



COMPARATIVE ANALYSIS OF CLOUD COMPUTING ADOPTION FOR AN E-COMMERCE PLATFORM IN THE MANUFACTURING INDUSTRY: A SYSTEM-DYNAMICS APPROACH USING AWS

Análisis comparativo de la adopción de la computación en la nube para una plataforma de comercio electrónico en la industria manufacturera: Un enfoque de dinámica de sistemas usando AWS

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ABSTRACT

The manufacturing sector has undergone significant transformation with the advent of Industry 4.0 and the emerging principles of Industry 5.0, integrating advanced technologies such as Cloud Computing (CC) and Big Data to optimize processes, improve operational efficiency, and enhance customer experiences. This study presents a systematic, step-by-step process for implementing a CC solution from scratch within the automotive industry, focusing on the development of an e-commerce platform to expand market reach and improve vehicle sales. The architecture was designed using Amazon Web Services (AWS) as the cloud provider, considering multiple technical and economic attributes. Industry experts evaluated the proposed solutions using the Analytical Hierarchy Process (AHP), incorporating critical factors such as performance, cost-effectiveness, and scalability to select optimal architecture. A System Dynamics (SD) simulation model was employed to analyze and compare the selected implementations; it provided quantitative insights into their long-term impact. Results demonstrate substantial differences in performance and costs across the analyzed architectures, highlighting the importance of a structured evaluation process when adopting cloud technologies. The study offers a replicable methodology for manufacturers seeking to transition to cloud-based infrastructures, contributes to a better understanding of the economic and operational implications of CC adoption. The findings underscore the relevance of cloud solutions in aligning manufacturing operations with the objectives of Industry 4.0 and 5.0.

Keywords: Amazon Web Services; analytic hierarchy process; cloud computing; e-commerce; stock and flow diagram; system dynamics.

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RESUMEN

El sector manufacturero ha experimentado una transformación significativa con la llegada de la Industria 4.0 y los principios emergentes de la Industria 5.0, integrando tecnologías como la Computación en la Nube (CN) y Big Data para optimizar procesos, mejorar la eficiencia operativa y la experiencia del cliente. Este estudio presenta un proceso sistemático para implementar una solución de CN desde cero en la industria automotriz, enfocándose en desarrollar una plataforma de comercio electrónico para ampliar el alcance de mercado y mejorar las ventas de vehículos. La arquitectura fue diseñada con Amazon Web Services (AWS) como proveedor de nube, considerando atributos técnicos y económicos. Expertos de la industria evaluaron las soluciones mediante el Proceso de Jerarquía Analítica, incorporando factores como rendimiento, rentabilidad y escalabilidad para seleccionar la arquitectura óptima. Se utilizó un modelo de simulación basado en Dinámica de Sistemas para analizar y comparar las implementaciones seleccionadas, proporcionando datos cuantitativos sobre su impacto a largo plazo. Los resultados evidencian diferencias sustanciales en rendimiento y costos entre las arquitecturas, lo que subraya la importancia de una evaluación estructurada al adoptar tecnologías en la nube. El estudio ofrece una metodología replicable para fabricantes que buscan migrar a infraestructuras basadas en la nube y aporta comprensión sobre las implicaciones económicas y operativas de adoptar CN. Los hallazgos destacan la relevancia de estas soluciones para alinear las operaciones manufactureras con los objetivos de la Industria 4.0 y 5.0.

Palabras clave: Amazon Web Services; comercio electrónico; computo en la nube; diagrama de niveles y flujos; dinámica de sistemas; proceso de jerarquía analítica.

ANÁLISE COMPARATIVA DA ADOÇÃO DA COMPUTAÇÃO EM NUVEM PARA UMA PLATAFORMA DE COMÉRCIO ELETRÔNICO NA INDÚSTRIA DE MANUFATURA: UMA ABORDAGEM DE DINÂMICA DE SISTEMAS USANDO AWS

RESUMO

O setor manufatureiro tem passado por uma transformação significativa com a chegada da Indústria 4.0 e os princípios emergentes da Indústria 5.0, integrando tecnologias como Computação em Nuvem (CN) e Big Data para otimizar processos, melhorar a eficiência operacional e a experiência do cliente. Este estudo apresenta um processo sistemático para implementar uma solução de CN do zero na indústria automotiva, com foco no desenvolvimento de uma plataforma de comércio eletrônico para ampliar o alcance de mercado e aumentar as vendas de veículos. A arquitetura foi projetada com a Amazon Web Services (AWS) como provedora de nuvem, considerando atributos técnicos e econômicos. Especialistas do setor avaliaram as soluções por meio do Processo de Hierarquia Analítica, incorporando fatores como desempenho, rentabilidade e escalabilidade para selecionar a arquitetura ideal. Um modelo de simulação baseado em Dinâmica de Sistemas foi utilizado para analisar e comparar as implementações selecionadas, fornecendo dados quantitativos sobre seu impacto a longo prazo. Os resultados evidenciam diferenças substanciais em desempenho e custos entre as arquiteturas, ressaltando a importância de uma avaliação estruturada na adoção de tecnologias em nuvem. O estudo oferece uma metodologia replicável para fabricantes que desejam migrar para infraestruturas baseadas em nuvem e contribui para a compreensão das implicações econômicas e operacionais da adoção de CN. Os achados destacam a relevância dessas soluções para alinhar as operações de manufatura com os objetivos da Indústria 4.0 e 5.0.

Palavras-chave: Amazon Web Services; comércio eletrônico; computação em nuvem; diagrama de níveis e fluxos; dinâmica de sistemas; processo de hierarquia analítica.

1. INTRODUCTION

The concept of Industry 4.0, introduced in 2011, marked a turning point in manufacturing by promoting digitalization, automation, and smart technologies aimed at enhancing production efficiency. This wave of transformation has continued to evolve into the paradigm of Industry 5.0, which not only prioritizes technological integration but also incorporates human-centric, ecological, and societal dimensions into industrial development [1]. As manufacturing ecosystems adopt these paradigms, the integration of emerging technologies—such as Cloud Computing (CC)—has become essential to achieve agility, scalability, and data-driven decision-making.

