

Enterprise Infrastructure Modernization beyond VMware: A Cost-Optimized Decision Framework for the Broadcom Era

Sudeept Srivastava
Independent Researcher, U.S.A.

Abstract - Modernization in terms of enterprise infrastructure has become a more significant topic due to organizations review their virtualization schemes in changing VMware licensing and commercial status alongside the acquisition of Broadcom. This proposed research paper presents a cost-efficient decision model adopting the Total Cost of Ownership (TCO) and Multi-Criteria Decision Analysis (MCDA) theories, to assess VMware continuation, alternative virtualization, and Private/HCI, Public Cloud, and Hybrid/Cloud-Native solutions. The framework takes into account the financial, technical, operational, and strategic criteria and is tested with representative enterprise cases, robustness and sensitivity analysis. Findings indicate that Public Cloud has the minimal five-year TCO, and least break even time, whereas Hybrid/Cloud-Native has the optimum score of 0.695 on the overall MCDA. Scenario analysis additionally illustrates that the best infrastructure decisions will depend on the enterprise characteristics and priorities. The sensitivity test suggests that rankings of the strategies are rather stable, with shifting migration-cost assumptions. The proposed framework offers enterprises with an organized and flexible tool of balancing the long-term cost-efficiency, technological viability, functional practicability, risk, and strategic adaptability.

Keywords - VMware, Broadcom, Enterprise Infrastructure Modernization, Total Cost of Ownership (TCO), Multi-Criteria Decision Analysis (MCDA), Public Cloud, Hybrid Cloud, Virtualization, Cost Optimization, Sensitivity Analysis.

I. INTRODUCTION

A. Background of Research

The changing nature of the workload requirements, a rise in the costs of operation, and the use of clouds combined with the need to have scalable and flexible computing environment are leading to great transformation in enterprise IT infrastructure [1]. Historically, VMware has been a dominant platform of enterprise virtualization but with the buy of VMware by Broadcom and subsequent licensing, subscription and changes to product portfolios, organizations have re-evaluated their long-term infrastructure planning [2]. Businesses are therefore considering other virtualization, private clouds, public clouds, containerized, and hybrid infrastructures [3]. Choosing the right

modernization strategy though should also take into account not just the cost of a license but also the cost of migration, the complexity of the operation, the compatibility on applications, the ability to scale, need of skills as well as dependence on vendors.

B. Problem Statement

The current infrastructure modernization research often analyses cloud migration, virtualization options or cost optimization separately. It provides a dilemma to companies interested in having an organized approach to arriving at the decision of either staying with VMware or implementing an alternative infrastructure model that offers them a more value over the long-run period [4]. The appropriate arena is thus the need to have an all-encompassing format comprising financial, technical, operational as well as strategic considerations that will allow implementing cost-effective decisions associated with modernization.

C. Research Aim and Objectives

Aim: To create an economical-based decision system of assessing enterprise infrastructure modernization initiatives beyond VMware in the Broadcom era.

Objectives:

- To determine the most significant financial, technical, operational and strategic criteria that affects the modernization of enterprise infrastructure.
- To create a Total Cost of Ownership (TCO) model to compare between alternative infrastructure strategies.
- To develop a multi-criteria decision model taking into account cost and non-cost.
- To test the suggested framework with enterprise scenarios and sensitivity analysis.

D. Novel Contribution

The paper suggests a novel decision model that consists of TCO analysis and multi-criteria evaluation as integrative methods to evaluate enterprise infrastructure modernization options. The framework, unlike other highly platform-oriented and cloud-relocation based approaches, employs the complexity of migration, compatibility, operational needs, scalability, risk, and vendor dependency as well as long-term cost. The resultant methodology offers businesses a systematic and flexible method of assessment of

the modernization strategies in the dynamic technological and business landscape.

