Cloud Computing Application for Digital Integration Between an Advanced Manufacturing Plant and a Model 4.0 Factory

João Vitor Mendes Pinto dos Santos[1*], Thamiles Rodrigues de Melo[2]
[1]SENAI CIMATEC University Center; Salvador, Bahia, Brazil

Industry 4.0 is a global digitalization goal for today's industries, and cloud computing is a solution that enables ubiquitous and convenient access to infrastructure, platforms, and services. Together with fog and edge computing, it leverages the advantages of manufacturing systems integration. This research proposes a cloud architecture to integrate an advanced manufacturing plant and a SENAI CIMATEC model factory. Before implementing this architecture, assessing whether the environment is adaptable is necessary. For this, fundamentals such as the TOE structure (Technology-Organization-Environment Framework) and the SEM model (Structural Equation Modeling) are used, which evaluate the degree of adherence for the application. As a methodological procedure for the research, a database is being modeled to serve the information flow between the systems. Therefore, adapting the environment to cloud computing is crucial to the success of digital system integration and process automation and optimization advances.
Keywords: Cloud Computing. Industry 4.0. Structural Equation Modeling. Database.

Introduction

The integration of manufacturing systems in Industry 4.0 has been widely adopted in different industrial sectors. It allows the connection of various production systems, including equipment, computational tools, and data management systems, to work more efficiently and effectively, aiming to improve productivity, reduce costs, and increase flexibility and agility in the production process [1]. For this integration, cloud computing is one of the technological pillars of Industry 4.0 that enables remote access to data from different processes. This computing paradigm enables ubiquitous, convenient, on-demand access to a shared network of configurable infrastructure, platforms, and service resources [2].

However, challenges are emerging, such as reducing latency between the cloud and production equipment. To solve this problem, new paradigms, such as fog computing and edge computing, have emerged. Fog computing is an extension of cloud computing to the edge network, providing services around devices close to the user, such as routers, instead of sending information to the cloud. In turn, edge computing provides services close to the data source to meet critical requirements in agile connectivity and intelligent applications [2].

In this context of system integration on a didactic scale, there is the advanced manufacturing plant (PMA), an automated production line that uses several cyber-physical systems to produce pneumatic actuators, generating a large amount of data about the production process. On the other hand, the model factory produces pistons from these actuators, but it does not have an automated system, relying only on a process management system.

This research aims to digitally integrate the systems of the advanced manufacturing plant and the model factory, following a customer-supplier proposal, to enable greater ease in the ordering process, agility in production, and traceability of ordered parts.

Theoretical Foundation

The TOE (Technology-Organization-Environment Framework) framework is a conceptual framework used to analyze the adoption of technologies in an organization. The SEM

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Address for correspondence: João Vitor Mendes Pinto dos Santos. Avenida Orlando Gomes, 1845, Piatã. Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: joao.v.m.p.santos@ieee.org.

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(Structural Equation Modeling) model is a statistical technique used to model the loading factor that represents the relevance of relationships between exogenous observable variables; i.e., variables external to the model represent its inputs. On the other hand, latent variables are endogenous variables that are not directly observed but are determined within the model and use observable variables as indicators. The following variables can be considered when applying the TOE framework with SEM models for adopting cloud computing: technological, organizational, and environmental (Figure 1). The the relationships between these variables and identifying those that have the greatest impact on the adoption of cloud computing services are possible by using the TOE framework in conjunction with the SEM model [3].

Kandil and colleagues [4] identified the best criteria for analyzing the adaptability of cloud computing by applying the SEM model. During the investigation, the authors reviewed several articles on adopting TOE focusing on cloud computing and selected the following variables as research instruments (Figure 2)

Among them, there are the following:

- Relative advantage, complexity, compatibility security, and trust in the context of technology;
- Management support, technological readiness and maturity, and performance issues in the context of the organization;
- Competitive pressure, telecommunications infrastructure, internet service provider, business partner support and business partner pressure in the environment.

