LEONARDO

CIRCULAR ECONOMY OPERATIONS

BST844 – ASSIGNMENT NO. 2
INDIVIDUAL REPORT

SECURING LEONARDO'S FUTURE:

Embracing Circularity Through Servitization

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Word count: 2208/2000+-10%

Contents

Introduction

This report examines how Leonardo Helicopters can pioneer a sustainable future by adopting a business model focused on retaining product ownership (RPO) through a leasing scheme while addressing the operational challenges and uncertainties of managing lease returns.

Organisations face growing accountability for wasteful practices as legislation tightens (Yuksek, 2024). The current helicopter industry focuses on extending product lifecycles but struggles with wasteful production and ineffective end-of-life (EOL) management, resulting in abandoned materials in helicopter graveyards (Elsayed, 2019; GAMA, 2024; NMG, 2024).

The situation is exacerbated by growing resource scarcity. Aluminium prices have skyrocketed by approximately 130% from 2016 (***Figure 1a***). The sharp increase reflects the increasing difficulty of extraction, which negatively impacts our production costs, reduces our products' affordability, and impacts our performance. Lenardo helicopter sales peaked in 2015 and have stagnated since (***Figure 1b***).

Meanwhile, the global helicopter market continues to grow steadily (***Figure 1c***), highlighting the organisation's growing obsolescence and the urgent need for transformation in its core operations. Adopting an RPO model will solidify Leonardo's market position, differentiate it by competing on sustainable production rather than volume produced, and pioneer the future of the helicopter industry.

Section one provides a background of core concepts throughout this report. Section two discusses how repair, remanufacture, and recycling can be applied and when it is appropriate to do so within the helicopter's lifecycle. Section three examines how we forecast demand and returns, solving the uncertainty of our consumer behaviours.

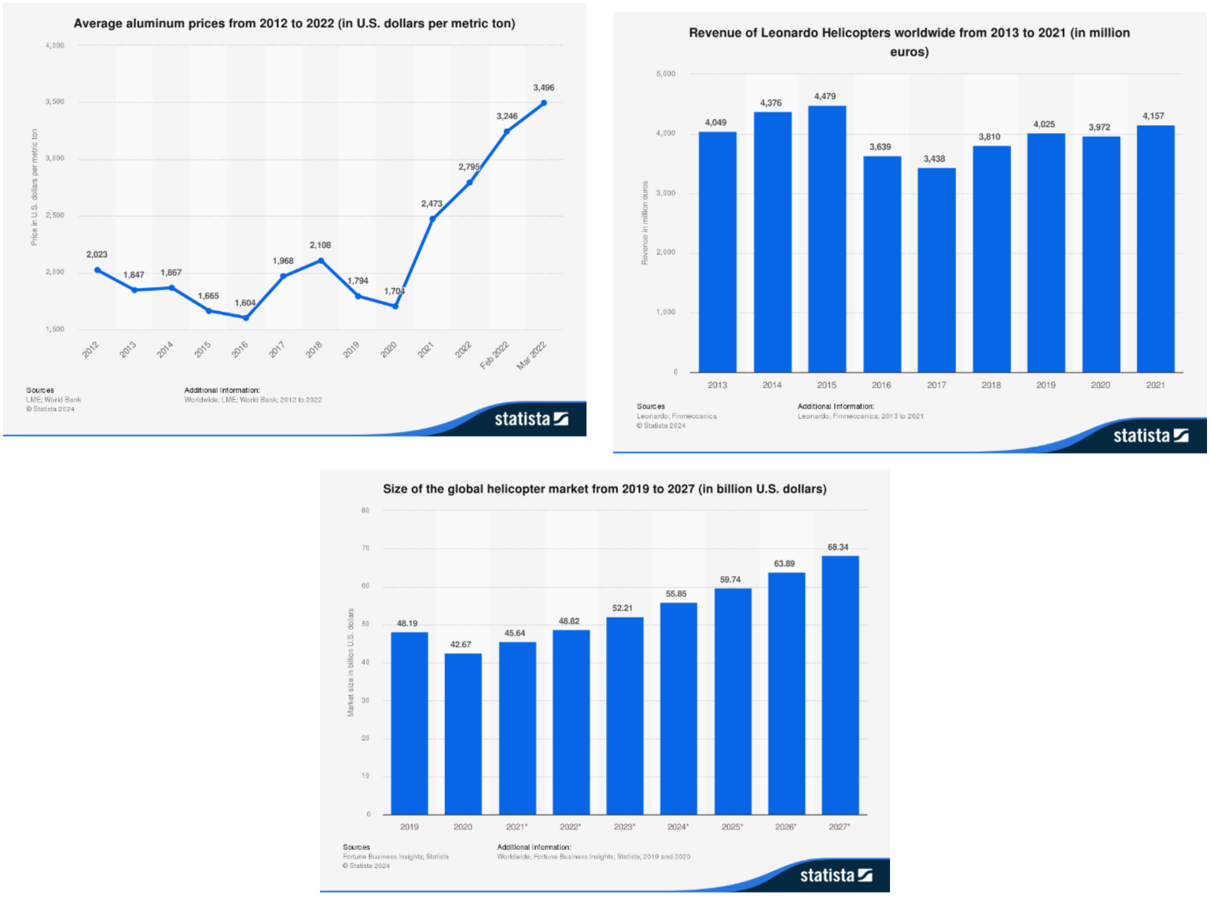


Figure 1a, b, c (Statista, 2024)

