

## Spare parts management with Additive Manufacturing (AM): a critical review

Coruzzolo A. M. \*, Balugani E. \*, Gamberini, R. \*

*\* Department of Sciences and Methods for Engineering (DISMI), University of Modena and Reggio Emilia, Via Amendola 2 – Padiglione Morselli, 42100 Reggio Emilia, Italy*

**Abstract:** Additive Manufacturing (AM) is a promising technology for producing spare parts, due to the wide variety of forms and materials that can be used and their enhanced mechanical properties. Given these features and the low lead times compared to classical manufacturing (CM), AM is now being investigated for the management of spare parts. This literature stream is relatively new, with many works based on different hypotheses (e.g., the reliability of AM parts) and with different conclusions. This critical literature review provides practitioners with information on the models available, their findings, and their limitations. Further research directions are also identified.

Copyright © 2022 The Authors. This is an open access article under the CC BY-NC-ND license (<https://creativecommons.org/licenses/by-nc-nd/4.0/>)

**Keywords:** Industry 4.0; Inventory control; Production planning and scheduling; Supply chain management

### 1. INTRODUCTION

Correct models for spare parts management are essential to ensure that machines are always available while minimizing the costs (Dellagi et al., 2020). Unavailability leads to high backorder costs and cause substantial financial losses (Muniz et al., 2021).

Correct spare parts management is challenging given their intermittent nature (Syntetos and Boylan, 2001) (Croston, 1972) and the extended lead time for classical manufacturing (CM).

Additive Manufacturing (AM) is a promising solution to overcome these issues. It has two particular features that make it perfect for on-demand printing. The first, identified by (Hällgren, Pejryd and Ekengren, 2016), is the lower lead times compared to CM that can make the whole supply chain more efficient (Togwe, Eveleigh and Tanju, 2019). The first, identified by Hällgren, Pejryd and Ekengren, (2016), is the lower lead times compared to CM, and AM can make the whole supply chain more efficient (Togwe, Eveleigh and Tanju, 2019). Secondly, the same printer can be used to produce a wide variety of metal parts (Galati, Minetola and Rizza, 2019) with post processing techniques to improve their mechanical properties (Peron, Torgersen and Berto, 2018).

AM is based on computer aided design (CAD). Objects can be created directly from CAD models (Zhang et al., 2019) by exploiting layer-by-layer deposition and energy delivery (Wong and Hernandez, 2012) (Gibson, Rosen and Stucker, 2015).

Initially AM was a prototyping technology, thanks to its very limited set-up time in producing complex geometries (Song and Zhang, 2016). Nowadays it is used for mass production in

various fields, e.g. the medical industry (Regis et al., 2015), thanks to the high variety of materials and the post processes that can be used. These post processes can increase the mechanical properties of parts at a higher cost (Liu and Shin, 2019) and are associated with specific operating conditions (Kumbhar and Mulay, 2018).

However, several obstacles limit the spread of AM for spare parts management. Manufacturers generally have the knowhow to source CM spare parts, but lack knowledge of AM features (Knofius, van der Heijden and Zijm, 2019b). In fact, there is a lack of failure data under different working conditions (Mellor et al., 2014), and given the continuous development of AM and related postprocesses, this makes accelerated tests (Razavi, 2019) and failure criteria (Peron et al., 2017) (Peron, Torgersen and Berto, 2018) the only ways to predict failures.

The other main barriers to the adoption of AM are the high production and equipment costs. Although these costs are expected to decrease over the next few years (Westerweel, Basten and van Houtum, 2018), it is difficult to predict the timing and magnitude of this improvement (Jiang, Kleer and Piller, 2017).

Despite these barriers, many works have started to integrate AM in spare parts management as testified by three recent literature reviews on this theme. The first and most recent one (Hettiarachchi, Brandenburg and Seuring, 2022) relates to the connection between AM, the circular economy, and their implementation strategies. The second (Kunovjanek, Knofius and Reiner, 2020) focuses on AM for supply chains, reviewing the literature through the SCOR framework with essential information for each industrial sector, supply chain area and purpose. The third (Kunovjanek et al. 2020) explains previous

approaches, limitations, and future research directions from a supply chain point of view.

