A System-Dynamic-based model to study the adoption of the Cloud Computing Platform of AWS into the Automotive Industry

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**Abstract.** The 4th industrial revolution (a.k.a Industry 4.0) has transformed the manufacturing field through smart production and service evolution. A key technology driving this transformation is Cloud Computing (CC), which leverages cloud technology to revolutionize traditional IT models with scalable, cost-effective, and accessible services. Organizations that embrace this approach aim to facilitate resource allocation according to fluctuating market demands and their specific needs and costs. Despite the industry's increasing digitalization, further research is needed to understand its impact on organizations. The adoption of CC and its economic influence on manufacturing remains underexplored. This study examines the risks, benefits, and investments required for transitioning to private digital services. It proposes a System-Dynamics-based model to investigate the economic impact of implementing a Cloud Computing AWS architecture in the automotive industry. Experts from various organizations designed a CC model to achieve a specific goal in an automaker. Such a Cloud Computing Implementation (CCI) model was designed based on the Analytical Hierarchy Process (AHP), which helps select the best option regarding benefits and costs. The simulation model allows for assessing the effectiveness of cloud computing in the automotive sector.

**Keywords:** System Dynamics, Simulation, Cloud Computing, AWS, Web Platform

1 Introduction

Cloud Computing (CC) comprises a network of services provided at varying costs based on customer demands. This approach enables organizations to access infrastructure without needing physical space, presenting both advantages and disadvantages, such as maintenance requirements [1]. In real-life applications, only a web browser is needed to connect to the provider and configure the environment. The primary services include Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).

These previously mentioned services are integral to Industry 4.0, which seeks to transform the manufacturing sector by creating innovative solutions for better decision-making processes. The computational power offered by CC facilitates integration with other technologies, such as Big Data, enhancing the ability to respond to various processes [2]. While Industry 4.0 promotes digital transformation in manufacturing, the transition involves multiple steps. Integrating new elements into existing processes requires coordination among suppliers, customers, human resources, materials, and more. This virtualization supports sustainable operations optimization through predictive analytics, devices, and robotics [3].

The strategy to apply any Industry 4.0 technologies depends on the company's needs and the economic impact that covers a complete implementation. Key technologies include Cybersecurity, Mobile, Machine-to-Machine communication, 3D Printing, Robotics, Big Data, Internet of Things (IoT), RFID, and Cognitive Computing. However, this research focuses on cloud computing, which began in the 1970s [1]. Nowadays, CC was become pivotal as a framework to integrate other Industry 4.0 technologies. In fact, Amazon Web Services (AWS), a leading cloud computing provider, started in 2002 with storage and computation services and has since expanded its offerings alongside other providers like Google and Microsoft.

Understanding how implementing CC can affect an organization is crucial for several reasons. Firstly, it enables informed decision-making regarding resource allocation, ensuring that investments in cloud infrastructure are both cost-effective and aligned with the organization’s strategic goals. Secondly, CC can significantly enhance operational efficiency by providing scalable and flexible IT solutions, which can adapt to fluctuating market demands and support innovation. Additionally, comprehending its impact aids in identifying potential risks, such as data security concerns and compliance issues, allowing for developing robust mitigation strategies. Despite the growing importance of this technology, there is a notable lack of studies addressing this critical industry need.

To address this issue, this study evaluates the impact of introducing CC in an organization using a System Dynamics (SD) simulation. This approach is based on an international automobile factory model, previously utilized to assess the implementation of other Industry 4.0 technologies [4]. Known as the VT model (stands for Visuwan and Tannock’s model), this framework leverages SD due to its effectiveness in making cause-effect phenomena visible and evaluable [5]. SD is a flexible tool for developing and testing Industry 4.0 technology models within the VT framework [6]. Several studies have established the foundation for this approach, demonstrating its utility in understanding the impact of Industry 4.0 through experimental simulation [4] [7] [8].

This study proposes an archetypal structure for implementing CC using the VT framework as a testing environment and AWS as an example. The paper outlines the methodology, solution, and modifications to the simulation model.

