The Effects of Adoption of 3D Printing Technology on the Operational Performance of the Companies of Cross Border Entrepreneurs: An Empirical Study

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ABSTRACT
This article examines the effects of the adoption of 3D printing technology (3DPT) applications on the operational performance of entrepreneurs’ companies in terms of time, cost, quality, competitiveness, and management processes. For this purpose, a study model based on the relevant previous studies was proposed. The data for this research was collected by means of a self-administered questionnaire given to 161 respondents. The target respondents were those employed in entrepreneurial companies in Jordan, and the data was analysed using multiple regression techniques. The findings indicate that the extent of 3DPT being adopted by entrepreneurial companies in Jordan should be considered moderate at this stage. Further, all integrated operational performance indicators (time, cost, quality, competitiveness, and management processes) were significantly influenced by the adoption of 3DPT; the most important performance indicators were found to be time, cost, and quality due to the business environment context found in Jordan.

KEYWORDS
3DPT Applications, Entrepreneurial Companies, Jordan, Operational Performances

1. INTRODUCTION
Disruptive innovations change business models in radical ways; this is especially true of the digital technologies, which have begun to cause major changes in the industries that have utilised them. Gradually over the past 25 years, new digital technologies have emerged that have transformed a number of tangible products into intangible digital content. This has also affected the manufacturing process, as previously, the design or production of tangible products required companies to participate in long series of processes, all of which had to be done in appropriate ways. These required various skills, professional staff, and time for development from idea to full production, as well as continuous development and modifications during production, in addition to any special requirement based on the product itself. These all cost a lot of money.

In the past few years, the technology adoption trend has accelerated significantly, due to the development of additive manufacturing technologies (AM). Three-dimensional printing technology

DOI: 10.4018/IJ3DIM.2018100102

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(3DPT) is often used as a synonym for AM, and this is more specifically defined as “the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies” (Wohlers Associates, 2010). More generally, AM is defined as “a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing technologies” (Niaki and Nonino, 2017).

Such technology can be used to print very complex designs, which is especially useful in the prototype stage of new product development, as it allows the value proposition of the design to be increased through using this technology to get fast feedback, making everything in-house, and lowering the cost of development processes, thus allowing firms to deliver maximum benefit from the product to the customer (Barros et al., 2017). However, 3D Printing is an innovative sector in which technologies change rapidly. As companies face economic world changes and new consumption standards, the concept of AM manufacturing to produce physical objects from digital information layer-by-layer has become increasingly popular (Thompson, 2016). Additive manufacturing represents a topical innovation in manufacturing technologies, however, and thus may significantly change value chains and business logics in manufacturing industries (Steenhuis and Pretorius, 2017).

Additive manufacturing technologies have now progressed through three stages of development. In the beginning, product designers used these only for new product development (NPD). The second development stage of AM included its application in creating end-use parts, a step defined as “direct digital manufacturing”. The third phase involves 3D printers that, as with desktop printers, can be used directly by end consumers (Berman, 2012). This phase has given entrepreneurial companies and industrial design studios access to AM processes such as stereo lithography (SLA) and fused deposition manufacturing (FDM), with costs from $300 to $2,000. The purposes for purchasing these printers differ, ranging from fully producing products such as accessories and toys to producing complementary materials such as covers, boxes, or parts to help entrepreneurial companies develop their competitiveness. To further help such companies to develop their competitiveness, changes must also occur in terms of cost, time, and quality in both product and management process terms. Three-dimensional printing has thus become an essential element in a new industrial revolution in which digitization, information, and communication are transforming product innovation. However, despite the many alleged benefits of 3DP, current research indicates that the expected benefits have rarely been examined in practice.

Understanding the factors influencing the adoption of 3D-printing applications has received great attention from academic researchers and professionals all over the World (Guo and Leu 2013; Rylands, et al., 2016; Martinsuo and Luomaranta, 2018). Other studies have emphasised the various benefits of adopting AM technologies, which include design freedom, efficiency and speed, customisation of products, enabling of small batches, flexibility, adaptability, simplification of supply chains, and reduction of waste (Weller et al., 2015). A review of previous studies also shows that the majority of the researches concerning challenges to AM adoption were carried out only among large firms (Flores et al., 2016; Rylands et al., 2017).

Studies empirically and practically examining the adoption phenomenon among entrepreneurial companies in developing countries, such as Jordan, are rare, however, particularly with regard to the impact of the adoption of 3D-printing applications on operational performance (time, cost, quality, competitiveness and management processes). Digital manufacturing technologies are regarded as offering tremendous advantages for businesses and industries, but these benefits appear to be barely examined in practice. Therefore, this study seeks to answer the following question: to what extent does the adoption of 3D-printing technology influence and enhance the operational performance of entrepreneurial companies in a Jordanian business context?
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