

# Chapter 3

## From 3D to 4D: The Evolution of Additive Manufacturing and Its Implications for Industry 5.0

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### ABSTRACT

*This chapter traces the evolution of additive manufacturing (AM) from a rapid prototyping technique to a disruptive technology that impacts various industries. It reviews the latest research and expert opinions on the effects of AM on industrial, societal, and environmental aspects. It also explores 4D printing (4DP), a novel branch of AM that creates dynamic and adaptive objects, and discusses its challenges and opportunities. It also considers the conjunction of AM with other emerging technologies such as AI, IoT, and blockchain, and how they shape the future of smart products and services. This chapter offers valuable insights into the development of AM, its transformative potential, and its crucial role in shaping the industries of tomorrow.*

### INTRODUCTION

Additive manufacturing (AM), also recognized as 3D printing (3DP), has emerged as a powerful technology that has transformed various industries and sectors. AM originated in the 1980s as a method for rapid prototyping, but it has evolved into a versatile technology that can create functional and complex products from different materials and functionalities. This book chapter provides a comprehensive overview of the evolution, impact, challenges, and prospects of AM, focusing on its multifaceted influence on industries, society, and the environment.

The inspiration for this study stems from the pivotal role that AM plays in contemporary manufacturing and its potential to mould the industrial horizon. As AM continues to redefine the possibilities of product design and production, it is essential to understand its history, applications, and implications. Moreover, the rapid growth and diversification of AM technologies, such as 4DP, require an in-depth investigation into their opportunities and risks. The problem statement for this study revolves around

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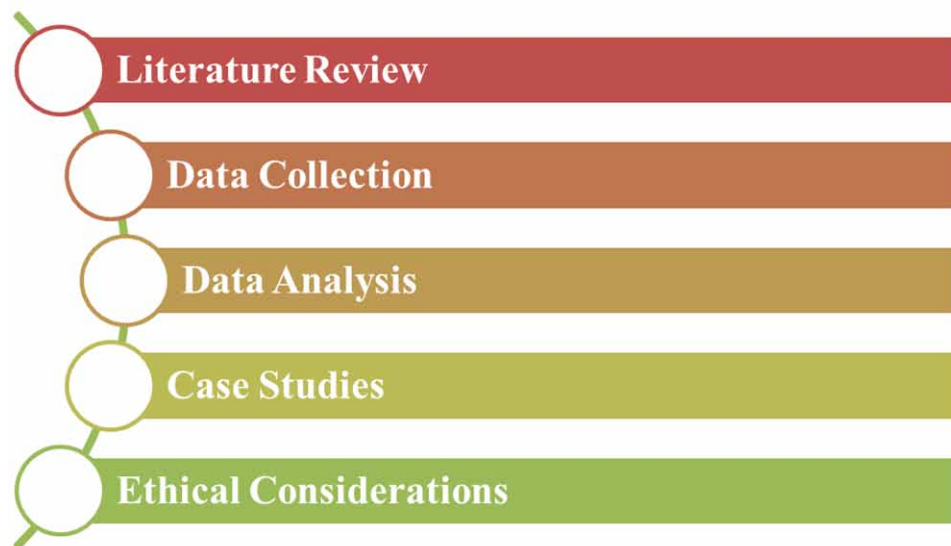
the imperative to comprehensively appraise the progress of AM, its power to innovate, and its essential role in remodelling domains, society, and the environment.

The contribution and significance of this study are four-fold. First, this is the foremost study that examines the journey of AM from its inception as a prototyping tool to its current status as a transformative force in multiple industries. Second, this chapter explores the emerging field of 4DP, an extension of 3DP that introduces time as a dimension and allows objects to change shape in response to external stimuli. The study examines the potential applications, challenges, and opportunities associated with 4DP, shedding light on its importance in the realm of smart materials and structures. Third, as AM increasingly integrates with other developing technologies, it points to a future where smart products and services interact in real time with users and the environment.

Fourth, the study investigates how AM influences the manufacturing, designing, and usage of products and services, emphasizing its role in stimulating creativity, reducing waste, enhancing customization, and allowing on-demand manufacturing.

This chapter employs a comprehensive approach that integrates a literature review and data analysis to explore AM and 4DP. It utilizes qualitative and quantitative data sources for a well-rounded perspective. The Figure 1 depicts the methodology followed in this book chapter.

*Figure 1. Methodology adopted*



In this chapter, we review the literature on additive manufacturing (AM) and its applications in various domains such as aerospace, fashion, robotics, etc. The results are summarized in Table 1.

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