Sustainability Forecast for Cloud Migration

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***Abstract*—In this paper, a sustainability driven approach is proposed to measure the viability of cloud migration. The decision on cloud migration is based on sustainability dimensions, i.e., economic, environmental, social and technology, and risks associated with in these dimensions. We use Analytic Hierarchy Process and fuzzy scale to prioritize the sustainability dimensions based on a migration context to calculate Total Sustainability Index (TSI). TSI is then used to determine the viability of cloud migration according to three different scales, i.e., convincing, moderate, and ineffective. Finally, we used a practical migration use case from Ministry of Health (MoH), Malaysia to demonstrate the applicability of our work. The results from the studied context concluded that economic and business continuity are the key influential concerns for a sustainable cloud migration.**

Index Terms—Cloud migration decision, sustainability, economic, technology, risk, analytic hierarchy process.

I. Introduction

Cloud computing enables organization to migrate from traditional managed in-house IT infrastructure to the outsourced virtual infrastructure. Organizations are now reluctant to purchase more in house hardware and software for managing their IT resources in order to support the critical business needs due to the economic and other benefits [4, 6]. The technology also perceives to enhance sustainability by energy saving to an organization, either in direct power costs or indirect process such as storage capabilities, information sharing and transfer of services [22]. However, despite of several benefits of cloud computing, it needs to balance the benefits against the potential risks that are associated from all aspects of cloud [21, 5]. In particular, risks relating to the technology, security, privacy, financial, and organization are vital and need adequate attention before a sustainable cloud deployment.

Within this context, we propose a sustainability driven approach for cloud migration support. The reason for considering sustainability is that it represents one of the practical approaches to assess forecasting viability of cloud within an organization context. Sustainability in our case comprises of four key areas (economic, environmental, social and technology) that are necessary to rationalize the benefits and associated risks before the management making an effective and long term viable migration decision [23].

Sustainability dimensions are refined with criteria and sub-criteria and prioritized using Analytic Hierarchy Process (AHP) [3]. The criteria and sub criteria are measured using fuzzy set scales 1-9 to determine the level of sustainability of these individual dimensions [1]. Risks are then identified for each sustainable dimension so that appropriate controls can be identified for the risks control. To demonstrate the applicability of our work, we consider a real migration use case from the Ministry of Health (MoH), Malaysia. The main goal is to evaluate the usefulness of the framework and to support the management with migration decision.

II. Related Works

In general, literatures on cloud migration focus on the issues relating to business benefits, security, and risk. For business to be more effective, migrating to cloud is perceived as an advantages to promote competitive advantage, minimized capital IT expenditure and optimize access to key technologies, software and skilled I.T personnel [13]. While, Wu et al., in [18] suggested that cloud computing needs to be reliable, include service existence, service availability, service usability and capability, and service-self healing in order to bring benefit to organization.

As risk and security are inter related in cloud similar to other computing platforms, several issues were discussed by different works such as data integrity, technology requirements for application, privacy and reliability of cloud provider [5,6,7]. Security and privacy are seen to be the critical elements of cloud computing [14, 16]. Johnson and Qu in [7] developed an analytic holistic model based on the business economics for analyzing cloud migration risks. Khajeh-Hosseini et al., in [6] introduced cost, benefits and risks tool for public IaaS cloud migration decision. Risks are considered from organizational, legal, security, technical and financial perspectives [6]. In terms of migration, Klems in [5] claimed that many companies that migrated into the cloud and other potential companies that intend to migrate in future lack in-depth analyzes to understand rationalization for migration and best possible time for migration. Mouratidis et al., in [22] systematically identify security and privacy requirements for choosing appropriate cloud deployment model for a specific context. Khan et al., in [8] identified a list of threats for the security risks analysis considering different cloud scenarios. Theoharidou et al., in [19] examined the privacy risks for the migrated data, applications or services into the cloud by following privacy impact assessment with ten fundamental privacy principals such as accountability, clear purpose, consent, collection, use, accuracy, security, openness, ability to access, and ability to challenge privacy practice [9]. Cost relating to prioritize the requirements is considered by [24, 25].