In contrast with the last one, our review focuses on different models for spare parts management with AM and on their characteristics, type of model exploited, the main hypothesis behind it, and the related findings and limitations. Consequently, our work is closer to (Peron and Sgarbossa, 2020), where papers that investigate AM for spare parts management are analysed in terms of findings and limitations. However, Peron and Sgarbossa did not analyse the mathematical background and theory nor the models' hypotheses. This is the gap we want to fill, within a literature review aimed at clarifying the state of the art related to AM for spare parts management with a focus on models, their underlying hypothesis, their findings, and limitations.

After the main literature review some suggestions are made on how to exploit existing models and improve the use of AM in spare parts supply chains. In detail: Section 2 proposes a literature review, Section 3 contains our suggestions for further developments, and Section 4 presents our conclusions.

## 2. LITERATURE REVIEW

### 2.1 Method

The articles were collected through searches in ScienceDirect, ResearchGate, Google Scholar.

Two groups of search terms were formed as reported in Table 1.

Then the following exclusion criteria were used:

- Qualitative assessment of papers that did not model the problem mathematically.
- Papers that only identified models for the selection of spare parts to be produced with AM.
- Literature reviews.
- Papers not written in English.

**Table 1. Search terms**

Group "A"		Group "B"	
Spare Part		Additive	
OR		Manufacturing	
AND		OR	
Part Management		3D Printing	
OR			
Supply Chain			
OR			
Part Inventory			

To identify the sample for our literature review, the following operational approach was used (Seuring et al., 2020):

1. Identification of the papers with the keywords.
2. Screening and reading of abstract.
3. Eligibility by applying content criteria.
4. Full text assessment.

Of the 58 papers identified, only 12 met our inclusion criteria.

### 2.2 Literature Review analysis

Although AM is potentially key to improving the management of spare parts (Knofius, van der Heijden and Zijm, 2019a), the number of works on this theme is limited. Such a limitation makes it possible to carry on a punctual analysis of each article, whose key points are reported in Table 2. For each paper we identified the type of model exploited (i.e. the mathematical approaches), its underlying hypothesis, the main findings, and possible future directions for each work.

Liu et al. (2014) investigated the reduction in safety stock in the aircraft supply chain considering two scenarios for AM: centralized (in distribution centres) and decentralized production (at the service locations). This was the first quantitative approach to modelling AM in spare parts management, in fact previous contributions had investigated the problem only qualitatively (Holmström et al., 2010). Liu et al. (2014) exploited the SCOR model within the two AM scenarios versus a classical supply chain. They considered different lead times for CM and AM, which is in line with the literature that assumes that the procurement lead time for AM is shorter. On the other hand, they applied the same demand for both AM and CM parts, an assumption challenged by the literature where it has been proven that AM parts can be more reliable than CM ones (Peron et al., 2018). Liu et al. (2014) found that AM can be beneficial for aircraft supply chains, leading to safety stock reductions of up to 70%, however they did not account for AM production costs and for the purchasing costs of the printer as shown in Table 2. A possible extension could apply their framework to real failure data, costs and lead times with a cost-based perspective to be added to the inventory one.

In line with the two scenarios proposed by Liu et al. (2014) and with the suggestion of (Holmström et al., 2010) Khajavi, Partanen and Holmström (2014) compared centralized and decentralized AM for a specific aircraft, considering 100 spare parts. They found that AM works well under a centralized scenario, which is only slightly better than the decentralized one when the comparison is made with data on future technological trends. However their study lacks a comparison with CM. Li et al. (2016) were the first to analyse the introduction of AM in spare parts management from a cost-based perspective and to compare it with CM.

