PAS 6001:2020

Factors to be considered in making and assessing the business case for additive manufacturing and 3D printing – Guide

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Foreword

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The PAS process enables a guide to be rapidly developed in order to fulfil an immediate need in industry. A PAS can be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

Use of this document

As a guide, this PAS takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

It has been assumed in the preparation of this PAS that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The guidance in this PAS is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. "organization" rather than "organisation").

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a PAS cannot confer immunity from legal obligations.

0 Introduction

0.1 What is AM/3DP?

Additive manufacturing (AM), also referred to as 3D printing (3DP), as defined in Annex A, refers to the application of a group of technologies which use 3-dimensional (3D) computer-aided design (CAD) data to produce tangible objects. These objects are constructed through the addition of multiple layers of material, using information derived from the 3D CAD data. The material in each layer is consolidated thermally or chemically. Each subsequent layer is then bonded to the previous layer thermally, chemically or mechanically, resulting in a tangible facsimile of the original 3D CAD data. There are seven recognized configurations of the AM/3DP process as defined in BS EN ISO/ASTM 52900. Annex B describes the seven configurations along with details of the materials that each technology can process.

0.2 The benefits of AM/3DP compared to established manufacturing processes

0.2.1 Production flexibility and geometric complexity

There are many inherent benefits to using AM/3DP, which are primarily a function of production flexibility and geometric complexity leading to improved availability and product performance.

0.2.2 Flexible production – toolless manufacture (cost reduction)

As a digitally enabled process, AM/3DP allows users to manufacture items with no associated tooling. AM/3DP differs significantly from processes such as moulding, casting and machining, where tools, patterns, jigs and fixtures are needed to enable production. AM/3DP removes the capital investment and risk associated with this general "tooling", along with the economies of scale and the need to amortize "tooling" cost across large production volumes. AM/3DP can, therefore, enable cost-effective low-volume production that is highly flexible to changes in customer demand.

0.2.3 Improving product performance – smart parts (revenue enabler)

As AM/3DP uses a layered approach to manufacturing, it is also possible to increase the geometric complexity of items beyond the level achievable using traditional manufacturing processes. This complexity can be achieved with little if no impact on production economics, but enables several potential benefits to the customer, which can be monetized, such as improved product performance and efficiency.

0.2.4 Part consolidation – fewer parts, less assembly (cost reduction)

By increasing geometric complexity, it is possible to consolidate multiple parts of an assembly together into a single component. Consolidation reduces the complexity of the supply chain, eliminates manufacturing and assembly operations, removes potential points of failure and can reduce life-cycle service costs.

0.2.5 Personalization and customization – new markets (revenue enabler)

By coupling the geometric freedom of AM/3DP with the low-volume production economics of the process, it is well suited to the manufacture of customized and personalized products such as medical devices, consumer goods and fashion items.

0.2.6 Repair and reuse – after market opportunity (revenue enabler)

AM/3DP technology can also be used in the repair and remanufacture of existing products where material can be added using an AM/3DP process onto an existing object.

0.3 Limitations of AM/3DP compared to established manufacturing methods

0.3.1 Process, productivity and economic challenges

There are many benefits to AM/3DP. However, the process also has limitations and drawbacks.

0.3.2 Low productivity rates

AM/3DP processes have low production rates when compared to more established production methods. For example, whereas an injection moulding machine might take less than a minute to produce a plastic component, an equivalent part produced by AM/3DP could take several hours. Similarly, whereas the cycle time of a computer numerically controlled (CNC) milling machine, cutting metal, might be less than an hour from a solid billet to a finished part, the equivalent part could take over 24 hours to produce using metallic AM/3DP technology.

However, the use of AM/3DP can also mitigate the need for injection mould, die-cast or investment cast tooling, which can take many months to produce. Moreover, the use of AM/3DP can reduce the number of manufacturing and assembly steps needed to bring a product to market. Hence, making the overall approach faster. It is therefore critical that any AM/3DP business case considers the end-to-end production lead-time of parts across the value chain, not solely the AM/3DP production rate.

0.3.3 Questionable production economics

Some high-end AM/3DP machines can cost many hundreds of thousands of pounds. Moreover, the material feedstock used by AM/3DP machines can be significantly more per tonne than the equipment material used in moulding, casting or machining. The relatively low productivity of machines coupled with the high cost of machines and raw materials can result in very high-cost components.