1. Background & Concepts

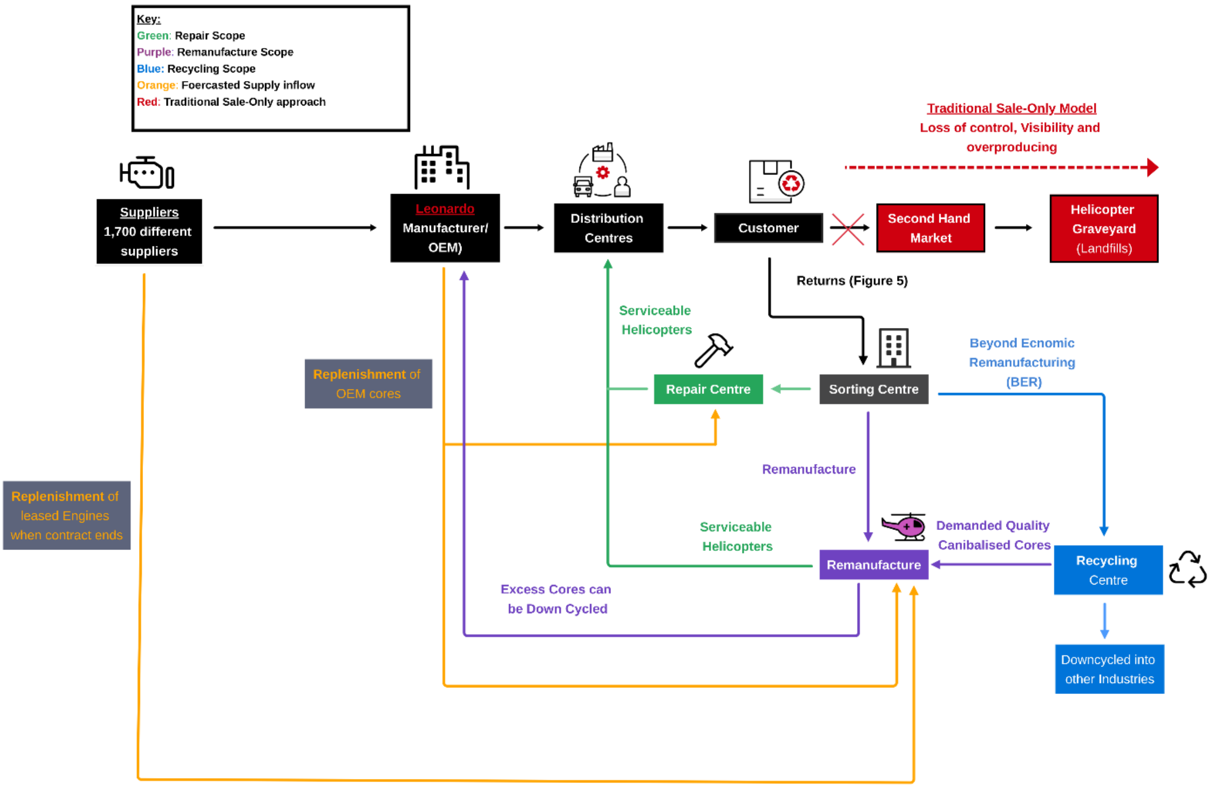


Figure 2: Helicopter Supply Chain Overview (Created By 21084397)

CE principles offer a sustainable alternative to the traditional 'take, make, dispose' model, focusing on maximizing resource use through recovery and regeneration (Macarthur, 2023; Morselette, 2020).

In the aviation industry, CE principles have been explored extensively, covering areas such as smarter design concepts and use of sustainable aviation fuel (SAF) (ICCT, 2020: Moyes, 2022), extending the product lifespan (ICAO, No-Date: Danson, 2024), and end-of-life processes (EOL) (Elsayed, 2019: Zhao, 2020). However, helicopters have been largely neglected, minimal information is publicly available.