II. RELATED WORK

A. Virtualization and VMware Ecosystem Enterprise

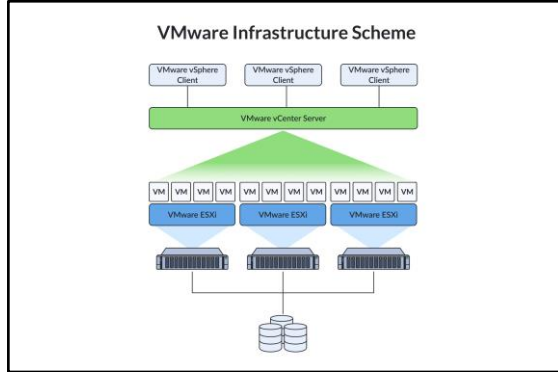


Fig. 1. VMware Infrastructure

Enterprise virtualization has emerged as an inseparable part of contemporary data centers providing the organizations with an opportunity to pay off consolidation of the physical servers, enhanced use of the resources, and easier management of the infrastructure [5]. VMware has been very instrumental in the virtualization of enterprises with its well-developed ecosystem, centralized management, workload availability, and compatibility with data-center technology [6]. Past research reports have confirmed that virtualization is able to lower hardware needs, and enhance infrastructure pliability [7]. The profound reliance on one virtualization ecosystem may bring about the issues of vendor lock-in, licensing, interoperability, and a long-term technology plan [8]. These attributes have augmented enterprise interest to assess other virtualization and infrastructure platforms.

B. Broadcom Era and Changing Enterprise Cost Considerations

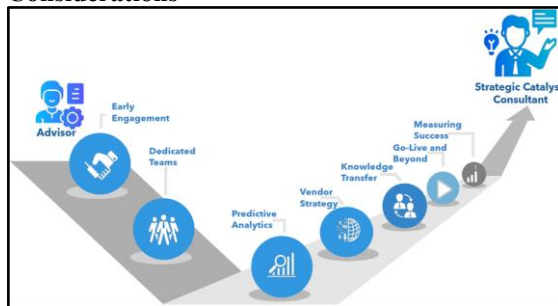


TABLE I. Alternative strategies and the Primary Benefit

Strategy	Primary Benefit
Public Cloud	High scalability & consumption-based cost

Fig. 2. Broadcom Era and Changing Enterprise Cost Considerations

The takeover by Broadcom of VMware has been ushering in a dynamic business environment to those companies that are reliant on VMware [9]. The modification of product packaging, licensing in subscription and reorganization of portfolio and enterprise procurement have put more focus on the long term financial viability of the current virtualization surroundings [10]. Research in the industry captures that decision making with regards to infrastructure must not only take into account the direct costs of software licensing since migration, hardware, support, training and operational needs can affect the overall cost a great deal [11]. Total Cost of ownership (TCO) has, therefore, come to the picture as a significant assessment tool in terms of infrastructure modernization. Business thus needs detailed cost analysis before making decisions to maintain, downscale or to upgrade on current VMware implementations [12].

C. Modernization of infrastructure and alternative strategies

The research on infrastructure modernization singles out several key strategies, such as alternative hypervisor, hyper converged infrastructure, private cloud, public cloud, containers, Kubernetes, and hybrid-cloud infrastructure [13]. Cloud-based solutions offer scalability and consume-based resource distribution, and private cloud might offer an organization more control over data, performance, and regulatory needs [14]. Containerization is also able to provide application portability and cloud-native development [15]. However, the current conditions of modernization are largely based on the workload traits, current application interdependency, and ability of an organization, security and complexity of migration [16]. This means that there is no universally best infrastructure strategy to use and therefore should always weigh modernization options based on enterprise financial, technical, and operational needs.

