Strategic Command
Defence Support

Sustainable circular economics for Defence concept note

Document information

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Foreword

The delivery of Defence support, which comprises logistics, engineering and equipment support, consumes around a third of the annual Defence budget[1]. It is a highly complex endeavour which must deliver support across the globe at scale and intensity to enable operational advantage to our Armed Forces. The Defence Command Paper 2023 outlined how Defence must respond to a more contested and volatile world, with subsequent analysis indicating even greater challenges for the delivery of support.

The support demand signal is likely to increase for the future force with it required to operate in a contested environment where lines of communication, digital networks and infrastructure will all be targeted or at risk of disruption due to volatile climatic events. Protection, dispersal, surety of supply and concealment will become essential. The future force will operate in degraded and confused environments where competition with both adversaries and allies for finite resources will increase. We are already operating in an era of unprecedented climate change where we need to both adapt to new realities and mitigate the risks posed by further change.

How can support respond to these challenges and continue to enable operational advantage? We previously advocated for Defence to move from a model of sustaining at reach, to one which is designed for self-sufficiency: Towards Self-Sufficiency (TSS). Not only will this help to reduce the demand signal, along what could be extended lines of supply, but it will also make the future force more resilient and agile. Defence could go further in this journey of self-sufficiency by embedding the principles of circular economy across the end-to-end supply chain.

Circularity will be driven by military necessity and this concept does not advocate an approach of ‘do without’. It explores how Defence can ‘do differently’ to better exploit what it already has. This concept examines how Defence approaches the management of its’ supply chain and engages with industry to maximise the value of its assets. In doing so, it provides a framework that will influence how Defence could engage with its suppliers to drive operational advantage, resilience, and derive the economic benefits of sustainable business practices. Ultimately this will enable Defence to deliver operational advantage through support.

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Sarah Liggins

[1] DSN Report 2017, issued at the end of the Defence Support Network (Programme) concept phase.

Contents

1. Preface

1.1 This concept note provides the conceptual narrative to how Defence Support will respond to the strategic direction of the Defence Support Strategy (DSS), the Defence Supply Chain Strategy, the Sustainable Support Strategy and the Defence Support Operating Concept (SptOpC). It explores how embedding a circular economy could mitigate some of the challenges of delivering operational advantage through support across the Integrated Operating Framework (IOF).

1.2 This concept note will help to inform policy direction out to 2035 to align with the headmarks of the DSS's 2035 vision. It will prompt areas that will require further exploration through research, innovation, and experimentation.

2. What is the vision for the future?

2.1 The future force will be required to operate in an environment where the impacts of climate change exacerbate problems such as government instability, the spread of disease, conflicts over water supplies, the strengthening of terrorism, and widespread migration. Although some experts affirm that climate change will not be the sole cause of major conflicts, its impact will act as a threat multiplier by exacerbating existing triggers and increasing Defences need to respond to concurrent crises[2] . These factors will contribute to accelerating instability across the globe, impacting on the supply of resources on which Defence is dependant, whilst increasing risk to supply chain disruption due to operating in more congested locations caused by the direct and indirect effects of climate change. This concept note provides an approach for the application of circular economics (CE) in Defence to enable the Department to keep pace with rapid technological advancements. This will result in increased resilience whilst upholding and contributing to environmental, social and governance (ESG) values. This includes realising better value for money, greater collaboration between stakeholders throughout the support network, reduced water intake, and attracting talent through social credibility[3].

2.2 Defence currently operates a linear acquisition cycle where capabilities follow a well-defined process from inception, into use through to disposal. This process has always included the ability to upgrade capabilities to meet changing threats or requirements. Increasingly it is starting to recognise the need to be more aware of the financial and environmental cost of product disposal, with increasing demand for rare earth materials exposing Defence's dependency on overseas resources[4].

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[2] Hendrix, C, 2020
[3] McKinsey Quarterly (2019) Five ways that ESG creates value.ashx (mckinsey.com)
[4] Hendrix, C, 2020

2.3 The Sustainable Support Strategy (SSS)[5] defines how Defence Support can meet the challenges of the future through optimising support to operations; increasing our military capability; reducing our vulnerability to environmental threats; and mitigating the impact Defence has on the environment. This concept note is aligned to the six strategic initiatives identified by the SSS. It has been developed with a wide range of input from Defence, industry, and academic stakeholders. Its purpose is to offer a model that can apply CE across the SSS initiatives and wider Defence, enabling effective actions to implement a sustainable transition to CE in Defence.

2.4 CE is a theoretical concept that uses the argument of creating a cyclical model in place of currently linear product flows. It is an important step in improving the resilience and agility of the supply chain through the delivery of longer product life cycles. Implementation of CE is an important step to aid in the evolution of Defence's current systems into something that better meets its needs. Anticipated benefits include improvements in the resilience and agility of the supply chain, and longer product life cycles resulting in long term value for money. Adopting CE reduces resource intensity and logistical footprint, improves standardisation (plug and play) and interoperability, improves self-sufficiency of operations, and increases technology sophistication.