Only 15% of helicopters are currently leased, all through third-party financiers with restrictive usage terms (IAM, 2024). The gap highlights the potential for innovative business models. By rethinking our current traditional sale-only approach, we can retain the majority of the valuable resources used in making the helicopter throughout its 18-year lifespan (Atasu, 2021; Weetman, 2016; HeliTrader, 2023), selling a service that is dependent on consumers time and usage of the product (Agrawal & Atasu, 2021; Sánchez, 2020). Through this scheme, our production can lease components rather than buy engines and rotor blades from current suppliers, such as Rolls Royce and General Electric, which will be upgraded at the end of each leasing contract (Leonardo, 2024). It is particularly advantageous for current consumers, which include public sector organisations such as medical, police, and fire and rescue services, which often operate under tight budget constraints, offering a convenient, cost-effective, dependable alternative to outright buying (Leonardo, 2024). Remanufactured helicopters would be an almost perfect substitution as Leonardo will hold tight maintenance controls and records, eliminating the uncertainties associated with relying on older, more affordable helicopters that the majority of our consumers currently use (Agrawal & Atasu, 2021). Leasing vehicles is a well-recognized practice, with major airlines frequently leasing airplanes, making this scheme a concept already familiar to many.

The concept of the “product life cycle” refers to the series of stages a product will go through its life, “from introduction, growth, maturity and decline stages” (Östlin, 2009, P.2). Return inflows will be subjected to repair, remanufacture and recycle. Repair involves mandatory Maintenance, Repair, and Overhaul (MRO), which includes replacing faulty components at predefined intervals to ensure safety and maintain the functionality of the helicopter's intended purpose (Potting, 2017; Jayaraman, 2006; Charter, 2007; Romero, 2014; Naim, 2007). Remanufacture involves the restoration of the product through comprehensive disassembly and replacement of components (Cores) to restore to similar “like-new” quality (Goltsos, 2019, 2023; Guide Jr, 2000; Wei, 2015). Finally, recycling aims to extract materials from discarded products that can be later downcycled back into the organisation’s production facility or cascaded into other industries’ production (Morselette, 2020; Worrell, 2014; Wolf et al., 2010; Campbell, 2020). Recycling should be the last process, as it requires substantial effort and capital to gain value from the product (Jensen, 2011; Allwood, 2012). Further details will be provided in Section 3, which offers an in-depth discussion of strategies, specific components, and the stages in the product lifecycle at which they are implemented.

By integrating into the CE, we face additional forecasting uncertainty. Forecasting is a critical control tool used to anticipate the future’s trends and influence informed decision-making by estimating what is likely to happen (Goltos, 2023, 2020; Östlin,2009). Accuracy heavily depends on the quality of information, which can be enhanced through blockchain technology (Rajpt et al., 2022). Section three will discuss this further.

TABLE 1:

LIST OF FACTORS AND CONCEPTS

Concepts	Description	Aurthors
Foundation of Circular Economy	Fundamental principles designed to address the "take, make, dispose" model by replacing it with sustainable circular practices focused on regerative system.	Ellen (2013, 2014, 2019): Morseletto (2020)
Aircraft CE	Strategies to inprove Airplane Circularity, Helicopters are neglected and lack research	Elsayed (2019): ICAO (2019): Danson (2023): ICCT (2020) : BP (2023): Zhao (2020): Al-Kaabi, Potter and Naim (2007)
CE Business Model	Business Models aimed to take responsibility of their products, implementing CE principles to recover/ regenerate the value of the products.	Atasu (2021): Weetman (2016): Agrawal, Atasu and Ülkü (2021)
Repair	Products that cycle back more quickly will undergo mandatory repair and servicing intervals to maintain quality	Reike (2018): Potting (2016): Jayaraman (2006): Charter (2008): Romero (2014)
Remaufacture	Process of comprehensive disassembly replacing damaged/ used cores to restoring used products "like new" condition	Guide (2000): Guide & Jayaraman (2000): Wei (2015): Goltsos (2019)
Recycle	Helicopters deemed beyond economic repair (BER) will be dismantled to salvage components that can either be recirculated within a closed-loop system or downcycled for use in other industries	Campbell (2020): Worrell (2014): Wolf et al. (2010): Jensen (2011): Haupt (2017): Allwood (2012): ILCD (2010)
Product Lifecycle	The stages of a product's lifecycle, from design to disposal, where maximum value can be retained	Stahel (1982): Slack & Brandon (2019), Östlin (2009)
Forecasting Return Flows	predicting the timing, quality, and quantity of product returns is essential for optimizing remanufacturing inventory management.	Sánchez (2019): Goltsos (2019, 2020. 2021, 2022): Cao, Patterson, and Bai (2005): Van & Zikopoulos, (2010): Shaw (2017)
BlockChains	Decentralized digital ledgers to enhance transparency and traceability throughout product lifecycle	Rajput et al. (2022):Saberi (2019): Weyns (2018): Kshetri (2018):Queiroz (2019): Chan (2023): Lee & Özer (2007):

Table 1: (Created By 21084397)

2. Circularity through the Product Lifecycle

The leasing program aims to minimize overproduction by satisfying demand with repaired/remanufactured helicopters returned from leasing contracts (**Figure 3**) (Goltsos, 2020). As returns surpass our demand, OEM should stop production of complete helicopters and focus on replenishment to repair/ remanufacturing centres. This approach allows Leonardo to efficiently manage demand while reducing the need to manufacture a new helicopter from scratch, mitigating the unnecessary take of raw materials and future wastage (Macarthur, 2023).