In light of sustainability perspective, Müller et al., in [17] emphasized that security and privacy are significant criteria for ensuring quality in cloud. The researchers claimed that security and privacy are factors that determine sustainable and non-sustainable cloud computing. They argued that any system is not sustainable if it fails to safeguard and assure a required computing quality. In addition, the Government of Japan [17] stated that sustainability is included in Japanese Cloud strategy as to ensure availability and flexibility of cloud computing as cloud computing infrastructure and services are closely related to social concerns. ISACA in [20] suggested that cloud service provider (CSP) needs to ensure cloud sustainability in terms of service availability and data accessibility. In summarize, all the above mentioned works are important and identify cloud specific risks and control actions. The works relating to sustainability are also mentioning its benefits towards a sustainable system. However, a limited effort has been taken into account the sustainability issues for cloud migration. We consider sustainability as a strategy to enhance performance and to coordinate social responsibility with business objectives and are relevant to address efficiency and effectiveness of an information system, risks, level of assurance and threats when migrating into cloud.

III. The Approach

Cloud migration is a complex decision making process that is subjected to internal and external factors such as changes in government policies, declining annual budget, application suitability in the cloud environment, and the emergence of new technology [22]. We use sustainability driven approach to bring together all factors that may impact the decision for cloud migration. Sustainability is also applied to highlight issues arising from economic, environmental, social and technology in making judgement for cloud migration. Therefore, four dimensions of sustainability (economic, environmental, social and technology) are categorized into criteria and sub-criteria. The sub-criteria derives from several factors that may influenced sustainability criteria. The criteria and sub-criteria are assessed to forecast how sustainable the cloud migration within an organizational context. Details of sustainability dimensions, criteria and sub-criteria are shown in Figure 1.

A. Sustainability Dimensions and Its Measurement for Cloud Migration

Sustainability is defined by Brundtland as development that meets the needs of current generation without compromising the ability of future generations to meet their own needs [10]. Since the definition provided by Brundtland, sustainability has been interpreted to the way on how organization are performing in terms of economic, environmental and social in an integrated way. However, technology is also considered as part of sustainability dimensions as it is increasingly convenient to the society. Sustainability measurement refers to the potential sustainability factors that may have influenced on cloud migration decision. For example, migrating to cloud will involve cost, security, business continuity, technical capability and environmental impact. Justifying these issues requires an integrated concept of sustainability to align the cloud migration strategy with business benefits. Going by this definition, economic criteria is developed to provide measurement for cost estimation in cloud migration that include cost of maintenance, training, consultant and migration. Extant the use of sustainability in cloud migration, it is including environmental practices as part of the cloud migration decision to better address issues such as energy savings and server utilization. Business continuity and compliance to rules and regulations are also received considerable attention for cloud migration. These requirements can also be supported by incorporating social criteria that can guide decision making for cloud migration. Technology is one of the most significant factors in cloud migration that may increases community concerns such as security, integrity and, business reputation. As for this reason, technology criteria is included as part of cloud migration decision.

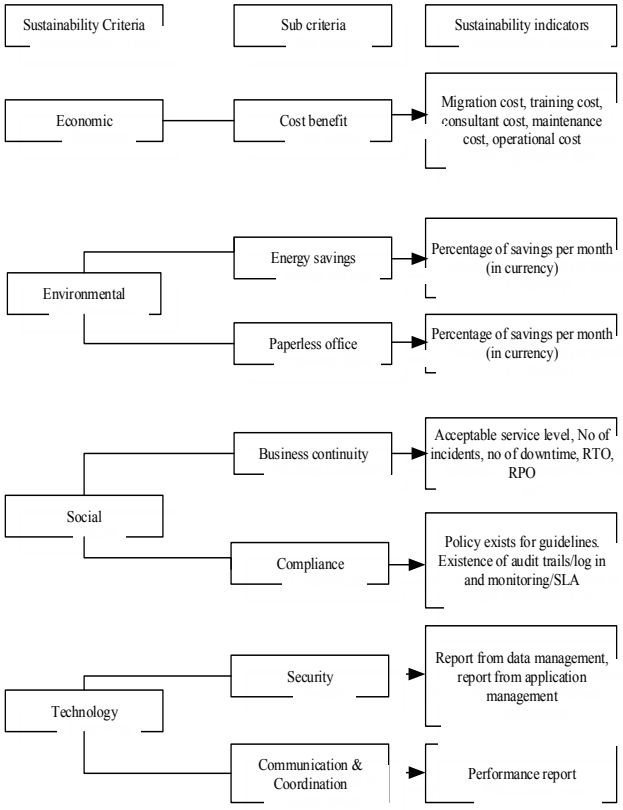

Fig 1. Sustainability criteria, sub-criteria and indicators.