2.5 To mitigate blockers to successful implementation, Defence must create a model for materiel classification. Van Buren at al. recognise 9 different CE options. These are called the 9Rs and are an evolution of the '3R (reduce, reuse, and recycle) framework'. The 9Rs could be a starting point for the classification of materiel (and parts) for implementation in the manufacturers' requirements to measure the circularity of each product[6]. It is worth noting that in academia 'all R-lists resemble each other and differ mainly in the number of circularity strategies they put forward. They typically present a range of strategies ordered from high circularity (low R-number) to low circularity (high R number). R0 and R1 strategies decrease the consumption of natural resources and materials applied in a product chain by less product being needed to deliver the same function. Therefore, R0 and R1 are generally also considered circularity strategies, even though they do not necessarily involve increasing the reuse of products and components, or reapplication of recycled materials.'[7]

- **R0 – Refuse:** preventing the use of raw materials/non-CE products and/or changing the product with a new one.
- **R1 – Rethink:** Review the product design or use a multi-functional product.

[5] MOD Strategic Command, Defence Support (2022). Sustainable Support Strategy (publishing.service.gov.uk).
[6] Van Buren et al., 2016
[7] Potting et al., 2017

- **R2 - Reduce:** reducing the use of raw materials, increase efficiency of products in use, and reduce the number of products used if operationally sustainable and advantageous.
- **R3 - Reuse:** product reuse (second-hand, sharing of products and loans).
- **R4 - Repair:** maintenance and repair of defective products.
- **R5 - Refurbish:** refurbishing a product.
- **R6 - Remanufacture:** creating new products from (parts of) old products.
- **R7 - Repurpose:** use discarded product for a different purpose.
- **R8 - Recycle:** processing products to obtain the same level of quality.
- **R9 - Recover energy:** incineration of residual flows (product's end of life.

2.6 Concept, Assessment, Demonstration, Manufacture, In-Service and Disposal (CADMID) is the MOD's framework for the acquisition of equipment capability. The acquisition lifecycle is pivotal to through-life management, as it outlines the process from identification of a Defence capability gap to delivering the capability to end users. The MODs acquisition lifecycle consists of two variants: CADMID for acquiring equipment capability and CADMIT (where the T stands for termination or transfer) for service provision.

Figure 1 CADMID

2.7 The CADMID diagram follows a linear cycle (Figure 1), which encompasses a distinct beginning and end to the through-life management of equipment. This has little to no consideration placed on how the decommissioning of an in-service capability can benefit next generation capabilities and beyond. Whilst the disposal phase aligns with the principles of the Sustainable Procurement Hierarchy (Figure 2) and aligns with 5 of the 9 R principles, more needs to be done in Defence to ensure that a capability's end-of-life has greater consideration at the concept phase of its acquisition.[8]

[8] Knowledge in Defence - The Sustainable Procurement Hierarchy

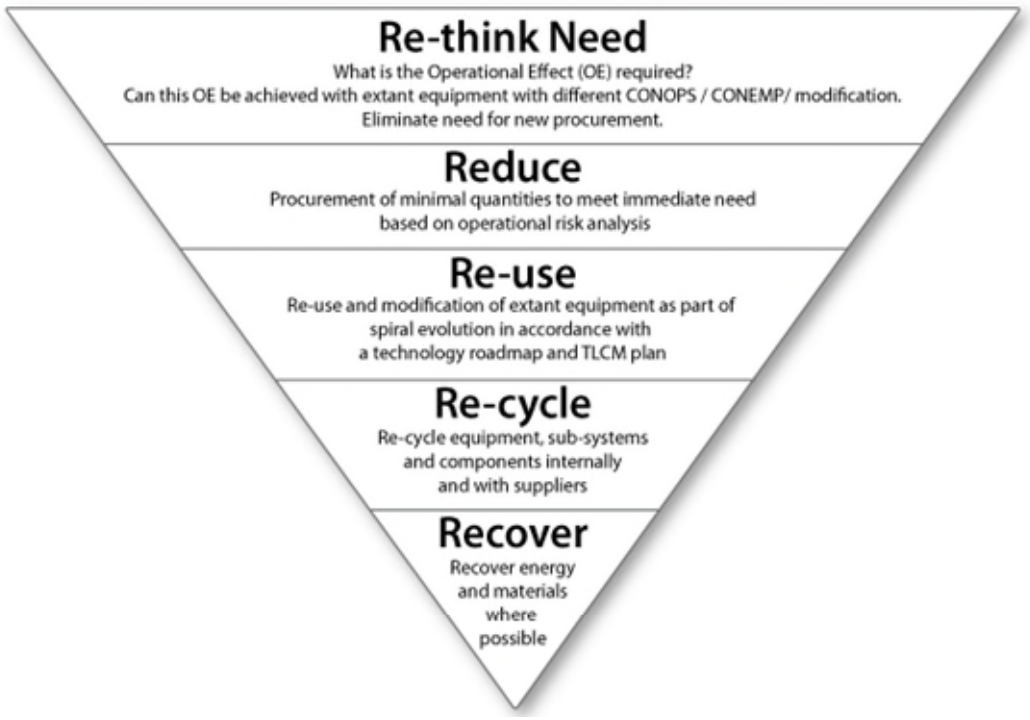

Figure 2 Sustainable Procurement Hierarchy

2.8 By integrating the R-list into the CADMID framework, a new acquisition framework can be established that implements circular economy principles into the acquisition lifecycle. This modified framework can be referred to as Concept, Assessment, Demonstration, Manufacture, In-Service and R-list (CADMIR). CADMIR (Figure 3) reflects the inclusion of the R-list and the transformation towards circularity. This new circular approach could aid Defence in the identification of critical minerals, rare earths and raw materials that are already within its inventory, sometimes at the sub-component level, that are required for its next generation assets. This approach will reduce Defence's reliance on the sourcing of critical resources from across the globe. This will result in a resilient supply chain, decreased down time of assets, greater value for money from its inventory and enhanced delivery of operational advantage, whilst maintaining its responsibility to help the country prosper through the sharing of resources that are surplus to requirements.