Table 2. Analysis of articles

Authors	Topic	Model	Hypothesis	Innovation	Findings	Limitations	Extensions
Liu et al., 2014	Safety Inventory reduction in aircraft supply chain	SCOR	1) Centralized or decentralized AM 2) Same failure rates for CM and AM 3) Different lead times for CM and AM 4) Six parts are included	First quantitative model to consider AM in spare parts supply chain	Up to 70% reduction in safety Inventories	1) Same failure rate for CM and AM 2) Inventory standalone perspective 3) Costs are never included	Considers a cost-based analysis of the three different scenarios
Khajavi, Partanen and Holmström, 2014	Centralized vs decentralized AM in aircraft supply chain	Simulation of the demand and optimization of replenishment interval and inventory level	1) Centralized or decentralized AM 2) Only AM is considered 3) Parts are all the same	First study to integrate machinery cost for AM and AM cost reduction considering future trends	AM machine acquisition price and personnel intensiveness obstacle distributed AM	1) No comparison with CM 2) Only considers identical spare parts	Multi item application with updated data
Li et al., 2016	Impact of AM on spare parts supply chain also considering CO2 emissions	Simulation-System Dynamics Model	1) Centralized or decentralized AM 2) Same failure rates for CM and AM 3) Different lead times for CM and AM	First quantitative model with a cost-based perspective that also evaluated CO2 emissions	Up to 46% reduction in total cost for the management within decentralized scenario	1) Same failure rates for CM and AM 2) Fixed investments costs are not accounted for 3) Data only from surveys	Use in conjunction with the simulation an optimization model for spare parts inventory management
Sirichakwal and Conner, 2016	Impact of AM on spare parts inventories	Inventory policy optimization	1) Different lead times for CM and AM 2) Same failure rates for CM and AM 3) AM less expensive than CM	Evaluates the effect of AM on stock out probabilities	Holding cost reduction positively affects stock out probabilities	1) Same failure rate for CM and AM 2) AM less expensive than CM	Multi item application with updated data
Song and Zhang, 2016	Impact of AM as pure on demand with multi parts and insourced printers	Optimization model for inventory management with multi-class priority queues dynamics at the printer	1) Same failure rates for CM and AM 2) Different lead times for CM and AM	First quantitative model with multi parts and insourced printer with queue	Up to 43% cost reduction for the stock system with a mean of 5%	1) Same failure rates for CM and AM 2) Costs for the insourced printer are neglected	Application with updated data on failure rates and purchasing costs for the printer
Ghadge et al., 2018	Impact of additive manufacturing on aircraft supply chain performance	Simulation-System Dynamics Model	1) Same failure rates for CM and AM 2) Different lead times for CM and AM 3) Decentralized AM	Evaluates the effect of AM on inventory in a real aircraft network	Up to 85% reduction in mean inventory using AM	1) Same failure rates for CM and AM 2) Purchasing costs not included	Application with update data considering purchasing costs
Knofius, van der Heijden and Zijm, 2019a	Effect of consolidated AM parts	Optimization model for inventory management	1) Lower or higher failure rates for AM 2) Lower or higher failure rates for AM	First study to account for the consolidation of AM parts with performance higher and lower than CM	Higher reliability, reduced lead time and lower price are required to achieve cost reduction with consolidate AM	No multi parts perspective	Application with updated data regarding multi parts
Westerweel et al., 2021	Use of AM at remote locations	Markov decision process to model the inventory and printing decision	1) Higher failure rate for AM than CM 2) Different lead times for CM and AM	First model to account for remote locations	Mean operating costs per year decrease by 55% on average	Higher failure rate for AM than CM	Application with updates on the parts reliability

Knofius et al., 2021	Dual Sourcing AM and CM compared to single sourcing (AM or CM)	Stochastic dynamic programming	1) Different failure rates for AM and CM 2) Different lead times for CM and AM both exponentially distributed	First model to account for dual sourcing with AM optimizing sourcing, maintenance, and inventory policy	Mean cost reduction with AM of 35%	Lead time exponentially distributed	Application with a dynamic inventory policy
Sgarbossa et al., 2021	Spare part inventory management with Poisson demand	Heuristic optimization of the inventory policy	1) Different lead times for CM and AM 2) Different levels of reliability based on accelerated test results	First work to account for different post-processing for AM and optimization routines	CM is often cheaper than AM except with limited storage area	1) Backorder cost not proportional to the waiting time 2) No multi parts perspective	Application with multi parts
Westerweel, Basten and van Houtum, 2019	Preventive maintenance policy with AM	Maintenance policy optimization	1) Different lead times for CM and AM 2) Lower reliability of AM parts 3) No failures in the lead time	First work to account for AM in a maintenance policy	High holding and failure costs favour AM	Lower reliability of AM parts	Application with update data
Lolli et al., 2022	Preventive maintenance policy with AM	Maintenance policy optimization	1) Different lead times for CM and AM 2) Different levels of reliability based on accelerated test results	First work to account for AM in a maintenance policy with data from a multidisciplinary approach	AM-based preventive maintenance is cheaper with high failure and maintenance costs	No multi parts perspective	Application with multi parts