Private Cloud / HCI	Maximum data control, performance & compliance
Containers & K8s	Portability & cloud-native agility
Alternative Hypervisors	Cost efficiency & vendor risk mitigation
Hybrid Cloud	Balances workload flexibility with local control

D. TCO and Multi-Criteria Decision-Making Approaches.

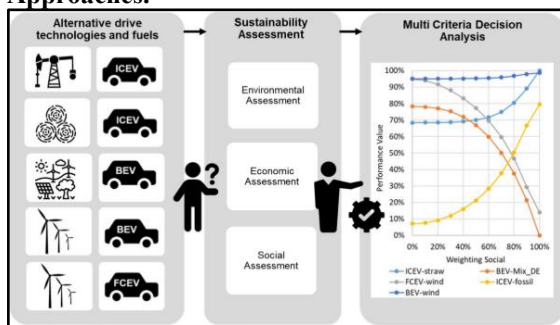


Fig. 3. Multi-Criteria Decision-Making Approaches

The previous studies have used Total Cost of ownership and Multi-Criteria Decision Analysis (MCDA) on technology selection, cloud adoption, outsourcing and infrastructure planning [17]. The TCO models measure, both directly and indirectly, the costs within an infrastructure lifecycle, consisting of acquisition, licensing, migration, operation, maintenance, training and support [18]. MCDA techniques are an addition to the methods of financial evaluation and use qualitative and quantitative elements of scalability, security, compatibility, reliability, operational complexity, and vendor dependency [19]. A combination of these strategies can offer a more holistic foundation of infrastructure decisions [20]. The available models are usually generalized to the process of cloud or technology choice and do not necessarily correspond to the needs of current VMware modernization choices.

E. Research Gap

The current literature focuses mostly on virtualization, cloud migration, TCO, and technology choice in isolation. The scant amount of literature incorporates cost, complexity of migration, compatibility of application, operational risk, and scalability and vendor dependency into a single construct dealing with VMware modernization in the Broadcom world. This paper fills this gap with the help of an inclusive TCO-MCDA decision model.

III. RESEARCH METHODOLOGY

A. Research Design

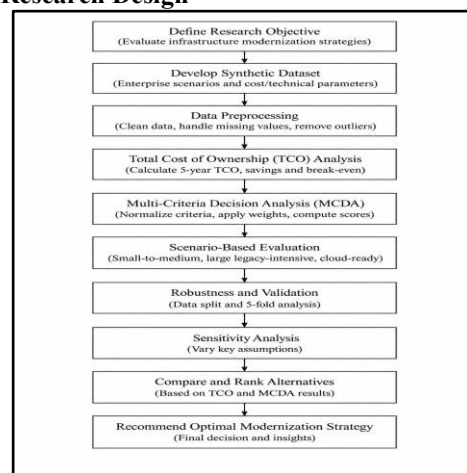


Fig. 4. Methodological Flow Diagram

The paper uses the secondary data-based quantitative decision-analysis approach and come up with and tests a cost-efficient model of enterprise infrastructure modernization outside of VMware. As the cost and migration data per enterprise are usually sensitive and hard to acquire, a synthetic dataset with 6000 records is generated based on realistic values and ranges based on secondary data. The method combines secondary data gathering, synthetic data generation, data pre-process, Total Cost of ownership (TCO) analysis, Multi-Criteria Decision Analysis (MCDA), scenario evaluation and sensitivity analysis [21].

B. Secondary Data Collection

Peer reviewed journal articles, IEEE conference papers, industry and technical white papers, vendor documentation, enterprise case studies and publicly available pricing and licensing data are the sources of secondary information. Database sources like IEEE Xplore, Scopus and Web of Science are given priority. The evidence gathered is utilized to determine pertinent modernization options, cost elements, technical needs, operational issues, migration issues, and decision criteria considerations.

C. Data Preprocessing

Synthetic dataset is preprocessed before the quantitative analysis is carried out as a means to enhance consistency and analytical reliability. The missing values are recognized and, where meant to be so to test robustness, addressed with suitable statistical imputation methods, such as median imputation of a numerical variable. The statistical methods used to identify the presence of outliers would be the Interquartile Range (IQR) and the analysis would be done against the set parameter boundaries [22].

