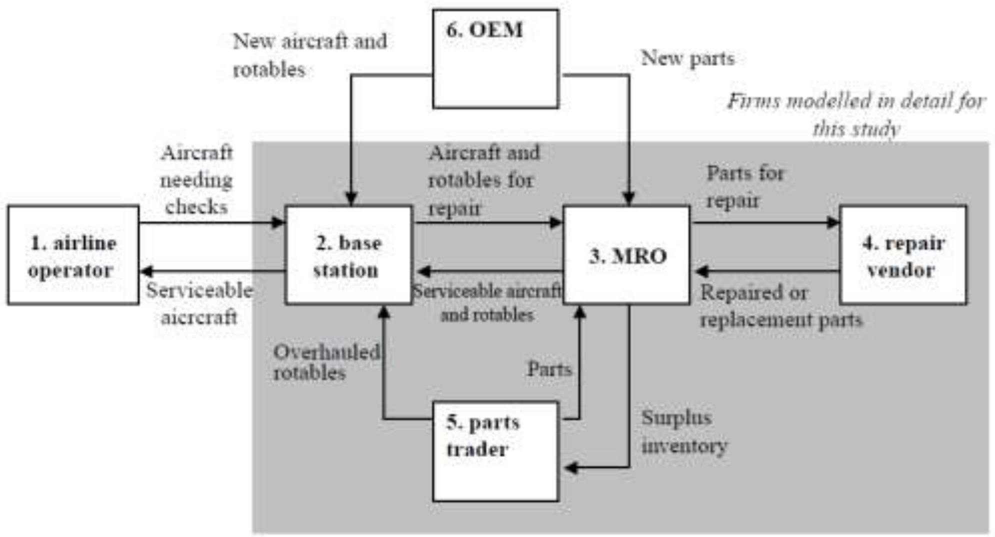

Figure 1: The aircraft MRO supply chain reference model (MacDonnell & Clegg, 2006, p. 142)

Supply chain of a typical MRO organization consists of three following streams:

1. Aircraft/airframe parts
2. Engine parts
3. Individual aircraft components (wheels & brakes, avionics, auxiliary power units, fuel systems, landing gear, flight controls, hydraulic power systems, electrical equipment)

For the purpose of the simplicity, they are referred to as 'parts' in the diagram.

The system displayed in the figure above is demand-driven, which implies that customer demand essentially triggers all the transactions between the organizations involved in the supply chain (Rainbird,2004 in MacDonnell & Clegg, 2006). One of the main features of aviation MRO supply chain is the physical flow of materials which occurs in two directions. Apart from the regular service provider to consumer flow, MRO is characterized by the so-called reverse logistics, where customers send their goods (known as ‘rotable items’) back to their suppliers for the overhaul purposes (Hayek et al., 2005 in MacDonnell & Clegg, 2006).

MRO service providers have three primary sources for spare parts procurement:

- **OEMs:** Manufacturers that produce the aircrafts would generally offer their original parts used for aircraft assembly for sale in the spare parts market. This makes them accessible for third-party MRO providers around the globe (ARSA, 2013).
- **PMA (Parts Manufacturer Approval)** holding manufacturers are companies that are approved by government agency, such as FAA, to design and produce replacement parts that could be used for installation or maintenance purposes despite the fact that they do not hold original manufacturer license (FAA, n.d.).
- **Surplus dealers:** Certain MRO providers would sell out the spare parts they no longer need for their daily operations in order to get rid of excess inventory which ties the capital and takes space in their warehouses. However, compared to the previous two sources, surplus dealers are rather small since the material flow is very limited. The exception are difficult-to-find parts or components needed for older aircraft models for which new spare parts are no longer produced by the original manufacturers (ARSA, 2013).

On average, MRO service providers would collaborate with 10 to 15 different suppliers. Nevertheless, in real life setting, majority of companies would not place orders directly from the OEM, but would rather do so from official distributors in close proximity to their facilities. Distributors (indicated as ‘parts trader’ on the diagram) are important intermediaries in the MRO supply chain considering the fact that spare parts manufacturers are mainly located in the North America and China. In other words, large distributors would consolidate and store parts from a variety of different producers and make them rapidly available for the MRO organizations located in the same geographic region (ARSA, 2013).

Just like the maintenance companies strive to achieve long-term contracts with suppliers, the same holds true for their customers. Having a contract with four to five big customers guarantees the revenue and it certainly makes the process of planning and scheduling considerably easier. In some cases, smaller organizations would even have a contract with larger MRO providers and take part in their work during the high demand season (Sahay, 2012).

3.3 Inventory in Aviation MRO

3.3.1 Types of Inventory

Classification of the airframe inventories held in an MRO warehouse is done based on the three factors which include: *scrap value, life cycle and financial status.*

3.3.1.1 Rotable Inventory

The scrap value for rotable inventory is considerably low or even trivial which implies that these items could be reused in other MRO activities for years to come. Their depreciation pattern typically follows the life cycle of the aircraft to which an item belongs to. In fact, rotables usually become unserviceable as a result of incident related events, such as foreign object damage, poor removal, ground damage on the aircraft etc. These items typically impose high costs for MRO organizations, hence, even in the case of failure, they would be repaired rather than simply replaced because this is more economically feasible solution for the majority of companies. Some of the spare parts that would be considered rotable are: hydraulic and fuel pumps, flaps, wheels, breaks etc. (IATA, 2015)

3.3.1.2 Repairable Inventory

Repairable inventory are items that have slightly higher scrap value compared to the previous category which suggests that such goods could be used for a significantly long time span; however, after certain period has passed they have to be replaced with a new item. Goods such as: oxygen bottles, any types of batteries, fire detectors, electric starters etc. would be classified as repairable.
Break-point between a rotable and repairable item is decided upon economic analysis conducted by a vendor and it is clearly mentioned in the contract since this information is vital for MRO inventory planning activities. In case Replenishment Lead Time (RLT) stretches out for an excessive period of time and there is heavy maintenance performed on an aircraft, the supply of repairable materials has to be monitored carefully in order to avoid possible stock-outs.

In terms of financial status of this type of inventories, it is identical to the rotary category (IATA, 2015).

3.3.1.3 Expandable Inventory

Expandable inventory is the type of inventory with absolute scrap value, which implies that these items have to be replaced after each use - the possibility of reuse is not feasible in this case. Items such as connectors, lamps, switches, terminals etc. would be an example of expandable goods.
Most of the MRO organizations would decide on the quantity of expandable items based on the data on previous usage and add a certain percentage as a safety stock. However, as it has been previously remarked, due to rapid changes in technology, some of these spare parts may quickly become obsolete and therefore useless, which results in a tremendous financial loss for the company. For this reason, managers would typically rely on sophisticated statistical and mathematical models when sourcing these goods and on inventory management strategies such as inventory pooling or consignment inventory (IATA, 2015).
"Financially, expendables are usually expensed at the time of the use or issue." (IATA, 2015, p. 24).

3.3.2 Most common Approaches in Inventory Management

Inventory management is, as it has been stated before, one of the crucial issues in MRO day-to-day operations and because of that, there has been a lot of research within academic and business circles. It is of high importance for organizations to understand the data around their inventory: what are the critical components that ought to be available at all times, what are the slow and fast moving items, the supplier performance for each type of inventory unit etc. (Baiju, 2017). The following are the three basic approaches used for inventory management with MRO providers (Boon, 2004).

3.3.2.1 MRP (Material Resource Planning)

MRP is a system that relies on "a master production schedule, a bill of materials listing every item needed for each product to be made, and information on current inventories of these items in order to schedule the production and delivery of the necessary items" (Womack and Jones, 1996 in Boon, 2004, p. 62). Apart from BOM and production schedule, these systems also incorporate data related to physical capacity of the MRO facility as well as financial planning tools. Orders are further made based on past experience (e.g. component lead times, breakdown rates etc.) and predicted demand which implies that the MRP system relies heavily on forecasts (Boon, 2004). Naturally, the more accurate the forecasts are, the less money is spent on safety stocks of the components and the Turnaround Time for an aircraft is lowered as well, which in turn, increases customer satisfaction.

However, depending on the type of MRO business and the area they specialize in, the number of different components in the warehouse could be huge. This intensifies the complexity of making precise forecasts drastically since management teams has to assess the demand for each individual spare part (Boon, 2004).

3.3.2.2 JIT (Just-In-Time)

In essence, JIT system relies on principle that the right parts, in the right quantity should be available for use at the right time (Womack et al., 1990; Womack and Jones, 1996, in Boon, 2004). According to JIT, inventory in stock is considered a waste of money, and should therefore be eliminated. However, suppliers in the MRO sector are unable to deliver the spare parts immediately upon receiving an order, which means that lead time of a zero cannot be achieved. As long as the lead time is higher than zero, inventory has to exist, but it should be minimized (Boon, 2004).

In order to make the JIT system work, inventories should be obtained based on the demand (PULL approach) and infrastructure of the supply chain ought to possess high-velocity. If suppliers are able to deliver the components at the high speed right after receiving an order from an MRO firm, not only would inventory (safety stock) requirements be reduced, but also the entire system would be less impacted by possible fluctuations in demand. Furthermore, MRO organizations are advised to find suppliers in close proximity to their facilities since this could positively affect the responsiveness of the suppliers and reduce overall turnaround time (Boon, 2004).

3.3.2.3 Theory Of Constraints

In MRO daily operations, there are multiple activities that occur simultaneously. However, some of them may take longer to complete which suggests that the rate of these activities affects the final processing time. Such activities are usually referred to as 'constraints' or 'bottlenecks'. What this theory basically argued is that inventory should not be regarded as complete waste. Instead, buffers ought to be kept for the purpose of speeding up the constraint activities to minimize delays. For any other processes that do not fall under category of bottlenecks, inventory should be eliminated (Boon, 2004).

3.3.2.4 Alternative Inventory Sources

Practices used to compensate for shortages in supply are cannibalization and lateral supply. In extreme cases, when companies absolutely cannot afford to wait for spare parts to arrive, they would typically remove required component from another aircraft to use it in repair of another piece of equipment. This procedure is known as cannibalization. Lateral supply, on the other hand, refers to obtaining missing components from other similar organizations (Boon, 2004).

Although these approaches are well designed to solve problems in the last minute, they do have several negative consequences. First and foremost, the potential for mechanical side effects and risk of error are increased significantly, as well as overall workload. However, the biggest disadvantage is the fact that the aircraft or equipment used to make up for missing parts remain non-operational for a longer period of time (Boon, 2004).

3.4 Drivers of Inefficiencies in Aviation MRO Supply Chain

1. Silo effect

Aviation MRO supply chains of today are characterized by the so called "silo effect", meaning that there is no sufficient coordination of activities and information sharing between departments. Functional and geographical siloes result in performance that is below firm's capacity (Buyukozkan & Gocer, 2018). This, in turn, could cause a lot of issues. For instance, repairable and rotable inventory holds a lot of value for a maintenance provider, therefore, it is less costly to repair these items once they are out of service instead of discharging them and buying new ones. However, in order to complete this process properly procurement, technical and engineering department have to work collaboratively and have an access to the same real-time information which usually does not occur causing certain aircraft components that had a longer life cycle ahead to be disposed of, consequently increasing inventory costs (IFS, 2017). Another example of a common issue which arises from the lack of integration is the warranty accessibility. Technical staff does not have an access to information in regards to which spare parts are still under warranty. Because of the lack of communication with the procurement department, components would often be sent to overhaul at cost, although it was not necessary. From the procurement perspective, the manager does not know the maintenance specifications given to each individual component which are necessary in order to make a warranty claim with a vendor or an OEM. As a result of inadequate communication between departments, company faces a cost (IFS, 2017).

