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Cloud-Based Design, Engineering Analysis, and Manufacturing: A Cost-Benefit Analysis

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Abstract

From a business perspective, cloud computing has revolutionized the information and communication technology (ICT) industry by offering scalable and on-demand ICT services as well as innovative pricing plans such as pay-per-use and subscription. Considering the economic benefits of cloud computing, cloud-based design and manufacturing (CBDM) has been proposed as a new paradigm in digital manufacturing and design innovation. Although CBDM has the potential to reduce costs associated with high performance computing (HPC) and maintaining ICT infrastructures in the context of engineering design and manufacturing, it is challenging to justify the potential cost savings associated with HPC in the cloud because of the complexity in the cost-benefit analysis of migrating to CBDM. In response, this paper provides important insights into the economics of CBDM by identifying key cost factors and potential pricing models that can influence decision making on whether migrating to the cloud is economically justifiable. Specifically, the cost breakdown of adopting CBDM is presented. The general key benefits are demonstrated using real case studies. In addition, a hypothetical application example is presented to compare costs in CBDM with that of traditional in-house design and manufacturing. Finally, some of the key issues and road blocks are outlined.

Keywords: Cloud-based design and manufacturing, Cloud-based engineering analysis, Cloud computing, High performance computing, Cost-benefit analysis

1 Introduction

The well-known Pareto's principle, also referred to as the 80-20 rule or the law of the vital few, can be used to illustrate the distribution of wealth in a country. The original Pareto's principle states that 20% of the population in Italy owned 80% of the wealth in 1906. Subsequently, Pareto's principle has been observed in many other areas. The generalized Pareto's principle suggests that, for many events, roughly 80% of the effects come from 20% of the causes. For example, it has been observed that many companies in the information and communication technology (ICT) industry have been

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faced with the same phenomenon in which 80% of their budget was spent on maintaining existing ICT services and infrastructures, while only 20% on their core business functions. As a result, a limited amount of computing resources and capital can be used to improve the core competences of small- and medium-sized manufacturers (SMMs), including the development of new products and the improvement of existing products.

Because cloud computing enables ubiquitous and on-demand network access to a shared pool of configurable computing resources, the ICT industry has been promoting cloud computing since the 2000s as a profound paradigm shift. Similar to the ICT industry, product design and manufacturing industries are also undergoing a seismic paradigm shift from traditional web-based distributed and collaborative design and manufacturing to cloud-based design and manufacturing (CBDM) by migrating increasing amounts of core manufacturing functions into the cloud. For example, in the broad computer aided technology (CAx) fields such as computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), major CAx vendors have been developing or developed cloud-based CAx tools. For example, in the field of CAE, the UberCloud has launched an initiative to help SMMs apply HPC-based modeling and simulation into engineering analysis such as finite element analysis (FEA), computational fluid dynamics (CFD), and multi-body dynamics (Gentzsch & Yenier, 2013). The UberCloud brings industry end-users, computing resource providers, software providers, and HPC and cloud computing experts together, helping SMMs explore how to integrate HPC and cloud computing with CAx vendors such as Autodesk and ANSYS (UberCloud, 2014). Consequently, we envision that cloud computing has the potential to transform the way in which both large-scale manufacturers and SMMs leverage advanced data analytics, modeling and simulation tools in product design and manufacturing.

With the increasing levels of attention paid to CBDM, high-level management leaders will face a number of important decisions, including what design and manufacturing services to move and when to move those services into the cloud, how to structure the relationship with the cloud service provider, and how to manage risks while operating in a cloud computing environment. As expected, different applications and organizations will have varying decisions associated with addressing the above issues. Therefore, answering these questions requires an in-depth understanding of the cost implications of all the possible decisions specific to different circumstances. In response, the purpose of this paper is to provide decision makers with insights into the economic impacts of CBDM, including cost breakdown and potential benefits. Specifically, we identify an initial set of key factors affecting the costs of implementing CBDM and perform a cost-benefit analysis through case studies. The remainder of this paper is organized as follows: Section 2 introduces the background of CBDM. Section 3 presents some of the most commonly used pricing plans. Section 4 presents cost breakdown in the adoption of CBDM. Section 5 discusses the key benefits of migrating to CBDM using application examples and experiments. Section 6 provides recommendations that are drawn from the investigation.

2 Background

In this section, a brief overview of CBDM is provided. CBDM refers to "a service-oriented product development model in which service consumers are able to configure products or services as well as reconfigure manufacturing systems through Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), Hardware-as-a-Service (HaaS), and Software-as-a-Service (SaaS) in response to rapidly changing customer needs" (Wu et al., 2012; Wu et al., 2013; Wu et al., 2014; Wu et al., 2015). In the IaaS model, cloud service providers offer on-demand access to computing resources such as virtual machines and cloud storage. Examples of IaaS providers include Rackspace, Amazon, and Google. In the PaaS model, cloud service providers deliver computing platforms such as social collaboration platforms, programming and execution environments for cloud computing. Examples of