Li et al. (2016) modelled the system under the same scenarios as Lui et al (2014), using a simulation based on System Dynamics (SD), and found that AM leads to savings of up to 46% in the decentralized scenario. Their paper did not account for real data and did not optimize the inventory management. However, it did assess the CO<sub>2</sub> emissions and found that a decentralised structure is better from that standpoint.

Sirichakwal and Conner (Sirichakwal and Conner, 2016) focused on the impact of AM on spare parts inventory. They optimized a (s-1, s) policy for AM and CM parts considering lead times and holding cost reductions for AM. They concluded that lead times and holding cost reductions can positively affect the stock-out probabilities, minimizing the total inventory costs. They considered AM to be cheaper than CM, though this has not been confirmed in recent literature (Lolli et al., 2022). Similarly, Gahdge et al. (2018) exploited SD to model a supply chain where parts inventories are managed through a (s-1, s) policy. They accounted for a lead time reduction for AM, finding a reduction of the mean inventory of up to 85%.

Song and Zhang (2016) evaluated AM on demand versus an overseas equipment manufacturer. They optimized a continuous review policy after having subdivided parts between make to stock and print on demand, while considering waiting times at the insourced printer with a multi class priority queue. This appears to be the first work to account for the waiting time at the printer. The work could be extended by considering the failure rate between AM and CM as not being identical, and by accounting for the printer purchasing cost.

Knofius et al. (2021) were the first to evaluate the effect of AM spare parts consolidation, accounting for both a higher or lower lead time and reliability than CM. They found that a combination of higher reliability, reduced lead time and lower

price is required to achieve cost reductions with consolidation using AM. More recently, Westerweel et al. (2021) investigated the effect of AM at remote locations. They extended the dual sourcing problem considering two supply sources with fixed order cycles. Their on-site on-demand printing leads to savings by reducing the inventory and increasing availability. The main limitation of this study is the lower reliability for AM parts compared to CM ones, in contrast with the current literature. On the other hand, Knofius et al. (2021) accounted for higher or lower AM reliability in a dual sourcing model applied to a real case study. They found that with dual sourcing it is possible to exploit most of the benefits of a typically short AM resupply lead time, while the common drawbacks of high AM piece price and low AM part reliability have a significantly lower impact.

Sgarbossa et al., (2021) modified the classic reorder model in (Babai, Jemai and Dallery, 2011) exploiting it for a periodic multi-technology scenario. The novelty of their work lies in the conjunction of spare parts management with different AM technologies and post processing to evaluate their impact, as well as the creation of a decision support system to help practitioners.

Finally, we analysed two works that focus on preventive maintenance policies with AM. Westerweel et al. (2019) were the first to develop maintenance policy featuring AM for on demand printing, finding that high holding and failure costs favour the adoption of AM. The main limitations of their work are the assumption of no failures in the replenishment lead time and the lower reliability of AM parts compared to CM ones. These two assumptions were relaxed in a recent work by Lolli et al. (2022) where an interdisciplinary approach, as in Sgarbossa et al. (2021), was followed to estimate the characteristics of parts. In line with Westerweel (2019), they found that AM-based preventive maintenance policies are

preferable when the mean time to failure and the backorder costs are low and when the failure and maintenance costs are high.

### 3. DISCUSSION

We identified four main limitations of the current works as well as some open issues.