Materials and Methods

After analyzing the TOE structure, digital integration between the advanced manufacturing plant and the model factory is proposed through a cloud architecture, which could be SaaS (software as a service), IaaS (infrastructure as a service), or PaaS (platform as a service) depending on the type of connection desired between the systems. A cloud database will be built synchronized with local data from both production systems to achieve this point. Based on the customer-supplier proposal presented in Figure 3, the operator of the model factory, as a customer, will be able to send requisitions and orders in the cloud, which will be processed and approved by the operator of the advanced manufacturing plant to start production there as a supplier. This way, optimizing the ordering and production process, guaranteeing the traceability

Figure 1. TOE framework for cloud computing adoption.

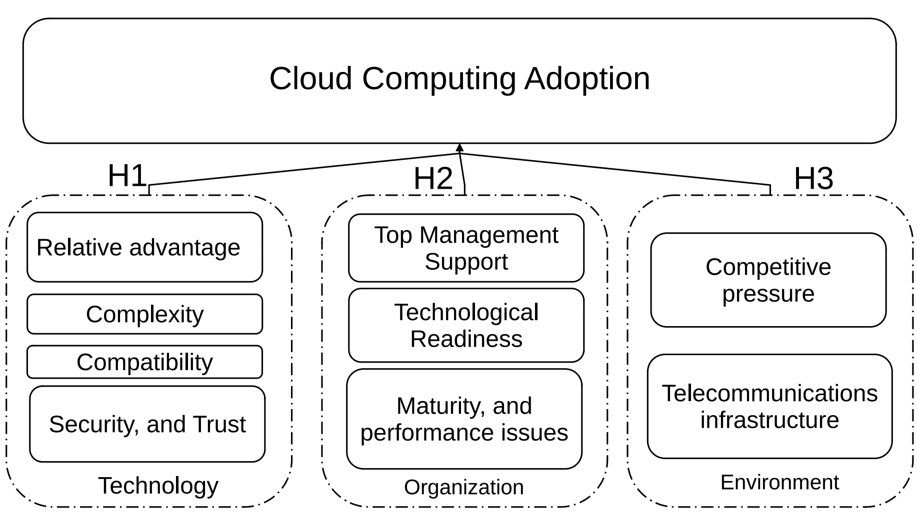


Figure 2. Example of an SEM model applied to the TOE criteria (technology).

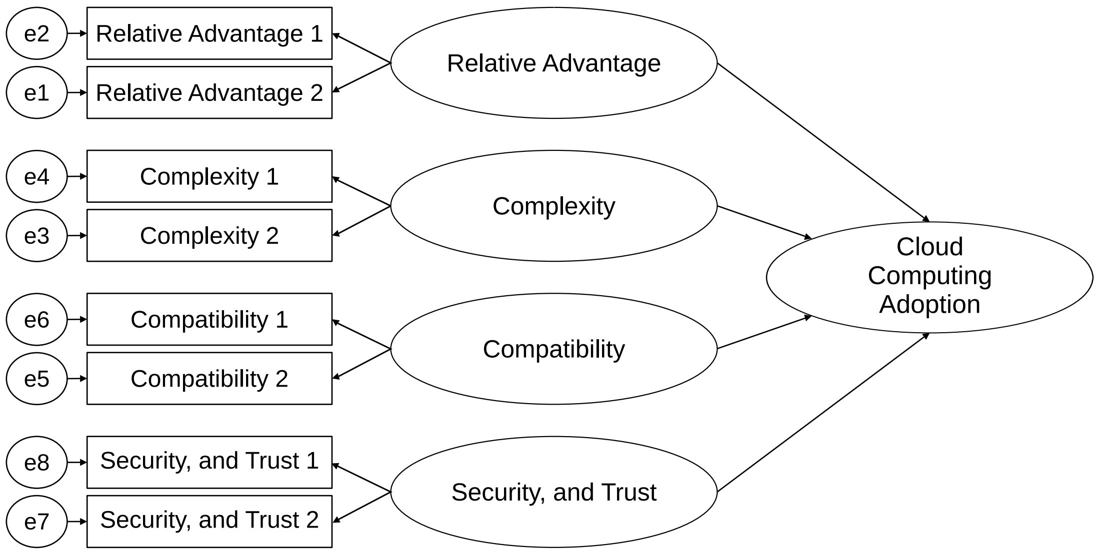
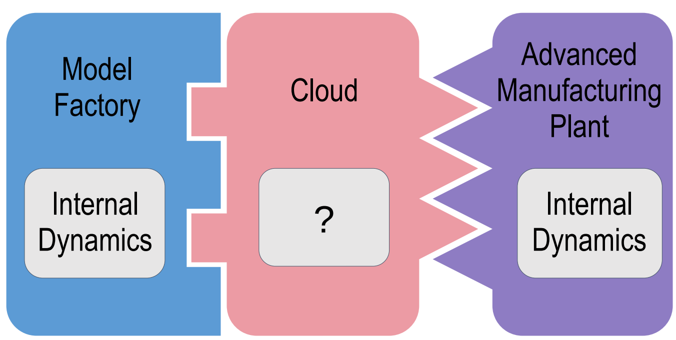


