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Abstract: Cloud computing has become an important part of IT infrastructure for both small companies and large enterprises over the last years. More organizations than ever consider it an enabler for their efforts in making IT more agile, reducing operating costs and gaining access to new technologies that will give them an edge over their competitors. In this paper we develop a conceptual model to explain the benefits of using cloud computing for delivering a digital product across several stages of its product lifecycle, emphasizing the importance of the four delivery models: public, private, community and hybrid cloud. While this distinction is theoretically novel and helps IS scholars to gain a more nuanced understanding of cloud computing in the enterprise, it provides practitioners with a decision frame to select the most effective mode of cloud computing given the specific lifecycle stage of their digital product. Ultimately, we discuss limitations of this approach and provide directions for future research.

Keywords: Digital Business Models, Cloud computing, Product Lifecycle, Agility, Delivery Models

Introduction

Cloud computing describes a way for organizations to obtain "ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources" (Mell & Grance, 2011 p. 2). By the end of 2019, an additional 17% of enterprises are planning to migrate at least partly to Cloud computing according to IDG (2018), one of the largest IT media and research companies worldwide, and will therefore face the decision as to which kind of cloud environment is right for their product. According to research company Gartner, by 2020 a “no-cloud policy” will not be an option anymore if companies want to stay competitive (Forni et al., 2020).

Cloud computing is considered a – and possibly the - strategic driver of digital product development (Bharadwaj et al., 2013; Hanelt et al., 2015). Traditionally, the product lifecycle model was used to explain the requirements for successful product development given the specific lifecycle stage of a product (Vernon, 1966). Digital products are no exception (Harik et al., 2016; Liu et al., 2014; Nambisan, 2009).

While extensive research has been conducted into the technological aspects and – to a lesser extent – business issues of cloud computing, conceptual research papers are still significantly underrepresented (Dempsey & Kelliher, 2017; Liu et al., 2018; Maston et al., 2011). In a recent review of the cloud computing literature, Senyo et al. (2018) find that only about 9% of the 285 articles under scrutiny were an attempt to conceptualize the phenomenon, while the vast majority of papers (235) were classified as atheoretical, meaning that no theoretical frame was provided. Attempting to address this shortcoming, the objective of this paper is to create a conceptual model, mapping the benefits of cloud computing to the product lifecycle stages of a digital product. We develop this conceptual model by using an established theory, i.e. the product lifecycle model, to explain a new phenomenon, i.e. cloud computing, following one of the approaches put forward by Yadav (2010). While this distinction is theoretically novel and helps IS scholars to gain a more nuanced understanding of cloud computing in the enterprise, it provides IT managers responsible for cloud computing with a decision frame to select the most effective mode of cloud computing given the specific lifecycle stage of their digital product.

The paper is structured as follows: we will first introduce the theoretical background of cloud computing and the product lifecycle model. Next, we will develop our conceptual model by analyzing the challenges of each lifecycle stage and linking them with the benefits cloud computing can provide. We will then discuss the model and its limitations before we conclude with recommendations for future research.

Cloud Computing

Cloud computing as a technological trend allows organizations to quickly and easily obtain IT resources over a network connection, for example through the public internet (Mell & Grance, 2011). As such it is a strategic driver behind developing digital products and enabling digitization of existing products (Bharadwaj et al., 2013; Hanelt et al., 2015). Extensive research has been conducted about the phenomenon of cloud computing, e.g. on the benefits of cloud computing for organizational agility (Liu et al., 2018) or even the impact of cloud computing adoption on stock prices of large enterprises (Mahmood et al., 2014).

Deployment Modes of Cloud Computing

One common definition of cloud computing is the NIST standard, developed by Mell and Grance (2018). In the standard, a differentiation between service models and deployment models is made. The term service models uses a simple taxonomy to distinguish between various degrees of integration. Deployment models on the other hand describe the degree of isolation of a cloud offering and, therefore, the amount of control the consumer can exercise over it. For the purpose of this paper, the differentiation between service models will be omitted when discussing the benefits of Cloud computing as the difference across the product lifecycle is mainly driven by the deployment model used. the impact of different service models is slim by comparison. The deployment models can be defined as follows (Mell & Grance, 2018):

- *Private Cloud*: The cloud infrastructure is provisioned for exclusive use by a single consumer
- *Community Cloud*: A community cloud is a special form of a Private Cloud where several consumers, for example companies within a large enterprise, join to create a Cloud environment that is exclusive to members of this group
- *Public Cloud*: The cloud infrastructure is provisioned for open use by the general public
- *Hybrid Cloud*: The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain as unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds)