1. Real data on the reliability of AM parts must be exploited in the models, as highlighted by Table 2. Although some studies have recently used a multidisciplinary approach to gain insights (Sgarbossa et al., 2021) (Lolli et al., 2022), such studies are limited and exploit accelerated tests. Existing models need to be applied with real shared failure data for AM in order to gain insights for future applications.
2. The literature review highlighted a limited comparison between models. The tendency is to propose new models and to derive insights based on them, but an extensive comparison based on shared data would be beneficial.
3. Different papers leveraged different cost structures thus making comparisons between models difficult. For a fair comparison, a shared cost structure is needed. The costs for the insourcing of the printer, for instance, are usually neglected and the backorder costs are not always proportional to the waiting time. A structured cost prediction approach is also needed for AM parts and equipment. Costs that are still high and have been identified as critical in the literature (Li et al., 2016) (Lolli et al., 2022) and for which a future cost reduction is estimated, for example in (van der Heijden and Zijm, 2019a), could be integrated into existing models.
4. A life cycle assessment perspective is lacking in all the studies except for Li et al. (2016) who used a carbon emission evaluation between CM and AM. Even if decentralized AM productions seem to reduce the carbon emissions, a life cycle analysis is still needed. Further analysis is also needed to consider the production phases as well as the displacement of parts. This can be done by considering a sustainability driven Circular Economy environment (Hettiarachchi, Brandenburg and Seuring, 2022).

### 4. CONCLUSIONS

AM is becoming more and more central in spare parts management given that it can be exploited for on demand printing. It entails lower lead times compared to CM and a variety of parts can be printed with the same printer (Peron, Torgersen and Berto, 2018). Many works have developed models to test the validity of AM and four main challenges have emerged from our analysis. First, real data are needed on the reliability of spare parts. One of the main limitations of reviewed works was the absence of real data on failures, as they simply assumed that AM is less reliable than CM; an assumption that is no longer valid (Peron et al., 2018). Second, existing models need to be compared, since there are currently no studies that provide a benchmark. Third, a structured approach is needed to predict future costs for AM, as this is the

greatest barrier to its adoption (Chaudhuri et al., 2021). Finally, the environmental aspects of AM have essentially been ignored, except for Li et al. (2016) who found a positive impact of decentralised AM on carbon emissions. Such environmental aspects should be investigated including the production process, post-processing and disposal.

### REFERENCES

- Babai, M. Z., Jemai, Z. and Dallery, Y. (2011) ‘Analysis of order-up-to-level inventory systems with compound Poisson demand’, *European Journal of Operational Research*, 210(3), pp. 552–558. doi: 10.1016/j.ejor.2010.10.004.
- Chaudhuri, A. et al. (2021) ‘Selecting spare parts suitable for additive manufacturing: a design science approach’, *Production Planning and Control*, 32(8), pp. 670–687. doi: 10.1080/09537287.2020.1751890.
- Croston, J. D. (1972) ‘Forecasting and Stock Control for Intermittent Demands’, *Journal of the Operational Research Society*, 23, pp. 289–303. doi: <https://doi.org/10.1057/jors.1972.50>.
- Dellagi, S. et al. (2020) ‘Integrated maintenance/spare parts management for manufacturing system according to variable production rate impacting the system degradation’, *https://doi.org/10.1177/1063293X19898734*, 28(1), pp. 72–84. doi: 10.1177/1063293X19898734.
- Galati, M., Minetola, P. and Rizza, G. (2019) ‘Surface Roughness Characterisation and Analysis of the Electron Beam Melting (EBM) Process’, *Materials*, 12(13). doi: 10.3390/MA12132211.
- Ghadge, A. et al. (2018) ‘Impact of additive manufacturing on aircraft supply chain performance: A system dynamics approach’, *Journal of Manufacturing Technology Management*, 29(5), pp. 846–865. doi: 10.1108/JMTM-07-2017-0143.
- Gibson, I., Rosen, D. and Stucker, B. (2015) *Additive manufacturing technologies: 3D printing, rapid prototyping, and direct digital manufacturing*, second edition, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Second Edition. doi: 10.1007/978-1-4939-2113-3.
- Hällgren, S., Pejryd, L. and Ekengren, J. (2016) ‘Additive Manufacturing and High Speed Machining -cost Comparison of short Lead Time Manufacturing Methods’, *Procedia CIRP*, 50, pp. 384–389. doi: 10.1016/J.PROCIR.2016.05.049.
- Hettiarachchi, B. D., Brandenburg, M. and Seuring, S. (2022) ‘Connecting additive manufacturing to circular economy implementation strategies: Links, contingencies and causal loops’, *International Journal of Production Economics*, 246, p. 108414. doi: 10.1016/J.IJPE.2022.108414.
- Holmström, J. et al. (2010) ‘Rapid manufacturing in the spare parts supply chain: Alternative approaches to capacity deployment’, *Journal of Manufacturing Technology Management*, 21(6), pp. 687–697. doi: 10.1108/17410381011063996.
- Jiang, R., Kleer, R. and Piller, F. T. (2017) ‘Predicting the future of additive manufacturing: A Delphi study on economic and societal implications of 3D printing for 2030’, *Technological Forecasting and Social Change*, 117, pp. 84–97. doi: 10.1016/J.TECHFORE.2017.01.006.