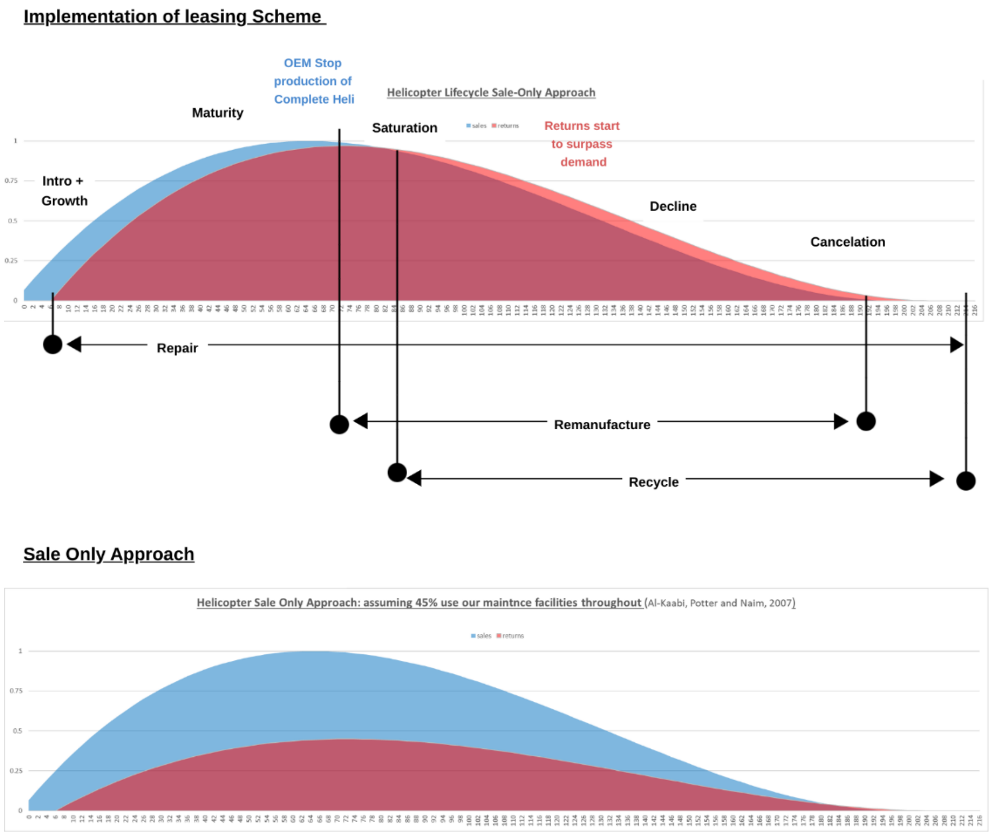


Figure 3: Helicopter Lifecycle, Projected forecast comparison between Lease & Sale only (Created By 21084397)

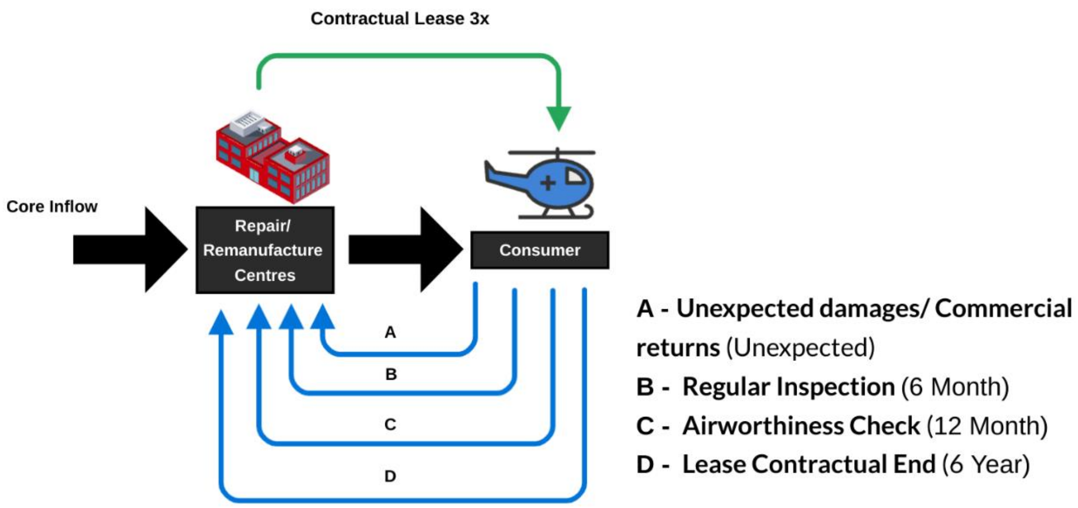


Figure 4: Return flow Intervals (Created By 21084397)