Benefits of Cloud Computing

Marston et al. (2011) have compiled a list of benefits that can be realized from a business perspective by using cloud computing:

- *Lower cost of entry*: Depending on the deployment model, cloud computing requires little to no upfront investment in infrastructure, making it easier for enterprises and new competitors to enter the market
- *Faster provisioning times*: Cloud computing can allow quicker access to IT resources, therefore reducing the time needed to provision new services
- *Lower barrier to innovation*: Due to access to new technologies and faster provisioning times cloud computing can be used to develop and experiment quickly

- *High scalability of resources*: Cloud computing is designed to scale both up and down quickly, allowing to react to higher demand and at the same time freeing resources if they are no longer required
- *Access to specialized technology*: Depending on the deployment model, cloud computing can provide access to new technologies and skills that an organization would not be able to provide internally.

Additionally, Litoiu et al. (2010) have observed that cloud computing can be optimized for specific workloads and the ability to optimize depends on the deployment model used. For example, according to Litoiu et al. (2010 p. 2), public cloud computing is often made up of "a layered architecture, where a feedback loop has only a limited view of resources and goals." Hence, the optimization techniques commonly used in private cloud computing, where full transparency of resources can be achieved, are not fully applicable here. This transparency given in private cloud environments in addition to the ability to make individual changes to the underlying architecture which would not be possible in public cloud environments allows for better optimization towards the specific workload.

The benefits described above can be mapped to the deployment model based on their degree of applicability. Generally, all deployment models can achieve faster provisioning times compared to traditional IT infrastructure. However, for other benefits, differences exist. If we take lower cost of entry as an example, Private Cloud would provide only a slight benefit regarding the lower cost of entry, as investments still need to be made to establish the cloud environment, similar to traditional IT infrastructure. On the other hand, in a Public Cloud environment, these resources are pooled by a cloud provider and can be accessed on-demand for a usage-based fee, leading to a high benefit for this deployment model. In community cloud environments, the pool of shared resources is limited due to the reduced amount of organizations sharing the cloud environment, resulting in a medium benefit. The same benefit is applied to hybrid cloud environments, as the cost of entry is low for public resources, but high for private resources, which are both part of the hybrid environment. The remaining benefits will not be discussed in detail; however, we followed a similar logic to derive the degree of applicability for each benefit.

	Degree of applicability to deployment models			
Benefit of Cloud Computing	**Private Cloud**	**Commu-nity Cloud**	**Public Cloud**	**Hybrid Cloud**
Lower cost of entry	Low	Medium	High	Medium
Faster provi-sioning times	High	High	High	High
Lower bar-rier to innova-tion	Medium	Medium	High	High
High scala-bility of re-sources	Medium	Medium	High	High
Access to specialized technology	Low	Medium	High	High
Ability to op-timize for spe-cific workloads	High	Medium	Low	High

Table 1. Benefits of Cloud computing depending on deployment model

While other benefits of Cloud computing have been described, we consider these to be the most relevant for the purpose of mapping them to the product lifecycle.

The Product Lifestyle

The product lifecycle is a tool first introduced by Vernon (1966), which has quickly been adopted as one of the fundamental instruments in economics (Cox, 1967; Rink & Swan, 1979). According to Cox (1979), the development of any product can be classified into four stages:

1. *Introduction Stage*: Initially, an idea is validated and at some point, offered to a specialized market or the broad market, thereby being introduced
2. *Growth Stage*: If a product is sustainable enough in the introduction stage, it will gain recognition in the market and begin to grow
3. *Maturity or Stabilization Stage*: After a certain time of growth, all products will eventually reach a point where sales incline stops. This phase can be triggered early by competitors entering the market, leaving less market potential to the original product
4. *Decline Stage*: Once a product has reached maturity for some time, sales will inevitably decline, and revenue will begin to fall

It is worth noting at this point that a product may fail in any of these stages and will then move directly to the last step, cancellation, without following through with the remaining steps of the PLC (Cox, 1967). A visual representation of the four stages can be seen in figure 1.