- Khajavi, S. H., Partanen, J. and Holmström, J. (2014) 'Additive manufacturing in the spare parts supply chain', *Computers in Industry*, 65(1), pp. 50–63. doi: 10.1016/J.COMPIND.2013.07.008.
- Knofius, N. et al. (2021) Improving effectiveness of spare parts supply by additive manufacturing as dual sourcing option, *OR Spectrum*. Springer Berlin Heidelberg. doi: 10.1007/s00291-020-00608-7.
- Knofius, N., van der Heijden, M. C. and Zijm, W. H. M. (2019a) 'Consolidating spare parts for asset maintenance with additive manufacturing', *International Journal of Production Economics*, 208, pp. 269–280. doi: 10.1016/J.IJPE.2018.11.007.
- Knofius, N., van der Heijden, M. C. and Zijm, W. H. M. (2019b) 'Moving to additive manufacturing for spare parts supply', *Computers in Industry*, 113, p. 103134. doi: 10.1016/j.compind.2019.103134.
- Kumbhar, N. N. and Mulay, A. V. (2018) 'Post Processing Methods used to Improve Surface Finish of Products which are Manufactured by Additive Manufacturing Technologies: A Review', *Journal of The Institution of Engineers (India): Series C*, 99(4), pp. 481–487. doi: 10.1007/S40032-016-0340-Z/FIGURES/3.
- Kunovjanek, M., Knofius, N. and Reiner, G. (2020) 'Additive manufacturing and supply chains—a systematic review', *Production Planning and Control*, 0(0), pp. 1–21. doi: 10.1080/09537287.2020.1857874.
- Li, Y. et al. (2016) 'Additive manufacturing technology in spare parts supply chain: a comparative study', <http://dx.doi.org/10.1080/00207543.2016.1231433>, 55(5), pp. 1498–1515. doi: 10.1080/00207543.2016.1231433.
- Liu, P. et al. (2014) 'The impact of additive manufacturing in the aircraft spare parts supply chain: Supply chain operation reference (scor) model based analysis', *Production Planning and Control*, 25(December 2017), pp. 1169–1181. doi: 10.1080/09537287.2013.808835.
- Liu, S. and Shin, Y. C. (2019) 'Additive manufacturing of Ti6Al4V alloy: A review', *Materials & Design*, 164, p. 107552. doi: 10.1016/J.MATDES.2018.107552.
- Lolli, F. et al. (2022) 'Age-based preventive maintenance with multiple printing options', *International Journal of Production Economics*, 243, p. 108339. doi: 10.1016/j.ijpe.2021.108339.
- Mellor, S. et al. (2014) 'Additive manufacturing: A framework for implementation', *International Journal of Production Economics*, 149(C), pp. 194–201. doi: 10.1016/J.IJPE.2013.07.008.
- Muniz, L. R. et al. (2021) 'Spare parts inventory management: a new hybrid approach', *International Journal of Logistics Management*, 32(1), pp. 40–67. doi: 10.1108/IJLM-12-2019-0361/FULL/PDF.
- Peron, M. et al. (2017) 'Fracture Assessment of PEEK under Static Loading by Means of the Local Strain Energy Density', *Materials* 2017, Vol. 10, Page 1423, 10(12), p. 1423. doi: 10.3390/MA10121423.
- Peron, M. et al. (2018) 'Fracture behaviour of notched as-built EBM parts: Characterization and interplay between defects and notch strengthening behaviour', *Theoretical and Applied Fracture Mechanics*, 98, pp. 178–185. doi: 10.1016/J.TAFMEC.2018.10.004.