We use Analytic Hierarchy Process (AHP) to determine the relative importance of the criteria and sub-criteria [3]. For decision making purposes, we calculate Total Sustainability Index (TSI) to arrive at a conclusion of sustainability assessment. The TSI is the aggregate score of sustainability index for economy, environmental, social and technology as shown in equation 1.

$$TSI = \sum SI\ (Eco + Env + Soc + Tech) \quad (1)$$

For sustainable cloud migration decision, three prediction categories are considered;

- *Convincing:* Convincing phase is determined when sustainability sub-criteria are measured in a scale of 7-9 (very and extremely importance). Cloud migration is predicted sustainable.
- *Moderate:* The moderate phase is defined when sustainability criteria and sub-criteria are measured in a scale of 3-5 (moderate and strong importance). Cloud migration is predicted fairly sustainable and further assessment is necessary on controls, planning or security.
- *Ineffective:* The ineffective phase indicates some sustainability criteria and sub-criteria are measured as 1 or equal importance. Under this context, management is unable to provide assurance on the sustainability status for cloud migration.

B. Sustainability Risks

Sustainability risks are the cross cutting concern from all sustainability dimensions and may have potential negative impacts that could out weight the expected cloud migration benefits[2,21]. We used management approach i.e. strategic, tactical and operational, so that the sustainability risks are aligned with the decision making level by following these three categories. Such risk derives from the management decision perspective where there is a flexibility to meet current (Tactical and Operational) issues and future (Strategic) requirements. In this paper, we referred strategic risk as a high level risk which can have significant impact to the economic, environment, social and technology. The strategic risk is mainly due to the likelihood of consequences of policy changes, transforming business activities into an advanced technology or decision for outsourcing. While the tactical risk refers to short term activities of the organization emphasizing on the management decision to improve business activities at some point one year or less in the future. Due to the time horizon, potential unexpected event may occur such as price increment, increase in energy consumption, and annual budget cut-off. Whereas, the operational risk such as cyber threat, data leakage, and internal attack signifies those events arising from the daily activities of the business that include systems, processes and people.

IV. EVALUATION

We implement the proposed approach into a real migration use case at the Ministry of Health, Malaysia (MoH) for the purpose of evaluation. One of the authors and her colleagues from the MoH were involved for this evaluation. The objective of the study is to evaluate the applicability of sustainability for cloud migration and to explore factors relating to the sustainability risks that influenced cloud migration decision.

A. Study Context and Data Collection

The MoH is a public organization and its operations are located at the Head Quarters in Putrajaya, in states and small district in Malaysia. For the confidentiality reason, we are not be able to disclose details information. Currently, there are more than 70,000 personnel in the MoH. Email is the key medium of communication in the MoH besides teleconferencing and other social media. Hence, MoH has a huge amount of email transactions that are operating under the internet connectivity of 32Mbps in the head office. Every user is allocated 500Mb email storage, allocation varies depending on the hierarchy, roles and responsibilities of the MoH staff. The high volume of emails requires a regular maintenance on the storage, transmission, delivery and access to the emails. Due to the budget restriction and maintenance overhead, MoH management decision is to migrate the whole e-mail service into cloud. The management required the migration to be performed by taking into account resources capabilities, e-mail archive, users' expectations, organization and stakeholders, relevant controls and risks mitigation. In order to fulfill the study objective, a set of questionnaires were used to assess respondents' perception on their understanding of sustainability dimensions, cloud migration and the relative importance of the sustainability criteria and sub-criteria. Responses from the questionnaires were recorded in a fuzzy type scale. About 20 questionnaires were distributed to the selected staff of MoH. The respondents were from the operational to senior level management and have been in services for more than 5 years. Based on the information gathered, we summarized the results and concluded the TSI as depicted in Table I.

TABLE I. TOTAL SUSTAINABILITY INDEX

Ec	Env	S	T	TSI
2.7	0.12	1.93	0.65	6.7

B. Risk Identification

The value of Sustainability Index (SI) determines the level of sustainability criteria and sub-criteria. Based on the SI and TSI, potential risks associated to these sustainability criteria and sub-criteria were identified by interviewing key personnel based on their experiences as shown in Table II. In conjunction to sustainability risk identified, we recommend ways to mitigate them based on practitioners' opinion, literatures and suggestion from the cloud service providers. We summarized the risks mitigation as depicted in Table III.

V. DISCUSSION

The sustainability index (SI) from the studied context is 2.7 for economic and 1.93 for social. Both economic and social criteria are ranked as the most important factors for the cloud migration decision, followed by technology (SI=0.65) and environmental (SI=0.12). Cost benefit was the most influential sub criteria under economy. Furthermore, business continuity and compliance with government legislation were also the influential factors for sustainability. For decision making purposes, the organization needs to evaluate the TSI that reflected the importance of overall criteria.