2.1 Repair

Repair operations commence at the launch of the leasing scheme and continue until its cancellation, as Leonardo will take responsibility for all repair activities throughout the lease term. To maintain airworthiness, we must conduct compulsory MRO on the aircraft every 6 and 12 months (FAA, 2024; Al-Kaabi, Potter and Naim, 2007). The six-month check will consist of a general inspection of the condition of the aircraft, servicing the engine and rotor blade, topping up oils, lubricants and replacing filters along with replacement of time-limited components such as belts, hoses and batteries (NTSB, 2024). twelve-month check consists of the annual airworthiness inspection, a comprehensive review of safety systems and airframe structure, and conducting servicing bulletins (CAA, 2024). However, uncertainty arises from unexpected repairs and helicopters damaged by customers and consequently returned (***Figure 4***). To address this, repair centres should take this into consideration and maintain an appropriate safety stock for common components.

Repair centres will operate on a repair-on-arrival procedure throughout the lifetime, repairing all returned helicopters as soon as they arrive as helicopter downtime is expensive and consumers are waiting for them (Haupt, 2012).

2.2 Remanufacture

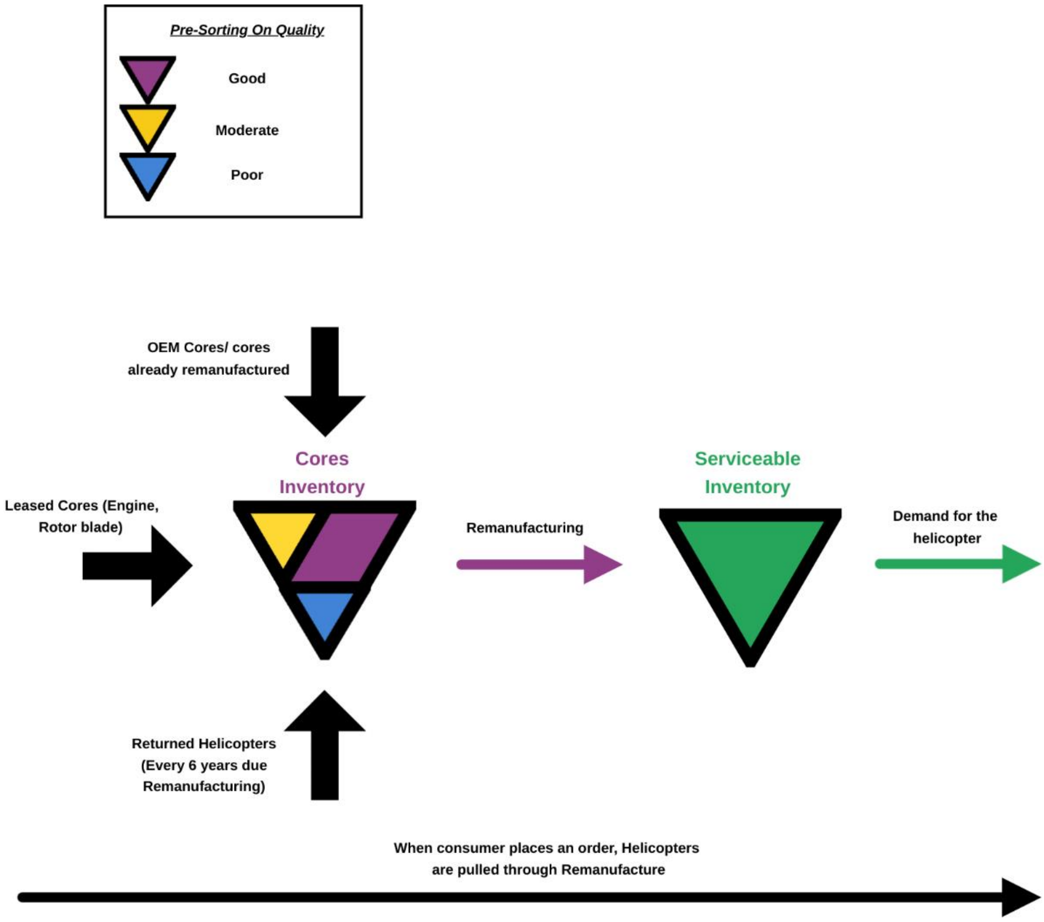


Figure 5: Remanufacture Pre-sorting Inventory Control (Created By 21084397)

Remanufacturing operations will commence during the growth phase, with a 6-year lag from the helicopter's launch. This lag aligns with the end of consumer leasing contracts.