2.9 Below is a visual representation of the CADMID to CADMIR (Figure 3) cycle which will act as a driving force behind implementing a circular economy within the current acquisition lifecycle[9].

[9] Introduction to acquisition lifecycles - Acquisition lifecycles - Knowledge in Defence, UK MOD

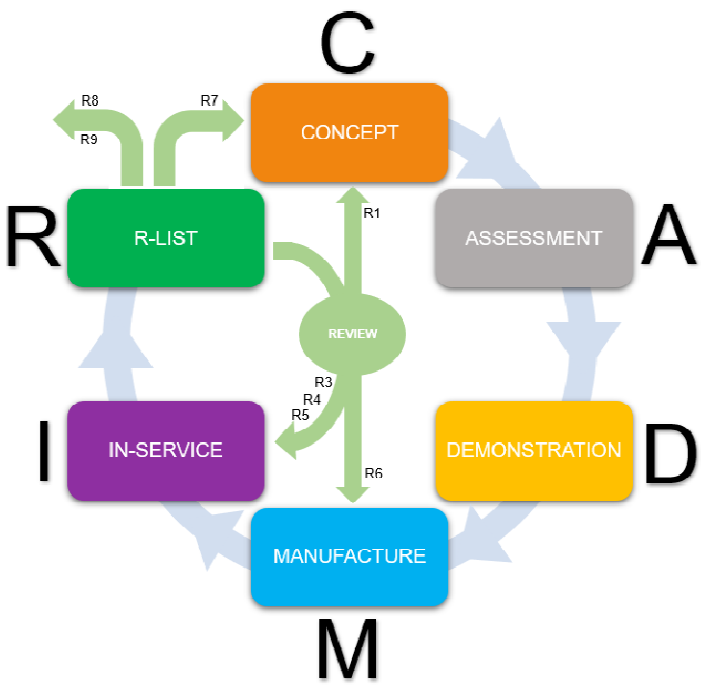

Figure 3 CADMIR

2.10 The incorporation of the R-list and circular principles allows for the application of circularity to the in-service phase of the acquisition lifecycle. This includes the R3 (Reuse), R4 (Repair), and R5 (Refurbish) principles. It is important to note that circularity is not limited to these areas alone. Some of the Rs also involve the concept phase, such as R1 (Rethink) which involves redesigning the acquisition of products that do not align with CADMIR. Additionally, the manufacture phase can incorporate R6 (Remanufacture).

2.11 To adopt the CADMIR framework, a plan must be put in place to transition away from CADMID throughout the acquisition cycle with consideration given to R7 (Alternative product). This will enable Defence to explore alternative cycles, with R8 (Recycling) and R9 (Recover energy) considered as final options in the circular economy approach.

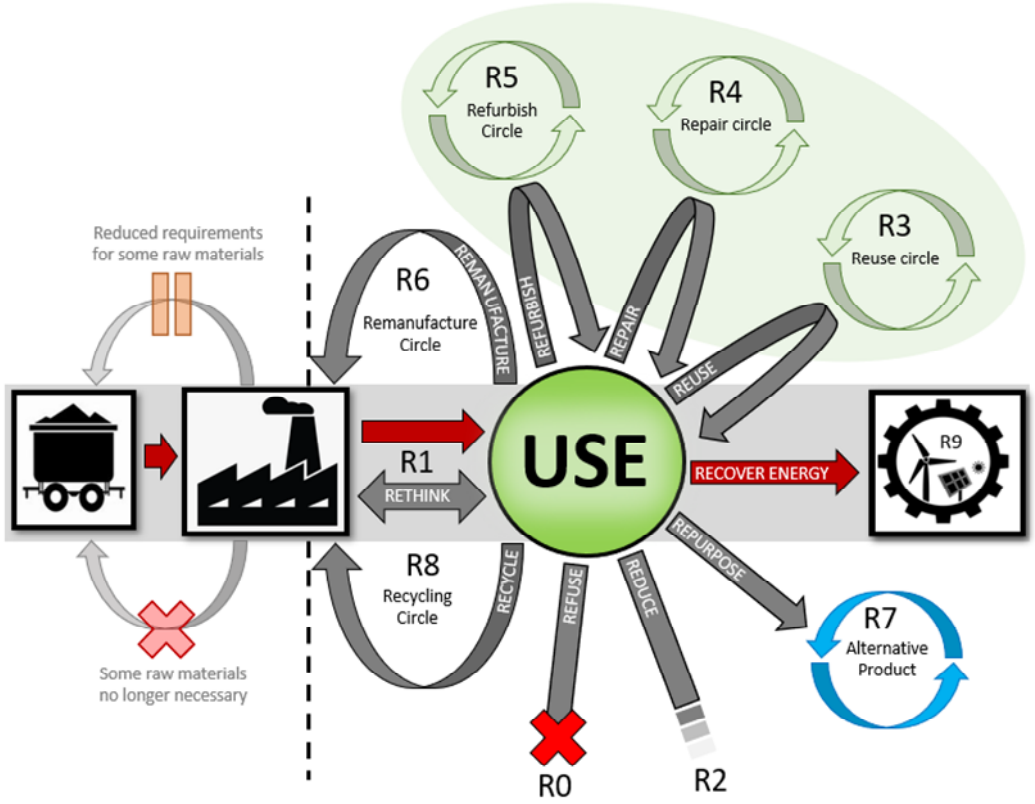

Figure 4 Circular economy model for Defence

2.12 A CE model for Defence has been created that focuses on the role of the final user of goods and services, rather than the perspective of the manufacturer. This model aids in identifying Defence specific requirements to support and improve resilience of supply whilst optimising products throughout their lifecycle. Defence must use and retain items within its inventory by maximising their use within the Department to achieve greater value for money, whilst also considering the impact on industrial partners, suppliers, and allies.