TABLE II . SUSTAINABILITY RISKS

Risks	Category & impact
Budget declining Cost overrun New taxation policy Schedule overrun Data loss The emergence of new technology	Strategic, Tactical, Operational Impact: Economic
Inadequate energy savings Inadequate awareness for paperless office	Strategic, Tactical, Operational Impact: Environmental
Vendor driven strategy Inadequate quality control Lack of motivation Lack of transparency Inconsistencies between existing e-mail policies with cloud environment Data leakage Violation of legal compliance Migration difficulties	Strategic, Tactical, Operational Impact: Social
Inadequate standard for in-house application integration Data leakage Poor awareness Service unavailability Migration difficulties	Strategic, Tactical, Operational Impact: Technology

TABLE III. SUSTAINABILITY RISKS MITIGATION

Category	Mitigation
Strategic	Establish plan for migration (design, test, migrate, post implementation review) Adequate estimation on cost and its variance Establish appropriate contingency plan and security parameters Appropriate plan for awareness on cloud migration through out organization Establish KPI for cloud migration Define adequate specification for training and maintenance of cloud
Tactical	Establish regular committee meeting for cloud migration Establish a structured work flow for cloud migration Establish sustainability risk identification for each dimensions Measure KPI for cloud migration Implement security measures for cloud
Operational	Assess KPI for cloud migration Perform continuous monitoring for cloud migration (compliance to service level) Conduct post implementation review for cloud Identify variance in cost estimation. Implement security measures for cloud

From the result, it showed that TSI for sustainability forecast was 6.7, based on the prediction categories, it is under the 'Convincing' phase. The rationale for this phase is that more assurance on sustainability is gained when the AHP demonstrates that sustainability criteria and sub-criteria are measured in high score. In practical terms, 'convincing' is determined by considering cost benefit, business continuity and compliance to government's rules and regulations are identified as significant for cloud migration. However, organization needs to consider external factors that may affect cloud migration such as government's transformation plan or annual budget declining due to recession. While, for the internal factors are the management decision to revise email retention policy or decision to use new technology for email service that may hinder the sustainability for cloud migration. Going by this point, further analysis to identify sustainability risks were carried out that considered the impact of risk to economic, environmental, social and technology.

Recommendations: Organization should make sustainability forecast for cloud migration in order to reach an effective decision making before migrating into cloud. Different organization may have different sustainability requirements, depending on its size, complexity and, nature of business. Besides the four dimensions and seven sub-criteria of sustainability as described above, organization may take other relevant criteria and sub-criteria that may be suited and applicable to their business activities. We believed the seven sub-criteria are the most influenced factors that may affect the decision for cloud migration. In term of risk identification and its mitigation, it is essential for the management to synchronize the mitigation method from planning to implementation activities. This includes the formation of committee to analyze sustainability risks, to formulate an appropriate method for risk mitigation and to develop appropriate controls.

VI. CONCLUSION

This paper analyzes how sustainability dimensions are incorporated in planning stage for cloud migration decision. The proposed approach identifies the relative importance of each sustainability dimension and provides result on the level of sustainability to justify the decision. Sustainability is about integrating economic, environmental, social, and technology for short and long term strategic for cloud migration. Given the future-orientation of sustainability, it is capable to address consequences that may impair the success of cloud migration such as technical integration, vendor management, security and cost estimation. The results from the studied context indicated that the approach is applicable and supports the organization with their cloud migration decision. Sustainability risks from the context are also identified and categorized according to strategic, tactical and operational aspects. This allows to balance the decision considering the benefits and risks that could outweigh the expected benefits of cloud migration. It is important to note that the nature of organization may influence the selection of criteria and sub-criteria of sustainability and they are subjected by the objective(s) and vision of the organization.

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REFERENCES

[1] P. Ghadimi, A.H. Azadnia, M.N. Yusof, and M.S.M. Saman, "A weighted fuzzy approach for product sustainability assessment: A case study in automotive industry", Journal of Cleaner Production, vol. 33 , pp.10-21, 2012

[2] S. Islam, H. Mouratidis, and E. Weippl, "An empirical study on the implementation and evaluation of a goal-driven software development risk management model", Journal of Information

and Software Technology, vol. 56, Issue 2, February, 2014, Elsevier

[3] T.L. Saaty, "Decision making with the analytic hierarchy process", International Journal of Services Sciences (IJSSCI), vol. 1, No. 1, 2008.