Cloud Computing Integration (CCI) enables manufacturing firms to access flexible, on-demand computing resources without big investment in physical infrastructure. This supports the development of intelligent systems and facilitates the capture and analysis of vast volumes of transactional data, commonly referred to as Big Data [2]. As a result, cloud-based platforms are increasingly being adopted to digitalize operations, particularly in small and medium-sized enterprises seeking cost-effective solutions. Among the leading cloud service providers—Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform—the first one was selected for this study due to its extensive suite of simulation and architecture planning tools (such as AWS Pricing Calculator and Well-Architected Tool), broad industry adoption, and alignment with the modeling requirements of the proposed framework. These capabilities were essential for structuring the system dynamics simulation and evaluating cost scenarios in a manufacturing context.

A literature review reveals how Analytic Hierarchy Process (AHP) and System Dynamics (SD) have been employed to evaluate the application of Cloud Computing in manufacturing and related domains. Several studies use AHP as a Multi-Criteria Decision-Making (MCDM) method to assess complex alternatives involving cloud service providers, ERP systems, and adoption strategies. For instance, AHP has been used to evaluate criteria such as security, cost, availability, migration, and accountability [3], while others apply it in more specialized contexts like healthcare technology assessment [2], automotive production lines [3], and ERP adoption in SMEs [8]. However, many of these works remain theoretical and lack implementation or empirical validation. Some studies combine AHP with tools like Structural Equation Modeling [6] or Fuzzy Logic [7], while others propose frameworks that have yet to be tested in real-world scenarios.

System Dynamics appears in fewer studies but plays a complementary role by modeling the dynamic behavior of systems over time. For example, SD has been integrated with ANP to evaluate manufacturing configurations using stock and flow diagrams and performance-based weights [3]. Another study combines SD and AHP to support Infrastructure-as-a-Service (IaaS) decision-making, using simulation to evaluate business and service variables [10]. While these contributions help model complexity and interdependencies, they are often limited to a specific organizational context, making generalization difficult.

This study builds on those insights by proposing a techno-economic evaluation of Cloud Computing acquisition in a manufacturing setting. Using validated cost data, it simulates a real-world scenario where Cloud Computing supports the digitalization of sales processes. Three alternative implementation strategies are proposed, enabling decision-makers to assess potential benefits and challenges based on organizational needs. This approach seeks to bridge the gap between theoretical models and practical applications, offering structured decision support for both management and technical teams involved in digital transformation.

This study is guided by the following hypothesis: An integrated AHP–System Dynamics (SD) methodology can support manufacturing firms in selecting and implementing a cost-effective and

operationally sustainable cloud-based eCommerce solution. To test this hypothesis, the research draws on two complementary decision-support tools. The Analytic Hierarchy Process (AHP) enables the structured prioritization of software architecture alternatives based on quality attributes evaluated by expert judgment. System Dynamics (SD) is also used to simulate the medium-term financial and operational impacts of each proposed solution [3]. The evaluation model is based on the Visuwan and Tannock (VT) framework—originally validated in manufacturing settings—which allows for the analysis of workforce allocation, resource planning, and technological investment over time [4][5].

The proposed methodology is applied to a real-world scenario within an automotive company undergoing digital transformation. Three implementation alternatives for cloud-based eCommerce are simulated, providing decision-makers with insights into financial sustainability, scalability, and implementation risks. The integration of expert-based prioritization (via AHP) with cost-behavior modeling (via SD) seeks to offer a replicable and practical approach to guide strategic cloud adoption in the manufacturing sector.

2. METHODOLOGY

Cloud Computing offers significant advantages across various industries by optimizing operations and reducing infrastructure costs. Cloud providers enable companies to pay only for the resources consumed, eliminating the need for substantial investments in complex infrastructure. However, implementing cloud-based services extends beyond selecting resources and technologies; it requires meticulous planning that involves budgeting, time management, resource allocation, security considerations, and more [9].

This study proposes a Platform as a Service (PaaS) model, as it allows the internal technical team to focus on developing the software without concerns about hardware configuration. Amazon Web Services (AWS) was selected as the cloud provider to build the e-commerce platform. The proposed solution, developed by [10], involved industry experts who analyzed a problem statement contextualized within the automotive sector. Based on this analysis, experts designed three potential architectures to address the identified needs.

The decision-making process considered software quality attributes—measurable properties that ensure the system meets functional and non-functional requirements while maintaining performance and reliability [11]. These attributes often involve trade-offs depending on the system's priorities [12]. To avoid subjective decision-making, the Analytical Hierarchy Process (AHP) was applied, enabling a systematic, data-driven selection of the most suitable architecture based on the company's requirements.

1. The Cloud Computing Implementation (CCI) was constructed as follows:
2. Develop multiple CCI architectures using appropriate technologies to address the identified problem.
3. Identify and prioritize the required quality attributes using the AHP methodology.
4. Calculate the costs associated with AWS components and the technical team.

2.1 Process to Develop the Multiple CCI Architectures

A structured participatory facilitation session was conducted with industry experts following the recommendations of [13]. The selected experts, each with at least ten years of experience in multiple

software development roles from various companies across Mexico. The facilitation process followed six key steps:

1. **Introduction:** The session started with an overview of how a CCI can enhance business operations in the automotive industry.
2. **Initial survey:** A qualitative survey was conducted to gather expert opinions on potential solutions, covering both infrastructure and platform considerations. Based on their experience, experts identified the most viable solutions and integrations.
3. **Analysis and contribution:** Two Mexican companies analyzed the survey results and proposed three industry-aligned solutions. Each proposal included an architecture diagram and a web platform solution.
4. **Second survey:** Experts were presented with a final survey detailing the three proposed solutions, including architecture diagrams, platform modules, and descriptions of user interactions and related entities.
5. **Data collection:** This phase focuses on gathering critical information, including infrastructure costs, project expenses, team composition, deployment timelines, and quality attribute considerations. The collected data was averaged to serve as input for the AHP, leading to the development of three architectural models.
6. **Final session:** The concluding session provided an in-depth explanation of AHP, outlining its advantages and key considerations. Experts then contributed their assessments to finalize the AHP evaluation tables.