2.13 The CE model for Defence is based on Defence as the final user. It focuses on the main objective of applying the R3 (Reuse) cycle for as long as possible. This prioritises returning products back into use, ensuring that this is considered during the conceptual design/redesign phase for maximum effect throughout the lifecycle. Although R8 (Recycling) is usually considered the optimised way for implementing CE, it is the last iteration of a products lifecycle within the 9Rs before being used to recover energy. R9 (Recover energy) should always be considered to maximise the end of linear life value of the product to Defence, following R8 (Recycling) as a last circular resort. To efficiently manage its resource in a circular way, Defence must prioritise the identification and measurement of all types of resources while resource substitution, recovery and recycling are carried out and improved to allow for the tracing of mass and value over time. The integration of a CE process within Defence Equipment and Support (DE&S) will enable Defence to embed CE within the acquisition and through-life support of Defence

capabilities. Applying the R-list to Defence platforms will improve operational effectiveness and deliver sustainable solutions across Defence without compromising capability, resulting in competitive advantage on the battlefield.

2.14 The CE model is further explained later in this concept note.

3. Circular economy as an opportunity for military support

3.1 Adopting CE will reduce competition for resource, improve standardisation (plug and play) and interoperability, improve self-sufficiency of operations, and increase technology sophistication, leading to a better reuse of valuable resources currently destined for disposal.

3.2 CE is vital to delivering operational advantage in austere environments where support challenges are further compounded by:

- Complexity of environmental risks and potential climate change scenarios that diverge from current operational planning assumptions.
- Adversaries rapidly adapting to changing scenarios meaning they increase their competitive advantage over UK Forces.
- Persistence of enduring competition undermining raw materials availability.
- Transregional/local challenges disrupting supply chains.
- Emerging patterns of hybrid competition (including competition with allies for resources) that can affect supply chain and resource availability for UK Forces.
- Challenge of integrating military activities across the force and aligning those activities with partners and allies.

3.3 Defence should apply targeted CE actions to current logistics processes to provide greater resilience and agility within the supply chain. This will result in optimised efficiency of the supply chain, increasing deployed UK Forces ability to be self-sufficient.

4. Current applications of circular economics

4.1 The application of CE varies from country to country. In China CE is viewed as a ‘top-down national political objective’ whereas in the European Union, the USA and Japan it is a tool used to ‘design bottom-up environmental and waste management policies’[10]. Currently, the UK focuses mainly on recycling, rather than other CE principles. Defence will need to analyse CE innovation projects on a case-by-case basis to understand if they are relevant. Defence must identify risks of not adopting CE correctly to avoid the risk of greenwashing which will reduce its credibility with suppliers whilst undermining any benefits that are

[10] Ghisellini et al., 2016

realised due to sustainable technologies and processes. CE should be embedded to drive optimisation within the supply chain and industrial base, with emissions reduction acting as a secondary benefit rather than the primary driver. A CE will be key to bettering support in Defence in readiness for the future.

4.2 Defence should consider CE a priority enabler in improving resilience, agility, and delivering reliable supply of resources. To maximise the benefits derived from CE, sustainability measures and renewable energies must be embedded to allow Defence to deliver on its vision of operational self-sufficiency. Due to the complexity of Defence operations, a hybrid top-down and bottom-up approach should be used in the embedding of CE. This could be delivered through the refreshing of Defence Support policies to embed CE throughout the Defence Support Enterprise (top-down), and through the exploitation of innovation in both technologies and processes (bottom-up). Exploiting innovation - as either a fast follower and/or first innovator – will aid in the initiation of discussions within Defence. These will help understand how best to implement circular, sustainable, and adaptable pathways of resilience to enable Defence to operate at its full potential in an increasingly challenging environment.

5. Timeline

5.1 Key activities for embedding CE in Defence have been broken down into 3 epochs that align with broader Defence strategies. These include the Defence Support Strategy (DSS)[11], MOD Climate Change and Sustainability Strategic Approach (CCSSA)[12] and the SSS[13].

5.1.1 Epoch one (2023-2025)

- Identify and quantify how CE contributes towards the resilience of operational support.
- Trial new and emerging processes, and equipment solutions.
- Understand the work of partners and allies for integrated CE solutions.
- Position Defence Support at the forefront of embedding CE throughout the Defence Support Network, engaging with industry to ensure success of future implementation.

5.1.2 Epoch two (2026-2035)

- Widescale adoption of CE within the supply chain.
- Embedding CE principles on operations.

[11] Defence Support Strategy - GOV.UK
[12] Ministry of Defence Climate Change and Sustainability Strategic Approach - GOV.UK
[13] *Ibid.*

- Adopting CE principles and understanding blockers to interoperability with partners and allies.

5.1.3 Epoch three (2036-2050)

- CE fully implemented into Business as Usual (BaU).
- More streamlined adoption of innovative technologies throughout Defence.