2. Demand unpredictability

There are two basic forms of maintenance: *scheduled* - performed at pre-set intervals as a measure of prevention and *unscheduled* - occur in case of unexpected aircraft breakdowns (Lee et al., 2008). Regardless of the case, spare parts and material required for the overhaul purposes have to be accessible at all times with no delays, since it is in the airline's best interest for their aircrafts to become operational again as soon as possible. However, in most situations, mechanics would not be familiar with the repairs that would have to be performed on the aircraft prior to its physical arrival to MRO facilities. Even if an aircraft or a component come with a planned work package, once the work starts new issues arise in nearly 100% of the cases (Sahay, 2012). This implies that it is exceptionally difficult to predict the demand for the majority of the components kept in the warehouse and strategies such as JIT delivery of supplies would not be possible to achieve. Such demand unpredictability and ineffective planning causes problems in inventory management:

- Excessive safety stocks which tie an immense amount of capital
- Higher level of inventories that are not moving or have become obsolete – loss of capital
- Lack of needed components – increase in TAT (Turnaround Times)
- Lower service levels due to delays caused by components with long procurement cycles

(Khandelwal, n.d.)

Since the majority of MRO service providers make unplanned and certainly non-essential material purchases, they would typically face high administrative and overhead expenses along with the issues listed above (Gueritz, 2001 in Basak, 2016) What is more, in the case of missing components, when companies ought to make last minute emergency purchases, occasionally they would have to choose non-preferred suppliers resulting in the higher cost of purchase (Rahim, 2008 in Basak, 2016).

3. Fragmented supply base

Due to a high number of different spare parts that circulate through aviation MRO processes, many organizations are forced to source their inventories from multiple different suppliers. Since aircraft manufacturing is rather very specific and legally constrained, there are not many OEMs of such parts. This implies that MRO organizations have their suppliers scattered around the globe which is both complex to manage in terms of material, information and financial flows (Rai et al., 2006), but may also result in increased lead time because of the large distance. This decentralized procurement process leads to restricted chances of influencing the suppliers in order to achieve the most favorable prices and conditions (Khandelwal, n.d.).

4. Slow and cost-ineffective transactions

In case of spare parts procurement, organizations would generally have to import their inventory from suppliers located in other countries. Import implies a rather complex exchange of trade documentation between a buyer and seller: shipping documents, certificates, bills of lading, air waybills etc. which are typically interchanged using the 'computer-paper-computer' manual model. The reason behind this is the fact that these crucial documents are generated using the seller's information system which is more often than not compatible with the buyer's system. Thus, seller's documentation that is sent in paper or electronic format has to be entered into the buyer's system either manually or via scanning the original which is certainly not time efficient. On top of that, apart from the indicated two parties, import of spare parts involves two more organizations: a bank and customs, which in turn makes the entire transaction process very slow and cost-ineffective (Korpela et al., 2017).

5. Constant changes and improvements

Generally speaking, MRO is the field that is constantly experiencing changes, not only in the way business operations are conducted, but also in terms of materials, parts and suppliers companies are working with. This comes only natural considering the fact that technology keeps advancing persistently which in turn brings modifications into the structure of the aircrafts and the way they are maintained. Therefore, MRO organizations have to frequently ramp up their inventory, facilities and technical infrastructure, as well as staff members through technical training, to be able to respond to current demand. Simultaneously, the management team has to decide when is the right time to stop providing services for older aircraft models that are slowly becoming obsolete. In other words, due to these constant changes and dynamic environment, MRO organizations are assuming great financial risk (ups, 2017).

6. Counterfeit parts

"The counterfeiting strategies are increasingly sophisticated as in many cases counterfeiters apply the same technologies and use the same suppliers as legitimate brands" (M.S.& J. Busby, 2015 as cited in Madhwal & Panfilov, 2017, p. 1052). In some cases, subcontractors would produce spare parts that are nearly identical to the original products. These would typically be distributed in the bundle with the genuine aircraft components in order to make the illegal actions more difficult to detect. Due to the overall low levels of integration and transparency in the supply chain, maintenance service providers would usually lack information and control of events below their second tier suppliers. This implies that it is often strenuous and nearly impossible to track the spare parts from the point of origin to the point of their consumption in MRO practices. In turn, this may potentially cause issues within both military and civil sectors of aviation industry, as illegally manufactured components sold in the black market carry a large risk in regards to operational safety of aircrafts (Madhwal & Panfilov, 2017).

3.5 Digitization in Supply Chains

One of the biggest changes that has occurred in the modern economy is that companies no longer compete individually, but rather as a network of several organizations forming a supply chain which is striving to deliver goods or services to their customers as efficiently and quickly as possible, with the lowest achievable costs (Patnayakuni et al., 2002). This has driven business consulting agencies and researchers to seek diverse ways of optimizing supply chains by using modern technology.
This is where the discussion about digitization comes in: "The term digitization refers to the extent to which supply chain activities and transactions are conducted online – captured, transmitted and cascaded in a digital form" (Patnayakuni et al., 2002, p. 1016).
However, as technology is advancing, 'going digital' is no longer a mere question of optimization, it is also becoming a necessity. Companies that want to collaborate with others and remain competitive in the market are under pressure to follow the pace of innovations (Deloitte University Press, 2017).

Digital Supply Chain is "a smart, value-driven, efficient process to generate new forms of revenue and business value for organizations and to leverage new approaches with novel technological and analytical methods. DSC is not about whether goods and services are digital or physical, it is about the way how supply chain processes are managed with a wide variety of innovative technologies" (Buyukozkan & Gocer, 2018, p. 157).
Thus far, there has been limited academic investigation dedicated to digitization of supply chains (Rai et al., 2006). Nevertheless, an increasing number of researchers and scholars are starting to explore this field as society has stepped into the fourth industrial revolution - Industry 4.0 (pwc, 2017).
Digital transformation in the supply chain has begun with digitizing internal activities within a single organization and its departments. Configurations such as ERP (Enterprise Resource Planning), Human Capital Management or systems which enable firms to manage their financial and accounting records represent great examples of early stages of digitization. The next step in supply chain transformation was forming the connection between an organization and its customers in order to

satisfy their demands more efficiently. This was achieved through CRM systems (Customer Relationship Management), POS systems, E-commerce etc. The last step towards the complete transformation is, naturally, to integrate and connect all of the partners and members that comprise a value chain of the particular organization, using the help of modern technology (Capgemini Consulting, 2016).

Integration framework in Figure 2 proposed by Buyukozkan and Gocer (2018), suggests that in order to achieve a Digital Supply Chain (DSC) companies ought to make changes in 3 different fields: Digitalization, Supply Chain Management and Technology Implementation. To be able to digitally transform an organization, managers and executives would have to think of a detailed strategy for going digital, since this is quite a lengthy process that requires planning and goal setting. Strategic planning also involves altering organizational structure and its culture to fit the new business model, as well as thinking of different ways how to digitize daily operations, products/services offered and customer experience. Technology Implementation refers to attaining a proper infrastructure that would facilitate the digitization process through different technology enablers (IoT, Cloud computing, Big Data etc.). In favor of reaching a sufficient level of technological development, a company has to invest into proper project management that would guide the implementation of digital solutions, including training of the existing staff. Lastly, an organization has to think of the reconfiguration of its existing supply chain network and enhancing its processes (e.g. sourcing, delivering etc.) through automation, integration and use of data analytics (Buyukozkan & Gocer, 2018).

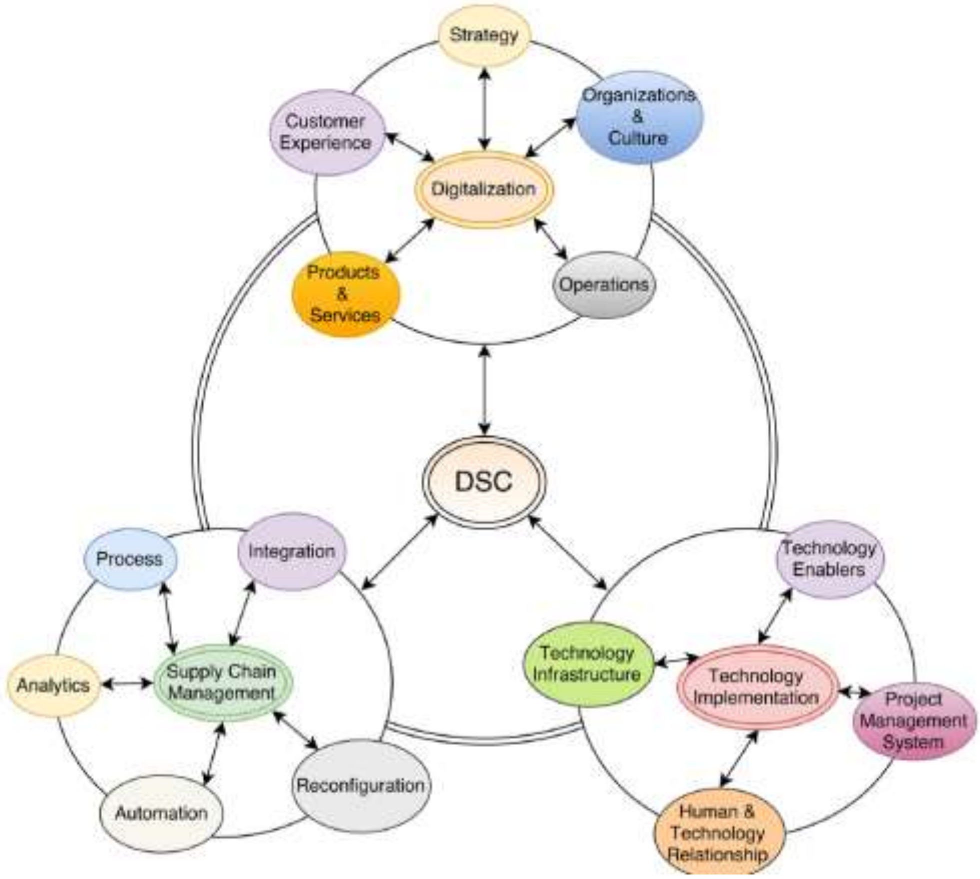

Figure 2: Integration framework for the development of DSC (Buyukozkan & Gocer, 2018, p. 170)

Despite the fact that this idea of complete supply chain digitization has been a buzzword in consultancy for a considerable amount of time, it has not been executed yet due to lack of awareness and knowledge among business executives and leaders, but most importantly inadequacy of past technology that would support this ambitious idea. However, in recent years digital technologies have experienced major alterations due to three important improvements: less costly bandwidth, more affordable storage and reduced computing costs (Deloitte University Press, 2017).

Firms are already investing into digitizing the basic functions which are part of their internal vertical and horizontal value chains. A global study conducted by Capgemini Consulting Group in collaboration with GT Nexus in 2016, surveyed 337 executives from 20 different countries in regards to their efforts and investments towards supply chain digitization. The study has revealed that, in fact, 70% of the respondents have already developed strategies that address the digitization issues (Capgemini Consulting, 2016). Nonetheless, other research has shown that even those organizations that have been putting effort into digitization, mainly focus on intra-organizational activities and outbound logistics which implies that there is more emphasis on servicing the market. Consequently, inbound logistics remain neglected despite the fact that digitizing this area could not only cut the expenses significantly, but also improve the efficiency of the entire downstream supply chain (Patnayakuni et al., 2002). Previously mentioned research has shown that nearly half of the respondents (48%) still rely on traditional means of communication with their suppliers, such as email, phone, even fax. This could explain why majority of surveyed companies (52%) have little to no access to data from the other parts of the supply chain.