2.2 Identify the Appropriate CCI Using AHP Methodology

The AHP followed by the experts consisted of:

1. **Problem definition:** The objective was to determine the most suitable CCI for the automotive company, considering cost implications and projected benefits over two years.
2. **Solution evaluation:** Experts assessed the proposed CCIs using measurable criteria, analyzing each alternative from a technical leadership perspective.
3. **Pairwise comparison:** A structured comparison was conducted to determine the relative importance of different criteria and alternatives. A numerical scale ranging from 1 to 9 was applied, where 1 represented equal importance, 2 denoted slight preference, 3 indicated moderate importance, and higher values progressively signified stronger preferences, with 9 being the highest.
4. **Weight calculation:** The pairwise comparison results were processed to generate weighted scores for each CCI alternative.
5. **Final selection:** Based on the computed scores, the optimal CCI was identified and selected for implementation (see [Table 1](#)).

The problem statement that guided the experts' decision-making process was: *"As a technical leader in an automobile company comparable in size to Tesla, serving a global customer base, you are responsible for*

developing an e-commerce platform to enhance customer experience and streamline operations. This platform must (1) accommodate thousands of existing customers, including individual car buyers, fleet managers, and corporate clients; (2) attract new prospects interested in exploring vehicle models, comparing prices, and inquiring about financing options; (3) securely process payments and provide seamless financing solutions; and (4) integrate communication and support channels to facilitate customer engagement.”

Table 1 [10] presents the key attributes considered in the selection process, including architecture importance, cost, implementation time, return on investment (ROI), and security, which were evaluated to determine the most suitable of the three solutions.

Table 1. Considered attributes and final result

	Architecture	Cost	Time	ROI	Total
Option 1	0.27	0.23	0.43	0.21	0.1466
Option 2	0.09	0.72	0.43	0.24	0.2173
Option 3	0.64	0.05	0.03	0.55	0.2598
Ponderation	0.10	0.16	0.03	0.34	

2.3 CCI Architecture Choices and Final Selection

Architecture option 1, illustrated in Figure 1, presents a viable solution; however, it was deemed inappropriate based on an evaluation of critical quality attributes, security considerations, available alternatives, implementation challenges, overall effectiveness, ERP integration, infrastructure, and web platform compatibility, as well as the applied methodology and strategies.

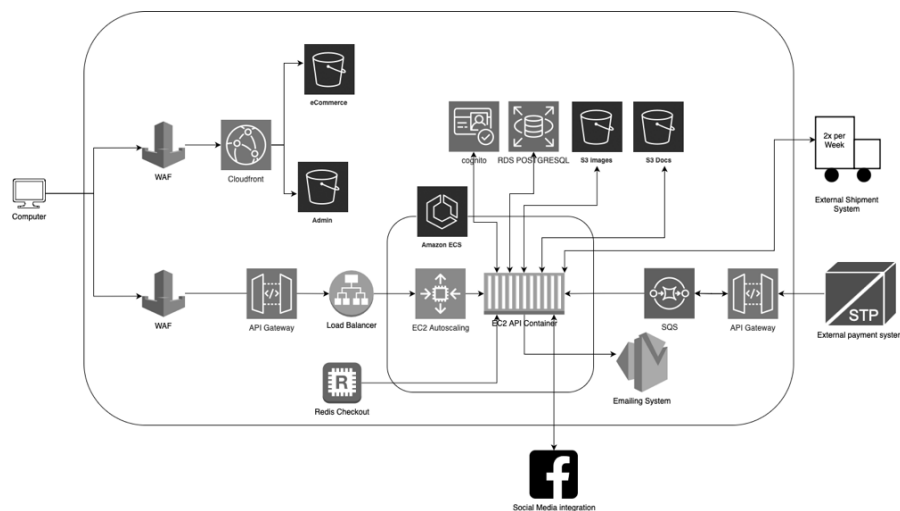


Figure 1. CCI Option 1, based on the problem statement.

Architecture option 2, shown in Figure 2, follows a serverless approach, which optimizes costs based on customer demand. However, due to insufficient security measures for the type of transactions involved, this option was also deemed unsuitable.

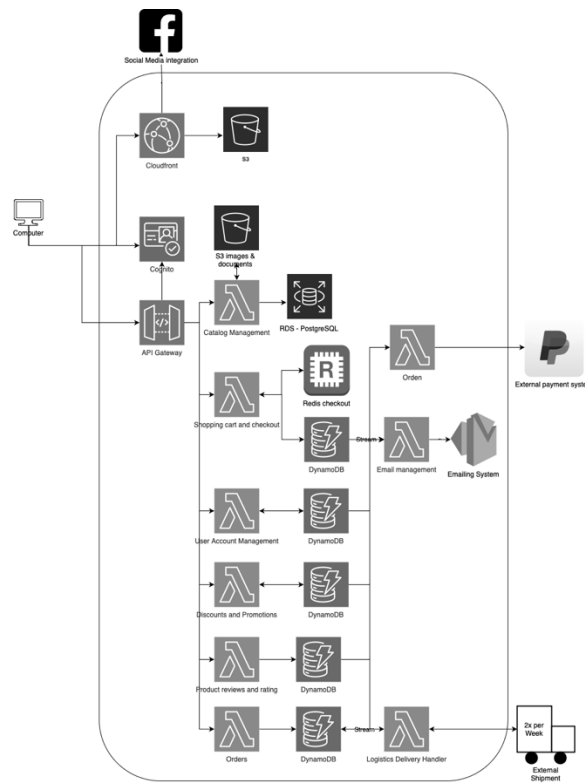


Figure 2. CCI Option 2, based on the problem statement.