Measurements of numerical criteria of decision, on various scales, are then normalized so that they can be compared during MCDA [23]. The dataset can also be split into development and validation subsets, such as 80% and 20%, respectively. Instead of being utilized in training predictive models, this split is utilized to investigate whether the resultant infrastructure rankings are consistent across independent synthetic splits. The robustness test on criterion weights, TCO patterns and MCDA rankings across samples can also be repeated and performed by k-fold cross-validation or other robustness testing methods [24].

D. Cost of Ownership Analysis

A three- or five-year TCO model is used to assess the financial impact of every infrastructure strategy:

$$TCO = CL + CI + CM + CO + CT + CS$$

Where (C_L), (C_I), (C_M), (C_O), (C_T), and (C_S) are the cost of licensing, infrastructure cost, migration cost, operational cost, training cost, and support cost respectively. This will help them compare budgets over time and not just in the area of licensing spending.

E. Multi-Criteria Decision Analysis.

MCDA combines financial and non-financial into a single decision score. The relative weights of each criterion are set and the performance scores of infrastructure alternatives are normalized [25]. The final decision score is arrived at as:

$$D_j = \sum_{i=1}^n w_i S_{ij}$$

Where (D_j) is the total score of the decision of alternative (j), w_i is the weight of criterion (i) and (S_{ij}) is the normalized score of the performance of criterion (i). The ranking of the alternatives is based on weighted scores.

F. Decision Analysis Under Scenario

The framework is assessed in three exemplary enterprise contexts, which cover: small-to-medium virtualized enterprise with few legacy workload dependencies; a large enterprise with many dependencies on legacy workloads; and a cloud-ready enterprise that is seeking hybrid or cloud-native modernization. Each scenario is allocated different cost structure, workload features,

technical demands and priority on decision making. The results of TCO and MCDA are then compared to understand the impact of the enterprise characteristics on the modernization recommendations.

G. Sensitivity Analysis

Sensitivity analysis is performed in order to analyze the strength of the decision structure with the variation of assumptions [26]. The main variables such as licensing expenses, migration expenses, operating expenses, weight of criteria, and infrastructure needs are varied systematically.

For a parameter X, the adjusted value can be represented as:

$$X' = X(1 + \Delta)$$

where X' is the modified value and Δ represents the percentage change.

It is found that changes in TCO values and changes in MCDA ranking help identify whether the desired modernization strategy can be sustained based on alternative assumptions or not.

H. Computational Analysis and validation

The data preprocessing, normalization, calculating TCO, scoring MCDA, evaluating scenarios, testing it with robustness, simulating sensitivity and visualizing findings are all implemented in Python. Analytical results are then correlated against trends and results published in published enterprise migration case studies and the literature of the publishing industry. This test combination of computational testing and secondary evidence gives an evaluation of reliability, stability, and applicability, in terms of cost-effectiveness of the proposed optimized infrastructure modernization framework.

I. Pseudo Code

```
BEGIN
Collect secondary information
Generate synthetic enterprise dataset
Preprocess data
    Handle missing values
    Detect and treat outliers
    Normalize variables
Calculate 5-year TCO for each strategy
Calculate MCDA weighted scores
Evaluate three enterprise scenarios
Rank infrastructure alternatives
Perform 5-fold robustness testing
Perform cost and weight
```

sensitivity analysis
Compare TCO and MCDA results
Select optimal modernization
strategy
END

There are five modernization strategies taken to be representative: the continuation of VMware implementation, alternative virtualization environment, in-house/hyperconverged infrastructure, public clouds infrastructure, and hybrid/cloud-native infrastructure. The alternatives are considered on a strategy level instead of concentrating on the specific vendors, enhancing the overall validity of the suggested framework.