Digital products are different from traditional, manufactured products in many ways. For example, the environment is more volatile and competitive, leading to an uncertainty in market and product development (Al-Debi et al., 2008). However, existing research has successfully applied the traditional product lifecycle model to digital products. One good example is the application to the field of mobile apps[8], as these apps make up a large market with about 178 billion downloads in 2017 (App Annie Research, 2017) and therefore provide a large basis for analysis. Furthermore, researchers have tied the product lifecycle model to digital products in a variety of ways (Harik et al., 2016; Nambisan, 2009). Therefore, we conclude that the stages laid out in the original product lifecycle model (Vernon, 1966) equally apply to digital products.

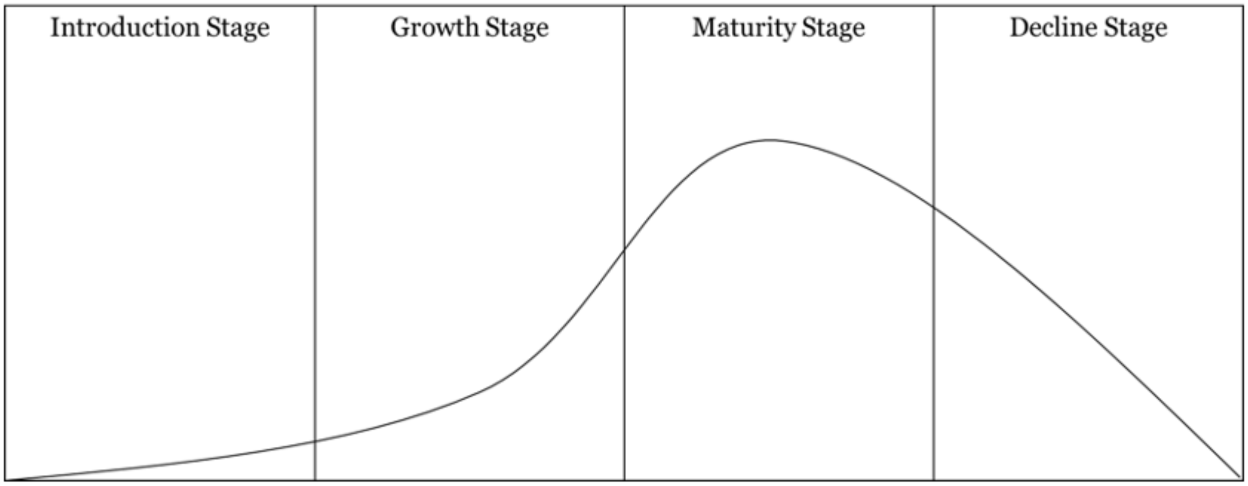

Fig. 1. The Product Lifecycle, adapted from Levitt (1965)

Using Cloud Computing for Product Lifecycle Management Deployment Modes of Cloud Computing

Using the product lifecycle model, distinct challenges of each stage can be defined (Cox, 1967; Levitt, 1965). The Introduction stage is mainly driven by an uncertainty of market success for the new product and a high up-front investment, which is required to develop and launch a product. During the Growth phase, if the product was successful during its introduction, the risk of competition entering the market to compete for market share will arise. Once the Maturity phase has been reached, the market will begin to be saturated, therefore slowing the growth rate of the product. Given the existing competition on the market by this point, this will lead to increased price pressure, as companies start to compete on price to gain additional market share. Lastly, in the decline phase, market demand will shrink, leading to lower utilization of the infrastructure and resources used for the product.

Using Cloud Computing to Address Lifecycle Challenges

It can be assumed that the change in challenges across the product lifecycle stages will also require a different setup of the underlying resources and infrastructure (Strader, 1998), of which cloud computing can be a key part in digital products (Marston et al., 2011). Therefore, we will link the benefits of cloud computing to the challenges of the product lifecycle stages in the next section.

The challenges of digital products across the product lifecycle can be linked to the benefits of cloud computing. During the introduction phase, uncertainty of market success can lead to a potentially unreliable forecast of required resources (Cox, 1967). On the one hand, the benefit of high scalability of resources can lead to quick upscaling, in case demand is higher than expected. On the other hand, in case of an unsuccessful product, cloud computing allows for quick downscaling to free resources for more successful products, thus lowering overall financial exposure. In the same phase, the challenge with high up-front investment is a potential financial loss of any upfront investments made into product design and launch (Levitt, 1965). If cloud computing is employed to reduce the cost of market entry, the potential financial loss is also reduced.

Once the growth phase has been reached, a high risk of competition entering the market can be tackled by cloud computing's lower barrier to innovation. With its quick access to scaling resources and easy access to experiments, cloud computing can enable faster iterations of digital products, therefore allowing better reactions to customer needs and thus lowering the risk of losing customers to the competition.

