**Appendix F. Supply Chain Capabilities**

In the following we summarize the main findings reported in the literature on how AM affects each SC capability. Out of the 14 SC capabilities defined by (Pettit *et al.*, 2010), Naghshineh and Carvalho (2022) reported that AM affects only 10 of them: adaptability, capacity, collaboration, dispersion, efficiency, flexibility in order fulfillment, flexibility in sourcing, market position, recovery and visibility.

***Adaptability***

AM is reported to support adaptability in two ways. First, the adoption of AM can have a positive impact by reducing lead times in production and sourcing (Sabarish, Udhayakumar and Pandiyarajan, 2021). Indeed, AM's ability to enable rapid prototyping and on-demand production (Li et al., 2019; Lolli et al., 2022) allows for quicker response times to unpredictable changes in customer demand. Then, AM offers an additional advantage to adaptability, i.e. production reallocation within the supply chain (Gao *et al.*, 2015). In fact, in the event of disruptions occurring in the upstream supply chain, AM provides the flexibility to quickly reallocate production to alternative manufacturing sites (Verboeket and Krikke, 2019).

In conclusion, the following two propositions can summarize what described above:

*C1i: AM strengthens the capability “Adaptability” by supporting short lead times in production.*

*C1ii: AM strengthens the capability “Adaptability” by supporting the possibility to reallocate production.*

***Capacity***

AM can play a significant role in enhancing capacity. First, it can provide a buffer to address volatile demand, hence facilitating redundancy in production (Attaran and Attaran, 2017). Then, it can facilitate production scalability without the risk of excess capacity (McDermott *et al.*, 2021). In fact, AM machines can be strategically integrated into the production system to establish an emergency production setup. In this way, in the event of disruptions causing extended lead times for critical components, AM can serve as a backup system allowing organizations to maintain continuity during unforeseen disruptions (Demir, Eyers and Huang, 2021). In addition, AM can further increase production scalability since the introduction of printers is easy for both centralized and distributed production and facilitated by the possibility to print directly from .stl files without previous knowledge required (these files are downloadable from online shared platforms) (Dalenogare *et al.*, 2018).

*C2i: AM strengthens the capability “Capacity” by facilitating redundancy in production.*

*C2ii: AM strengthens the capability “Capacity” by increasing production scalability.*

***Collaboration***

AM supports this SC capability in two ways. First, AM enhances collaborative information sharing among partners (Parvanda and Kala, 2023). Indeed, AM enables the digitalization of the inventory, with parts stored as digital files rather than as finished goods. This not only facilitates the sharing of parts’ design and information, but it also enhances the collaborations between SC partners since they can work together to continuously update the design of parts (Kunovjanek, Knofius and Reiner, 2020). Additionally, this ease of collaborative information sharing and of access to accurate inventory information favors collaborative demand forecasting (Chilkapure and Pillai, 2019), which can help in predicting changes in demand as well as customer/supplier disruptions (Naghshineh and Carvalho, 2022b).

*C3i: AM strengthens the capability “Collaboration” by promoting an increase in collaborative information sharing between supply chain partners.*

*C3ii: AM strengthens the capability “Collaboration” by enhancing the increase in collaborative demand forecasting between partners in the supply chain.*

***Dispersion***

AM plays a significant role in enhancing the dispersion SC capability: AM’s possibility to produce on-site (even at remote location), in fact, enables to bring manufacturing capabilities (i.e. AM machines) close to the point of demand (Boer, Lambrechts and Krikke, 2020). This is made possible by the already cited characteristics of AM to print parts directly from a digital file. In addition, the on-site production is also favored by the near net-shape production that limits the number of processes required and relative equipment (Riveiro *et al.*, 2019).

*C4: AM strengthens the capability “Dispersion” by enhancing the ability to distribute capacity in multiple locations.*