2 Overall Study Methodology

Cloud computing has the potential to significantly enhance the capabilities of any industry through various implementable features. Developing a comprehensive platform begins with establishing the infrastructure, which sets the scope for integration. The transparency of virtualized resources enables the transformation of any idea into practical applications within various processes. However, the quality attributes of the infrastructure solution are crucial, with security being one of the most challenging yet essential aspects to consider [9]. Security, integrity, and performance are all critical for different users, highlighting the importance of addressing these attributes comprehensively.

Quality attributes are essential for meeting user demands. They can be operational or developmental, focusing on either maintaining the solution or enhancing it from the user's point of view[10]. Applying these attributes often involves tradeoffs; prioritizing speed may compromise security [11].

The study involved using an AWS infrastructure and web platform, with input from Mexican professionals to tailor a CCI for an automobile company. The multiple solutions obtained were evaluated using the Analytic Hierarchy Process (AHP) to ensure they meet the identified needs effectively. The resulting structure was tested within the VT model to assess its viability and effectiveness.

2.1 Integral Solution Selection for Cloud Computing implementation

A session was established with experts based on the recommendations of [12] following a structured participative facilitation approach. These experts, each with at least ten years of experience in roles such as architecture leader, technical leader, or senior developer, came from various companies around Mexico. The steps to implement the participative facilitation approach are described below:

* Introduction: The session began with an explanation of how a Cloud Computing Implementation (CCI) can enhance a company in the automotive industry.
* Initial Survey: A qualitative survey was conducted to gather expert opinions on a comprehensive solution encompassing both infrastructure and platform aspects. Based on their experiences, experts selected the most favorable solutions and integrations.
* Analysis and Contribution: Based on the survey responses, two Mexican companies analyzed the contributions and provided three possible solutions with real industry approaches. Each solution included an architecture diagram and a web platform solution.
* Second Survey: The experts received a last survey presenting the three possible solutions, complete with architecture diagrams, web platform modules, and descriptions of users and related entities.
* Data Collection: This survey aimed to gather information on infrastructure cost, project cost, required team members and roles, deployment time, and quality attribute features. This data was averaged to provide enough information for the AHP.
* Final Session: The final session explained AHP's meaning, advantages, and essential information. Experts then provided input on the attributes to complete the AHP tables.

AHP is a multicriteria decision-making process (MCDM) that determines the best option among all possible solutions [13]. The AHP process includes the following steps [14].

* Problem Definition: The goal was to achieve a CCI for the automotive company, considering cost and potential benefits over two years.
* Explanation of Solutions: Potential CCIs were explained using measurable criteria, with experts evaluating the propositions from a technical lead perspective.
* Pairwise Comparison: Using a scale, criteria, and alternatives of CCI were compared to determine their relative importance (see Tables 1 to 4). Such a scale ranges from 1 to 9 (1 equal, 2 more than equal, 3 moderate, 4 strong moderate, 5 strong, 6 stronger, 7 very strong, 8 extremely, and 9 the most extreme).
* Weight Calculation: Pairwise comparison judgments were used to calculate scores for each alternative of CCI (see Table 5).
* Selection: Based on the results, one of the three potential CCIs was selected (see Table 6).

The evaluated data focused on four attributes to choose the best option for the automotive industry. Experts were given the scenario:

"As a technical leader in an automobile company similar in size to Toyota or Volkswagen with global customers, you are tasked with building an eCommerce platform to enhance customer experiences and streamline operations. This platform will (1) serve thousands of existing customers worldwide, including individual car buyers, fleet managers, and corporate clients. The platform will also (2) attract prospects and visitors interested in exploring car models, comparing prices, and inquiring about financing options. The solution should securely (3) process payments, offer convenient financing solutions, and (4) include communication and support channels."

Table 6 and Figure 1 show the three selected architectures. With the chosen integral solution for CCI, the next steps involve calculating implementation costs using the AWS Calculator, considering inflation, and integrating the workforce during the adaptation period.