This benefit can also help when facing slowing growth due to market saturation in the maturity phase: As market growth slows, companies will start competing for existing customers rather than trying to acquire new customers (Levitt, 1965). A high ability to innovate and iterate on a digital product will allow the company to differentiate its digital product from the competition. Additionally, cloud computing provides access to specialized technology, which is beneficial because as a market becomes saturated, digital products will require more unique and differentiating features (Al-Debi et al., 2008). These often come from new technological developments; therefore, cloud computing can be a supporting factor if it provides access to specialized technology that a company would not be able to provide internally. To tackle increased price pressure from competition, the ability to optimize for specific workloads becomes more important: As price pressure increases, a main goal is to reduce operating cost. Optimizing infrastructure for specific workloads will allow the infrastructure and transaction costs to decrease, therefore bringing the overall costs down.

Once a digital product enters the decline phase and faces shrinking market demand, so does the amount of infrastructure required. Scalable cloud computing resources allow the organization to re-purpose resources for other products and thus keep overall utilization of IT resources high.

A Conceptual Model for the Deployment of Cloud Computing

The relationship between product lifecycle stage, challenges, cloud computing benefits and deployment model described in previous paragraphs can be summarized in one unified model, linking the product lifecycle stage to potentially viable cloud deployment models using the challenges and benefits associated with them. The result of this consolidation is displayed in Table 2:

			Applicability of Benefit			
Stage	**Challenge**	**Cloud computing Benefit**	**Private Cloud**	**Community Cloud**	**Public Cloud**	**Hybrid Cloud**
Introduction	*Uncertainty of market success*	High scalability of resources	Medium	Medium	**High**	**High**
	High up-front investment	Lower cost of entry	Low	Medium	**High**	Medium
Growth	*High risk of competition entering the market*	Lower barrier for innovation	Medium	Medium	**High**	**High**
Maturity	*Slowing growth due to market saturation*	Lower barrier for innovation	Medium	Medium	**High**	**High**
		Access to specialized technology	Low	Medium	**High**	**High**
	Increased price pressure from competition	Ability to optimize for specific workload	**High**	Medium	Low	**High**
Decline	*Shrinking market demand*	High scalability of resources	Medium	Medium	**High**	**High**

Table 2. Relationship of product lifecycle, cloud computing benefits and deployment model

For readability we have highlighted those deployment models that have a high applicability of the corresponding benefit. As is evident from the consolidated view, between one and two deployment models are dominant in each stage of the product lifecycle. These are:

1. Introduction: Public Cloud
2. Growth: Public Cloud or Hybrid Cloud (The product will likely remain on public cloud infrastructure during the growth stage, as no dominant benefit can be achieved by changing the deployment model now)
3. Maturity: Hybrid Cloud
4. Decline: Public Cloud or Hybrid Cloud

Given these dominant deployment models, we can deduct that an optimal path for introducing a digital product using cloud computing starts off with using public cloud resources to reduce the upfront investment. The product will likely remain on public cloud infrastructure during the growth stage, as no dominant benefit can be achieved by changing the deployment model now. At the maturity stage, price pressure and competition will increase the demand for more optimized computing resources, leading the organization to add private IT infrastructure, thus creating a hybrid cloud environment. In the decline phase, the organization will retain a hybrid cloud environment for a time, while scaling back resources and deploying them to other products. This can lead to either retaining the hybrid cloud infrastructure or, if cutting back on private IT resources first, can result in a move back to a purely public cloud environment.