As the company expands, the architecture must be designed to scale efficiently while ensuring continuous service availability for all users. Sales representatives require a systematic approach to track and engage with prospects and customers effectively. The platform must support user management, customer profile tracking, and sales monitoring while providing seamless communication channels for potential buyers seeking assistance.

Figure 3 illustrates the selected Cloud Computing (CC) solution, which integrates key business functions, including Customer Relationship Management (CRM), e-commerce, and data analytics to enhance operational efficiency and decision-making.

This solution scales according to demand with a fixed cost structure based on the selected components. To accelerate development, certain external services previously used in similar integrations were incorporated. The payment process ensures security and is seamlessly mapped to shipping logistics, while the analytics integration enables historical data analysis, facilitating data-driven decision-making and supporting potential predictive capabilities.

Overall, this architecture offers a robust and adaptable framework designed to evolve with business needs while ensuring a seamless and user-friendly experience. To optimize costs and enhance functionality, third-party providers were integrated, including HubSpot for CRM, Google Analytics for user insights, external shipment services, Facebook for social media integration, and STP for payment processing.

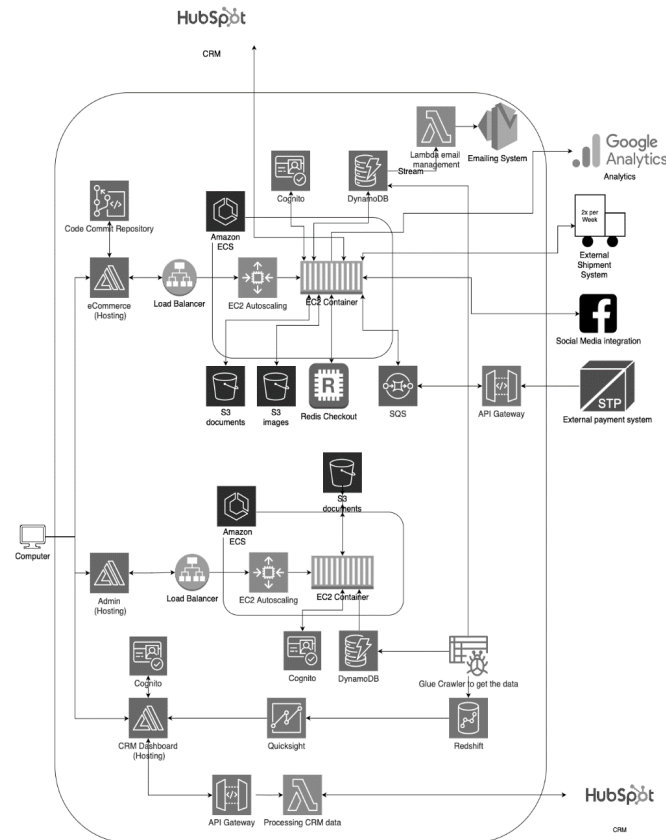


Figure 3. CCI Option 3, based on the problem statement. Source: [10].

3. BUILDING THE ARCHETYPE FOR THE SD

This study represents the full acquisition of CCI, encompassing workforce salaries and AWS infrastructure services. These factors are analyzed over time to determine the monthly cost, providing a comprehensive evaluation of the solution's financial feasibility.

3.1 Resources

The two key components required to develop the archetype are the work team and AWS services, both of which are incorporated into the VT model to assess their impact within the automotive company. The VT simulation model consists of fifty-eight equations and has previously been used to evaluate the effects of new technologies. The model has already been calibrated and validated using the Vensim software [14].

The VT model operates with the Thai Baht exchange rate from the year 2000 [4] and requires an inflation calculator to represent costs in the current economic environment. During that period, the exchange rate was 0.56 Baht. Work team salaries were estimated based on the average salary data obtained from employment websites, using at least three job vacancies to establish a representative

salary range. Infrastructure costs were determined using the AWS pricing calculator, which adjusts expenses based on the configuration of each selected service.

3.2 Work Team Salaries

The work team responsible for developing the architecture and coding the project consists of seven different roles. The number of team members was determined based on the expertise and recommendations of the specialists who proposed the CCI. [Table 2](#) provides an overview of the assigned responsibilities and corresponding salaries.

Table 2. Technical Team Composition [10].

Role	Members needed	Salary (Monthly, USD)	Salary (Monthly, Baht)
Project Manager: Controls project execution to achieve the defined objectives, managing human resources, budget, and time.	1	\$ 1,891.02	\$75,640.80
Architecture Leader: Defines the appropriate architecture to meet the project's objectives. Analyzes the current situation, identifying necessary components and resources, and designing a comprehensive solution.	1	\$ 1,788.89	\$71,555.60
Technical Leader: Defines technical decisions and standards, ensuring the delivery of software components.	1	\$ 1,134.59	\$45,383.60
Frontend Developer: Develops the user interfaces that enable interaction with the web platform and ensures integration with the backend solution.	2	\$1,058.97	\$42,358.80
Backend Developer: Builds the API and implements the business logic solutions using various approaches tailored to the infrastructure requirements and the functions of the database.	2	\$ 907.69	\$36,307.60
Designer: Ensures a positive user experience (UX) and a visually appealing user interface (UI).	1	\$665.75	\$26,630.00
Tester / QA: Tests and creates automation from a quality assurance (QA) perspective. Their primary objective is to ensure reliability and functionality.	2	\$596.31	\$23,852.40

Team members are responsible for collaborating to ensure the successful completion of the project; however, the specific methodologies, development practices, and activities involved in implementing the solution fall outside the scope of this study. For this research, the team is considered a functional unit.