**Table 1.** Architecture Cost Criteria Comparison

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Criteria: Cost | | | | | | | |
|  | Option 1 | Option 2 | Option 3 | Standard Matrix | | | Average Vector |
| Option 1 | 1 | 4 | 4 | 0.24 | 0.36 | 0.22 | 0.27 |
| Option 2 | 0.25 | 1 | 1 | 0.06 | 0.09 | 0.11 | 0.09 |
| Option 3 | 3 | 6 | 1 | 0.71 | 0.55 | 0.67 | 0.64 |
| **Sum** | 3 | 11 | 1.5 |  |  |  |  |

**Table 2.** Project Cost Criteria Comparison

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Criteria: Scalability | | | | | | | |
|  | Option 1 | Option 2 | Option 3 | Standard Matrix | | | Average Vector |
| Option 1 | 1 | 0.13 | 9 | 0.11 | 0.10 | 0.47 | 0.23 |
| Option 2 | 8 | 1 | 9 | 0.88 | 0.81 | 0.47 | 0.72 |
| Option 3 | 0.11 | 0.11 | 1 | 0.01 | 0.09 | 0.05 | 0.05 |
| **Sum** | 9.11 | 1.24 | 19 |  |  |  |  |

**Table 3.** Implementation Time Criteria Comparison

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Criteria: Performance | | | | | | | |
|  | Option 1 | Option 2 | Option 3 | Standard Matrix | | | Average Vector |
| Option 1 | 1 | 1 | 3 | 0.43 | 0.43 | 0.43 | 0.21 |
| Option 2 | 1 | 1 | 3 | 0.43 | 0.43 | 0.43 | 0.24 |
| Option 3 | 0.33 | 0.33 | 1 | 0.14 | 0.14 | 0.14 | 0.55 |
| **Sum** | 2.33 | 2.33 | 7 |  |  |  |  |

**Table 4.** Return of Investment Criteria Comparison

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Criteria: Benefit | | | | | | | |
|  | Option 1 | Option 2 | Option 3 | Standard Matrix | | | Average Vector |
| Option 1 | 1 | 1 | 0.33 | 0.20 | 0.25 | 0.18 | 0.21 |
| Option 2 | 1 | 1 | 0.50 | 0.20 | 0.25 | 0.27 | 0.24 |
| Option 3 | 3 | 2 | 1 | 0.60 | 0.50 | 0.55 | 0.55 |
| **Sum** | 5 | 4 | 1.83 |  |  |  |  |

**Table 5.** Pairwise Comparison of Criteria

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Pairwise Comparison | | | | | | | | | |
|  | Architecture | Cost | Time | ROI | Standard Matrix | | |  | Average Vector |
| Architecture | 1 | 4 | 0.13 | 0.11 | 0.22 | 0.01 | 0.01 | 0.16 | 0.10 |
| Cost | 0.25 | 1 | 6 | 0.17 | 0.05 | 0.54 | 0.01 | 0.04 | 0.16 |
| Time | 8 | 0.17 | 1 | 0.13 | 0.01 | 0.09 | 0.01 | 0.01 | 0.03 |
| ROI | 9 | 6 | 8 | 1 | 0.33 | 0.72 | 0.07 | 0.23 | 0.34 |
| **Sum** | 18.25 | 11.17 | 15.13 | 1.40 |  |  |  |  |  |

**Table 6.** Final ponderation and decision

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Results | | | | | |
|  | 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 |  |

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**Figure 1.** Architecture diagram chosen

Experts recommended separating environments to avoid isolated servers providing service. The appropriate distribution includes an eCommerce platform, an administrator dashboard, and a Customer Relationship Manager (CRM) dashboard to track prospects. Third-party providers were selected to reduce costs and enhance functionality.

* HubSpot for CRM to track users and maintain communication.
* Google Analytics for user insights, including location, gender, and age.
* External shipment system for vehicle delivery.
* Facebook for social media integration and marketing.
* STP for secure payment processing.

Database components include DynamoDB and Redis for checkout management, S3 for document and media storage, Redshift for data warehousing, and Quicksight dashboards for reporting. A load balancer reduces downtime, and autoscaling replicates EC2 servers as needed. The front end is hosted on Amplify, with authentication handled by Cognito.

* 1. Architecture Proposal for the selected alternative of CCI

The architecture proposed for the selected CCI alternative was selected based on the survey questions outlined in the previous section. Experts were asked about the following points to finalize the scope:

* Critical quality attributes required to enhance productivity.
* Security aspects prioritized.
* Best alternatives to current platforms to boost organizational productivity.
* Challenges associated with migrating to the cloud.
* Cloud services needed for effective company management.
* ERP perspective.
* Methods to improve company efficiency and productivity.
* Relationship between infrastructure and web platform.
* Considerations for selecting cloud components to develop a platform.
* Recommendations for creating a Cloud Computing implementation strategy.