[4] C. Kalloniatis, H. Mouratidis, and S. Islam, "Evaluating cloud deployment scenarios based on security and privacy requirements", Requirements Engineering Journal (REJ), Springer-Verlag, vol. 18, Issue 4, 2013

[5] M. Klems, J. Nimis, and S. TaiDo, "Clouds compute? A framework for estimating the value of cloud computing , designing e-Business systems. markets, services, and networks", Lecture Notes in Business Information Processing, vol. 22, pp. 110-123, 2009

[6] A. Khajeh-Hosseini, I. Sommerville , J. Bogaerts, J. and P. Teregowda, "Decision support tools for cloud migration in the enterprise", IEEE 4th International Conference on Cloud Computing. IEEE Computer Society, pp. 450-457, 2011

[7] B. Johnson and Y. Qu, "A holistic model for making cloud migration decision: A consideration of security, architecture and business economics," IEEE 10th Int. Symp. on Parallel and Distributed Processing with Applications, pp. 435-441, 2012

[8] A.U. Khan, M. Oriol, M. Kiran, J.Ming and K. Djemame, "Security risks and their management in cloud computing", IEEE 4th International Conference on Cloud Computing Technology and Science (CloudCom), 2012.

[9] S. Vimercati, S. De Capitani di. Foresti, S. Jajodia, S. Paraboschi, and P. Samarati, "Over-encryption: Management of access control evolution on outsourced data," 33rd International conference on very large data bases , Vienna, Austria, Sep. 2007.

[10] WCED, Our Common Future: The Brundtland Report 1987, World Commission on Environment and Development: Oxford.

[11] A. Barin, A. da Rosa Abaide, and K.F. Magnago, "Selection of storage energy technologies in a power quality scenario: the AHP and the Fuzzy logic", IEEE, 2009.

[12] C.Gong, J.Liu, Q.Zhang, H.Chen and Z. Gong., 'The characteristic of cloud computing', IEEE 39th International Conference on Parallel Processing Workshops, , pp. 275-279, 2010.

[13] R. Bedward and D. T. Fokum, " A cloud computing adoption approach for Jamaican Institution", IEEE, pp. 1-6, 2014

[14] T. Dhillon, C. Wu and E. Chang, "Cloud computing: Issues and challenges", IEEE 20th International Conference on Advanced Information Networking and Applications, pp. 28-33, 2010

[15] S. Qamar, L. N. Lal and M. Singh, " Internetware cloud computing challenges", IJCSIS International Journal of Computer Science Information Security, vol.7, no.3, March 2010.

[16] T. Schaefer, M, Hofmann, P. Loos and P. Fettke, " Selecting the right cloud operating model, privacy and data security in the cloud", ISACA Journal, vol. 3, pp. 1-7, 2014.

[17] G. Müller. N. Sonehara, I. Echizen and S. Wohlgemuth, " Sustainable cloud computing", Business Information Systems Engineering, vol.3, pp.129-131, 2011

[18] Z. Wu, N.Chu and P. Su, " Improving cloud service reliability: A system accounting approach", IEEE 9th International Conference on Service Computing, pp. 91-97, 2012

[19] M. Theoharidou, N. Papanikolaou, S. Pearson and D. Gritzalis, "Privacy risks, security and accountability in the Cloud", IEEE International Conference on Cloud Computing Technology and Science, pp. 178-184, 2013

[20] An ISACA. Emerging Technology White Paper, "Cloud computing: business benefits with security, governance and assurance perspectives", pp. 1-10, 2009

[21] S. Islam, E. Weippl, K. Krombholz, "A decision framework model for migration into cloud: Business, application, security and privacy perspectives", Proceeding on 16th International Conference on Information Integration and Web-based Applications & Services(iiWAS 2014)

[22] A.B.L.A. Aida, A. Al-Nemrat, and D. Preston, "Sustainability in information systems auditing", European Scientific Journal, Special Edition, vol. 3, pp. 458-472, 2014.

[23] A.B.L.A. Aida, S. Islam, and A. Al-Nemrat, "Measuring sustainability for an effective information system audit from public organization perspective", IEEE 9th International Conference on Research Challenges in Information Science, 2015.

[24] J. Karlsson and K. Ryan, "A cost- value approach for priotizing requirements", IEEE Software, vol. 14 (5), pp. 67-74, 1997.

[25] P. Avesani, C. Bazzanella, A. Perini, A. Susi, "Facing scalability issues in requirements prioritization with machine learning techniques", Proceedings of IEEE 13th International Conference on Requirements Engineering, IEEE Computer Society, Paris, France, pp. 297–306, 2005.