IV. PROPOSED COST-OPTIMIZED DECISION FRAMEWORK

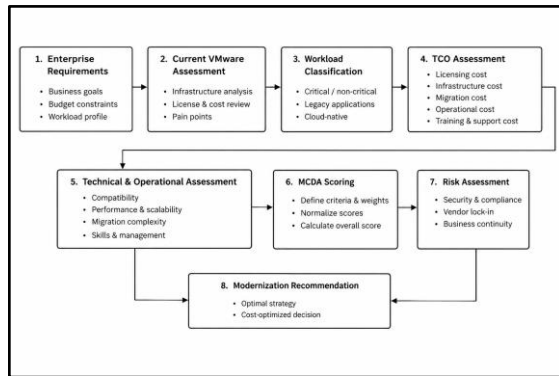


Fig. 5. Cost-efficient decision Framework

The proposed cost-efficient decision model offers a methodical framework of systems analysis of the enterprise-wide strategy of infrastructure modernization in the post-Broadcom VMware context. The framework will start with determining the requirements of the enterprise such as business goals, workload nature and budget limit, then an evaluation of current VMware environment and the classification of workload. This is followed by Total Cost of Ownership (TCO) analysis assessing the licensing, infrastructure, migration, operational, training, and support costs [27]. Technical and operational evaluations look at compatibility, performance, scalability, complexity of migration and organization capabilities. All these are then combined under the Multi criteria Decision Analysis (MCDA) in which the normalized criteria is weighted based on enterprise priorities to produce comparative scores of infrastructure alternatives. Risk assessment also takes into account the migration, operational, security and compliance risks [28]. Lastly, the framework also compares the available modernization options and advises on the opportunity that offers the best balance between long-term cost efficiency, technical appropriateness, operational feasibility and strategic flexibility of the enterprise.

V. TOTAL COST OF OWNERSHIP MODEL

TCO model is an evaluation of the long term financial impact of every enterprise infrastructure modernization strategy. Instead of looking at the licensing costs alone, the model will include infrastructure, migration, operational cost, training and support costs [29]. This analysis could be performed on a three- or five-year basis to give a long-term comparison among maintaining deploying VMware, alternative virtualization, and private/HCI infrastructure, public cloud, and strategizing hybrid/cloud-native.

A. TCO Calculation

The total cost of infrastructure alternative in option j in the period of T years is determined as:

$$TCO_j(T) = CL_j + CI_j + CM_j + CT_j + \sum_{t=1}^T T(CO_j, t + CS_j, t)$$

Licensing and subscription cost (CL), infrastructure and hardware cost (CI), migration and implementation cost (CM), training cost (CT), annual operation costs (CO) and maintenance and support cost (CS).

B. Initial and Recurring Costs

The original cost of modernization is estimated at:

$$C_{Initial,j} = CI_j + CM_j + CT_j$$

Recurring costs are obtained by:

$$C_{Recurring,j}(T) = CL_j + \sum_{t=1}^T T(CO_j, t + CS_j, t)$$

Thus, TCO can be determined as:

$$TCO_j(T) = C_{Initial,j} + C_{Recurring,j}(T)$$

Such a difference is essential since a lower licensing cost infrastructure option can mean that the initial migration, hardware, or training of workforce costs is greater.

C. Cost per Workload

TCO may also be per-workload, to compare enterprises of various sizes with respect to infrastructure:

$$TCOPW_j = \frac{TCO_j}{NW}$$

Where, NW is the number of workloads or virtual machines enabled.

D. Cost Savings

The cost savings of alternative infrastructure strategy are estimated compared with the current VMware infrastructure:

$$Savings_j = TCO_{VMware} - TCO_j$$

The change in TCO is computed as a percentage, which is:

$$Savings\%_j = \frac{TCO_{VMware} - TCO_j}{TCO_{VMware}} \times 100$$

When the percentage is positive, it implies that the alternative is less expensive financially than the

cost of continuing using VMware, whereas a negative value implies greater overall spending.

E. Break-Even Period

The break-even period will show when the total time needed to pay off the initial investment in modernization will change:

$$BEP_j = \frac{CM_{,j} + CT_{,j} + CI_{,j}^{Additional}}{AnnualCostVMware - AnnualCost_j}$$

The reduced duration to break-even means that the business is able to pay back the migration investment within a shorter period of time.