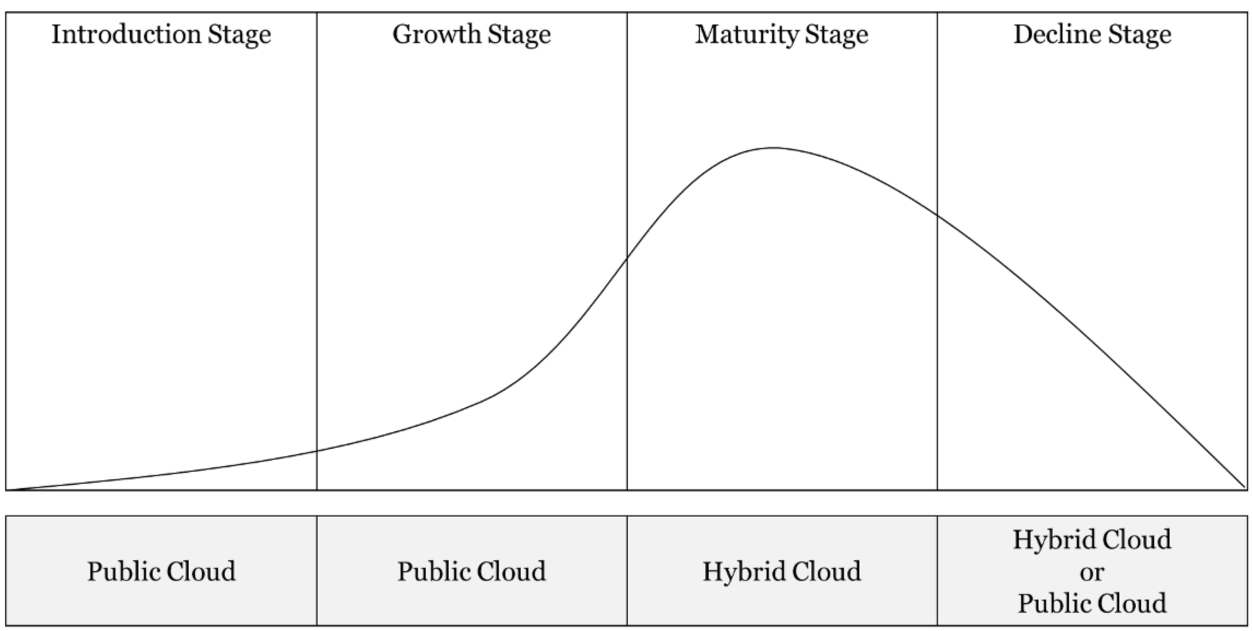

Fig. 2. Cloud computing deployment models by product lifecycle stage

Limitations and Recommendations for Future Research

The conceptual model links cloud computing deployment models to stages of the product lifecycle for digital products. It provides a basis for determining the appropriate use of cloud computing when developing and maintaining a digital product. However, the model is based purely on the goal of achieving the highest benefit for developing a digital product. It does not consider other factors commonly associated with selecting a cloud computing deployment model. These factors include privacy, security or organizational factors like optimizing the utilization of existing IT infrastructure of the organization (Chen, 2012).

At first glance, our model suggests that private or community cloud deployment models are not relevant when developing new digital products. However, it must be acknowledged that any decision for or against cloud computing as a whole or one particular deployment model is always based on a multitude of factors, which are – as discussed previously - not all represented within our model. Reasons to choose private or community cloud models may include security concern, privacy requirements or legal / regulatory limitations (Chen, 2012).

We therefore encourage further development of the conceptual foundation, possibly resulting in the development of an advanced model, incorporating more of the dimensions mentioned above. Further research should be done to develop such a holistic model as a foundation for research into cloud deployment models and as a guidance for practitioners to select a cloud deployment model for their digital products. An additional research area is comprised of ways the critical shift from public to hybrid cloud environments, taking place between growth and maturity stage, can be facilitated by organizations as well as methodologies and tools that might support this shift. Lastly, empirical research into actual cloud computing usage in digital product development can help support the assumptions underlying our conceptual model and verify the validity of the suggested relation between product lifecycle stages and cloud computing deployment models.

Conclusion

Within this paper, we aim to introduce a conceptual model that links the benefits of cloud computing to the challenges of digital products across several stages of their product lifecycle. The focus therefore is on the different deployment models for cloud computing. We have covered the theoretical background of both cloud computing and the product lifecycle and have linked both concepts using by using an existing theory to explain a new phenomenon, as suggested by Yadav (2010). The contribution of this paper is twofold: We offer a theoretical concept for connecting the product lifecycle with cloud computing as a foundation for further research and discussion by other researchers, thus contributing to closing the gap identified by Senyo et al. (2018). Secondly, the paper provides a means for IT managers who are responsible for cloud computing in their organization for determining the appropriate use of cloud computing when developing or improving a digital product. Based on the model suggested, if no other factors like security, privacy, or regulatory concerns demand a private / community cloud environment, new digital products should be developed in a public cloud environment to reduce the risk and up-front investment associated with launching a product in a volatile market environment. Later, when cost reduction and optimization become more relevant in the maturity stage, a strategic shift towards a hybrid cloud environment is recommended to facilitate these optimizations using private cloud resources in selected areas of the product infrastructure.

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