5.2 This concept note is the first step towards implementation of CE within Defence to align with the ambitions set out within the SSS and to ensure that Defence stays in lockstep with the drive towards sustainability across industry and wider society.

6. Supporting benefits hypotheses

6.1 Anticipated benefits to Defence in adopting a CE are:

- Cost reduction due to reduced acquisition and longer product life spans.
- Operational self-sufficiency by minimising disruption of supply chains resulting in competitive advantage over our adversaries and reducing competition for scarce resources with our allies.
- Reduced distribution due to sustainable choices, micro-circularity[14].
- Reduced use of raw materials and reliance on a single country for resources – especially from strategic competitors and adversaries.
- Innovative routes to market (i.e., raw materials) and regeneration projects allowing Defence to better exploit novel technologies and approaches that aid in delivering operational advantage.
- Innovative repair, reuse, remanufacturing and recycling of components and materials. This includes raw materials and rare earths to maximise efficiency within Defence's supply chain and industrial base.
- Creation and implementation of proximity (i.e. short shoring) in the supply chain and reduced import dependency (especially from adversaries and competitors) increasing resilience within the supply chain.
- Improved maintenance leading to higher quality and/or more reliable and climate resilient capabilities with an increased lifespan and climate resilience.
- Transparency within Defence's end to end (E2E) supply chain.
- Incentivising industry to adopt CE by acting as a forcing function.
- Cost effectiveness by rethinking design and supply chain innovation to deliver quality products that are value for money.
- Greater understanding of through life versus up front cost of Defence's inventory, aiding in greater utilisation and value realisation.

[14] micro-level (i.e., single supply chain), meso level (i.e., across Defence) macro level (i.e., allies, partners), Franco, 2017

7. Risks

7.1 Anticipated risks to Defence if it doesn't adopt CE are:

- Increased cost of products or materials due to international and global supply chain challenges. This is evidenced by rising costs of energy following Russia's invasion of Ukraine.
- Insufficient capacity of Defence connectors, such as strategic lift, impacting maintainability of assets and operational success.
- Reputational and interoperability risk when operating with allies, due to a failure to adopt CE impacting the maintainability of equipment.
- Reliance on areas of the globe that are at greater risk of disruption degrading resilience of the supply chain.
- Failure to fully realise operational advantage.
- Incoherent adoption (or lack of adoption) across Defence resulting in internal misalignment.
- Failure of Defence to meet the Greening government commitments.

7.2 These risks can be mitigated through greater transparency between Defence and its multi-tier suppliers to allow greater oversight of inventory moved through the end-to-end supply chain. This will place UK Defence at the forefront of delivering sustainable operational self-sufficiency and allow for the sharing of best practice with allies, partners, and other government departments (OGDs).

8. CADMID to CADMIR

8.1 The CADMID[15] cycle, an acronym for Concept, Assessment, Demonstration, Manufacture, In-Service, and Disposal, is the framework used in Defence acquisition. Key elements of the CADMID cycle are:

8.1.1 Concept: The initial stage involves identifying the requirements, objectives, and potential solutions for a defence project. This phase includes conducting feasibility studies, defining user needs, and establishing the project's scope.

8.1.2 Assessment: In this phase, the proposed concepts are evaluated against technical, operational, and financial criteria. This stage involves conducting risk assessments, cost-benefit analyses, and technology readiness assessments to determine the viability of the concepts.

8.1.3 Demonstration: Once a concept is deemed feasible, it moves into the demonstration phase. This stage involves developing

[15] CADMID Content - Knowledge in Defence - UK MOD

prototypes or conducting trials to validate the concept's technical capabilities and operational effectiveness.

8.1.4 Manufacture: After successful demonstration, the project progresses to the manufacturing phase. This stage focuses on producing the required equipment, systems, or platforms in line with the project's specifications and quality standards.

8.1.5 In-Service: The in-service phase involves the deployment and operation of the manufactured equipment within the defence organisation. This stage includes training personnel, conducting maintenance, and monitoring performance to ensure the equipment meets operational requirements.

8.1.6 Disposal: The final phase of the CADMID cycle deals with the end-of-life management of the equipment. This includes decommissioning, recycling, or disposing of the equipment in an environmentally responsible manner.

8.2 While the CADMID cycle provides a structured approach to Defence acquisition, it is not without limitations. Issues include:

8.2.1 Lack of flexibility: The cycle's linear nature limits adaptability to changing requirements or emerging technologies. To address this, incorporating iterative feedback loops and agile methodologies will enhance flexibility and responsiveness.

8.2.2 Lengthy development times: The CADMID cycle can be time-consuming, resulting in delays in delivering capabilities to end-users. Implementing concurrent engineering practices, modular designs, and leveraging digital technologies could help streamline the process and reduce development times.

8.2.3 Limited stakeholder involvement: The cycle's hierarchical nature restricts collaboration and input from end-users and other stakeholders. Encouraging early and continuous engagement with end-users, industry partners, and subject matter experts can enhance the cycle's effectiveness.

8.2.4 Insufficient consideration of sustainability: The disposal phase often lacks emphasis on sustainability and environmental impact. Integrating sustainable design principles, promoting circular economy practices, and ensuring proper disposal and recycling processes will address this concern.