The results of the survey analysis indicate there is a need for a high availability and performance platform to help the company increase sales. As the company grows, the number of customers increases, making it difficult to manage the expanding volume of documents. Sales workers need a systematic method to follow up with prospects and customers. The platform will manage registered users, track customer profiles, and monitor sales per customer. It will also provide a way for new customers interested in acquiring a car to contact employees for assistance. Currently, the organization has no cloud service or local server, so the implementation will be from scratch. Thus, the selected CCI alternative must focus on meeting such required functions for an organization.

2.2 Cost Definition for the selected alternative of CCI

To assess cost factors for the proposed CCI alternative, such as the platform, infrastructure, and workforce, are considered to determine acquisition expenses. The input costs required to define the selected CCI alternative in the SD model to couple it to the VT model were obtained from varied vetted sources. The VT model incorporates 58 equations in Vensim and serves as a framework to evaluate new technology implementations in organizations. In fact, the VT model [6] has been calibrated, validated, and previously used to test other approaches, such as Big Data [15]. The currency used in both the proposed SD model for the CCI alternative and the VT model is the Thai Baht, with an exchange rate of 2000 [4]. Using an inflation calculator, all possible input costs for the CCI SD model were adjusted to the currency of the respective year. During that year, the dollar's value was 0.56 Baht. This calculation is replicated in the Vensim VT model to ensure accurate cost assessment. Additionally, measuring outcomes is crucial to understanding not only the input cost but also the resultant productivity improvements, demonstrating how effectively and efficiently the approach enhances the company [16].

2.4 Technical Team Requirements for the selected alternative of CCI

Once the scope is chosen according to the owners' demands, establishing protocols among a competent team to achieve a CCI in a firm is mandatory. The team was then assigned to ensure the project's success [17]. Table 7 describes the roles of the different team members for the selected alternative of CCI.

**Table 7.** Technical Team Composition

|  |  |  |  |
| --- | --- | --- | --- |
| Role | Members needed | Salary (Monthly, USD) | Salary (Monthly, Baht) |
| **Project Manager:** This role oversees and controls project execution to achieve the defined objectives. By effectively managing human resources, budget, and time, the project manager ensures that all team members are engaged and that the project delivers high-quality value. | 1 | $ 1,891.02 | ฿75,640.80 |
| **Architecture Leader:** In collaboration with the technical leader, this role is responsible for defining the appropriate architecture to meet the project's objectives. The architecture leader begins by analyzing the current situation, identifying necessary components and resources, and designing a comprehensive solution for cloud implementation. | 1 | $ 1,788.89 | ฿71,555.60 |
| **Technical Leader:** This role requires advanced technical expertise to define technical decisions and standards, ensuring the delivery of software components that meet quality requirements. | 1 | $ 1,134.59 | ฿45,383.60 |
| **Frontend Developer:** This role focuses on developing the user interfaces that enable interaction with the web platform. Additionally, the frontend developer ensures seamless integration with the backend solution to provide a cohesive user experience. | 2 | $1,058.97 | ฿42,358.80 |
| **Backend Developer:** This role involves building the API and implementing the business logic solutions using various approaches tailored to the infrastructure requirements. Additionally, the backend developer oversees service maintenance and ensures the proper functioning of databases. | 2 | $ 907.69 | ฿36,307.60 |
| **Designer:** The role of a software development interface designer is crucial for ensuring a positive user experience (UX) and a visually appealing user interface (UI). This involves creating intuitive and efficient software interfaces that enhance usability and engagement. | 1 | $665.75 | ฿26,630.00 |
| **Tester / QA:** This role is responsible for overseeing testing and automation from a quality assurance (QA) perspective. Their primary objective is to ensure the reliability, functionality, and overall quality of software products before they are released to end-users. | 2 | $596.31 | ฿23,852.40 |

Note: This table presents the average salary in USD and Thai Baht base year 2000.

