***Lack of Supplier***

The lack of suitable suppliers is quite discussed in the literature. As an example, Naghshineh and Carvalho (2022a), stated that there is a *“limited number of suppliers who can provide the powder according to the quality standards”* required. Similarly, Naghshineh and Carvalho (2022b) also reported a lack of suitable raw material suppliers as one of the main challenges faced by AM as they stated that “the production capacity of the manufacturers becomes highly reliant on the capacity of (a limited number of) suppliers to deliver the promised AM material at the right time, in the right quantity, and at the right price”. Additionally, Naghshineh and Carvalho (2022a) not only discussed the lack of suitable suppliers of raw materials, but also of AM machine: *“the high dependence of AM firms on machine suppliers creates vulnerability to reliance on specialty sources”*.

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

***Proposition C1:*** There is a lack of suppliers capable of providing suitable AM machines, raw materials and/or parts

***High Investment Costs***

As staed by den Boer at al. (2020), *“the costs of AM can be seen as a barrier for implementation”*. As discussed by Sæterbø and Solvang (2024), both investment and operational costs are high: adopting AM *“presents a complex set of challenges and opportunities, primarily influenced by substantial investment and operational costs. The initial financial outlay for DED equipment often represents a significant barrier”*. Similarly, Chatterjee et al. (2023) stated that the high costs of AM machines *“was another inhibiting factor for implementation”.*

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

***Proposition C2:*** The investment costs necessary to purchase AM machines are high

***High Operational Costs***

As discussed in the previous challenge, not only the investment costs represent a challenge, but also operational ones. For example, den Boer at al. (2020) stated that *“AM machine is quite sensitive and vulnerable for damages and disruptions, making it susceptible for high maintenance costs”*. Additionally, Sæterbø and Solvang (2024) stated that the high investement costs are *“compounded by ongoing operating expenses, such as maintenance, energy, and material costs”*.

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

***Proposition C3:*** Operational costs, including raw materials, machine maintenance, and energy consumption, are high

***IP Issues & Data Breaches***

*“The use of AM opens the door to IPR (Intellectual Property Rights) threats because of the ease with which illegally acquired digital models may be used to produce copies of products”* (Haug et a;. 2023). Additionally, Peron et al. (2024) stated that, in addition to the risk of IP losses, *“the digital nature of AM exposes it to higher risks of [...] data breaches than CM”*. Indeed, according to Tan and Choong (2021) *“the seamless flow of information [...] opens more pathways for intellectual property (IP) rights and product liabilities [...]. Protection of IP rights is of high importance”*. However, as stated by Verma et al. (2023), there are *“weak IP protection laws and inadequate data protection”*.

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

***Proposition C4:*** The use of AM is accompanied by issues related to IP infringements and data breaches

***Workforce Resistance***

As stated by Dwivedi et al. (2017), *“as automation process results in reduced dependency on manual labor, a perceived fear of job cuts by workers due to adoption of AM may lead to workers’ resistance”*. Similarly, Peron et al. (2024) stated that *“AM is perceived as ‘job killers’, rendering employees reluctant to its adoption”* as *“workers have a fear of losing their jobs and resist to work with new technology”*. In addition to the fear of losing their jobs, employees might be reluctant to using AM as *“the use of AM technology can imply changes in job characteristics and work practices. Such changes may lead to resistance to AM projects since workers are often reluctant to learn new technologies or change practices at which they excel”* (Haug et al., 2023).

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

***Proposition C5:*** Personnel are reluctant to adopt AM due to, e.g., fear of job losses, lack of knowledge on the benefits, and conservative mentalities

***Standardization and Certification***

Ronchini et al. (2023) reported the *“lack of technical standards and specification”* as one of the main operational barriers. Indeed, Bernard et al. (2023) stated that “the lack of AM part qualification and certification standards has slowed the industrial adoption of this technology” and that in the future *“industry-wide standards will be essential for ensuring the product quality independent of the fabrication location, the machine, or the powder material used. This topic should be tackled by established committees at International Organization for Standardization (ISO) and ASTM International”*. Similarly, Chatterjee et al. (2023) interviewed several practitioners working with AM and they concluded that “due to a perceived lack of standardisation and certification, participants believed there was a challenge in terms of conforming to the complex landscape of AM safety and legal standards”.

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

***Proposition C6:*** The lack of standardized protocols and certification processes complicates the adoption of AM for military applications

***Material Limitation***

As stated by den Boer et al. (2020), the *“availability of raw materials […] is not yet optimally operational within military […] supply chains”*. This is quite commonly reported in the literature. Bernard et al. (2023), for example, stated that *“the challenges regarding AM materials are well known as only a limited palette of materials can be processed or are commercially available today”*. Similarly, Priyadarshini et al. (2022) stated that AM *“production technology barriers include material variety limitations”* and they motivated it saying that *“the raw material suppliers, to carve a niche for themselves, limit the availability of raw materials for AM”*.