Overall, it is apparent that the progress towards total digitization of supply chains does exist, but it is rather slow. In fact, 33% of the Capgemini survey participants have indicated that they are extremely dissatisfied with the progress made so far, but have also stated that they expect the digitization to escalate rapidly within the following 5 years, hence, they want to be prepared (Capgemini Consulting, 2016).

3.6 Traditional VS Digitally Enabled Supply Chains

Majority of the companies today have rather fragmented traditional supply chain, where different stages are “siloed” and largely disconnected (pwc, 2017). This type of supply chain is also known as linear since the “chain of events is linked in a very structured way: develop, plan, source, make, deliver, support” (Deloitte University Press, 2017). In industrial sector most supply chains operate on the, so called, hybrid model, which means that its structure uses both traditional paper-based approach as well as limited IT supported procedures (Deloitte University Press, 2017).

Supply chains that are digitally enabled are, compared to traditional linear supply chains, more superior in the following areas:

Transparency: Each entity in the chain could have a complete overview of real time activities performed online, which is not the case in the traditional supply chain format (pwc, 2017). This absence of visibility often results in lack of an organization's ability to properly react or adjust to activities of other members that might have disrupted the performance of the entire chain simply because the managers were not aware of the changes on time. Transparency would allow organizations to create what-if scenarios and be prepared because they have the possibility to track the current activities in the chain (Buyukozkan & Gocer, 2018). Digital supply network would thus help solve this delayed action-reaction process by utilizing sensors and location-based technologies which would help in keeping all the supply chain members informed about current material flow, schedule synchronizations, ongoing financial flows and other key aspects of the supply network. (Deloitte University Press, 2017).

Communication: All members would be able to communicate simultaneously, without unnecessary delays caused by passing information from one entity to the other (pwc, 2017). Communication between organizations is at the heart of supply chain transformation considering that majority of companies nowadays still rely on traditional communication methods which could be extremely inefficient as this approach may result in significant amount of errors and false information (Capgemini Consulting, 2016). By connecting all the relevant parties: suppliers, partners, dealers etc. within one centralized network and enabling constant communication, it would be ensured that every entity is working with the same data when making important decisions (Deloitte University Press, 2017).

Collaboration: Due to lack of connectivity and transparency, collaboration between members of the chain was difficult to achieve in the traditional supply chains, which is overcome in digitized world (pwc, 2017). "Inefficiencies in one step can result in cascade of similar inefficiencies in subsequent stages" (Deloitte University Press, 2017, p. 6). However, once organizations are interconnected, such scenarios are less likely to occur since the network would be enabled to collaborate and make decisions as a whole system in order to achieve the best possible results for everyone.

Flexibility and Responsiveness: Digital solutions enable organizations to assess changes in demand and respond to them rapidly, while this data usually gets distorted in the case of linear networks which in turn often causes unnecessary delays (pwc, 2017). Linear supply chains depend on periodic forecasts that in today's fast-moving economy quickly become out-of-date and therefore inaccurate. With real-time data available at all times, digitization would diminish latency and risks associated with traditional supply network configurations. In other words, constraints of space and time would be considerably reduced (Deloitte University Press, 2017).

Intelligent optimization: Centralized data sources would be used to in order to establish learning culture within the network by combining the following elements: human resources, machines and data-driven analytics (Deloitte University Press, 2017). In the far future, there is a possibility that smart devices would possess sufficient computing power to achieve automated decision making which would be based on algorithms (Buyukozkan & Gocer, 2018). There is an array of different concepts related to this topic, such as: augmented reality, machine learning or m2m (machine-to-machine) communication, however, as of now, these ideas only have a status of 'buzzwords' and are yet to be explored (Barkawi Management Consulting, n.d.).

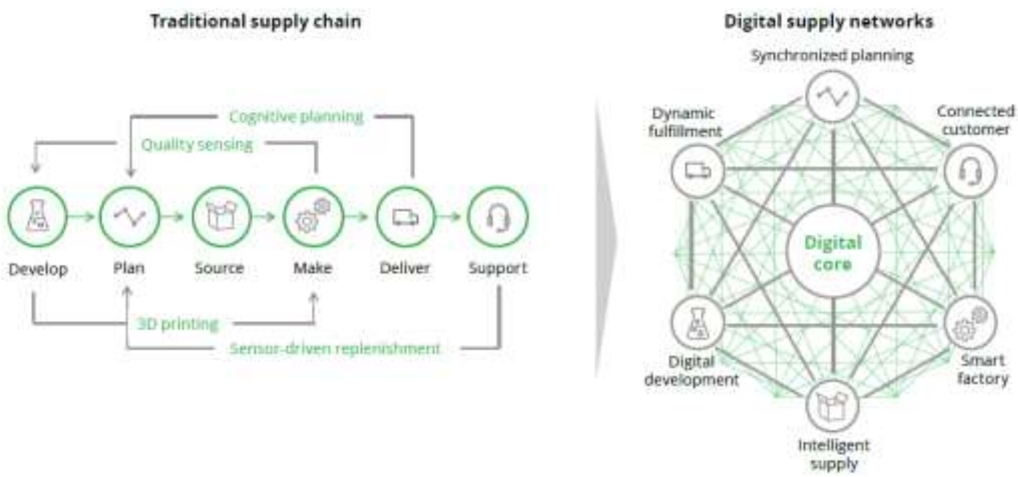

Figure 3: Traditional and Digital Supply Chain (Deloitte University Press, 2017, p. 6)

Web technologies and digitalization can largely contribute to complete integration of the entire supply chain making them more efficient and responsive in return. This newly achieved real-time visibility of resources can optimize the three key flows of every supply chain: information, physical and financial flow (Rai et al., 2006).

3.7 Web Technologies that enable SC Digitization

3.7.1 Cloud Computing

Cloud computing could be defined as “IT deployment model, based on virtualization, where resources in terms of infrastructure, applications and data are deployed via the Internet as a distributed service by one or several service providers” (Leimeister, 2010, as cited in Akinrolabu & New, 2017).This technology represents an innovative move from a conventional approach where companies would have expensive independent software models, to a new age when organizations have an access to needed resources and computer-intensive applications without actually owning any of the costly equipment, but rather paying a cloud service provider per use (Akinrolabu & New, 2017). According to Wang, L. et al. (2012), cloud-based services could be divided into four distinctive categories: (1) HaaS (Hardware-as-a-Service) which offers hardware support for the users, (2) SaaS (Software-as-a-Service) that enables the use of software applications, (3) IaaS (Infrastructure-as-a-Service) which is responsible for supplying organizations as well as cloud service providers with necessary computing resources and (4) PaaS (Platform-as-a-Service) that essentially operates a social platform where companies and cloud service providers could network and collaborate (Zhang et al., 2015). There are three possible deployment models for organizations interested in utilizing the cloud: private, community and public cloud, and recently introduced hybrid model that represents a mixture of previously mentioned cloud systems (Zhang et al., 2015). In the case of MRO organizations, according to Wu, D. et al. (2013), research conducted so far has not really put an emphasis on closing the loop of information that exists within the MRO supply chain. A lot of parties are involved in daily operations, such as: MRO provider itself, aircraft OEMs, spare parts producers etc. and yet the information and data exchanged between them is neither structured nor consistent enough. Employing the cloud system for communication among the stakeholders would significantly

facilitate the flows of materials, knowledge and information and hence “bridge the gap between service providers and consumers” (Zhang et al., 2015, p. 1).
There are multiple benefits related to the usage of the Cloud. First and foremost, due to the nature of the technology itself, companies do not have high IT operations or IT infrastructure costs, because renting a cloud essentially implies that the major part of IT functions is outsourced to the Cloud Service Provider. Another advantage of implementing this technology is certainly the fact that unlike traditional systems - which demand months to be adopted, cloud systems take considerably less time for installation and do not require expensive resources. This also suggests that cloud solution is very cost-effective in the long run since there are no high maintenance costs associated with it, making it a perfect system for small and medium sized enterprises (Leung, 2010; Christian, 2011 in Ayob, 2016).
According to Felici and Pearson (2010), significant benefit of the cloud technology is the fact that its operations are automated which lowers human involvement and thus, the occurrence of errors. However, possibly the biggest advantage, from the business point of view, is data duplication which implies that data stored in the cloud would not be lost, even in the case of a server failure. Last but not least, utilizing the cloud technology allows its users to access the data any time at any location (Akinrolabu & New, 2017). If cloud was implemented for the purpose of supply chain management, it would offer a 360, end-to-end view of the entire chain for all of the entities and provide them with the ability to communicate and exchange information in a timely and efficient manner. For this reason, the cloud essentially represents a foundation for successful implementation of IoT, Blockchain as well as big data analytics.
Despite all the benefits that cloud technology could potentially bring to organizations, there are, nevertheless, several risks associated with it, such as the lack of transparency between the CSP and cloud users. Organizations are largely afraid of sabotage, espionage, data segregation and leakage, even potential malicious insiders. While these issues would in normal circumstances be covered by the law, in case of cloud technology this represents a problem, especially when an organization utilizes the services of several different providers that operate in different countries with different legislation - “multi-tenancy liability” (Akinrolabu & New, 2017). What is more, because the cloud servers hold an immense amount of

very valuable information, they become prosperous targets for cyber attacks and hackers (Akinrolabu & New, 2017).

3.7.2 IoT (Internet of Things)

The term 'Internet of Things' (IoT) refers to the communication of two or more physical objects over the Internet for the purpose of exchanging some valuable data. "The IoT enables physical objects to see, hear, think and perform jobs by having them to 'talk' to each other, to share information, and to coordinate decisions" (Haddud et al., 2017, p. 1057). The core technology behind the IoT is RFID tag - a device which allows the information to be transmitted from the object to the reader using the wireless communication. If implemented, this technology could largely contribute to the integration of the supply chain since it would make real time information visible and available for all chain members using cloud system or mobile apps specifically designed for this purpose (Haddud et al., 2017).

IoT would improve the transparency and visibility of information flow throughout the supply chain, as well as overall responsiveness and agility. What is more, since this technology allows the users to track and trace the location of all connected physical objects, material flows would experience an upgrade likewise. Furthermore, because users would be informed about the real time demand and facilities capacity and their fluctuations, inventory and warehouse management would be significantly upgraded. Organizations would not have to rely on excessive safety stocks and would be able to utilize just-in-time delivery system more efficiently, leading to better replenishment process (Haddud et al., 2017).

Although benefits of the IoT technology have been recognized, research has shown that not many companies have invested into its implementation. The reasons naturally include internal issues related to the lack of knowledgeable and skilled staff, inadequate IT infrastructure, capital etc. Furthermore, there has not been much empirical research with a focus on economic or managerial aspects of the IoT, rather technological, hence majority of leaders and managers of today are reluctant to invest more time and money into it. Due to the lack of expertise and the fact that all the published papers so far were mainly theoretical, organizations are not even sure how to proceed with the implementation process, nor if it would bring any considerably high financial gains in the long run (Haddud et al., 2017).