By aligning consumer leasing contracts to our own engine and rotor blade leases from suppliers, we can swiftly return the used cores and rent complex parts from suppliers, reducing production costs by paying only for the usage of the components and providing consumers with constant efficiency upgrades, reducing their operational costs. Additionally, remanufacturing will be responsible for an overall review of the airframe's structural integrity, replacing likely degraded components such as the landing legs, doors and driveshaft (CAA, 2024; Guide, 2000).

During the entire lifecycle, remanufacturers must align restoration efforts with actual demand-pull, as Leonardo will operate on a make-to-order framework due to the risks of overproduction, leading to unnecessary waste and expensive contractual lock-in with supplier cores (Yang, 2004; Olhager, 2003). While awaiting placed orders, remanufacturers can pre-sort and assess returned helicopters depending on quality, gaining visibility on what must be changed (Poles, 2013) (***Figure 5***). However, a pull system will lead to longer lead times, which we must take into consideration and inform our consumers.

When demand starts to die off at saturation, remanufacturers can expand their scope to component remanufacturing as cannibalised components will begin to inflow from recyclers, which can be remanufactured back to standard and stored or distributed to other centres (Atasu, Guide & Van, 2011).

2.3 Recycle

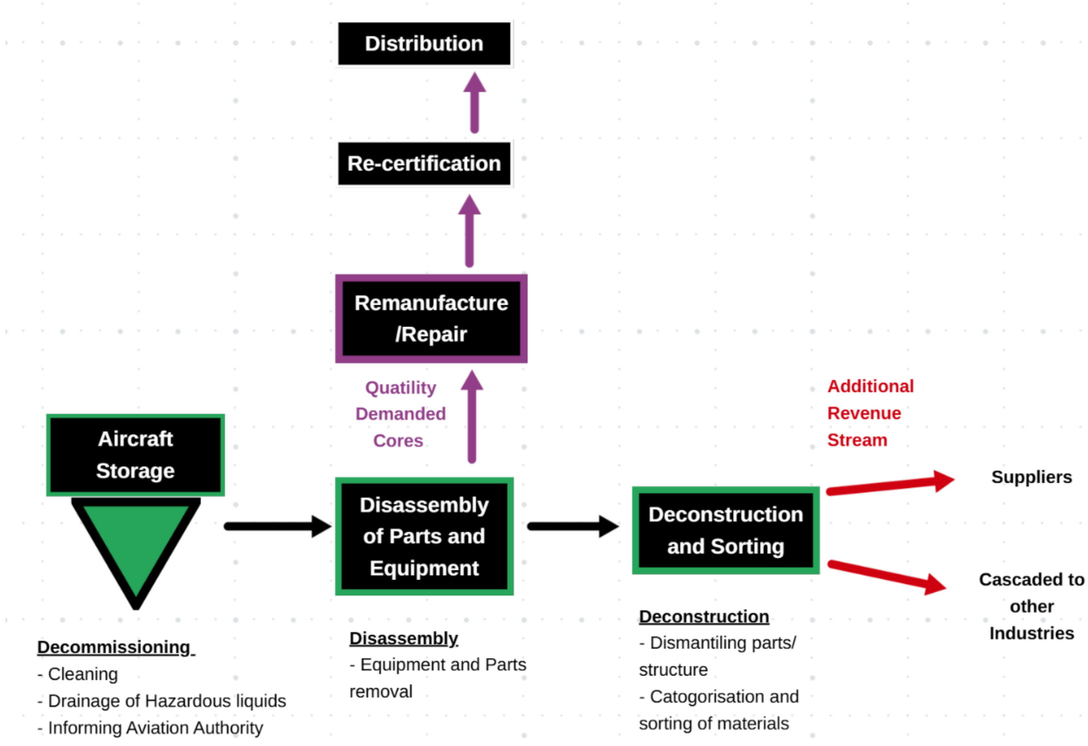


Figure 6: Recycle Operations (Created By 21084397)

During the decline stage, recycling centres will be introduced and responsible for managing the EOL process for excess returns. As demand decreases, the need to remanufacture aircraft also decreases, pushing aircraft to recycling centres (Östlin, 2007). As demand plummets, a higher proportion of aircraft will be recycled.

Helicopters coming in will be beyond economical repair (BER) and too costly to restore (Goltsos, 2019). Those can be cannibalised and disassembled for higher-quality components that will be kept and downcycled to remanufacture and recertified as a source of core supply (***Figure 6***). Additionally, almost 20% of old components are used in new production versions, these can be stored (Jensen et al., 2011; Atasu, Guide, and

Van, 2010; Leonardo, 2024). The remaining material can be deconstructed and sorted, sold to our suppliers, or cascaded to other industries (Airbus, 2021).