VI. SCENARIO-BASED EVALUATION

The presented framework is tested with the help of the synthetic dataset in three typical scenarios associated with an enterprise in order to estimate the influence of organizational aspects on the choice of infrastructure modernization.

Scenario 1 - Small-to-Medium Enterprise: Small business entities have moderate workload, have less IT assets, and are very sensitive in costs. Analysis focuses on the cost of licensing, cost of running, portability and complexity of management.

Scenario 2 - Large Legacy-Intensive Enterprise: Reflects a large organization with a variety of virtual machines and legacy applications. Greater emphasis is made on application compatibility, migration risk, service continuity, security as well as infrastructure reliability.

Scenario 3 - Cloud-Ready Enterprise: Reflects an organization that has more modern applications and is well-prepared to adopt clouds. Priority is on scalability, flexibility, cloud integration, automation and decreased vendor dependency. In all scenarios, the TCO and MCDA score of VMware continuation, alternative virtualization, private/HCI, public cloud and hybrid/cloud-native strategies is computed. These options are then put in order with regard to their general appropriateness.

VII. ANALYSIS RESULTS AND DISCUSSION

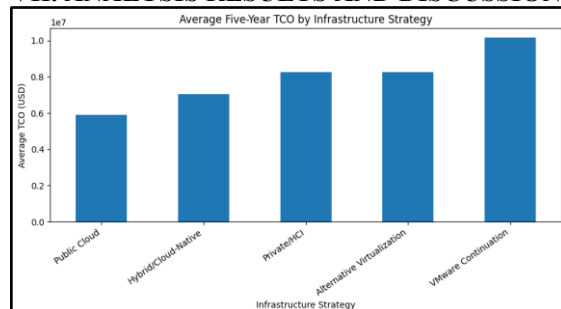


Fig. 6. Five-Year TCO by Infrastructure Strategy

Public Cloud has the lowest average five-year TCO which stands at about \$5.9M and Hybrid/Cloud-Native stands at \$7.0M. VMware Continuation is greatest at almost at \$10.1M.

Infrastructure_Strategy	Migration	Training	Infrastructure \
Alternative Virtualization	429045.212155	100128.934938	1.094823e+06
Hybrid/Cloud-Native	518690.145098	117936.650786	6.375761e+05
Private/HCI	319868.302662	74125.648191	1.193780e+06
Public Cloud	501434.952414	107282.380859	2.501741e+05
VMware Continuation	44948.832821	29800.234215	1.014222e+06

Infrastructure_Strategy	Annual_Recurring	Additional_Initial_Investment \
Alternative Virtualization	1.330081e+06	609775.615828
Hybrid/Cloud-Native	1.155021e+06	636626.795884
Private/HCI	1.332202e+06	573552.348927
Public Cloud	1.011502e+06	608717.333272
VMware Continuation	1.815751e+06	74749.067036

Infrastructure_Strategy	Annual_Savings	Break_Even_Years
Alternative Virtualization	485669.282077	1.255537
Hybrid/Cloud-Native	660729.892486	0.963520
Private/HCI	483549.132537	1.186130
Public Cloud	804249.124751	0.756877
VMware Continuation	0.000000	NaN

Fig. 7. Break-Even Analysis

Public Cloud has the shortest break-even time of 0.757 years with Hybrid/Cloud-Native coming next at 0.964 years. Approximately 1.26 and 1.19 years are needed in the case of Alternative Virtualization and Private/HCI respectively.

Infrastructure_Strategy	MCDA_Score
Hybrid/Cloud-Native	0.694992
Public Cloud	0.690725
Private/HCI	0.612519
VMware Continuation	0.611751
Alternative Virtualization	0.592095

Name: MCDA_Score, dtype: float64

Fig. 8. Overall MCDA Ranking

Hybrid/Cloud-Native has the largest MCDA score of 0.695 just above Public Cloud, which is at 0.691. VMware and Alternative Virtualization have 0.612 and 0.592 respectively; and the HCI has 0.613.