As far as application in aviation maintenance is considered, experts believe that the IoT could not only contribute to supply chain integration, but also help improve the safety of aircrafts by reducing the risk of counterfeiting, which has been previously identified as one of the challenges of the MRO organizations. Identifying Suspected Unapproved Parts (SUPs) has been an issue since they could only be detected by either excessive material analysis or inspection of documents that come along with the parts. Both of these processes are neither time-efficient nor do they guarantee success, however, tracking abilities offered by IoT technology could help identify the origin of a spare part faster. On top of that, IoT would enable real-time wireless monitoring of an aircraft's condition by equipping the components with intelligent devices that could send the data to the staff on the ground. These devices would be able to track temperature, pressure, usability etc. As such, IoT would help enhance maintenance planning and forecasting (Sundmaeker et al., 2010).

3.7.3 Big Data Analytics

Within the consulting circles, 'Big Data' is perceived as a trending solution that would change the economic and organizational infrastructure. Today's organizations tend to deal with an increasing amount of data which "is gathered by advanced information technologies such as ubiquitous-sensing mobile devices, aerial sensory techniques, cameras, microphones, Internet of Things (Iot) technologies (e.g. RFID, Barcode), and wireless sensor networks (as cited in R.Y. Zhong et al., 2016). Conventional processing methods as well as traditional data management approach have become unfitted, hence the increasing need for Big Data analytics (R. Y. Zhong et al., 2016). However, as it has been the case with other IT trends, there has not been much practical application in this area, especially supply chain field, although the theory recognizes a lot of benefits associated with its implementation, such as improving demand visibility and enhancing responsiveness. According to Richey et al. (2015), supply chain managers are largely confused and lack concrete knowledge regarding Big Data, how it is created and what it actually means (Richey et al, 2016). The concept of Big Data could be described through the four following dimensions:

- *Volume:* the amount of data, especially machine-generated, largely transcends the capacity of traditional tools used in the past for the purpose of data collection and storing (Zicari, 2014);

- *Velocity:* data is flowing into the system on continuous basis due to the increasing use of RFID tags, scanner data, ERP systems, Warehouse Management Systems, social media etc., which implies that the company has to be able to carry out the analysis in near real time in order to cope with a high rate of data inflow and not miss out on anything that might be of high importance (Richey et al., 2016);
- *Variety:* data comes from various different sources inside and outside of organizations, that are not mutually compatible. The system collects data from transactional and ERP systems, social networking platforms, webpages, sensors, machines etc. In addition, this Big Data often arrives in very unstructured format, such as text documents, audio or video files, email, tweets, transactions etc. Majority of supply chain managers and systems implemented by organizations so far are used to solely numerical data that could be presented in rows and columns and easily analyzed, such as accounting information, operational numbers, statistics, forecasting data etc. It was not as complex to develop a system that would successfully deal with the data presented in the same format, however, unstructured data poses a major concern (Zicari, 2014);
- *Veracity:* in the large mass of information, the system must be designed to filter and distinguish between important and non-important data, as well as reject data that is not correct or does not come from a legitimate source. False data, imprecise or missing values, timeliness, sampling biases etc. represent a genuine challenge. This might remain the biggest issue for supply chain managers and organizations in general, since there is no manual which suggests how to program the system to achieve this key capability (Richey et al., 2016; Zicari, 2014).

A study performed by R. G. Richey et al. (2016) has revealed that, despite the uncertainties concerning the concept of Big Data, managers around the world generally recognize the potential benefits that usage of Big Data could bring to their organizations. First and foremost, unlike the conventional approach to decision making, that is largely based on authority and relationships, Big Data would introduce a new era where decisions are made in a more informed and analytical manner. In addition, an immense amount of data available to organizations that deal with a great quantities of inventory - such as aviation MRO, would help enhance forecasting and make it more accurate. It could also facilitate trend detection (e.g. procurement trends) and overall upgrade the organization's operational efficiency in the long run (Richey et al., 2016).

Although this appears to be a rather appealing innovation, managers have also indicated several concerns that they share in regards to Big Data. The first issue is related to an organization itself and the lack of appropriate human capital. What is more, vast majority of companies do not possess an adequate technological infrastructure required for Big Data execution. In fact, because Big Data implies heavy use of large pool of data, storage and its security become an important challenge among managers (Richey et al., 2016). Lastly, there are discrepancies regarding the issues of privacy, data ownership and sharing. Certain information, such as customer personal information, delivery data etc., are prohibited from being shared in some countries unless an individual has given his/her consent. In international supply chain networks, these legal constraints become even more complex since different countries may have different policies and laws about the same issue. This incompatibility may hinder the usefulness of Big Data and impede the speed of its implementation in organizational culture (Richey et al., 2016).

As far as the usage of Big Data within the aviation MRO sector is concerned, opinions regarding this topic vary since some believe that maintenance field cannot benefit significantly from its application while others state how MRO is late to adapt. Using Big Data could certainly enhance the predictive maintenance in operations, but this predictive analysis could also be applied in inventory management, planning and scheduling etc. where large amount of gathered data could help improve forecasts and increase their reliability (Baiju, 2017).

3.7.4 3D printing (Additive Manufacturing)

Additive Manufacturing refers to the process of combining different materials into a 3D object that was previously designed using the CAD (Computer Aided Design) software. Since 3D printing is an automated process, it could improve supply chain management drastically by eliminating the human errors and reducing the time needed to obtain spare parts, since these could easily be printed inside the company's own facilities (Joshi & Sheikh, 2015). "Using AM technology, manufacturers can produce parts on demand and thus reduce the need of maintaining safety inventory" (Akinrolabu & New, 2017, p. 1169).

What is more, 3D printers do not use any expensive molds typically needed in traditional manufacturing, nor do they require an abundance of tools to perform the task. 3D printing devices also use less material which contributes to waste minimization. In other words, in the long run they have a potential to become a very cost effective solution since their usage would contribute to decrease in company's operational costs (Akinrolabu & New, 2017).

Furthermore, 3D printed components are considerably lighter in weight compared to the conventional ones, which in turn reduces the weight of an aircraft. This could potentially lead to massive fuel savings for aircraft operators.

However, research has shown that the adoption rate of Additive Manufacturing is still rather low in the aerospace industry. GE Aviation has made an official announcement that the fuel nozzles for their next engine model would be manufactured using the 3D printing technology. This particular part is rather complex to construct since it is composed of many smaller individual components; however, AM would consolidate the process and make it significantly more efficient and faster, since there is no need for assembly, inspection, human labor etc. (Chua & Leong, 2014). Other large manufacturers such as Boeing have also invested into 3D printing R&D and plan to produce over 100,000 AM engine components by 2020, which still ought to be approved by FAA and EASA. (Joshi & Sheikh, 2015). This leads to the main issue of AM implementation in the avio sector - legal constraints and strict certification policies established in order to ensure the safety of the aircraft. "Testing and safety standards for AM in aerospace is still under development" (Joshi & Sheikh, 2015, p. 11). Another obstacle in full implementation of 3D printing is the threat of counterfeiting since it would be difficult to track the origin of individual spare parts.

3.7.5 Blockchain

Blockchain is, in simple terms, defined as a public ledger which is designed to verify, execute and store all the transactions that occur within the network. However, unlike the traditional payment and banking systems, this ledger is not under control of any authority and it is often referred to as 'decentralized' (Weber et al., 2016). The way data is structured in the blockchain is in 'blocks', hence the name, which essentially represent the boxes that compile all the transactions that took place. After one box is filled out, the next one is added to the chain and so on. For a transaction to occur, its initiator has to sign it digitally and send it along the network in order to be verified by other nodes. Once the verified data reaches the miners, transaction is sealed into the blockchain and cannot be deleted, reversed or altered (Weber et al., 2016).

Iansiti and Lakhani (2017) also point out that the communication is achieved directly between the two peers without any party involved in between. What is more, blockchain allows the "transparency with pseudonimity" (Iansiti & Lakhani, 2017, p. 9) which implies that every single transaction that is transmitted through the blockchain is visible to each node in the network. However, possibly the biggest advantage is the fact that transactions have the possibility to be programmed or in other words automated - users could write algorithms that may trigger a certain transaction between the nodes upon completion of a defined action. This way, manual operations are reduced (Iansiti & Lakhani, 2017).

Transactions are decrypted and encrypted using the so called Public Key Infrastructure (PKI) and secured by 'smart contracts'. This is not an actual contract, but rather a term used for a "computerized transaction protocol that executes the terms of a contract" (Korpela et al., 2017, p. 4185). This implies that the typical clauses such as payment, confidentiality, enforcement or liens are automatically applied once the transaction has been made. Using the concept of smart contracts, companies would be able to fully automate their transactions, regardless of the fact if it is single or a multi-tranche one, and thus move one step further towards the complete digital integration of the supply chain (Korpela et al., 2017).

Due to the transparency offered by the blockchain technology, in case of a failure or a defective product, component etc., the responsible party could easily be detected. This naturally improves the dependability within the supply chain since there is a lot more pressure on the partners to be accountable for their performance and its outcome (Kshetri, 2018).

As it has been stated, IoT technology and Additive Manufacturing are gradually finding its application in the SCM. However, some of the major issues associated with it are trust and information security, which is particularly important in a highly regulated sectors such as aviation maintenance. James Regenor, the director of Moog's AM has once raised the question: "How can the maintenance crew on a U.S. aircraft carrier have absolute confidence that the software file they downloaded to 3D print a new part for a fighter jet hasn't been hacked by a foreign adversary?" (Casey & Wong, 2017, as cited in Kshetri, 2018, p. 87). This is where the discussion about the blockchain comes in: the transparency it provides, as well as its structure make it nearly impossible to be hacked. Hence, the blockchain might soon become an attractive and very affordable solution for the trust issues that prevent the digitization to develop at full speed (Kshetri, 2018).

Furthermore, companies that rely heavily on imports and exports, such as aviation MRO providers, would benefit from blockchain dramatically, since the amount of human interactions and administrative paperwork would be reduced as a result of automation of certification processes. Firms would no longer have to cope with delays in delivery caused by missing or inappropriate paperwork. In addition, operational expenses would be lowered since typically keeping track of all the required administrative documentation imposes immense costs for organizations (Kshetri, 2018).

Last but not the least, by combining the blockchain and IoT technologies, organizations would have an ability to track the shipments and inventory from their point of origin. The system would also assess the expiration dates on perishable items and usage rates on rotable and repairable inventory, and use the collected information to automatically refill orders when necessary. An upgrade from the previous tracking systems is that blockchain, due to its structure and the way it functions, allows organizations to track individual units - instead of batches, as well as the smallest transactions that took place since the marginal costs associated with the blockchain are nearly zero or extremely low (Kshetri, 2018). Nevertheless, despite all the advantages that the blockchain technology imposes, its deployment outside of the financial sector has remained on theoretical and experimental level.

There are many obstacles that need to be overcome for this technology to really find its implementation in the industry (Kshetri, 2018).
"First, the global supply chain operates in a complex environment that requires various parties to comply with diverse laws, regulations and institutions. They include maritime laws and regulations, commercial codes, laws pertaining to ownership and possession of multiple jurisdictions in the shipping routes." (Kshetri, 2018, p. 88). In other words, it would be extremely difficult to utilize the blockchain to its full potential due to the existence of certain institutions and customs which regulate the international trade. In addition, the vast majority of companies willing to explore the possibilities of blockchain has agreed that they would opt for, so called, 'permissioned blockchains' where access must be granted. It is a form of private blockchain network designed specifically for the needs of a certain company (Bussmann, 2017 in Kshetri, 2018). Bringing all the parties together and negotiating terms of use would take a lot of time and effort. What is more, blockchain is considered an advanced technology which requires a high degree of computational resources and skills. However, many of the industries' key suppliers are located in geographic regions where implementation of such technology is not yet feasible (Kshetri, 2018).