Figure 3. Proposal for integration between the model factory and PMA in the context of cloud computing.



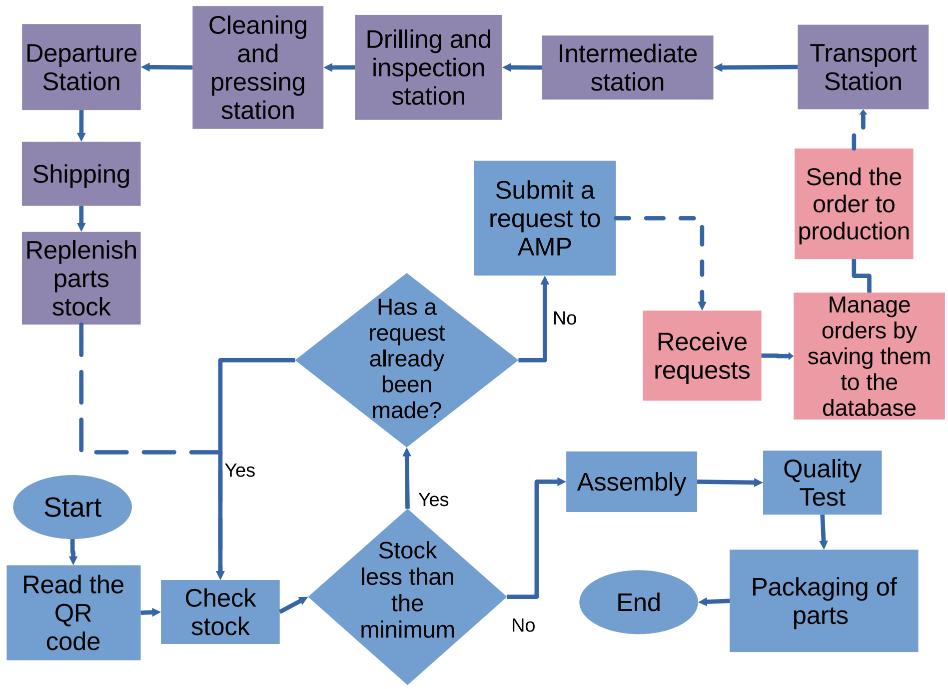
of ordered parts, and increasing production agility will be possible.

The construction of a database follows a sequence of steps inspired by the work of Date [5]. The first step is the analysis of the system requirements, where all the database's needs are identified. In the second stage, the conceptual project is carried out, where concepts and entities and their relationships are defined. In the third stage, the logical project is created, transforming the conceptual project into tables and columns of a relational data model. Finally, the database is implemented in the last step, creating the tables and columns defined in the logical project. This way, a database will be modeled that covers the entire data flow between the advanced manufacturing plant and the model factory (Figure 4).

Final Considerations

The following steps of this project consist of advancing the TOE framework to numerically evaluate the adaptability of cloud computing for data integration between the advanced manufacturing plant and the model factory. Data will be collected, and the best way to obtain the SEM model will be assessed through ordinary least squares or generalized least squares estimation. A cloud architecture will be set up based on a requirements survey to carry out integration between the parties to verify what type of service will be needed and which computational tools will be most appropriate. Finally, the cloud service will be implemented, following the defined architecture, to enable digital connection between production systems.

Figure 4. PMA and model factory data flow diagram.



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