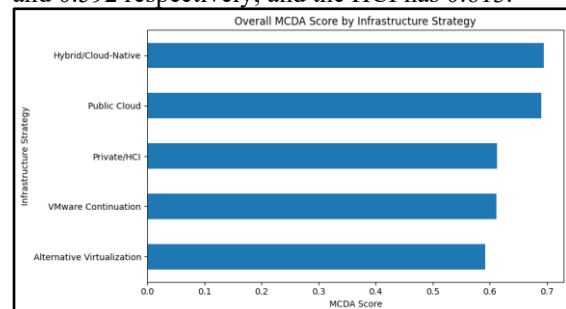


Fig. 9. Comparisons of final scores of MCDA

The MCDA chart validates Hybrid/Cloud-Native and Public Cloud as the most powerful strategies with scores about 0.69, and Alternative Virtualization as the lowest with a score of about 0.59.

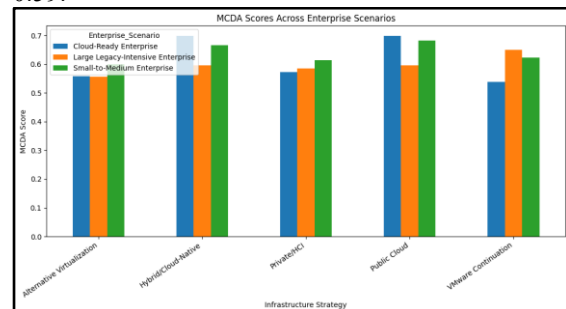


Fig. 10. Scenario-Based MCDA Evaluation

At approximately 0.70, Public Cloud proves to be the most suitable in Cloud-Ready scenario and, at approximately 0.67, Hybrid/Cloud-Native is found to be the most suitable in the Small-to-Medium Enterprise scenario, which indicates that they have preferences based on the scenario.

Fold	Infrastructure Strategy	MCDA Score	Rank
0	1 Hybrid/Cloud-Native	0.686191	1.0
1	1 Public Cloud	0.683359	2.0
2	1 VMware Continuation	0.605676	3.0
3	1 Private/HCI	0.597386	4.0
4	1 Alternative Virtualization	0.575278	5.0
5	2 Public Cloud	0.683404	1.0
6	2 Hybrid/Cloud-Native	0.683009	2.0
7	2 Private/HCI	0.584559	3.0
8	2 Alternative Virtualization	0.571151	4.0
9	2 VMware Continuation	0.563290	5.0
10	3 Hybrid/Cloud-Native	0.688255	1.0
11	3 Public Cloud	0.687807	2.0
12	3 Private/HCI	0.597188	3.0
13	3 VMware Continuation	0.582952	4.0
14	3 Alternative Virtualization	0.570354	5.0
15	4 Hybrid/Cloud-Native	0.673074	1.0
16	4 Public Cloud	0.672252	2.0
17	4 Private/HCI	0.570844	3.0
18	4 VMware Continuation	0.567699	4.0
19	4 Alternative Virtualization	0.559867	5.0
20	5 Public Cloud	0.677636	1.0
21	5 Hybrid/Cloud-Native	0.674689	2.0
22	5 Private/HCI	0.591753	3.0
23	5 Alternative Virtualization	0.576675	4.0
24	5 VMware Continuation	0.575915	5.0

Fig. 11. Five-Fold Robustness Analysis

In five folds, Hybrid/Cloud-Native is first, Public Cloud first once, second most frequently suggesting that the preferred modernization strategies remain relatively stable across folds.