3.3 Cost of Architecture Services

The services required for the selected option (3) are detailed in [Table 3](#), including their functions, technical configurations, and costs in Thai Baht, adjusted for the VT inflation rate of the 2000s.

Table 3. AWS infrastructure components [10].

Component	Description	Technical	Price (Baht)
AWS Firewall	Oversees and manages incoming and outgoing network traffic based on predefined security rules.	Web ACLs used 5 per month, Rules added per Web ACL 2 per month.	฿26,136
CloudFront	Delivers data, videos, applications, and APIs globally with low latency and high transfer speeds.	Data transfers out to origin 5818.010156 GB per month, Requests 60625000 per month.	฿104,599
S3	Stores and retrieves any amount of data from the web.	S3 Standard storage 118.4082031 GB per month.	฿113
Load Balancer	Distributes incoming network traffic across multiple servers to prevent overload.	Two load balancers.	฿1142
API Gateway	Acts as an intermediary between clients and backend services, handling requests and routing them.	Four API Gateways with REST API request units (millions per month), Average message size (32 KB).	฿1069
Amazon Simple Email Service (SES)	Sends bulk emails for marketing, transactions, and notifications.	Email messages sent from EC2.	฿985
Amazon Cognito	Handles user authentication, authorization, and management for web services.	Monthly active users (177833).	฿6439
AWS Lambda	Runs the code in response to events, without the need to manage servers.	Invoke Mode (Buffered), Number of requests (4000000 per month).	฿142
AWS Fargate	Serverless computing engine for containers to run and manage Docker containers.	Two services working with ECS.	฿3,179
Amazon QuickSight	Enables creating and sharing interactive dashboards and reports.	Working days per month (30), Authors (10), Number of readers (290).	฿33,702
Amazon Redshift	Data warehouse service designed for fast and scalable data analysis.	Nodes (1), Instance type (dc2.8xlarge), Utilization (On-Demand only).	฿3504
DynamoDB eCommerce	Serverless NoSQL database service designed for high performance and scalability.	Table class (Standard), Average item size (all attributes) (1 KB), Data storage size (670.9798177 GB).	฿3,778
DynamoDB admin	Isolated database to save the admin information.	Table class (Standard), Average item size (all attributes) (1 KB), Data storage size (67.1 GB).	฿838
Amazon RDS for PostgreSQL	Managed service that simplifies setting up, operating, and scaling PostgreSQL databases.	Storage volume (SSD), Storage amount (2048 GB), Instance Type (db.m4.4xlarge), Utilization (On-Demand only) (100 %Utilized/Month).	฿61,820
Amazon Simple Queue Service (SQS)	Allows developers to send, store, and receive messages between software components.	DT Inbound: Internet (5525 GB per month), DT Outbound: All other regions (5525 GB per month).	฿3,116

Note: This table presents costs in USD and Thai Baht, base year 2000.

3.4 Archetype Integration in SD

The archetype was defined using the data from [Tables 2 and 3](#). [Figure 2](#) illustrates the integration of both datasets within Vensim, modeling the CCI with its respective formulas to represent the independent behavior of each component.

AWS services are accounted for up to the ninth month using a pulse train function, aligning with the initial development phase of the solution. The simulation extends over twenty-four months to analyze cost behavior and assess affordability.

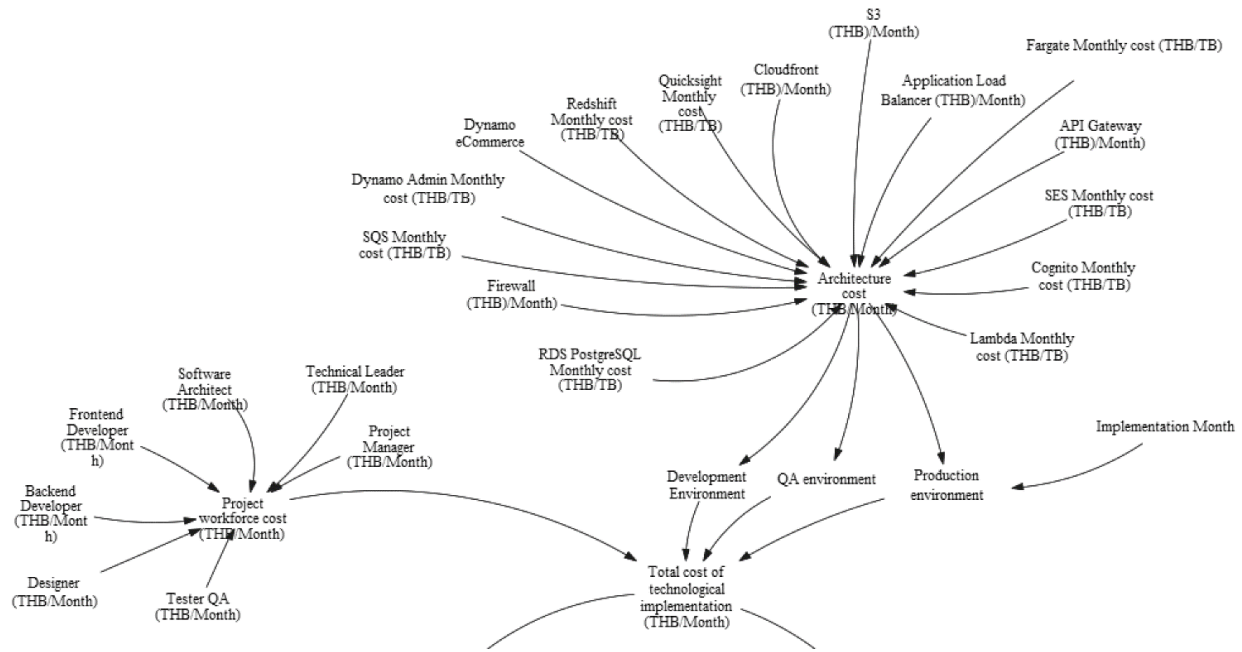


Figure 4. CCI Archetype representation [10].