However, AM/3DP can also mitigate the need for fixed assets such as tooling and can be used to reduce down-stream processes and assembly tasks. It is therefore critical that any AM/3DP business case considers the end-to-end production cost of parts, not solely the piece-part production cost of the AM/3DP step.

0.3.4 Limited process capability

AM/3DP is often considered as an alternative to established production processes such as moulding, casting and machining. Although AM/3DP is capable of making suitably sized parts in the same or similar materials, it might not be able to achieve the accuracy, resolution or surface finish of these processes without additional post-process machining, which increases part cost.

0.3.5 Limited material properties

Although AM/3DP machines can process conventional engineering polymers and metals, the resulting mechanical properties of the parts produced might not be equivalent to the same material when processed by casting, moulding or machining. In some cases, this can result in the need for post-process heat treatment and an increased level of part inspection, which increases part cost.

0.3.6 Costly product certification

Many of the benefits of AM/3DP are achieved through redesigning a product or part specifically for an AM/3DP process. In many cases this results in a new product, being made using a new method, in a material with new mechanical properties. In such a circumstance, it might be necessary to certify the capabilities of the product through testing; for example, a new medical device, aerospace component or consumer product. Product certification can add both time and cost to the adoption of AM/3DP.

0.3.7 Difficult process validation

When AM/3DP is used to manufacture certified products or products with a high level of criticality, it is essential that the process remains within specified limits. Like many manufacturing processes, the uniformity of parts produced using AM/3DP can vary significantly as a result of small changes in the process environment. It is therefore important to consider the cost of establishing, mitigating and monitoring any process variance.

Figure 1 details the primary value propositions of AM/3DP adoption and the fundamental limitations to consider when developing or assessing the business case for AM/3DP.

Figure 1 – Primary value propositions and limitations of AM/3DP

The value proposition of AM/3DP	Limitations and consideration for adoption
Flexible production	Limited productivity
Low-volume economic production	Production economics
Part count and assembly reduction	Process capability
Improved product performance	Material property and consistency
Personalization and customization	Product certification
Repair and reuse	Process validation

***NOTE** Other benefits and limitations to AM/3DP are explained in detail throughout PAS 6001.*

0.4 How to use PAS 6001

There are a multitude of economic, legal, social and human factors to consider when either building or assessing an AM/3DP business case. PAS 6001 provides the information needed in the evaluation of these factors.

PAS 6001 uses a number of hypothetical examples of financial business cases relating to different applications of AM/3DP. These financial models are provided for illustration purposes only, to help navigate the information provided within PAS 6001.

When building a business case for AM/3DP using the financial models presented in PAS 6001, the business model canvas presented in Annex C can be used. Based on the Alexander Osterwalder [1] business model canvas, Annex C provides a framework to capture the value proposition of AM/3DP and the information needed to build a financial model and business case. This canvas can be used to capture ideas stimulated by PAS 6001. Annex D provides a series of self-assessment questions relating to the business drivers for AM/3DP adoption, capital investment and outsourcing, the implications of AM/3DP on human resources and commercial risk.

PAS 6001 does not make recommendations on which AM/3DP technology is the most appropriate for a given application; instead, it provides a framework for how technology investment and adoption should be assessed. It considers the broader implications of AM/3DP on the business, the supply chain and the customer.

[1] www.strategyzer.com/canvas/business-model-canvas

1 Scope

This PAS provides guidance to directors, senior management and accountants of companies of all sizes who wish to explore or assess the business case for the adoption of AM/3DP for the production or repair of end-use products, systems and services.

The insight provided enables readers to understand where AM/3DP can contribute to top-line business growth, bottom-line profitability and productivity improvement.

This PAS considers how to build the most appropriate supply chain and how to quantify the broader social, environmental and economic benefits of the technology.

It considers the impact of AM/3DP technology adoption both internally and externally, including investment, risk, skills, change management and customer expectation.

This PAS does not cover the business case for rapid prototyping (RP) or digital product development.

NOTE *Although written in the language of profit and loss, this PAS can also be used by anyone looking to develop a business case for AM/3DP within their organization or, inversely, anyone looking to assess an AM/3DP business case presented to them by others.*