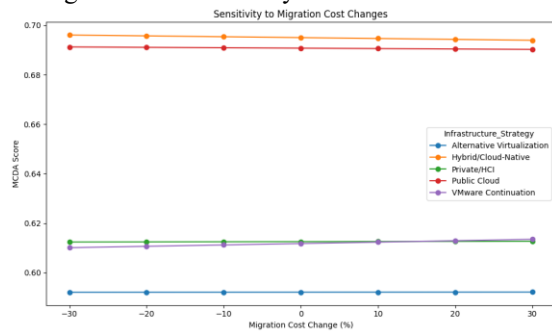


Fig. 12. Migration-Cost Sensitivity Analysis

TABLE II. STATISTICAL SUMMARY DETAILS

Infrastructure Strategy	Avg. 5-Year TCO (\$M)	MCDA Score	Overall Rank
Hybrid/Cloud-Native	~7.0	0.695	1
Public Cloud	~5.9	0.691	2
Private/HCI	~8.2	0.613	3
VMware Continuation	~10.1	0.612	4
Alternative Virtualization	~8.2	0.592	5

The indications of the sensitivity and robustness analyses also show that the desired course of modernization do not change much with varying assumptions.

VIII. LIMITATIONS AND FUTURE WORK

A. Limitation

Hybrid/Cloud-Native has the greatest score at approximately 0.694 to 0.696, then Public Cloud with a score of about 0.690, proving to be the strongest rankings regardless of a fluctuation in migration-cost.

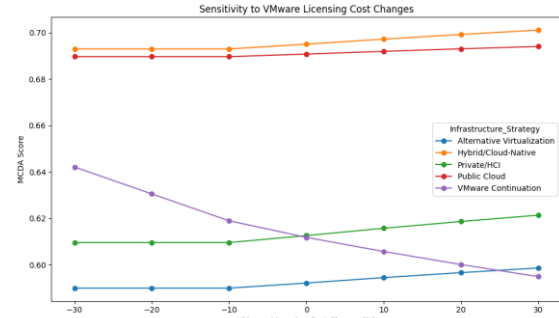


Fig. 13. License-Cost Sensitivity Analysis

In all price scenarios, Hybrid/Cloud-Native and Public Cloud both have the highest MCDA scores. In contrast, VMware Continuation significantly decreases with a more expensive cost of licenses, and reaches the lowest feasibility thresholds compared to private/HCI at a cost increase above 25%.

Discussion

The results show that the costs of licensing or acquisition should not be the only basis of the infrastructure modernization decisions. Public Cloud had the best five-year TCO and the break-even time but Hybrid/Cloud-Native has the best MCDA score of 0.695. This disparity makes it apparent that there is a need to balance financial efficiency and scalability, compatibility, security, complexity of migration, and vendor dependency.

- The cost parameter, criterion weights and enterprise scenarios might not be a complete representation of the differences in the workload architecture, regulatory necessities and pricing geographically, the contractual environment, and the

organizational IT capacity in real world companies.

- The fast transformation of virtualization and cloud technologies, the organization of vendor licenses, and price models might influence the ability of certain cost estimates in the long run and need to regularly adjust the prototype framework.

B. Future Direction

The proposed framework should be applied in future studies, in which the validity of the suggested framework is assessed based on real-life cases of enterprise migrations and longitudinal cost data of organizations that migrated away, leaving a VMware environment. Criterion weighting and decision validation could be enhanced with expert surveys that use CIOs, enterprise architects, FinOps professionals and infrastructure managers as respondents [30]. This could be extended in future research, where more variables like sustainability, energy usage, regulatory adherence, and importance of the application will be involved. Decision support based on machine-learning may as well be considered to be dynamically recommending the options of modernization based on the changing enterprise needs.

IX. CONCLUSION

The research established a cost-optimized decision model that can be used to consider the enterprise infrastructure modernization policies beyond VMware during the Broadcom age. The framework offers a combination of financial and non-financial aspects by incorporating TCO, MCDA, scenario evaluation and sensitivity analysis. Findings demonstrate that Public Cloud is best in terms of cost advantages, and Hybrid/Cloud-Native has the best score in general decision. The framework facilitates systematic, clear, and dynamic decisions on infrastructure modernization based on enterprise priorities.

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