3. Reducing Forecasting uncertainty

By integrating into the CE, we face additional operational challenges. Not only do we face the uncertainty of forecasting the demand of consumers wanting this leasing service, but it is also critical to accurately predict both the rate and quality of returns (Goltsos, 2019). With operations spanning over 100 facilities across more than 40 countries, the scale and complexity of our global reach further complicate effective management and coordination of returns.

Forecasting returns for repair and remanufacturing centres is relatively simple. During the leasing, consumers will be contractually obliged to return the aircraft at set intervals at geographically close repair centres. By maintaining product ownership, we have precise control over forecasting and collection strategies, ensuring each leased helicopter is returned to us through designated channels at predetermined intervals, for every aircraft sold assumed will be returned (M1) (Goltsos, 2021). However, we must understand that some helicopters may crash. Our Initial market research shows that 3% are non-recoverable (EASA, 2020).

Returns from past sales (Recycling)

Assuming 3% are non recoverable
100-3(3%)= 97Helicopters

Demand	100	0										
Demand Forecast												
Returns	0	0	0	0	0	97	0	0	0	0	0	97
returns forecast	0	0	0	5	0	97	0	0	0	0	0	97
Time (Months)	1	2	3	4	5	6	7	8	9	10	11	12

Table 2: (Created By 21084397)

Repair centres anticipate helicopter returns approximately six months after the lease hand-off date (***Table 2***). On the other hand, Remanufacturers expect helicopters to return to them at the end of the 6-year lease (***Table 3***). Understanding the number of helicopters each centre manages, combined with precise time-series sales data, allows centres to adequately prepared with the resources, labour, and processes needed to handle incoming returns effectively (Sanchez, 2019).

Returns from past sales (Remanufacture)

Assuming 3% are non recoverable
100-3(3%)= 97Helicopters

Demand	100	0										
Demand Forecast												
Returns	0	0	0	0	0	97	0	0	0	0	0	97
returns forecast	0	0	0	0	0	97	0	0	0	0	0	97
Time (Years)	1	2	3	4	5	6 (72 Months)	7	8	9	10	11	12 (144 Months)

Returns will inflow from previous sales, but must only remanufacture once consumer orders

Table 3: (Created By 21084397)

Stochastic Bill of Materials
(Calculating inventory)

Replaced Part

Returns	Gearbox	Landing Grear	Instrument panel	Battery	Driveshaft	Fuel Hose	Belts	Seats	Other Components ...
Heli 1	0	0	0	1	0	2	2	0	
Heli 2	1	0	0	0	0	0	0	0	
Heli 3	0	1	0	1	0	0	0	0	
Heli 4	0	1	0	1	0	3	0	0	
Heli 5	0	0	0	0	0	0	0	0	
Heli 6	0	0	0	0	0	0	0	0	
Heli 7	0	0	1	1	0	0	0	0	
Heli 8	0	0	1	1	0	1	1	0	
Heli 9	0	0	1	0	1	0	2	0	
Heli 10	0	0	0	0	0	2	2	0	
Mean	0.1	0.2	0.3	0.5	0.1	0.8	0.7	0	
Probability (%)	10%	20%	30%	50%	10%	80%	70%	0	
Components needed (Assuming returns = 97)	(10% of 97)= **10**	(20% of 97)= **19.4**	(30% of 97)= **29.1**	(50% of 97)= **48.5**	(10% of 97)= **10**	(80% of 97)= **77.6**	(70% of 97)= **67.9**	(0% of 97)= **0**	

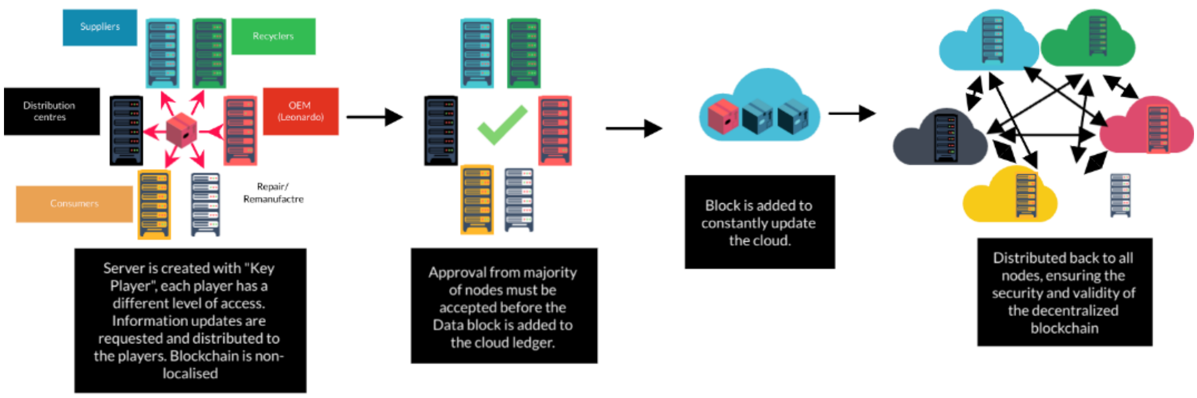
Components needed + Safety stock = Inventory