8.3 The CADMID cycle provides a comprehensive framework for managing Defence equipment acquisition projects. By understanding its key elements and limitations Defence can make informed decisions and implement improvements. In doing so it can enhance efficiency, flexibility, stakeholder involvement, and sustainability throughout the cycle. Adapting the cycle from CADMID to CADMIR to address these concerns will

contribute to more effective and timely delivery of defence capabilities. Circular economy principles can be effectively applied to the CADMID cycle, enhancing sustainability and resource efficiency throughout the process. By adopting circular economy principles, the CADMIR cycle can focus on the transformation of waste into a resource, promoting reuse, and maximising the value of resources within its inventory. In the concept phase, emphasis can be placed on designing products and systems with a focus on durability, modularity, and ease of repair. During the manufacture phase, incorporating recycled or remanufactured materials can reduce the demand for virgin resources. Finally, the disposal phase can be transformed into an opportunity for resource recovery and recycling. This will ensure that materials are diverted from landfill and reintroduced into the production cycle for maintenance of current capabilities or to act as feedstock for next generation and beyond equipment. Through the integration of circular economy principles into the CADMID cycle, the defence sector can contribute to a more sustainable and resilient future.

9. A circular economy model for Defence

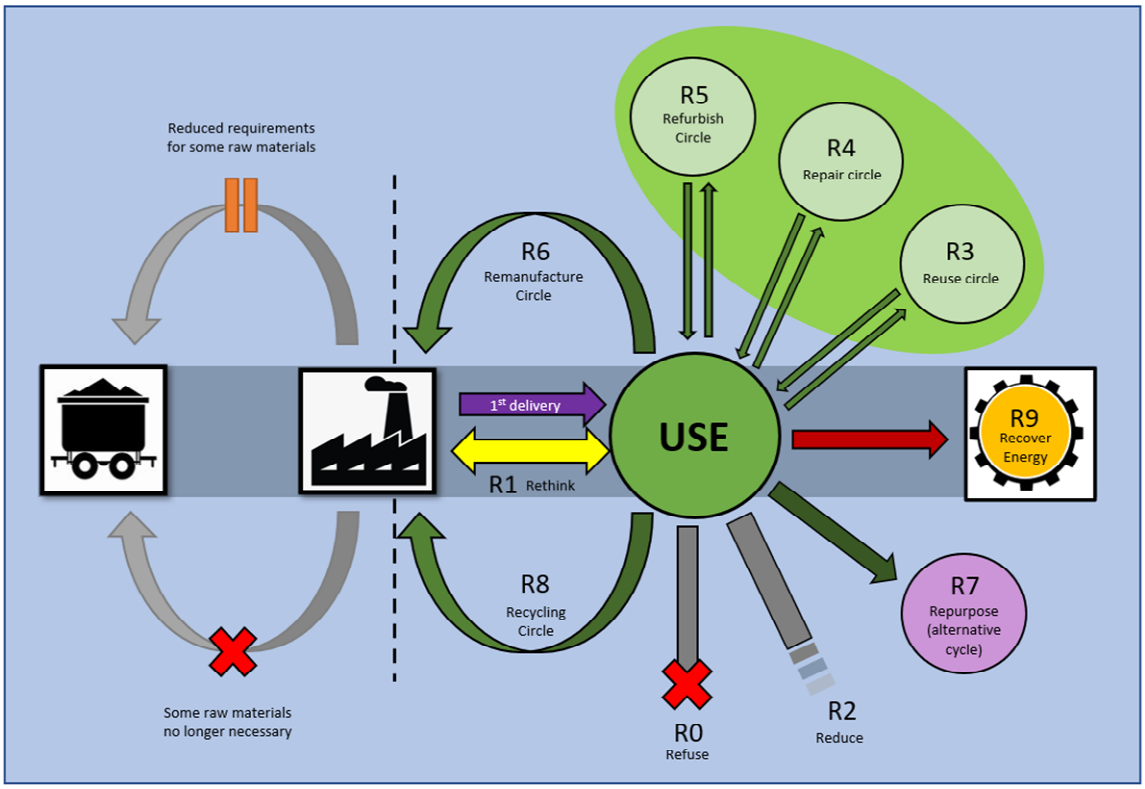

Figure 5 Circular economy model for Defence

9.1 To successfully embed CE within Defence, an integrated approach must be adopted. In the past efforts have been made to implement social value (environmental, social, governance - ESG) in the Defence procurement system, however utilising the Social Value element of an Invitation to Tender (ITT) cannot be relied upon to deliver benefits. This is because

social value is about the additional, non-costed, benefits of a contract being delivered and so is not measurable. Defence should develop a new approach in addition to the Government Commercial Function's Social Value Model[16] to ensure sustainability is classed as a key user requirement in Defence's procurement process. This will encourage suppliers to actively adopt CE and allows Defence to monitor the sustainability performance of its suppliers. CE does not fully fit within the Social Value Model - even though it has a positive environmental impact – and must be considered as separate from current social value that is included within the Defence tender process. This will deliver high level value to Defence by taking an integrated approach to considering products' life cycles and involving the wider supply chain to provide coherence across siloed single-industry ESG strategies.

9.2 A new circular approach in Defence must focus on a long-term transition to implement a successful and sustainable circular strategy. This includes changes that must be made at the operational and tactical level[17]. This is important as inefficient circular systems can cause social, economic, and environmental damage[18]. Initial efforts to implement CE within Europe were characterised by an absence of stakeholder engagement with a fragmented and siloed vision and governance which prevented systematic implementation. This combined with uncertainty around system boundary limits, the unpredictability of the waste sector, and ambiguous governance contributed to difficulties in measuring, assessing, and improving circularity within the economy[19].