Equation 1 defines the monthly architecture cost, incorporating AWS expenses, while Equations 2, 3, and 4 address the infrastructure requirements for development, QA, and production environments. Equation 4 specifically simulates the production environment for nine months post-implementation, marking the project's completion.

Architecture cost (THB/Month) = "API Gateway (THB)/Month"+"Application Load Balancer (THB)/Month"+"Cloudfront (THB)/Month"+"Cognito Monthly cost (THB/TB)+"Dynamo Admin Monthly cost (THB/TB)+"Dynamo eCommerce"+"Fargate Monthly cost (THB/TB)+"Firewall (THB)/Month"+"Lambda Monthly cost (THB/TB)+"Quicksight Monthly cost (THB/TB)+"RDS PostgreSQL Monthly cost (THB/TB)+"Redshift Monthly cost (THB/TB)+"S3 (THB)/Month"+"SES Monthly cost (THB/TB)+"SQS Monthly cost (THB/TB)" (1)

Development Environment = "Architecture cost (THB/Month)" (2)

QA Environment = "Architecture cost (THB/Month)" (3)

Production Environment = "Architecture cost (THB/Month)"*PULSE TRAIN (Implementation Month, 1, 1, 25) (4)

Equation 5 represents the cost of work team salaries per month.

Project workforce cost (THB/Month) = "Frontend Developer (THB/Month)"*PULSE TRAIN(Implementation Month+1, 1, 1, 25)+"Backend Developer (THB/Month)"*PULSE TRAIN(1, 1, 1, 25)+"Project Manager (THB/Month)+"Technical Leader (THB/Month)+"Software Architect (THB/Month)+"Designer (THB/Month)+"Tester QA (THB/Month)" (5)

Equation 6 shows the development environments needed during the project execution.

Total cost of technological implementation (THB/Month) = Development Environment + Production environment + QA environment + "Project workforce cost (THB/Month)" (6)

3.5 Results in VT Model Integration

The VT model includes a Research & Development section that enables the measurement of the economic impact of the full Cloud Computing Implementation (CCI). Figure 5 presents the company's current costs, while Figure 6 illustrates the financial impact after twenty-four months of operation, reflecting an increase of 1.15206 million Baht, resulting in a final cost of 792.27 million Baht.

Total cost = Admin cost + Manu Cost + Sale cost (7)

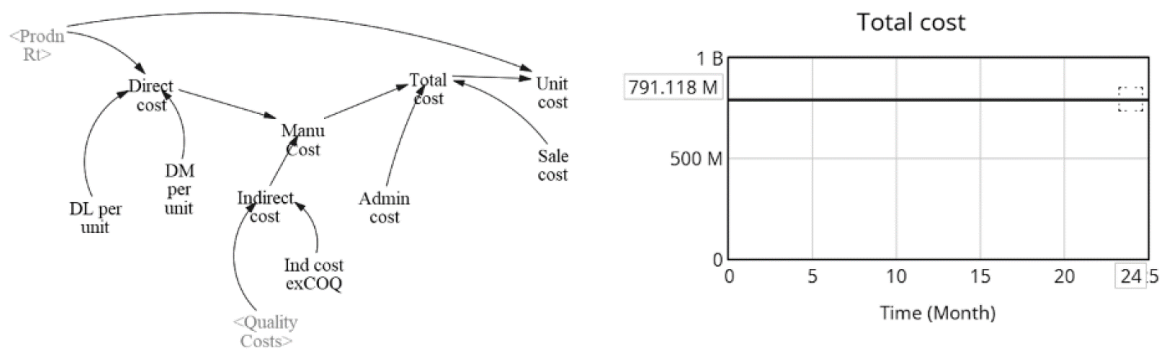


Figure 5. Total Cost Before the CCI and Current Cost [10]

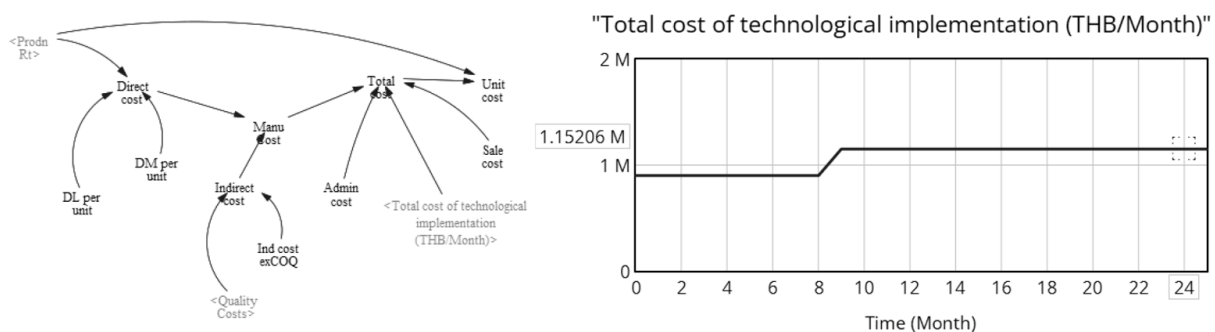


Figure 6. CCI impact on the Current Cost [10]

Figure 7 demonstrates how this decision significantly alters the cost trajectory; experts estimate a final cost of 798.904 million Baht.