Safety Stock Considerations
- Targeted service level
- Space available
- Lead time variability
- Supply reliability (Cores with long backorder

***Table 4:* (Created By 21084397)**

But how can we confidently prepare for our inventory system when the quality and performance of returned helicopters remain uncertain (Gurnani and Gerchak, 2007)? Returned aircraft will vary in quality, with excessive usage accelerating the deterioration of components, requiring more parts to be replaced (Van & Zikopoulos, 2010). Sectors such as offshore experience higher utilisation, more frequent landings and take-offs, and frequent exposure to saltwater, facing accelerated corrosion and degradation of components (CRS: 2012; IOGP, 2023). The lease price should reflect sector usage to account for the increased need for component replacement and processing time at repairs (Cao, Patterson, and Bai 2005).

The bill of materials is no longer deterministic, but stochastic ranges of the probability of component replacement, and therefore, must be forecasted for (Shaw 2017). Data should be collected to identify the probability of each component being replaced, multiplying it by the expected aircraft we assume to return. Additionally, sufficient safety stock must be considered to meet a targeted service level (Goltsos, 2022). The stochastic probability of core replacement must be regularly updated as the likelihood of repair evolves throughout the helicopter's lifecycle (***Table 4***). Critical components, such as the structure, are expected to show an increased probability of replacement in the later stages of the lifecycle.



Key Players	Responsibility on Blockchain
Suppliers	- Contracts for leased Cores
OEM	- Specification of every helicopter Produced matched with vehicle identification number (increased visibility to Recyclers and Remanufacturers) - Components and structural bill of materials (visibility to recyclers) - Forecasted demand, close connection with refurbishes to aline efforts to reduce net demand
Distribution Centres	- Consumer Contracts -Locations of Helicopter Usage and Repair/ Remanufacture centres allocation
Consumers	- Ability to update financial records, location of helicopter usage - Update remainders of repair intervals - Reminders of end of leasing - Ability to end/ extend contracts, under conditions
Recyclers/ Remanufactures	- Last repair/remanufacture interval for each helicopter - Stochastic probabilities for each component changed (may change depending on region of usage, sector dominance, and average usage) - Time left on Supplier cores
Recycle	- Number of helicopters Recycled

Figure 7: "Key Players" blockchain integration (Created By 21084397)

Under these circumstances, forecasting rate and quality of returns rely significantly on the authenticity and accuracy of historical hand-off date and return data (Goltsos, 2019). Blockchain technology can future-proof operations using a cloud-based ledger shared amongst key players, creating an in-depth, detailed timeline of the aircraft's lifespan (***Figure 7***) (Saberi, 2019). The blockchain integration ensures data is transparent and stored securely, enabling enhanced traceability of the helicopter through the aircraft's Vehicle identification number (Rajput, 2022; Kshetri, 2018), allowing repair and remanufacturing centres to predict the quantity and quality of returns with greater precision, utilising visibility of previous repair records (Wamba, 2019).

Conclusion

To conclude, his report highlights the strategic potential for Leonardo Helicopters to adopt circular economy practices by shifting to a business model focused on retaining product ownership through direct leasing. This approach reduces excess production and raw material use, offering consumers an alternative to outright buying by launching a leasing scheme charge based on time held and product usage.

By retaining ownership of the aircraft throughout its lifecycle, Leonardo maximises its value by implementing efficient repair, remanufacturing, and recycling processes. Additionally, the ability to delegate and lease complex components from suppliers suggests that helicopters will be updated throughout, offering more efficient upgrades and the ability to compete with newer competitors' helicopter versions.

Closing the loop introduces additional complexities to forecasting processes. Beyond accurately predicting consumer demand, it's critical to forecast both the quantity and quality of returned products, adding a new layer of uncertainty to operational planning. These uncertainties can be mitigated by implementing forecasting procedures incorporating sales and quality data, where adopting blockchain technology enhances traceability and accuracy.

Leonardo's next steps involve conducting comprehensive market research to understand consumer willingness to pay, collaborating with suppliers to ensure a reliable supply of leased components, and executing smaller-scale market testing in targeted regions before broader implementation. These efforts represent a critical future stepping stone toward reducing environmental impact, enhancing customer satisfaction, and solidifying Leonardo's position as a sustainable leader in the aviation industry.

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