9.3 When applying CE to Defence, the range of options from R0 to R7 must be considered. As the UK currently focuses on recycling (R8), Defence could wrongly assume that recycling is evidence of already employing a CE process. Although R8 is usually considered the optimised way for implementing CE, it is the last iteration of a products lifecycle within the 9Rs before being used to recover energy. For anything within the supply chain that does not have an alternative to a linear supply chain or other iterative lifecycle (i.e., perishable products such as food waste), R9 (Recover energy) must always be considered to maximise the end-of-life value of the product to Defence. Defence should consider R8 (Recycling) as the last circular resort. By placing responsibility on external suppliers that benefit from recycled materials through the reverse supply chain, Defence will not only incentivise industry partners to innovate in a more sustainable way, but also strengthen its partnership with industry partners through the sharing of raw materials and critical resources. This aids in reducing Defence's reliance on areas of the globe for critical resources that pose a risk to the resilience of the global defence supply chain.

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[16] Procurement Policy Note 06/20 – taking account of social value in the award of central government contracts - GOV.UK
[17] Van Buren et al., 2016
[18] *Ibid.*
[19] Corvellec, 2021

Closing resource flows involves establishing systems and processes that enable resource recovery. Slowing resource flows involves keeping resources in use for as long as technically and economically possible.

9.4 The CE model for Defence is based on Defence as the final user, focusing on the main goal of applying the R3 (Reuse) cycle for as long as possible, in addition to R4 (Repair) and R5 (Refurbish). This will help Defence to deliver R3 (Reuse) by prioritising returning products back into use. Defence should perform a gap analysis to understand where R4 (Repair) and R5 (Refurbish) is not already applied within its supply chain and inventory management processes to aid in early identification of blockers to success. Successful implementation of the reuse, repair and refurbish cycles will be limited by product design. Ensuring that these cycles are considered during the conceptual design/redesign phase of a capability or product will be essential in exploiting Defence's inventory to maximum effect throughout its lifecycle.

9.5 The integration of a CE process within DE&S business processes will be a key enabler for Defence to embed CE within both the acquisition process and through life support of Defence capabilities, whilst encouraging the industrial base to innovate towards a circular process. This will require the sharing of responsibility across the supply chain between Defence and its industrial partners. Applying the R-list to Defence platforms will improve operational effectiveness without compromising capability whilst delivering sustainable solutions across Defence resulting in competitive advantage on the battlefield.

10. Responsibility and accountability in the supply chain

10.1 Defence must collaborate with internal and external stakeholders to improve transparency when monitoring resource stock and flow on an ongoing basis. This will aid in the identification of opportunities to add, retain, recover value, track, and manage its resources. Defence must seek solutions that focus on optimising and balancing the use of products and processes. It must consider the optimal approach for operations and not only consider a product's specific use, but also the full effects of the system generating and supporting it. Responsibility and accountability should be shared between all stakeholders involved throughout a capability or products life cycle. Alignment between Defence and its partners on where responsibility and accountability will lie can be enacted using agreements, traceability of a product through its lifecycle, data sharing and the creation/application of technical/official standards that consider the totality of the CADMIR cycle. By identifying responsibility and accountability, Defence will share the responsibility for sustainable products and processes, whilst encouraging innovation within its industrial base. Application of these principles in conjunction with a stakeholder map and the R-list will help to identify any weak points in the product's life cycle. This will allow Defence to generate targeted actions to improve the circular process and the sustainability of each stage of the life cycle.

10.2 Applying these principles in the Defence supply chain will assist in the identification of priority areas and enable Defence to better exploit innovative technologies and processes to aid in the improvement of operational effectiveness. For example, identifying products categorised only as R8 and R9 will allow focused research and innovation to enhance the application of R1-R7, whilst also identifying where responsibilities sit, and which department/stakeholder must take action to improve the sustainable efficiency of a product and reduction of waste.

11. Extended producer responsibility (EPR)

11.1 EPR is an overarching policy principle that is enacted through several tools[20]. CE needs to be a shared contribution between stakeholders involved in the products' life cycle and can be enacted using EPR as a policy principle. Potential tools that Defence could employ to drive EPR within its supplier base are agreements, traceability, monitoring options and technical/official standards. By adopting and embedding EPR, Defence will share responsibility for sustainable products and processes within its supply chain, whilst driving innovation within its industrial base.

11.2 Circular procurement must consider the long-term circularity impacts of each purchase. Defence must scrutinise the purchases it makes to ensure it purchases products, services or solutions that seek to contribute to closed resource cycles within supply chains. This will enhance the positive circularity impacts of the solution(s) for defence and its stakeholders across its whole life cycle. To achieve this, Defence should update its policies, and circular economy principles should be embedded into its contractual requirement set to demonstrate Defence's commitment to its CE strategy.

11.3 Applying EPR in conjunction with a stakeholder map, the R-list and a defined measurability of data will help to identify weak points in a product's life cycle. This will allow Defence to improve the circular process and sustainability of each stage of the life cycle. It would do this by identifying responsibilities, accountabilities and further actions that are required to increase resilience and reduce potential weaknesses in the supply chain.

11.4 Utilising EPR would aid Defence in identifying priority areas, and in exploring innovative technologies and processes that will aid in improving operational effectiveness. Identifying products categorised only as R8 and R9 would allow focused research and innovation to enhance the application of R1-R7, whilst also identifying where responsibilities sit, and which area of Defence should take action to improve the sustainable efficiency of a product.