Total cost of technological implementation (THB/Month) = Development Environment + Production environment + QA environment + "outsourcing cost (THB/Month)" (8)

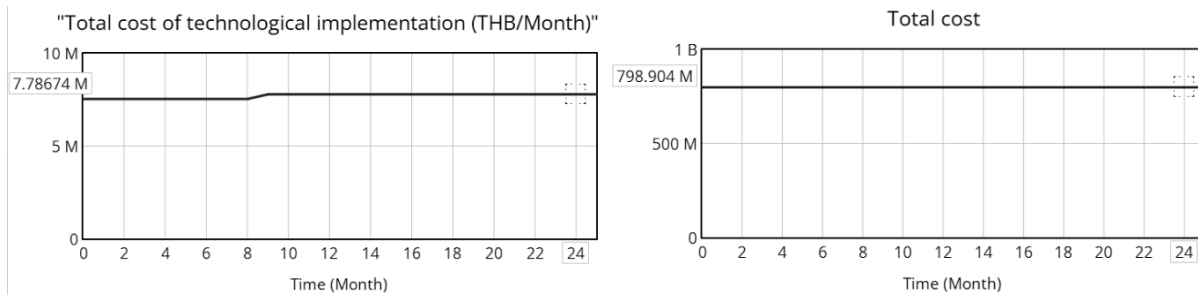


Figure 7. CC Vensim Implementation [10].

Based on expert assessments and previous technological integrations, the implementation of the e-commerce platform is expected to increase sales by at least 15%. The VT model projects an initial demand of 1,975 units, after incorporating this value into Figure 6 there is a substantial increase up to 2,182.97 units at twenty-four months of operation.

Equation 9 incorporates a delay function, considering that the solution requires at least nine months for development before becoming operational. Consequently, benefits begin to materialize in the tenth month, where an increase of 207 automobiles in sales is recorded. This outcome confirms the positive impact of the implementation and demonstrates the company's ability to sustain the financial impact of the acquisition within a two-year timeframe.

Additionally, the charts illustrate a stable behavioral trend, indicating that no significant disruptions occur in normal operations. Beyond its immediate benefits, this implementation also lays the foundation for future enhancements, such as measuring sales trends, incorporating customer insights, reducing defects, and optimizing warehouse management decisions.

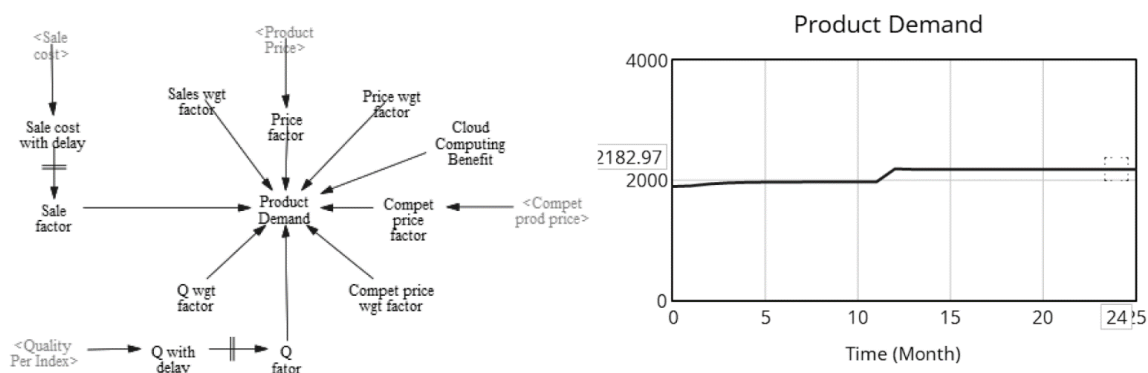


Figure 8. Product Demand VT model and chart [10].

Cloud Computing Benefit = DELAY FIXED(1.5, 12, 1) (9)

Equation 10 presents the complete solution:

$$\text{Product Demand} = (\text{Q fator} * \text{Q wgt factor}) + (\text{Price factor} * \text{Price wgt factor}) + (\text{Sale factor} * \text{Sales wgt factor}) + (\text{Compet price factor} * \text{Compet price wgt factor}) * \text{Cloud Computing Benefit} \quad (10)$$

3.6 Comparative Cost Analysis Between the CCIs

The process to create the archetype was replicated for Options 1 and 2 to compare the cost increment across the three solutions, regardless of the selected option. The serverless approach in Option 2 requires the use of a default value, as its cost structure is directly dependent on demand. Figure 9 presents a comparative overview of the acquisition costs for each solution.

After two years of operation, the total cost for Option 1 is 818.182 million Baht, Option 2 costs 798.749 million Baht, and Option 3 costs 798.904 million Baht. Given that the pre-implementation cost was 792.27 million Baht, the minimum cost increase is 6.634 million Baht, while the maximum reaches 25.912 million Baht.

Option 3, which was selected, includes Amazon QuickSight integration; it provides built-in analytics capabilities for future enhancements. Additionally, the cost analysis presented in this archetype does not account for third-party services, which could introduce additional expenses related to logistics, payment processing, ERP, and CRM systems.

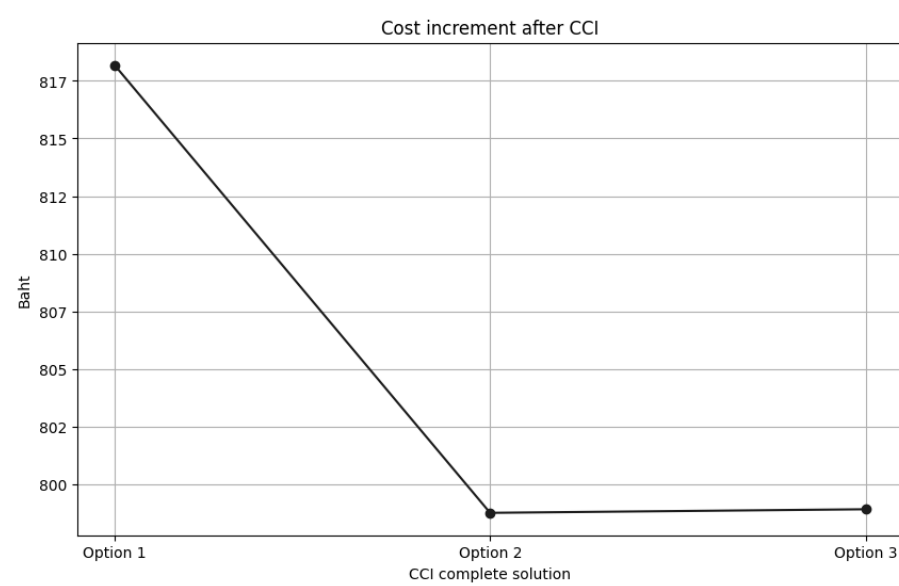


Figure 9. Three architecture cost comparisons [10].