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

***Proposition C7:*** There is a limited variety of materials producible via AM

***Lack of Skilled Personnel***

Peron et al. (2024) stated that *“before wide spread AM adoption on large scale certain obstacles need to overcome like […] shortage of well-trained skilled labor”*. Similarly, Ronchini et al. (2023) carried out interviews with practitioners and reported that *“companies struggle with the technology due to a lack of skills and knowledge. […] Company F has had difficulty hiring AM-qualified personnel because of the labour shortage. Hence, P1 reported that the lack of skills and knowledge was a barrier to entry because employees had to study and acquire hands-on experience with the printers and raw materials before understanding the parts using AM”*. To conclude, as stated by Thomas-Seale et al. (2018), “AM is a tremendous opportunity, but it requires engineers to develop a set of skills to support it […]; that is the biggest hurdle for the adoption of AM”

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

***Proposition C8:*** There is a shortage of skilled personnel able to exploit AM design advantages and operate AM machines efficiently

***Lack of Managerial Support***

*“For the successful implementation of advanced technologies, the literature generally agrees that management support is essential, which is also the case for AM technology”* (Haug et al., 2023). Indeed, from interviews with practitioners, Ronchini et al. (2023) reported that one practitioner *“explained that the main difficulty experienced was convincing top management. This barrier was reinforced by P8: ‘The biggest difficulty was explaining to management why they should spend €25,000 on a plastic printer’”*. Stentoft et al. (2018) stated that *“a relevant theme discussed during several interviews is the need for change of mindset in many companies”* as *“findings clearly establish that the role of management is crucial in mitigating workers’ resistance to AM implementation”* Dwivedi et al. (2017).

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

***Proposition C9:*** Managers are reluctant to adopt AM due to factors such as limited knowledge of its benefits, conservative mindsets, and resistance to change

***Production Limitation***

As described by Haug et al. (2023), AM *“production technology barriers include […] issues related to […] production speed, throughput rate, and part size”*. Similarly, Ronchini et al. (2023) interviewed practitioners and stated that *“informants reported that manufacturing times are still too long”* and that *“there is a major dimensional constraint, because the manufacturing chambers for metal powders are still relatively small”*.

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

***Proposition C10:*** Production speed and size are limited and lower than conventional manufacturing techniques

**Need for Post-Process Operations**

Peron et al. (2024) wrote that *“the main limitation of AM continues to be the surface finish that is produced as well as tolerances able to be achieved, which induces AM production to be followed by post-process operations”*. Indeed, *“post-processing is often required. This may be due to the stair stepping effect that arises from incrementally placing one layer on top of another, or because finishing layers are needed”* (Ford and Despeisse, 2016). Hence, as discussed by Bernard et al. (2023), *“the first and foremost point that must be addressed to support further growth of AM technologies is to increase productivity and to lower costs. This includes improvements of the processes themselves and also automation of pre- and post-processing steps”*.

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

***Proposition C11:*** AM parts typically require post-processing operations after production to remove support material, improve surface quality and/or improve properties

***Low Quality***

Durach et al. (2017) interviewed different practitioners working on AM and reported the *“insufficient quality of parts as the most important impediments to the dissemination of AM technologies”*. Similarly, Ronchini et al. (2023) also interviewed practitioners working on AM and they reported that *“quality issues are the most frequently recurring barrier highlighted by interviewees in all the investigated industries”*. Additionally, Chatterjee et al. (2023) stated that quality appears to be *“one of the primary barriers to broader adoption (of AM)”*, which is in line with Peron et al. (2024) who reported *that “quality concerns about AM goods are one of the major obstacles for AM adoption”* as *“ AM products can be prone to various defects such as porosity, cracking, balling, warping, and many others”*.

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

***Proposition C12:*** AM parts face quality challenges, such as dimensional inaccuracies or material strength

***Lack of Governmental Support***

Dwivedi et al. (2017) reported that the lack of governmental support was among *“the two most critical barriers”*. Exemplificatory in explaining this is the paper of Priyadarshini et al. (2022) who stated that *“the government is not doing enough to support the adoption and implementation of AM, especially when the initial investment of time and money required is so high. Government support and intervention are very important for developing a workforce for AM, fulfilling market requirements, and assessing the environment for technology adoption”* and that *“government needs to step in and provide support, especially for SMEs and MSMEs who cannot afford to spare the huge set-up costs that AM requires. The government also needs to provide tax rebates and subsidies on AM machines and input materials”*. Additionally, Stentoft et al. (2021) stated there is *“a need for government initiatives to avoid IPR violations”* and that *“government support is important in relation to workforce development and market support”*.

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

***Proposition C13:*** There is insufficient governmental support to promote and incentivize AM adoption in the sector

***Difficult Ecosystem Establishment***

Priyadarshini et al. (2022) mentioned the *“difficulty in establishing an ecosystem”* as an environmental barrier for AM adoption (environmental barriers are barriers driven by external factors). Indeed, Verma et al. (2023) stated that there is often a *“lack of creating trust in business partners”*, which complicates the adoption of AM. Similarly, Stentoft et al. (2021) reported that *“information asymmetry and a lack of trust in technology vendors are identified issues”* to hinder AM adoption as vendors *“may be unwilling to disclose information that could expose the weakness of the technology being supplied”* (Dwivedi et al., 2017). Therefore, in the future, there should be a push to *“reduce the information asymmetry among stakeholders”* (Dwivedi et al., 2017).

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

***Proposition C14:*** There are difficulties in establishing and operating a successful ecosystem for AM in the defence sector

***Lack of Process Repeatability***

As stated by Bernard et al. (2023), *“repeatability needs to be addressed as part-to-part variations significantly hinder a wide industrialization of AM processes as unpredictable changes in material properties hinder certification”*. Indeed, *“the process variability often results in variable part quality and in unexpected defects (pores, cracks, unmolten powder particles, melt pool Raleigh instabilities, balling, distortion due to residual stresses, undesired inclusions, local part overheating affecting the microstructure and part properties, etc.) which are only detected after the part is totally built, resulting in high scrap rates”*. As identified by Thomas-Seale et al. (2018), this clearly hinders AM diffusion as one of the practitioners interviewed in their work stated *“we know the repeatability is a problem, because properties changes across batches, then that presents as a business problem”*.

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

***Proposition C15:*** AM machines exhibit process instabilities and other issues that limit the repeatability of the production process

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