- Peron, M. and Sgarbossa, F. (2020) 'Additive Manufacturing and Spare Parts: Literature Review and Future Perspectives', *Lecture Notes in Electrical Engineering*, 737, pp. 629–635. doi: 10.1007/978-981-33-6318-2\_78.
- Peron, M., Torgersen, J. and Berto, F. (2018) 'Rupture Predictions of Notched Ti-6Al-4V Using Local Approaches', *Materials* 2018, Vol. 11, Page 663, 11(5), p. 663. doi: 10.3390/MA11050663.
- Razavi, S. M. J. (2019) 'Structural Integrity of Additively Manufactured Metallic Components under Fatigue Loading'. Available at: <https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2644657> (Accessed: 9 December 2021).
- Regis, M. et al. (2015) 'Additive manufacturing of Trabecular Titanium orthopedic implants', *undefined*, 40(2), pp. 137–144. doi: 10.1557/MRS.2015.1.
- Seuring, S. et al. (2020) 'The application of theory in literature reviews – illustrated with examples from supply chain management', *International Journal of Operations and Production Management*, 41(1), pp. 1–20. doi: 10.1108/IJOPM-04-2020-0247.
- Sgarbossa, F. et al. (2021) 'Conventional or additive manufacturing for spare parts management: An extensive comparison for Poisson demand', *International Journal of Production Economics*, 233(June 2020), p. 107993. doi: 10.1016/j.ijpe.2020.107993.
- Sirichakwal, I. and Conner, B. (2016) 'Implications of additive manufacturing for spare parts inventory', *3D Printing and Additive Manufacturing*, 3(1), pp. 56–63. doi: 10.1089/3dp.2015.0035.
- Song, J. S. and Zhang, Y. (2016) 'Stock or print? impact of 3-d printing on spare parts logistics', *Management Science*, 66(9), pp. 3860–3878. doi: 10.1287/mnsc.2019.3409.
- Syntetos, A. A. and Boylan, J. E. (2001) 'On the bias of intermittent demand estimates', *International Journal of Production Economics*, 71(1–3), pp. 457–466. doi: 10.1016/S0925-5273(00)00143-2.
- Togwe, T., Eveleigh, T. J. and Tanju, B. (2019) 'An Additive Manufacturing Spare Parts Inventory Model for an Aviation Use Case', *EMJ - Engineering Management Journal*, 31(1), pp. 69–80. doi: 10.1080/10429247.2019.1565618.
- Westerweel, B. et al. (2021) 'Printing Spare Parts at Remote Locations: Fulfilling the Promise of Additive Manufacturing', *Production and Operations Management*, (April). doi: 10.1111/poms.13298.
- Westerweel, B., Basten, R. J. I. and van Houtum, G.-J. (2019) 'Preventive Maintenance with a 3D Printing Option', *SSRN Electronic Journal*, (February). doi: 10.2139/ssrn.3355567.
- Westerweel, B., Basten, R. J. I. and van Houtum, G. J. (2018) 'Traditional or Additive Manufacturing? Assessing Component Design Options through Lifecycle Cost Analysis', *European Journal of Operational Research*, 270(2), pp. 570–585. doi: 10.1016/J.EJOR.2018.04.015.
- Wong, K. V. and Hernandez, A. (2012) 'A Review of Additive Manufacturing', *ISRN Mechanical Engineering*, 2012, pp. 1–10. doi: 10.5402/2012/208760.
- Zhang, B. et al. (2019) 'CAD-based design and pre-processing tools for additive manufacturing', *Journal of Manufacturing Systems*, 52, pp. 227–241. doi: 10.1016/J.JMSY.2019.03.005.