4. DISCUSSION

This research provides valuable insights into CCI by considering key factors such as team composition, architecture, and development time; therefore, it allows organizations to better understand the requirements for implementing cloud-based solutions. The SD model and simulation

offer a comprehensive analysis of the cost implications of AWS services and team roles over a two-year implementation period. The findings highlight several critical aspects:

- The successful adoption of cloud-based infrastructure is highly dependent on the expertise of the development team. Factors such as programming paradigms, testing strategies, and security measures must be carefully considered during project definition to ensure a robust implementation.
- The process of introducing CCI should be based on a thorough evaluation of the company's existing challenges. The final problem statement directly influences the selection of quality attributes, which, in turn, determine the required services for an effective solution.
- Companies that aim at adopting Industry 4.0 or 5.0 technologies should establish a dedicated IT department to mitigate the risks associated with implementing new technologies. Alternatively, leasing or outsourcing the project could be viable options, though these considerations fall outside the scope of this study.
- AWS service costs vary significantly based on transaction volume and user demand, which directly influence expert decision-making. Likewise, on-demand services, such as serverless architecture, can be cost-effective for specific functionalities or smaller companies. They may not be suitable for high-value transactions. In such cases, even Option 3, despite its scalability, may prove unaffordable for certain organizations.

The AHP methodology supported the prioritization of three proposed digitalization alternatives by weighing financial sustainability against operational risks. Notably, the simulation showed that one alternative incurred high costs without delivering proportional benefits, whereas another—leveraging third-party services—proved to be more cost-effective. However, technical and economic criteria are not the only factors decision-makers must weigh. Elements such as team cohesion, experience, and adaptability can significantly influence project outcomes. If mismanaged, issues like software bugs or coordination delays can escalate costs during development. Although this study does not delve into managerial dynamics, it emphasizes the importance of aligning the development strategy with project scale to avoid unnecessary risks.

While several previous studies have applied AHP or SD to evaluate technological adoption in manufacturing, they often do so in isolation or within limited theoretical contexts. For instance, some works focus solely on ranking cloud providers [5], while others propose hybrid models (e.g., AHP-Fuzzy Logic, AHP-SEM) that remain untested in practice [6][7]. SD has been used to simulate operations or service performance [4][10], but without a structured integration of decision-making frameworks. In contrast, our study offers a novel combination of AHP and SD applied to a realistic manufacturing scenario, supported by a previously validated VT model. Initially developed and tested in an organizational setting [15], the VT model has been replicated in studies [4] and [5], which reinforce its applicability and relevance.

Since this study constitutes an *ex-ante* analysis, it is not intended to offer empirical results from real company implementations. Instead, it provides a decision-support framework grounded in validated modeling, realistic assumptions, and expert-informed parameters. Although limited to a specific use case—e-commerce digitalization in manufacturing using AWS—the approach demonstrates how integrated modeling can inform strategic planning in contexts of technological transformation. Future research may extend this framework to other industries, cloud platforms, or include empirical validation to broaden its generalizability and impact.

5. CONCLUSIONS AND FUTURE WORK

This study presents a structured methodology that supports manufacturing companies when evaluating the adoption of cloud-based eCommerce platforms, with a particular focus on time, budget, and resource feasibility. By integrating Analytic Hierarchy Process (AHP) and System Dynamics (SD), the research bridges theoretical decision-support frameworks with practical implementation objectives. AHP enables systematic prioritization of architectural and operational alternatives based on expert judgment, while SD provides insights into the long-term financial and organizational implications of each option. Together, these tools help address the study's main objective: to support strategic decision-making during the early stages of Cloud Computing Integration (CCI) in manufacturing.

The methodology involves building the infrastructure from scratch with a dedicated development team and gradually integrating platform components until full deployment. While the simulation suggests a cost-effective option for small-to-medium enterprises over a two-year period, the results also emphasize the importance of aligning technical choices with project-specific requirements. The findings highlight that although serverless architectures (Option 2) offer cost advantages, they may pose scalability and security challenges depending on transaction volume. As a result, Option 3—leveraging third-party services—emerged as the most balanced alternative in terms of cost, security, and scalability. These insights are particularly relevant for the automotive sector, where the proposed platform could support a projected 15% increase in sales.

Furthermore, the study underscores that successful CCI implementation in manufacturing requires more than technological adoption. Key success factors include team cohesion, development process management, and long-term monitoring. Cloud providers like AWS, through a PaaS approach, can reduce infrastructure burdens and allow organizations to focus on execution; however, a skilled and integrated team is essential to ensure success. Although the study is limited to a theoretical simulation using a specific scenario and provider, it offers a replicable approach that can inform similar initiatives. For future research, incorporating machine learning into the SD model could enhance trend forecasting and decision optimization. Additionally, evaluating the cost implications of large-scale data management would be beneficial for organizations considering more advanced analytics strategies.

AUTHORS' CONTRIBUTION

Mario Negrete-Rodríguez: Methodology, Writing – Original Draft, Visualization, Formal Analysis, Investigation, Software.

Armando Elizondo-Noriega: Conceptualization, Project Administration, Formal Analysis, Validation, Resources, Software.

Mirna Muñoz Mata: Supervision, Data Curation, Writing – Review & Editing, Validation.

David Güemes-Castorena: Supervision, Data Curation, Writing – Review & Editing, Validation.

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