To sum up, it is evident that crypto economy has a potential to carry out a revolution in, not only financial field, but also other industrial sectors as well. However, these claims should be taken lightly considering the fact that more advanced implementation of blockchain would cause a great amount of changes in social, technological and organizational circles. What is more, law is being silent on this emerging technology at the moment, but if blockchain is to become widespread certain regulations would have to be applied. For these reasons, many academics do not view blockchain as a disruptive, but rather foundational technology. In other words, it is still unable to take over the current business models and organizational practices, it only represents a good building block for the future. It would take years, perhaps decades, for the blockchain to replace current TCP/IP approach entirely (Iansiti & Lakhani, 2017).

3.8 Issues Associated with Supply Chain Digitization

Considering the fact that complete supply chain digitization is a rather new phenomenon that has suddenly caused a boom in the aerospace and other industrial sectors, there has not been much practical execution yet, nor there are plenty of solutions currently available on the market. For this reason, there is a fair amount of technological risks associated with its implementation due to the fact there are is a considerable lack of standardization of coding, process specifications etc. So far, complete and advanced digitization was merely on an experimental and theoretical level (Basak, 2016). What is more, working with advanced technology has naturally imposed questions related to privacy, intellectual property and data security (pwc, 2017). Companies are largely reluctant to open up and share their information (Buyukozkan & Gocer, 2018).

Furthermore, there is a fair amount of internal issues inherent in the ability of an organization to completely implement digital solutions. Vast majority of companies are concerned with their existing resources and whether or not they are appropriate for the revolutionary changes (Basak, 2016). Unsuitable infrastructure would require a lot of investment and yet firms are not able to precisely predict how much benefits they would gain. Even if the implementation of the advanced technologies takes place, a company would have to make it compatible with existing systems used for accounting, HR, inventory management etc. On top of that, current business culture and practices might impose problems as well. Organizations are largely convinced that their present workforce is not skilled or educated enough to handle such radical alterations in the way daily activities are performed, which would require either change in the employee structure by recruiting new workers or excessive training (Basak, 2016). Both options would, nevertheless, add to the already high expenses of digitization implementation. Apart from the human capital, the issue also resides in the top management as many leaders do not have a clear vision or a strategy for the future (pwc, 2017).

Apart from the internal, there are a lot of obstacles in the external environment. To be able to fully digitize the supply network and reach the maximum potential of what advanced IT solutions have to offer, all members of the chain would have to align and use the technological configurations that could enable constant connection with one another. However, many organizations stated that their supply chain partners lack not only the knowledge and awareness, but also skills and talent (Capgemini Consulting, 2016). This might actually represent the biggest barrier to the completely integrated and digitized system since small and medium sized enterprises, that are often important suppliers, cannot financially afford to adhere to such innovations (pwc, 2017). Companies that do not have large scale operations or high turnover may not even recognize the need for joining the digitized networks. Does this imply that SMEs are about to be eliminated in the future because they would not fit into the perfect idea of the interconnected economy?

3.9 Digitization in Aviation MRO

As it has been stated, aerospace industry has been experiencing considerable growth in the previous decade, in both general aviation and commercial air transportation sector. This has naturally imposed certain changes in the MRO field as well, that is now facing a challenge of finding perfect ways of predicting customer demands and responding to them more rapidly and effectively (pwc, 2017). To be able to provide such a quick response to their client, an MRO organization has to ensure that there are no disruptions within the supply chain and that all spare parts are available on time when needed. To put it differently, the management of an MRO company has to work with an immense amount of data and information to assure that there is alignment between the company's activities:

- *Hangar capacity scheduling* (ensure that there would be enough space to take in the incoming aircrafts for a required time period)
- *Information in regards to the existing inventory* (lead time, expiry date, number of available units in stock etc.)
- *Procurement information* (supplier invoices, purchase orders, payment information etc.)
- *Work Orders* (ensure that the necessary equipment, tools and components are available for overhaul)
- *HR information and task scheduling* (ensure that there is sufficient workforce to perform the overhaul activities at a given time frame)

(Jalil et al., 2017)

"Data is coming from multiple sources, in different formats, and there is a need to combine internal data with data from outside sources" (pwc, 2017, p. 8). In order to achieve a smooth flow of processes through the supply chain, there has to be a substantial level of integration: alignment and coordination of activities from the main suppliers for the MRO industry all the way to the customers demanding maintenance services. Integration would reduce delays, eliminate redundancy, minimize the occurrence of errors and maximize the agility of the chain through more effective planning and forecasting (Rai et al., 2006).

As it has been discussed prior, this degree of integration and efficiency could be achieved through IT solutions and digitization of the supply network. The field of commercial aviation has experienced dramatic changes in regards to IT development: online booking platforms, online check-in, cargo and baggage handling system etc. while the maintenance sector has remained intact and still relies heavily on the systems developed in the late 20th century. It is quite surprising how an industry which is so strictly regulated, globally standardized and more or less homogenous, has not taken the full advantage of IT solutions that would facilitate reporting and execution of maintenance tasks and make them significantly more efficient and cost-effective. Experts agree that one of the potential reasons is the fact that the aviation industry has entered its maturity stage long before the business IT support systems, which has caused a huge gap between them. Even today, a vast majority of programs created for MRO service providers is managed using a simple PC or a small server (Sahay, 2012).

There are only a few serious MRO systems on the market: from simple ones that could be installed for several thousand dollars to the exquisite custom built systems suitable for large MRO service providers willing to invest millions in their IT configurations (Jalil et al., 2017). 'Ramco systems' currently offers several different options, such as Ramco ERP that operates both on SaaS (Software-as-a-Service) mode and on Cloud platforms as well, which covers a wide range of functions such as HR management, Enterprise Asset Management (EAM), CRM, Supply Chain management, advanced planning, analytics, process control and financial management, making it an optimal solution for large organizations. Ramco Series 5

Suite is another option more fit for smaller organizations. It offers assistance in maintenance planning, hangar management, keeping technical records etc. It is available on Cloud, which does not impose any maintenance or implementation costs and it also minimizes the expenses for the overall IT infrastructure. What is more, an application has been developed for managers to access the system on their mobile devices (Ramco, n.d.). Other software developers such as Swedish company IFS (Industrial and Financial Systems) are also offering digital solutions for aviation MRO organizations that would help manage warehouse, assets, work orders, component or complex assembly MRO by integrating and streamlining all company activities (IFS, n.d.). Similar solutions have been presented by other key players in the industry such as Infor, IBM, EZOffice Inventory etc. (SoftwareAdvice, 2018), however, majority of the currently available technological solutions are mainly focused on optimizing and improving internal activities and operations, but do not offer the ability of connecting with suppliers, distributors or any other important entities in the supply chain, which again indicates the lack of integration. “The information asymmetry among the stakeholders results in low MRO working efficiency and resource waste” (Zhang et al., 2015, p. 2).

In fact, according to the global survey conducted by the PwC consulting agency in 2017, only 25% of the participating aerospace companies stated that they have invested into some degree of digital business models. Although managers and leaders are aware of the importance that data sharing and visibility imposes, most companies still have so called ‘ad hoc’ approach to data analytics. Immense amount of data and constant flow of information has little value if it is not analyzed and put to a greater use, yet today 74% of aerospace companies lack a structured and defined approach to data analytics, leaning on individual employees and their skills instead. Only around 16% of the survey participants stated that they consider their data analytics capabilities to be at advanced level (pwc, 2014) .

Interestingly, however, many software developers have started exploring the blockchain and its potential use in the MRO field by collaborating closely with largest organizations in the aviation industry. One of the latest examples of such collaboration is between Ramco Systems and the Engineering and Maintenance division of Air France KLM, that are collectively working on a system that would facilitate transactions and repairs of spare parts. Apart from Ramco, Microsoft has also been developing the blockchain architecture which would be compatible with their Azure cloud. IFS Labs is in the pursuit of developing a distributed ledger that could be integrated with a company's ERP system. SITA, a multinational company which specializes in IT and communication solutions for aviation, is jumping on the blockchain trend as well. These recent changes in the aviation computer systems have shown that experts do see an immense potential in the blockchain technology and how it can be utilized in the supply chain management: tracking spare parts, asset management, financial transactions management etc. (Canaday, 2017).

There is no doubt that the digitization will completely change the landscape of the aerospace industry in just several years. It still may be considered a novice, but it is more than evident that companies do not lack ambition or awareness about digital solutions and their benefits. In fact, on average, they plan to invest 5% of company's annual revenue in digitizing their operations in the following 5 years which implies that the competitive environment would change tremendously in less than a decade (pwc, 2017).

3.10 Summary and Conclusion

Literature review conducted suggests that aviation MRO sector does indeed face a lot of inefficiencies which have been indicated in the previous segments. These problems are largely caused by the overall lack of integration between the members of the supply chain, meaning that there is no proper alignment and coordination of each party's activities.

Emerging digital and information technology might impose an effective solution for correcting these issues and optimizing the aviation MRO supply chain in the long run. Demand unpredictability could be solved using the IoT technology and Big Data analytics, which enable the real time exchange of data coming from multiple sources, including suppliers, aircraft itself, RFID tags or barcodes attached to spare parts etc. Mining of this data would provide MRO organizations with accurate, up-to-date information, consequently enhancing decision making process and improving inventory forecasting. The problem of fragmented supply base, which causes increase in lead times and delays in spare parts delivery, could potentially be reduced by introducing Additive Manufacturing to the aviation maintenance sector. Urgently needed spare parts could be produced relatively quickly with 3D printers, instead of relying on the distributors to send the required components to the MRO facilities. Blockchain and integrated cloud systems could also help streamline the process of spare parts procurement, by integrating all suppliers into a network where information is shared with everyone simultaneously, instead of having to communicate with each party separately. Another obstacle to everyday MRO activities are slow and expensive transactions, which could potentially be eliminated by utilizing the key capabilities of blockchain technology. Transactions would be executed faster, without a bank as an intermediary. What is more, with the existence of 'smart contracts' issuance of required documentation and certificates could be completely automated, resulting in decrease in delays and human factor errors. Another potential use of blockchain, as well as the IoT, is the establishment of intelligent tracking systems that could be used to mark the original serviceable parts and track their movement from the point of origin to consumption and re-use (in case of rotable inventory), facilitating the process of fraudulent component detection. In other words, this approach could represent a potential solution for counterfeit spare parts that are circulating the MRO market.

However, as it has been emphasized already - despite the fact that digital technologies have a lot of potential for solving the current issues in the aviation maintenance sector, literature suggests that these strategies have not been researched enough from the business standpoint. "The Digital Supply Chain is in its infant steps, and the most of its potential for value creation remains unclaimed" (Buyukozkan & Gocer, 2018, p. 157). Studies conducted on digital supply chains so far largely focus on DSC enabling technologies, instead of the concept as a whole. No research suggests the proper framework for DSC development nor does it give clear managerial guidelines for its implementation. What is more, papers mainly concentrate on benefits of DSC without addressing the problems or barriers that might arise in digital environment. A vast majority of studies are industry reports or white papers published by consulting agencies, software developers etc. There is a considerable lack of reliable and proper academic papers (Buyukozkan & Gocer, 2018). Hence, implementation in the field has been limited thus far and the story of complete supply chain integration has remained largely theoretical. Majority of companies still rely on traditional approaches and simple ERP systems, especially the small and medium size enterprises. Interestingly however, big corporations seem to see potential in the blockchain revolution as some of the major airlines as well as aviation software developers have already made substantial investments towards the R&D of blockchain in MRO.