[20] Massarrutto, 2014

12. Circular economy as a measure of resilience

12.1 NATO defines resilience as the capacity to prepare for, resist, respond to and quickly recover from shocks and disruptions[21]. Several industries and organisations are starting to recognise the value of circularity in building resilience[22]. Due to the complexity of Defences supply chain, a specific standardised measure for wide-spread adoption of CE must be considered, taking into consideration the impact on stakeholders.

12.2 In May 2024 the new ISO 59000 family was published which provides an overview of the vocabulary, principles, and guidance for supporting a successful implementation of CE within an organisation. ISO 59020 focuses on measuring and assessing circularity performance by providing methodologies for data collection and indicator selection, whilst complementing extant sustainability assessments[23].

12.3 The ISO59000 family is a useful instrument for Defence to use in embedding tracking systems and data analysis of material flows, providing an opportunity to adapt Defence standards. This will enable Defence to better define measures of effectiveness and measures of performance relating to CE.

13. Circular economics as a driver for innovation

13.1 To better define CE innovation within Defence, three different CE cycles, could be implemented:

13.1.1 Biological cycle – products that can return to the biosphere and has a linear process (usually compostable). It can be made circular by using the end-of-life product for biological purposes (i.e., compost) or to recover energy (i.e., creation of hydrogen from food waste).

13.1.2 Technical cycle – products that cannot return to the biosphere and must be made fully circular.

13.1.3 Mixed cycle – products that are partially technical and partially biological.

13.2 Both biological and technical cycles follow three processes.

13.2.1 Adapt existing linear business models to include circular strategies.

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[21] NATO - Topic: Resilience, civil preparedness and Article 3
[22] *Ibid.*
[23] International Standard published, ISO 59020:2024 Circular Economy

13.2.2 Renew any existing circular business models to consolidate circularity strategies and processes that are already in place.

13.2.3 Design a brand-new business model based on circularity strategies to replace linear business models with no transition period built in[24].

13.3 Products are then divided into subgroups to aid Defence in the analysis of through-life costs, whilst also aiding in the identification of areas where intervention is required and where the application of the R-list and the biological/technical/mixed cycle can be used within the supply chain. The below categorisation can be used as a guideline:

13.3.1 Group 1 - Green cycle (R3 – reuse, R4 – repair, R5 – refurbish) technical, mixed.

13.3.2 Group 2 – Biological cycle (R9 – recover energy, return to biosphere) biological, mixed.

13.3.3 Group 3 – Alternative cycle (R8 – recycle, R6 – remanufacture, R7 – repurpose) technical.

13.3.4 Group 4 – Non-CE cycle (R0 – refuse, R2 – reduce) technical, biological.

13.4 CE is a system of systems. To develop understanding of Defence's baseline, analysis should focus on the whole life cycle of a product. To inform the baseline, Defence should consider the initial CE maturity level of a product, scarcity of materials, possible implementation, and optimisation of CE principles onto the product, and how the application of CE can deliver military advantage.

13.5 Industry is increasingly investing in innovations that aid in the application of CE into their business processes. As there is no specific branch of innovation relating to CE, each business looks to their own cycle and products and applies new technologies and models that best fit their purposes. This provides an opportunity to implement a CE approach in different areas simultaneously if cohered correctly, with innovation focusing on operational models based on sustainable CE.

13.6 Defence should focus on reuse, repair, and refurbish, before moving onto the recyclability of products (including those subjected to ACTO (Attractive to Criminals and Terrorist Organisations) whilst concurrently investing in alternative solutions. Innovations must be focused on alternative materials, components - including novel transformative technologies - and product circularity.

[24]Susur and Engwall, 2023.

13.7 To identify potential CE innovations for Defence, it should consider the impact of including it in business as usual. Potting et Al. (2017) developed a list of diagnostic questions that prove useful for considering a product's measurability and effect during the transition phase of implementing CE principles[25]. These questions can be used as a guideline for creating a Defence specific question set.

13.8 Defence needs to have the ability to diagnose CE innovations at an early stage to encourage innovation. Where innovation is not happening Defence will need to kick-start it to understand the sustainable potential of new products/processes in the transition to a CE model and for implementation in future BaU. This can be delivered by incorporating sustainable considerations and tailoring diagnostic questions for all projects, programmes, and processes by focusing on the desired outcomes.

14. Conclusions

14.1 This concept note aligns with the SSS and focuses on the application of CE in Defence. It highlights the benefits that implementing a CE will have on Defence and identifies the opportunity for a coherent implementation plan. There are clear benefits and identified risks that can be mitigated through implementing CE and including EPR in a products' life cycle. The R-list provides a useful instrument for prioritisation and traceability and must be adopted in collaboration with internal and external stakeholders to aid in the development and understanding of priorities across the Defence Support Enterprise. CADMID to CADMIR provides a framework that allows Defence to embed CE principles at the heart of its acquisition process and highlights the importance of circularity to not just the building of resilience with Defences industrial base, but also the importance of exploiting resources within its inventory in a more effective and sustainable way. The Defence CE model provides an overview of how CE can be applied to the Defence supply chain, and the new ISO 59000 family provides guidance on how best to measure the performance of CE. The diagnostic questions offer an opportunity to understand innovation potential in Defence applications and can be tailored to the area of interest. In conclusion, CE offers a model that Defence can utilise to reduce supply chain vulnerabilities, increase resilience, reduce emissions, maximise the use of material within its inventory and ultimately enhance operational effectiveness.

[25] Potting et al, 2017

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