***Resilient Supply Chain***

As discussed by den Boer et al. (2020), the defense sector is characterized by high operational instabilities and it requires “a robust and well managed supply chain” which is resilient to any potential disruption. AM can improve supply chain resilience. Indeed, as stated by Tan et al. (2021), *“AM technology has demonstrated operational resilience and provided a wide spectrum of on-demand solutions to provide rapid emergency responses and solve supply chains disruptions issues”*. Similarly, Patil et al. (2023) stated that *“AM adoption can pave proactive and reactive ways to improve resiliency and continuity contingent on practicing AM as an alternative source of manufacturing”*.

In light of this, we can derive the following proposition:

***Proposition O1:*** By enabling on-demand production and manufacturing close to the point of use, additive manufacturing (either adopted independently or integrated to conventional manufacturing) can reduce and mitigate the impact of supply chain disruptions.

***Environmental Sustainability***

AM has the potentialities to reduce the environmental footprint. As discussed by Attaran (2017), this is possible thanks to two characteristics of AM, i.e. the possibility to produce close to the point of use and layer-by-layer. Indeed, Attaran (2017) stated that *“by manufacturing items closer to the end destination, AM reduce […] environmental impact”* and that *“AM leaves a smaller environmental footprint. The technology generates little waste as only the needed materials are used”*. Similar statements can be found in other papers (e.g., Peron et al. (2024), Murmura and Bravi (2018), and Ford and Despeisse (2016)).

In light of this, we can derive the following proposition:

***Proposition O2:*** AM reduces the environmental footprint by enabling localized production, which minimizes transportation requirements, and by employing a layer-by-layer fabrication method, which reduces material consumption.

***Reduced Need of Employees***

AM is a digital and automated manufacturing technology whose adoption is reported to reduce the number of workers required to carry out the operations. As stated by Franco et al. (2020), “a consequence of 3D printer use is that the technology could leave workers unemployed as a result of eliminating many labor-intensive assembly processes”. Additionally, Peron et al. (2024) stated that “contrarily to most of the CM technologies, with AM one operator can operate more than one AM machine per time”.

In light of this, we can derive the following proposition:

***Proposition O3:*** AM requires less workforce than conventional manufacturing techniques

***Customization and Complexity***

As mentioned by one of the practitioners interviewed in Ronchini et al. (2023), *“the biggest advantage of AM is the freedom of shape and the ability to make very complex geometries that do not have constraints linked to mechanical or casting technologies”*. Indeed, contrarily to CM technologies, the layer-by-layer production of AM processes “enables production flexibility and design freedom” (Peron et al., 2024), which allows *“customization and personalization of the product”* (Bernard et al., 2023). As stated by den Boer et al. (2020), *“personalization can help to improve the circumstances in which soldiers are working. In a situation where original (universal) face brackets for night vision goggles were defect, AM was used to produce personalized ones”*.

In light of this, we can derive the following proposition:

***Proposition O4:*** AM enables the easy and fast production of highly customized and complex parts

***Responsiveness***

AM can increase the responsiveness in two ways. First, as stated by Franco et al. (2020), *“AM allows goods to be produced […] at the point of use in space and time according to the exact required specifications. This access to local […] manufacturing improves flexibility and responsiveness to fast-changing market demand”.* Then, as suggested by Akbari (2023), *“AM enables companies to produce parts and components on demand, reducing lead times and the need for large inventories. This can result in a more agile and responsive SC”*.

In light of this, we can derive the following proposition:

***Proposition O5:*** AM assures quick responses to new orders due to production on demand and close to the point of use

***Production Efficiency***

As already described, AM produces parts and components layer-by-layer. As stated by Peron et al. (2024), this *“leads to a raw material utilization that is much higher than CM technologies”*. A common metric for evaluating efficiency is the buy-to-fly ratio. AM enables the creation of near-net-shape products, achieving a buy-to-fly ratio close to 1:1. In contrast, CM generally results in a buy-to-fly ratio between 10:1 and 15–20:1, with some complex components reaching as high as 40:1 (Yusuf, Cutler, and Gao, 2019).