4 Case Study

4.1 Case description

The subject of a case study used for the purpose of empirical research part of this paper is “GAS Aviation”, established in 2004 in Serbia. It predominantly specializes in maintenance, repair and overhaul services in General Aviation sector, particularly in the following aircraft types:

- Light aircrafts (Cessna and Piper): used for the purpose of aerial surveying, light cargo operations, sightseeing, passenger transportation (airtaxi), flight training etc.
- Business jets
- Agricultural aviation: used for crop dusting and aerial firefighting
- Sport aviation
- Helicopters

“GAS Aviation” is officially authorized to perform preventative line maintenance – types A and B; as well as scheduled base maintenance activities in the C category. Apart from providing the MRO services for whole aircrafts, the company also offers overhaul services of various individual aircraft components, which involve engines, turbines, radio and electric equipment (avionics).

The company is a holder of both domestic and international aviation authorities’ certificates, which include the license issued under the Civil Aviation Directorate of

Republic of Serbia and EASA.145.0713 certificate obtained by the European Aviation Safety Agency, whose aim is to ensure that a company operates under conditions that comply with prescribed standards and provides a good quality service which is in line with the EU requirements. In addition to formal certificates, the company also holds a license from OEMs of aircrafts and aircraft components they work with, such as: Piper, Lycoming, Continental Motors, Inc., Pratt & Whitney etc.

The EASA certification has allowed "GAS Aviation" to collaborate with clients not just from the eastern European region, but also EU countries, such as Austria, Hungary, Slovakia, Germany etc. Regular customers are aeroclubs, individual aircraft owners, other businesses and governments of Serbia and Montenegro.

4.2 Operations

The first part of the case study would focus on description and analysis of operations within the company for the purpose of gaining more insight into what the daily challenges of a typical MRO business as well as potential impediments to efficiency.

4.2.1 Supplier evaluation

Logistics department of the company is in charge of maintaining the relationship with suppliers and regulating all the formalities in terms of procurement, documentation handling, payment, delivery etc. However, in order for suppliers to get approved, logistics manager has to consult quality manager of the company who evaluates whether they satisfy technical requirements. Suppliers must be able to show proof of spare parts origin and quality, usually granted under the license of aviation authorities such as CAA of a country, FAA in case of the United Sates or EASA in case of the EU. If these order qualifiers are met, "GAS Aviation" makes a final choice based on price, terms of payment, location of the supplier and delivery time. Ms. Matovic, the logistics manager of "GAS Aviation" states that the location and delivery time are of crucial importance for the company, since providing the timely service for the customer is critical in the aviation MRO industry and there is very little room for delays. This physical remoteness of the suppliers, however, poses difficulties in achieving this goal. For instance, "GAS Aviation" is working a lot with spare parts and engines produced by American manufacturers, but it would be too risky and inefficient to rely on suppliers located in the States. It is not solely the question of long distance in terms of delivery of physical goods, but according to the interviewee, even the simple things such as time differences could represent an impediment to communication between the parties. For this reason, the company has signed a contract with a distributor from Belgium which acts as a hub for components made in the US and delivers them to the MRO service providers across Europe. She has also indicated how making the right choice of suppliers and maintaining the good relationship with them is largely beneficial in the long run. The company would often be offered discounts and more flexible terms of payment since they have a status of loyal and frequent customer.

Suppliers, which include OEMs and authorized distributors, are monitored on continuous basis in terms of the condition and quality of parts delivered, which is the responsibility of the Quality manager, as well as accompanying documentation and timely delivery, performed by logistics manager. Thus, in case of spare parts procurement, steady collaboration and communication between technical and logistics departments is a necessity, Ms. Matovic says.

4.2.2 Orders

As stated in the exposition, technical staff and logistics department are both involved in the procurement process. Maintenance manager receives information from both line and base maintenance divisions about the upcoming work orders, which is then used to make a list of required spare parts, materials or tools. The maintenance manager would then input the orders into the storage software and label them as either ‘normal’, ‘rush’ or ‘urgent (AOG)’ to signal the logistics department when they should proceed with procurement process. Any specifications, such as quantity and requested parts manufacturer should also be stated in the order. The logistics department has an access to information about current inventory in the storage and if the items requested are available, they are released from the warehouse and automatically reordered. In case, however, that components are not in stock when requested, procurement takes place.

For standard parts and equipment produced by different manufacturers (such as gaskets, bushings, nuts, screws and caps, rings etc.) that are used on continuous basis, Ms. Matovic claims that “GAS Aviation” already has suppliers for individual items and there is no need to place RFQ (Request For Quotation). However, if there is an expensive piece of equipment that is not frequently in use, there is obviously a need to evaluate all the options available and choose the best offer according to either price or delivery time, depending on the urgency of the situation. In the case of AOG, which has to be resolved as quickly as possible, the company opts for suppliers that guarantee the fastest delivery and good quality of products. Obviously, the associated procurement costs would be much higher than usual, but as Ms. Matovic states, the situation of AOG is classified as top-priority which requires immediate treatment and therefore, postponement is not an option. What is more, customers are also willing to pay a higher price which also partially compensates for the extra expenses. The interviewee has also indicated that, even though the AOG does not occur that frequently, it still represents an issue for virtually every MRO provider because there is little that could be done to be prepared for such an emergency.

“Not even the most sophisticated technology of today could help predict every possible technical failure that may occur and cause AOG. What if there is an external factor responsible, such as weather or ground damage and so on? You can’t predict such things,” adds Mr. Dabic, employed as a mechanic in the company.

Mr. Lukic, the quality manager, states that in some cases, when it is absolutely necessary, the company opts for cannibalization strategy, previously discussed in the literature review. “GAS Aviation” owns 15 aircrafts of various different types, mainly Cessna and Piper. When the situation demands, certain components are removed from the currently non-operating aircrafts and installed into the AOG as the last resort option. It might be inconvenient for the company, but the customer’s interests come first. However, even in this case, according to the exposition, airworthiness of the component has to be examined as well as logbooks to make sure that it has not been involved in some accidents during previous flights, heavy landing or any other activity that could have a negative impact on spare part’s serviceability. Mr. Lukic claims that the company has never faced any issues due to the implementation of this strategy and says how this is a rather common practice in aviation.

Just-in-time delivery is, unfortunately, not a feasible option for "GAS Aviation" since suppliers are scattered around Europe and customs also represent an immense obstacle. From the interview with Ms. Matovic as well as personal observation during the temporary employment, the conclusion is that the process of import is quite lengthy and formality driven. It includes a list of documents that need to be exchanged between the MRO provider, the supplier and freight forwarder: pro-forma invoice, commercial invoice, bill of lading, airway bill, packing slip, Shipper's Export Declaration (SED), Inspection Certificate, Insurance certificate etc. The main issue is the fact that, due to different requirements of each country, as well as well as lack of standardization of documents, these files usually cannot be transferred electronically. The originals are scanned manually and saved into the company records which is a rather cumbersome process, especially in the case of large shipments that contain an immense amount of papers and certificates of different kinds. All the required documentation is then sent from the logistics department to a so called Custom Clearing Agent, a third party company in Belgrade, in order to handle the shipments and forward them to the company.

"There have been numerous occasions when the freight has been kept by the authorities simply because there was some information missing from the supplier, error in documents, additional fee that had to be paid and so on. With bureaucracy, there is usually some paper missing," says Ms. Matovic. Due to the fact that demand for spare parts is rather difficult to forecast and that import process takes a considerable amount of time, she states how the company has to rely on larger safety stocks to be able to complete the work in timely manner.

4.2.3 Incoming Inspection

Due to a massive circulation of counterfeit or 'bogus' spare parts in the market, the company has established a system of inspecting the upcoming parts that are delivered by the suppliers. The logistics manager would perform visual inspection in order to determine if there are any external damages to the inventory and if the quantity corresponds to the order. If specified by regulations, certain components would be sent to assigned workshops for functional test before they could be filed and put into a warehouse. Part of the incoming inspection also involves inevitable paperwork. According to Ms. Matovic, logistics department has to make sure that all the required documentation has arrived along with the package, especially if spare parts are ordered from a distributor and not directly from the manufacturer. As stipulated in the exposition, this documentation involves: Identification of Manufacturing Source, EASA/FAA approved certificates, Design Holder license in case the part comes from a PMA source and Conformity Certificate in case of raw materials. What is more, if the imported inventory is a component that had been previously sent to overhaul or calibration, there is additional documentation involved: Release Certificate, workshop reports from the overhaul provider as well as Airworthiness Approval. Chemical inventory, such as: adhesives, primers or sealing materials etc., also come with manufacturer's specifications in regards to conditions under which the inventory should be stored and recommended shelf life for the items. Expiry dates have to be input into the software system and respectful items labeled with a special card that signals the storage personnel how the items should be handled.

If all requirements are fulfilled, inventory is handed to the storage keeping staff, otherwise it is labeled with a red card and sent to a so called 'Quarantine' room where it has to be further examined by the Quality Manager who would make a final decision whether the part is 'Bogus' or not. According to Mr. Lukic, the company has not had an incident with counterfeit components so far and states how this represents much bigger issue in air transport sector rather than General Aviation.

The same procedure applies in the case of tooling and equipment which is used for maintenance purposes. The logistics department has to ensure that the equipment comes with all the necessary documentations and licenses, especially in case of measuring instruments that have been sent to calibration to a third-party certified laboratory.

As it could be seen, even the takeover of inventory is a time-consuming process mainly due to all the formalities that ought to be fulfilled:

"Employees often complain about paperwork. It does, indeed, give everyone a headache, but that is a rule and we cannot go against it. Aviation is generally highly regulated field and for an obvious reason. It is too late to fix the mistakes once that aircraft is in the air. However, some changes would have to made to make the process more time efficient," says Mr. Lukic, the Quality Manager.

However, Ms. Matovic states that choosing a good supplier and maintaining a professional and fair relationship with them also has a great impact on efficiency because it helps to establish trust between two parties. "GAS Aviation" trusts the suppliers they have been working with for several years and is perfectly accustomed to their practices and policies. Similarly, the suppliers would trust the company as a customer due to financial reliability, lack of incidents and the fact that collaborating with "GAS Aviation" also brings them a substantial and secure amount of profit on annual basis.

"In case we receive a shipment from our regular, loyal supplier the inspection process is not as rigorous and lengthy, since we trust the company when it comes to validity of certificates, quality of goods and so on. This shortens the procurement process significantly and gets the job done faster," says Ms. Matovic and adds that such level of trust takes time to establish and could never be achieved with all suppliers due to communication issues and especially lack of transparency. She has also emphasized further on the supplier-customer relationship indicating that in case a problem arises, "GAS Aviation" could be sure that their loyal supplier would react immediately, decreasing the delay in maintenance of an aircraft.

4.2.4 Storing and inventory management

As stated in the previous section, items that have passed the inspection are sent to the warehouse where they are stored, along with all the relevant technical documentation, based on storing requirements specified by the manufacturer.