***Efficiency***

AM offers several benefits that contribute to improved operational efficiency within the supply chain. First, AM is able to produce parts with minimal raw materials requirements: the production of parts layer-by-layer, in fact, leads to a high efficiency in raw material utilization, much higher than CM technologies (Meyer, Glas and Eßig, 2022). Moreover, always dealing with raw material requirements, AM generally necessitates a limited and specific range of materials, which facilitates the sharing of AM machines across different production processes and applications, resulting in improved resource utilization and reduced costs (Do Chung, Kim and Lee, 2018). Moreover, AM, being able to produce complex geometries and intricate designs as a single consolidated part, eliminates the need for assembly or multiple manufacturing steps, hence improving the overall operational efficiency (Edgar and Tint, 2015). This is also improved by the fact that AM is a tool less manufacturing approach (Badiru, Valencia and Liu, 2020). Furthermore, AM improves operational efficiency since less labor is required than with CM (one operator can control multiple AM machines) (Cui *et al.*, 2021). Additionally, AM enables increased production efficiency by facilitating on-demand production: parts are manufactured only when needed, hence minimizing inventory levels and reducing the risk of obsolete products (Singamneni *et al.*, 2019). Lastly, AM is reported to increase efficiency since, when compared to CM technologies, it leads to extended products’ lifecycles, especially thanks to the possibility to produce topology optimized parts (Taddese, Durieux and Duc, 2020).

*C5i: AM strengthens the capability “Efficiency” because there is minimum raw material consumption during production.*

*C5ii: AM strengthens the capability “Efficiency” because there is increased capacity sharing.*

*C5iii: AM strengthens the capability “Efficiency” by allowing complex products to be produced in an easy way.*

*C5iv: AM strengthens the capability “Efficiency” because AM promotes a tool-less manufacturing approach.*

*C5v: AM strengthens the capability “Efficiency” because there is an extension of the product's life cycle.*

*C5vi: AM strengthens the capability “Efficiency” because there is a reduced need for labor.*

*C5vii: AM strengthens the capability “Efficiency” because production is on-demand according to customer orders.*

***Flexibility in order fulfillment***

AM plays a significant role in enabling flexibility in order fulfillment since it enables production postponement to accommodate last-minute changes in customer demands (Weller, Kleer and Piller, 2015). Indeed, AM’s possibility to postpone production until an order is received is due to (i) the shorter lead time of AM compared to CM (Hällgren, Pejryd and Ekengren, 2016) and to (ii) the decentralized production approach achievable via AM which reduces the need for long-distance transportation (Rauch, Unterhofer and Dallasega, 2018).

*C6: AM strengthens the capability “Flexibility in order fulfillment” by allowing the possibility to postpone production until a customer order is received.*

***Flexibility in sourcing***

AM has a negative effect on flexibility in sourcing. Indeed, AM production is limited by limited suppliers and material availability (Niaki and Nonino, 2017). Indeed, according to (Choudhary *et al.*, 2021), the *“non-availability of a variety of materials”* is listed among the top three limitations of AM, and this limits AM usability. Additionally, there are few suppliers able to meet the demand in terms of quality of parts, especially due to a lack of specialized expertise (Simpson, Williams and Hripko, 2017).

*C7i: AM weakens the capability “Flexibility in sourcing” because there is a limited availability of substitute suppliers.*

*C7ii: AM weakens the capability “Flexibility in sourcing” because there is a limited availability of raw materials required for production.*

***Market position***

The adoption of AM strengthens market position since it allows a customer-centric approach. Indeed, AM enables the so-called customer-centric production since it enables customized manufacturing tailored to individual customer preferences (Abdulhameed *et al.*, 2020): customers can even be involved in the design process, allowing them to customize and contribute to the creation of their desired products (Kudus, Campbell and Bibb, 2016). In this way, organizations can build stronger relationships, positioning themselves as partners rather than mere suppliers.

*C8: AM strengthens the capability “Market position” because it enables customer-focused production, even allowing products co-design with customers.*

***Recovery***

The adoption of AM can enhance this SC capability. In fact, as discussed above, AM offers the possibility to outsource production in a fast way to alternative facilities or service provider in case of disruptions (Friedrich, Lange and Elbert, 2022a; Friedrich, Lange and Elbert, 2022b).

*C9: AM strengthens the capability “Recovery” by enhancing the ability to outsource production in the event of capacity/distribution shortages.*

***Visibility***

As discussed above, especially thanks to the possibility to digitalize the inventory, AM provides a tight collaboration with customers and supplier, thus improving information sharing and SC transparency (Liu *et al.*, 2022). This ensures a high visibility of stocks: storing digital files provides an on-time inventory revision process, hence reducing the time required for the revision and the natural dealignment of physical and supposed stocks (Chekurov *et al.*, 2018). As discussed by Naghshineh and Carvalho (2022b), this increased visibility helps in anticipating customers’ demand.

*C10: AM strengthens the capability “Visibility” because the reliance on ICT systems for information sharing helps in anticipating customer demands.*

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