In light of this, we can derive the following proposition:

***Proposition O6:*** AM offers production efficiency by achieving a nearly 1:1 buy-to-fly ratio, significantly minimizing material waste compared to conventional manufacturing techniques

***Inventory Reduction***

Many papers report the capabilities of AM to reduce inventories (e.g., Bernard et al., 2023; Olsen and Tomlin, 2019; Attaran, 2017). However, exemplificatory in this perspective is den Boer et al. (2020) who stated that *“semi-structured interviews with internal and external stakeholders within the Royal Netherlands Army demonstrate that Additive Manufacturing can reduce […] inventories”*. They motivated this referring to the capabilities of AM to produce on demand and close to the point of use.

In light of this, we can derive the following proposition:

***Proposition O7:*** AM minimizes inventory needs as parts can be produced on demand and close to the point of use

***Simpler supply chain***

As stated by Naghshineh (2024), *“AM simplifies the SC operations by reducing the number of process steps (i.e. process integration) and mitigates congestion in the SC by reducing the number of items being ordered, sorted, and managed”*. According to Ford and Despeisse (2016), this is mainly possible thanks to the possibility of AM to consolidate parts: *“simplifying complex multi-component products into single-component products will in turn simplify the complex value chains associated with them, with value chains becoming less hierarchical and having fewer production stages”*. Additionally, den Boer et al. (2020) reported also *“localized production”* to simplify the supply chain.

In light of this, we can derive the following proposition:

***Proposition O8:*** AM simplifies the supply chain by reducing the number of actors involved in the manufacturing and procurement process

***Part consolidation***

Many authors elaborated on the possibility provided by AM to consolidate part (e.g., Akbari, 2023; Naghshineh and Carvalho, 2022; Kunovjanek et al., 2020). Exemplificatory in this perspective is Ford and Despeisse (2016), who stated that using AM *“several parts made of the various material can be replaced by one integrated assembly, which will reduce or eliminate cost, time and quality problems resulting from assembling operations”*. According to Son et al. (2021), part consolidation is *“the best approach to exploit the design freedom of AM”* and it represents *“the most significant advantages of AM”*.

In light of this, we can derive the following proposition:

***Proposition O9:*** AM allows for the consolidation of complex part assemblies, combining multiple components into a single, integrated part

***Enhanced Functionality***

As reported by Murmura and Bravi (2018), one of the main drivers of adopting AM is the possibility to produce *“products with increased functionality through design optimization”*. Indeed, Ronchini et al. (2023) reported that *“all informants reported having adopted AM to improve the functionality of prototypes, components or products. Indeed, the ability to create the product layer by layer allowed new designs that enhanced the technical characteristics and the weight”*.

In light of this, we can derive the following proposition:

***Proposition O10:*** AM enhances part functionality by leveraging topology optimization, enabling the creation of parts that maximize performance and efficiency

**Accelerated Prototyping and Deployment**

As stated by Attaran (2017), AM technologies *“reduce time to market by accelerating prototyping”*. Indeed, Ronchini et al. (2023) stated that AM adoption allows a *“new product development process that is shortened thanks to rapid prototyping”*. Similarly, Bernard et al. (2023) stated that *“applying AM for rapid prototyping during product design decreases the time to market for new products significantly”*.

In light of this, we can derive the following proposition:

***Proposition O11:*** AM reduces the time between product design and deployment, enabling faster transitions from concept to utilization

**Cost Effectiveness**

Although AM can be characterized by high investment and operational costs, the literature is quite aligned in stating that AM can be a cost-effective solution for low-volume production and complex parts. Indeed, Franco et al. (2020) stated that AM *“yields better performance for small-batch and personalized products”* compared to CM. Similarly, Patil et al. (2022) stated that *“for products that belong to any combination of contingent factors including high customization level, […] and low product volume, AM should be chosen as a primary method of production”*.

In light of this, we can derive the following proposition:

***Proposition O12:*** AM is cheaper than conventional manufacturing for low-volume production and complex parts

**Accessibility**

As stated by Akbari (2023), *“AM has the potential to greatly impact supply chains in a number of positive ways, particularly in regional and remote locations”*. Indeed, Patil et al. (2023) stated that *“AM is a preferable method of production”* in remote locations. Notably, “operations in remote locations are a common way of operating for Defense” and “producing out of area at remote or isolated locations” is a great advantage provided by AM (den Boer et al., 2020).

In light of this, we can derive the following proposition:

***Proposition O13:*** AM enables the production of parts in hard-to-reach areas

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