Simultaneously, using a bar code scanner all the components are filed into a software, where each part has its tracking number and could also be explored using the manufacturer's part number, part name or stock location. There is also a hard copy, as well as electronic log book embedded into the software, for certain spare parts known as rotables. It is important to have an insight in how many times they have been used, in which aircraft, for how many hours etc. since they have to be discarded after a certain time of usage as stipulated by the manufacturer. This information is also crucial for the procurement purposes.

Ms. Matovic stresses how vital it is to have a software for tracking the movement of spare parts within the company, especially because the logistics department has no influence on operations in hangars. In MRO companies, inventory does not come only from external sources, but also internal. There are occasions when spare parts are taken from the warehouse, but end up not being used and having to be returned. In addition, certain components are subject to overhaul or calibration for measuring instruments. In other words, they have to be temporarily taken out of the storage. What is more, in case of damaged aircrafts that are no longer operational, some parts could be taken out and after official confirmation of serviceability put into warehouse for further use on another aircraft. According to the interviewee, these actions may have an impact on how and when the logistics handles procurement with the outside suppliers. Hence, it is of great importance that technical and logistics department are connected and share the same information in order to improve efficiency and minimize unnecessary costs. The most optimal way to achieve this integration, according to her, is through the use of a computer system so that each department of the company is aware of the other department's actions. However, only the logistics, storage handling workers and maintenance managers have an access to the system to ensure the maximum safety and reliability.

According to Mr. Dabic, regular technicians employed in the maintenance department use the 'card labeling system' to identify the current status of spare parts circulating around the hangars or workshops:

- Green card indicates a serviceable part which is ready to be installed
- Red card indicates unserviceable rejected parts that are either ready for repair or to be scrapped, the decision is up to a quality manager
- White card indicates 'temporary removal' of a spare part that belongs to an aircraft that is currently a work in progress. It could be removed for testing purposes, or simply to be able to physically access another part of the aircraft while maintenance activities are taking place

All cards have to be signed by an authorized manager to be considered valid.

4.2.5 Technical Record Control

As stated in the exposition, every time a new aircraft is brought to hangar space for base maintenance activities, a new Work Pack is opened. Before any maintenance work commences, however, senior technician would complete the preliminary inspection and write a so called ‘Work Card – Task list’ which indicates all the defects and maintenance requirements on the aircraft, but is also used to procure necessary spare parts from the warehouse. As the work continues, any additional maintenance activities that took place are added, describing all the parts and materials that were used (along with the parts number, batch, quantity and other information retrieved from the card label), services that have been performed, time it took etc. To simplify it, Work Pack basically explains the scope of work done on a particular aircraft. This pack is used to determine the price charged to clients, but also in case of regular customers it is a useful track of aircraft’s condition over the years.

“Regular clients have their own unique work order number which we use to file new work packs every time the same aircraft comes for an obligatory checkup. We like think of it as the ‘aircraft’s medical record’ and this historical information could actually help us prepare better and anticipate the maintenance requirements during the follow up checkup,” says Mr. Lukic.

In case of Line Maintenance that occurs outside of the hangar facilities, all the performed work is filed into Tech Logs prior to aircraft’s departure.

However, the Work Pack system has not been fully computerized yet and, according to Mr. Dabic, is still performed using the ‘pen and paper’ approach where forms are filled out manually while maintenance is taking place. Later on, after the Work Pack has been approved by the Maintenance manager, the respective Work Pack is either scanned or typed using Excel and saved electronically. Up until several years ago, technical records have been kept in an archive for minimum 3 years before they would be discarded, but this was largely inefficient, as Mr. Ivosevic states, since it was taking up a lot of space, it was difficult to find the required documents no matter how organized it was, and it was, more than anything, rather costly to keep these physical records.

4.3 Modern technology in supply chain

During the interview with Mr. Ivosevic, Mr. Lukic and Ms. Matovic, the topic of supply chain digitization was discussed. The purpose of discussion was to find out how informed the interviewees were about this phenomenon, if they think that DSC has a potential to improve the supply chain integration in aviation MRO significantly and how. All the participants seem to be aware of the web technologies that could enable digitization in the supply chain, and that were previously discussed in the literature review portion of the paper. However, interviews have also revealed that, while all three participants were largely familiar with Cloud computing and 3D printing, they were considerably lacking knowledge in the area of Big Data, IoT and especially Blockchain technology.

Mr. Ivosevic has shared that the company is, indeed, taking steps towards digitizing their operations. In fact, "GAS Aviation" has recently filed an application for state funding since they would be working collaboratively with a group of software developers from Faculty of Mathematics in Belgrade on creating and implementing a new system for MRO providers that would not only help internal operations, but also stimulate integration between MRO providers and their suppliers.

"We are currently looking into potential options for implementing the Cloud system mainly in order to achieve much faster and more transparent communication with our suppliers," says Mr. Ivosevic. The company is hoping that this would decrease delays and replace phones and emails as main communication tools which enable only one-on-one conversations. Apart from networking, the company is considering utilizing the Cloud for the purpose of data storage, but Mr. Ivosevic expresses his skepticism towards Cloud Service Providers. He has explicitly stated that he does not like the idea of having company's confidential information stored somewhere else, where they do not really have control of it. However, the affordability of Cloud as a solution is the main incentive for continuing with this upgrade.

"We wouldn't have to hire more IT people and it virtually costs nothing compared to having our own server within the company facilities," he says. However, he has also stressed how implementing the Cloud platform for communication and information sharing is a job that requires collaborative efforts between them and their key suppliers, hence it would take longer time until it actually comes to life. Majority of their suppliers still rely largely on emails, fax and other simple business practices and seem to show reluctance to change.

“I personally believe that it is, not just a matter of habit, but also fear,” Mr. Ivosevic says, “I think that majority of managers don’t know where or how to start.” His opinion is that, although majority of companies are perfectly aware that digitization and overall incorporation of IT in daily activities is becoming a necessity, managers know that this will spin the organizational culture completely.

“Digitization will not change only maintenance and procurement; every single employee in the company would be affected. And people are normally afraid of such radical changes because they are unsure of the outcome and whether they would be able to handle it,” he states.

When it comes to 3D printing, Mr. Ivosevic revealed that this topic has been discussed in the MRO circles for a while and states how he, himself, sees an immense potential in this technology since it could lower the necessity of keeping extra inventories in stock and reliance on suppliers and their fast delivery. This would, according to him, be especially useful in the case of AOG. However, he also expresses his thoughts in regards to feasibility of this approach:

“While these are great news for MRO companies, spare parts manufacturers and distributors might not benefit from the implementation of this technology. A lot of them make money on the basis of urgent and big orders from MRO providers.”

Mr. Lukic has also shown his concern in regards to safety of the 3d printed spare parts, saying that a system would have to be established for licensing purposes and to control the production and quality of these components. At this point in time, additive manufacturing cannot be applied since it would be illegal to do so.

In terms of Big Data, none of the three participants seemed enthusiastic about its potential application in the company. Their overall impression is that Big Data is a technology that might be potentially useful for large companies that operate on global scale and have an immense amount of suppliers and customers, but for SMEs it does not do much.

As far as Internet of Things is concerned, Mr. Ivosevic indicated how this technology has a vast potential to improve the efficiency of MRO activities due to real-time data, since receiving this piece of information could help MRO providers to be prepared in advance. They could anticipate what maintenance activities would have to be done before the aircraft arrives to the facility. He has shared how something similar actually already exists, called Aircraft Health Management - a monitoring system that captures the data about the aircraft in which it is installed. According to the interviewer, this is currently heavily researched topic in the field. The goal is to allow the real time transfer of data from the sensors in the aircraft to the MRO staff on the ground. However, the interviewee's opinion is that this technology has to be collaboratively implemented between aircraft operators and their MRO providers. In addition, because it is still on the rise, it is quite expensive, more than smaller organizations would be able to afford.

Interestingly, all of the participants have expressed lack of understanding when it comes to blockchain technology and its possible applications within aviation MRO. Interviews have indicated that the term 'blockchain' itself is mainly associated with Bitcoin, cryptocurrencies and financial sector among the participants. None of the interviewees were aware of the possibilities of its implementation in the maintenance industry. Mr. Lukic has also stated how he believes that majority of people who are not part of the IT industry, including himself, have a hard time understanding how this whole technology actually works.

"I think it is still something very new and confusing. This all sounds very nice and futuristic, but I'm sure it will take a very long time until it is actually applied. You would have to change the entire system. That doesn't happen overnight," says Ms. Matovic.

The questions about the technological enablers were followed by the discussion with Mr. Ivosevic on what are the next steps in regards to digitization in the company. He has stated how anyone who is serious about their business must be aware that digitization is inevitable. He also said that in case of "GAS Aviation" the company started small, without much capital available to work with, and was established in a developing country where the term digitization is still not very well known.

"Our team was comprised of talented and experienced mechanics, but most of them were old-school and preferred doing things the 'good old way'", he claims.

However, the company soon started experiencing rapid growth and collaborating with the customers from all over Europe and it became certain that changes will have to be made soon to be able to keep up and retain the clients. The first step is modernizing the workforce that would be able to understand the necessity of these technological changes and essentially possesses sufficient education. According to the interviewee, right people and mindset are necessary for radical steps. Starting from 2016, "GAS Aviation" have been collaborating with Aviation Academy, which is a school operating under EASA certificate, as well as Faculty of Mechanical Engineering in Belgrade. The company offers internship opportunities for their students and retains the best ones. Mr. Ivosevic states how this approach allows them to have an access to a pool of skilled, educated employees; but also to keep the fresh workforce that is generally more knowledgeable about modern technology.

"We often joke how young generations can teach us more than we teach them," the interviewee says.

Apart from the internal alterations, according to him, it is also very important to work closely with the suppliers, because integration cannot be achieved if not all parties are engaged in the process. In his opinion, this is the biggest issue and obstacle towards digitization at the moment, especially for companies that work with a relatively large number of suppliers that are not in close proximity to the company itself. What is more, he says that it is also difficult for suppliers that work with a lot of clients to adhere to all of them. According to Mr. Ivosevic, for this whole integration approach to work, everyone in the chain would have to rely on more or less same system and protocols.

He also believes, that big companies would handle the Research and Development and smaller ones would follow, since they do not own enough capital nor other resources to invest into such innovations, but rely on the finished product instead. However, he personally did not express much concern, since, compared to the Air Transport category, General Aviation is more or less a niche market where competition is not so strong and dynamic. Thus, it is not as urgent to adapt to the changes as it is among big air carriers and company can afford to take small steps towards digitization.

5 Discussion of the Results

This section would discuss and compare the conclusion withdrawn from the literature review, as well as findings of the empirical research conducted through thorough examination of exposition, temporary employment in the company and the execution of interviews, in order to answer the research questions proposed in section 1.

5.1 Key drivers of inefficiencies in Aviation MRO supply chains

Literature review has indicated, which was confirmed by the case study, that demand unpredictability is, indeed, one of the key drivers of inefficiencies in the supply chain of MRO service providers. Due to the uncertainty in regards to quantity of spare parts requirements that would be needed for maintenance activities, "GAS Aviation" is obliged to keep safety stock in its warehouse to be able to act quickly upon the arrival of the aircraft to the hangar. In case necessary components are not available, the company either opts for ordering from the supplier that grants fastest delivery or the cannibalization strategy, both of which are largely inefficient and drive up the expenses for the company.