In fact, the SD archetypical model proposed in this work (see Section 3) for the selected CCI considers factors such as team configuration and member wages to be tested in the VT framework as other authors did in the past [18] for other industry 4.0 technologies. Creating a successful solution requires a technical team driven by a shared objective. This underscores the importance of having team members with diverse roles to handle leadership, tracking, guidance, and flexibility, ensuring the project's successful completion [19]. The team comprises a project manager, architecture leader, technical leader, frontend developer, backend developer, designer, and tester. Table 7 details each team member required for the full integration. The salary information for each member is based on a scoping review [20], collecting data from multiple sites. LinkedIn and Computrabajo were selected for the authors' country, and JobThai was used to establish an average wage in Baht. This research was conducted in March 2024. The columns include data about the team members' names, the number of members needed during project execution, and salaries adjusted for inflation to 2000 Baht's value [21].

3 Study Design

The SD simulation model incorporates various formulas to replicate the CCI process. Three key factors define this approach: the development team, infrastructure cost, and project expenses, where the team's salaries replace the project cost. These factors are interrelated over time, each contributing essential attributes to the solution's construction. The infrastructure component costs are estimated using the [AWS Calculator,](https://calculator.aws/#/) with prices consulted in April 2024.

Table 8 details each AWS infrastructure component, providing descriptions and prices, each of which is interpreted in the VT Vensim Model as a variable to input costs. Both infrastructure and team salaries are adjusted for inflation to 2000s values using a suitable [calculator](https://www.usinflationcalculator.com/) and currency conversion.

**Table 8.** AWS infrastructure components

| Component | Description | Price (Baht) |
| --- | --- | --- |
| AWS Web Application Firewall | Web ACLs) utilized 5 per month, Rules added per Web ACL 2 per month, Rule Groups per Web ACL 5 per month, Rules inside each Rule Group 2 per month | ฿26,136 |
| CloudFront | Data transfer out to origin 5818.010156 GB per month, Requests 60625000 per month | ฿104,599 |
| S3 | S3 Standard storage 118.4082031 GB per month) | ฿113 |
| Application Load Balancer | Two load balancers | ฿1142 |
| API Gateway | Four API Gateways with REST API request units (millions per month), Average message size (32 KB) | ฿1069 |
| Amazon Simple Email Service (SES) | Email messages sent from EC2 (169750 per month) | ฿985 |
| Amazon Cognito | Monthly active users (177833), Advanced security features (Enabled) | ฿6439 |
| AWS Lambda | Invoke Mode (Buffered), Number of requests (4000000 per month) | ฿142 |
| AWS Fargate | Two services working with ECS | ฿3,179 |
| Amazon QuickSight | Working days per month (30), Authors (10), Number of readers (290) | ฿33,702 |
| Amazon Redshift | Nodes (1), Instance type (dc2.8xlarge), Utilization (On-Demand only) | ฿3504 |
| DynamoDB eCommerce | Table class (Standard), Average item size (all attributes) (1 KB), Data storage size (670.9798177 GB) | ฿3,778 |
| DynamoDB admin | Table class (Standard), Average item size (all attributes) (1 KB), Data storage size (67.1 GB) | ฿838 |
| Amazon RDS for PostgreSQL | Storage volume (General Purpose SSD (gp2)), Storage amount (2048 GB), Nodes (1), Instance Type (db.m4.4xlarge), Utilization (On-Demand only) (100 %Utilized/Month) | ฿61,820 |
| Amazon Simple Queue Service (SQS) | 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.

3.2 Proposed SD model for the selected CCI and adaptation of the VT model

Figure 2 exhibits a proposed SD model in Vensim to represent the selected CCI, where the variables are listed according to the equations shown. The cost of adopting the CCI involves the technical team, AWS infrastructure, and web platform expenses. The integration process is progressive, with some aspects proceeding concurrently while others depend on preceding implementations.

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**Figure 2.** SD model in Vensim for the selected CCI. Source: Author's creation

The entire integration timeline spans approximately nine months, from initial setup to full company implementation. The simulation period extends over twenty-four months to assess affordability and anticipated benefits from the web platform. Several equations were incorporated into the model to facilitate comprehensive cost estimation and planning.