Secondly, all the formalities associated with import practices of spare parts are causing the company to lose an immense amount of time on verifying the validity and credibility of documentation that comes alongside the shipment. In addition, the company has dealt with issues related to shipments kept in confinement by the customs due to errors in transactions or documentation handling. These delays make operations extremely inefficient. The analysis of relevant literature has also confirmed that MRO providers, indeed, struggle with slow and costly transactions.

What is more, even though "GAS Aviation" has not faced any difficulties so far when it comes to counterfeit spare parts, the fact that they still circulate the market implies that the company has to adhere to strict inspection guidelines. This, in turn, causes more paperwork and, as a result, even more delays in operations.

Related to this issue, both Ms. Matovic and Mr. Ivosevic have spoken about importance of trust among the supply chain members. However, without proper communication and transparency, this trust cannot be achieved. Miscommunication and mistrust may, again, decrease efficiency in company's activities.

Another problem is the fact that majority of company's suppliers are not located nowhere near the company's facilities, but mostly in Western Europe and some in the US. This prolongs the delivery process and aggravates the communication. In addition, it also limits the collaboration opportunities. It is apparent that geographical silo between different parts of the supply chain does, indeed, occur. This drives inefficiencies in daily activities because information cannot be shared excessively nor in timely manner to be able to achieve the optimal performance of both parties. According to the analyzed literature, the silo effect seems to be an issue that majority of the MRO providers are facing due to lack of integration in their supply chain.

5.2 How can digital solutions help correct the inefficiencies?

Considering the fact that the case study company has not implemented any of the discussed technologies yet, answer to this question would be mainly provided through information gained from interviewees' opinions and secondary research of published sources.

The issue of demand unpredictability, as it has been emphasized before, is difficult to handle due to the nature of the aviation industry itself. However, Mr. Ivosevic has implied that the Aircraft Health Management system is working on solving this particular problem and could be enhanced with the IoT approach to be able to transmit data to ground staff as the sensors measure it. As it has been discussed in Section 3.7.3, Big Data analytics could also have an impact on enhancing demand forecasting by providing an access to a pool of useful information from suppliers, customers, RFID tags etc.

The problem of slow transactions could be potentially solved by implementing the technology that would allow faster and more efficient data exchange. “GAS Aviation” is currently working on employment of a cloud system that would increase the speed of communication. This technology would create a platform where e-procurement would be possible, which significantly facilitates negotiation, information tracking and sharing; and creates the space where a company could communicate with multiple suppliers instead of having to contact them separately. Formal requirements related to all the previously addressed certificates, documents and licenses could only be solved by global standardization which would enable the companies to electronically transmit these files. For example, blockchain allows automation of transactions with minimum to none human involvement, as previously discussed in the literature review.

Trust issues between the members of supply chain could be solved, as the interviewees have suggested, by increasing transparency and communication efforts. For this reason, they are currently working on the said Cloud platform which would provide more insight into transactions. However, even higher degree of transparency and security of information could be achieved through blockchain, as it has been explained in Section 3.7.5.

Lastly, academic sources have revealed, and the interviewees also agreed, that 3D printing would help deal with remoteness of suppliers and demand unpredictability by allowing them as an MRO service provider to ‘print’ their own spare parts when needed instead of waiting on a supplier to ship them.

As stated earlier, although managers of “GAS Aviation” are familiar with 3D printing and Cloud Computing; they are not sufficiently educated in the area of Blockchain, Big Data and IoT. The potential reason behind it might be the fact that Cloud computing and 3D printing have been present for a while and heavily discussed not just in academic sources, but also in commercial media outlets. However, the overall impression is that the company has recognized the importance of digitization and is taking step-by-step approach towards implementation of more technological elements, as well as building the right organizational culture to be able to withstand these changes in the future.

6 Conclusion

In conclusion, it is apparent that MRO service providers are dealing with challenges and inefficiencies on daily basis. Some of the problems are the result of the poor internal management activities – such as the silo effect, while others are difficult to handle since they essentially stem from external forces – such as legal formalities and constraints, or even the nature of the industry itself, for instance inability to accurately forecast the demand for the spare parts. As the industry continues to grow these issues would become more prominent and important since they would hinder not only efficiency, but also profitability of MRO organizations. With the development of information technology, new web solutions have emerged that have a potential to fix these inefficiencies within the MRO supply chain by providing speed, transparency, connectivity, flexibility and intelligent optimization. This lowers human involvement and enables more analytical approach to decision making. By digitizing the supply chain activities and connecting the parties together in one network, total integration would be achieved where information and data are shared in real time, allowing every entity to be prepared in advance and respond to demand accordingly. However, in order for these digital solutions to be implemented and used to their full potential, certain changes have to be made, on small scale – adapting organizational culture, to big scale ones that are in the hands of legislators – standardization of trade documentation or system for counterfeit spare parts tracking. Nevertheless, academics and leading consulting agencies are convinced that digitization is inevitable and that organizations should act accordingly to be able to stay in the game.

6.1 Limitation

Conclusions and remarks made in this paper should be taken with caution. The literature review does rely for the most part on the findings drawn from academic sources. However, due to the fact that certain web solutions discussed in this paper (such as Blockchain) are still in the phase of development are and are largely unexploited, a considerable amount of information is based on assumptions of what might happen in the future and therefore remains rather theoretical. Secondly, the methodology used for the purpose of empirical research does have its weak points which have been addressed in the section 2.4. Moreover, because the method relies on a case study of one single company, the conclusions and findings are specific to that organization and could not be completely generalized for all MRO providers in the market since their organizational culture may differ, but also simple factors such as country of origin might have an impact on how operations are handled.

6.2 Suggestions for further research

According to Buyukozkan and Gocer (2018) digitization of supply chains is still in the early stage of its development. Hence there is still a lot of room for research of potential technological enablers and more importantly, of how they could be implemented. The article states how the research conducted so far does not really address the phenomenon from the business perspective and managers are lacking guidance that would help them handle digitization appropriately. Therefore, future research should focus on practical point of view and develop frameworks and systems for successful implementation of digital solutions, and not just simply address the benefits and challenges that characterize the digitization as a new business approach.

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Appendices

Appendix 1

Interview Guidelines (Ms. Matovic, employed at the Logistics Manager position):

1. What are the main criteria for choosing the suppliers?
2. Approximately how many suppliers do you work with and where are they located?
3. What channels of communication are used between the suppliers and the company?
4. Has the company ever faced issues with suppliers in terms of late delivery, false documentation, conflicts etc.?
5. Could you briefly explain the procurement process in the company? How is it decided which item (spare part or another component) should be ordered and in which quantity?
6. Documents handling and formalities related to the import of inventory seem to prolong the procurement process. Why is this the case? In your opinion, is there anything that could be done to make this process more efficient?
7. In company's exposition, it is mentioned that spare parts also come from 'internal sources'. Could you elaborate on that and explain how it might affect inventory management and procurement process?
8. How do you keep track of rotable inventories?
9. How often does the company face the situation where required spare part is not available? How is this issue handled?
10. You have been in a company for several years now. What changes have you seen once the inventory circulating within the company has started to be tracked using a software?
11. The exposition describes the incoming inspection process and the procedure for checking the validity and quality of inventory. In your opinion, how could this process be performed in a more efficient manner?

12. Have you ever had cases where you had to discard items from the warehouse because they became obsolete?
13. According to your work experience so far, how effective is the process of information sharing between different departments in the company? Would you agree that internal integration has an impact on procurement activities? Explain.
14. How familiar are you with the following technologies: cloud computing, big data, additive manufacturing (3D printing), Internet of Things and Blockchain?
15. Based on your knowledge and experience, do you think that these technologies and digitization might have an impact on MRO activities? If so, please elaborate.

Appendix 2

Interview guidelines (Mr. Zeljko Ivosevic, general manager):

1. How familiar are you with the following technologies: cloud computing, big data, additive manufacturing (3D printing), Internet of Things and Blockchain?
2. Based on your knowledge and experience so far, do you think that these technologies and digitization might have an impact on MRO activities? If so, please elaborate.
3. “GAS Aviation” still largely relies on conventional business practices, as well as majority of your suppliers (as previously stated by Ms. Matovic). Why is this the case?
4. Is “GAS Aviation” taking any steps towards digitization?
5. Would you argue that digitization is a source of competitive advantage among other MRO providers or is it becoming a necessity?
6. In your opinion, what are the most important factors for successful implementation of digital solutions?
7. In your opinion, what are impediments to complete digitization of supply chains? Why are companies reluctant to invest more into DSC?
8. In your opinion, considering the current state of technology, how feasible is the idea of the total DSC?

Appendix 3

Interview guidelines (Mr. Nikola Lukic – quality manager):

1. The exposition describes the lengthy incoming inspection process and the procedure for checking the validity and quality of inventory. In your opinion, how could this process be performed in a more efficient manner?
2. Has the company ever dealt with an issue of counterfeit spare parts?
3. Apart from aircraft spare parts, the company also has to source tools and other equipment, such as measuring instruments. Do same inspection rules apply for this kind of inventory?
4. Do you outsource the overhaul and calibration of instruments? What methods do you use to keep track on their serviceability levels and warranties?
5. Ms. Matovic has stated that the company sometimes opts for cannibalization in case of an urgent AOG. How safe is this method in terms of airworthiness? And also, what costs does it bring to the company?
6. How does the company keep technical records of performed work – is it electronic or paper based?
7. Are technical records of previous work performed used for demand forecasting purposes?
8. According to your work experience so far, how effective is the process of information sharing between different departments in the company?
9. How familiar are you with the following technologies: cloud computing, big data, additive manufacturing (3D printing), Internet of Things and Blockchain?
10. Based on your knowledge and experience so far, do you think that these technologies and digitization might have an impact on MRO activities? If so, please elaborate.
11. In your opinion, considering the current state of technology, how feasible is the idea of the total DSC?

Appendix 4

Interview guidelines (Mr. Stefan Dabic – mechanic)

1. *Да ли је могуће предвидети захтеве за одржавање летилице пре доласка у хангар? Објасните.* (Would it be possible to predict maintenance requirements for an aircraft prior to its arrival to hangar? Elaborate.)
2. *Шта је са случајем AOG? Који све фактори могу проузроковати изненадан квар или оштећење? На који начин се компанија носи са овако ургентном ситуацијом?* (What about the case of AOG? Which factors could potentially cause unexpected breakdown? How does the company handle such an urgent case?)
3. *Да ли технолочко (механичарско) одељење има утицаја на количину и фреквенцију поруџбина резервних делова?* (Does technical department have an impact on quantity and frequency of spare parts procurement?)
4. *На који начин одржавате комуникацију са логистиком? Је ли икада било проблема проузрокованим преносом погрешних информација?* (What channels do you use to share information with the logistics department? Has the company ever faced issues or costs due to miscommunication between departments?)
5. *Ваша колегиница је напоменула да је од велике важности пратити шта се дешава са деловим након што напусте складиште. Како механичарско осбље разазнаје стаус робе која циркулише у хангару? Да ли постоји посебан систем?* (Your colleague has stated how it is very important to track inventories once they are released from the warehouse. How does the technical staff differentiate between the status of spare parts circulating in hangars?)
6. *На који начин се попуњавају и чувају технички подаци током трајања ремонта летилице?* (Which approach do you use for filling out and storing technical records of aircrafts that are subject to maintenance?)