Equation 1 computes the monthly architecture cost, factoring in the AWS expenses described. Equations 2, 3, and 4 address the distinct environments required for development, quality assurance (QA), and production. The pulse train function in Equation 4 simulates the production environment over 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 has the results of the variables, representing the members needed per role.

**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 has the total cost of the three environments needed infrastructure.

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

3.3 Cloud Computing Implementation Results

Implementing the selected architecture for CC, as represented in the archetypical model in Figure 2 for selected CCI, has a substantial impact on the Research and Development section of the VT model, particularly in economic terms. Figure 3 illustrates the Total Cost variable projected by the VT model before coupling with the model in Figure 2 over twenty-four months of operation, amounting to 791.118 million Bahts. Meanwhile, Figure 4 shows the VT model’s Total Cost variable after implementing CC, where the total cost after twenty-four months increased by 1.15206 million Bahts, representing a final cost of 792.27 million Bahts.

**Total cost** = Admin cost+Manu Cost+Sale cost ……………………………………………... (7)

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**Figure 3.** Cloud Computing Vensim Implementation and Current Cost. Source: Author's creation

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**Figure 4.** Cloud Computing Vensim Implementation and Implementation. Source: Author's creation

However, in the proposed archetypical model shown in Figure 2, the cost increases if the company opts to hire a development team to implement the selected CC Architecture instead of outsourcing. Equation 6 reflects this change. Figure 5 demonstrates how this decision significantly alters the cost trajectory, with experts estimating 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)"…………………………………………………………………...……………. (9)

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**Figure 5.** Cloud Computing Vensim Implementation. Source: Author's creation

Based on the eCommerce implementation discussed earlier in Section 2.4, experts projected that the proposed technological integration would increase sales by 15%. Given the current product demand at 1975 units, Figure 6 indicates a substantial increase to 2182.97 units post-implementation. Equation 10 quantifies the benefits of Cloud Computing, which begin to accrue one month after implementation initiation, following the nine-month development period. the implementation resulted in an increase of 207 additional production units (automobiles) compared to business as usual. This outcome confirms that the integration benefits the company significantly, demonstrating a positive impact. The solution enables enhanced data gathering from external sources, contributing to increased sales, reduced defects, and informed decision-making based on robust warehouse implementation.

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**Figure 6.** Product Demand. Source: Author's creation

**Cloud Computing Benefit** = DELAY FIXED(1.5, 12 , 1) …………………………..…..… (10)

Equation 11 has the formula with the addition of the complete solution.

**Product Demand** = (Q fator\*Q wgt factor)+(Price factor\*Price wgt factor)+(Sale factor\*Sales wgt factor)+(Compet price factor\*Compet price wgt factor)\* Cloud Computing Benefit ……………………………………………………………………………………………..… (11)

4 Conclusions and Future Work

Integrating technology in Industry 4.0 offers a rapid and effective means to enhance any company, contingent upon precise cost definitions and potential benefits. However, the responsibility lies in finding a suitable solution that aligns with company objectives and financial capabilities. CC, coupled with eCommerce implementation, holds significant promise due to its potential for post-deployment improvements across various company facets. Nevertheless, success hinges on proper alignment and affordability; if not, outcomes may fall short.

Cloud services like AWS provide scalable solutions tailored to diverse needs, facilitating multiple technical approaches when appropriately configured. This versatility underscores the need for specialized roles within the technical team, capable of navigating the vast options available in cloud environments.

The SD model for a CCI proposed in this work helps to quantify uncertainties associated with technology adoption over time, offering insights for comparative analyses within hypothetical scenarios, particularly in bolstering sales capabilities.

In real-world scenarios, the complexity of project implementations can overwhelm stakeholders due to diverse requirements and sources necessitating clarity. Simulations become indispensable in estimating potential risks and managing uncertainties that could unpredictably impact outcomes. The VT model, in combination with the model proposed in this work, provides a robust quantitative framework to envisage implementation scenarios for CC, factoring in costs, technical expertise, and client requirements.

In brief, this research underscores substantial benefits, such as a 15% sales increase, even when outsourcing platform development. It demonstrates manageable acquisition costs and positive medium-term returns. This study offers a measurable solution for evaluating CC adoption and sheds light on industry boundaries and their potential expansion.

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1. [↑](#footnote-ref-1)