A Roadmap for Migration System-Architecture Decision by Neutrosophic-ANP and Benchmark for Enterprise Resource Planning Systems

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ABSTRACT The selection of the system-architecture is critical step in software-engineering lifecycle. Unfortunately, the selecting a suitable architecture is a hard mission. The difficulty of the adopting architecture increases in inconsistence case as in SOA and MSA. The paper answers “when architecture transform”, “to which architecture migrate” and “how”. The paper addresses the lack of evaluation ERPs in post-implementation phase. The paper provides static and dynamic analysis for monolith, SOA and MSA by numerical-comparison and Benchmark. This paper proposes a roadmap for migration-architecture. The roadmap consists of flowchart of migration and migration-decision model that is supported with criteria of evaluation form for assessing system’s baseline and making a consistence decision by Neutrosophic-ANP. Because of the dependency between factors of information system evolution, ANP is used. Furthermore, Neutrosophic set is selected because its accuracy in inconsistence. Benchmark assesses OpenBravoERP, Odoo12 and Metasfresh5.144 to represent monolith, SOA and MSA respectively. Benchmark assesses performance, time to the market, stability, future proof, network issue and cost. They are tested based on scenario tests which guarantee that transactions are executed within more than one module of ERPS, simulates real business’s procedures, huge number of records and concurrent load by virtual users. The proposed model and benchmark help “Hitac’ enterprise in two decisions for its expansion-plan in COVID-19 crisis. The numerical steps of this case-study are provided. Most published papers and literatures about Microservices are not empirical. The main paper’s result is filling this gap by a one of the empirical aspects with an academic study support.

INDEX TERMS Performance testing, benchmarking, system architecture, monolith, service-oriented architecture (SOA), microservices architecture (MSA), neutrosophic-analytic network process, multi-criteria decision analysis (MCDA), and enterprise recourse planning (ERP).

I. INTRODUCTION System Architecture predicts the system’s ability for scalability, Return on Investment (ROI), stability, availability, business competition, robustness. Non-functional requirements are vital parameters for ERPs, where its architecture supports higher degree of these requirements. Architecture style is a higher level abstraction of design system such as layered (n-tier), monolithic, event-driven, service-oriented and Microservices. System Architecture is one of the outputs of system design phase in software engineering life cycle, and it is a pointer of the whole system efficiency in the long term. Architecture style or system architecture is a description for whole system’s relationships and elements to implement software system under constraints. It is not a descriptive style but also it describes how elements interact with each other, with system goals and enterprise objectives. System-Architectures provide optimize security, robustness, scalability, reusability, maintainability, efficiency, reliability, modularity etc. to software system with a different level. Therefore, trades off between these advantages of different architectures and enterprise’s needs are a hard mission face software architect, developer or decision maker. Monolithic architecture is a best choice until it doesn’t scale and develop continuously, but it turns to disaster at infrastructure and operational levels. Service-oriented architecture (SOA) supports
scalability and other useful features especially for distributed system but has many limitations with modern operational, running and delivery quality technology as containers, cloud and DevOps [1], [2]. This constrains effect on system performance and development even on time to the market and competition ability.

Monolithic architecture [3]–[7] is one of the simplest architecture styles for designing software. Software consists of one business logic file, DB and interface. This one file provides fast deployment, easiest development and scaling until it is light. With many developments and upgrading business services and features, this turns to nightmare for developers and software architects at a technical level and for business decision makers at financial level. OpenERP, Openbravo, ERPNext and Tryton are some examples of open-source ERP for this architecture.

Service-oriented architecture (SOA) [8]–[10] instead of dealing with business logic file as one block, SOA splits it to many services based on reusability principle and common DB. These services are communicated by synchronous protocol. That provides many advantages; such as many developers implement these services in parallel or in different programming languages. The fast development and fast deployment are initial advantages of SOA. That made OpenERP vendor after released version 7, switch from monolith to SOA. The new product called Odoo. Some examples of open-source SOA ERP systems are Odoo, Apache OFBIZ and Openpaps. Unfortunately, SOA stills have same monolith limitations and shortages. This was a motivation for many large-sized enterprises such as Ebay and Netflix to switch to Microservices architecture (MSA).

Microservices (MSA) [3], [11]–[14] is a modern competitor architecture suitable enterprise’s software system that has grown scale (horizontal/vertical), distributed, continues development and continues deployment features. Microservices supports orchestration and Domain based model (business-bounded context) architecture, also container, DevOps, Cloud. Terms Microservices and SOA are used interchangeably, but they are completely different. For example, Services in Microservices-architecture are business object or a domain, and they are the inverse of services in SOA. Database is shared between all services in SOA; while many DBs may be used in one system is built based on MSA. Thereby, Microservices-based software may have schema and non-schema DB. Comparing with other architectures, a few MSA-based ERP exists such as Microsoft Dynamic ERP, Salesforce and Adaptive ERP are closed source, Metasfresh after release 5.9 and NiennaAdvantage are open source.

Enterprise resource planning system (ERPs) [4], [15]–[20] are chosen in this paper rather than other type of information systems because (1) enterprise resource planning system consists of numerous and variety transactions and multiple modules, (2) its functionality and objectives make it has a continuous manner of releasing, restoration, renovation and innovation, (3) the position of enterprise in the future is related to efficacy of the enterprise software system. So, studying and evaluation of enterprise’s architecture (monolith, SOA or MSA) is essential and raise the most superior architecture. That reflects the value for each architecture’s characteristics. There are many ERP vendors who provide various close and open-source systems. Open-source ERP [21] with its free licenses is very popular and powerful competitor because of (1) high flexibility of customizing many features that meet enterprise requirements. (2) Continuous improvements by developers of ERP community which will enrich quality, continuity and maturity (3) high scalability for adding features or unique industry solution. Open-source is a suitable choice for ERP system architecture comparison by setting up three different ERPS on same environment and applying unified scenario tests.

The decision of choosing cloud service provider or even buying a car requires a precise analysis and consideration of many cross, close and conflicting criteria. Therefore, the selection an ERP system is a nightmare for software consultant, system architect and enterprise managers (chief executive officer (CEO), chief financial officer (CFO), chief human resources officer (CHRO), general manager (GM), and marketing manager) due to its importance. Decision making is selecting the most suitable among multiple and convergent alternatives keeping in sight the heterogeneous decision criterion, objectives and priorities of decision maker [22]. Decision making is very important at strategic-level management. Therefore, Difficulty of decision making is a motivation for developing many approaches and tools not only to support a decision but also making it. Multi-criteria decision making (MCDM) aims to provide a model for decision problems by capturing and addressing both qualitative and quantitative characteristics of alternatives, then assigning numerical values to intangible aspects inherent to decisions, and estimating better or worst options that have difficult cost and benefits relationships.

Analytic Network Process (ANP) is one of MCDM approach that cares about sub-criteria and its relation with multi alternatives and gets more accurate results. The distinguishing of ANP is declaring the actual relationships between criteria, alternatives and between sub-criteria whatever in same cluster or not. AHP only has a direct relationship between criteria and alternatives in one direction. In ANP, the inner dependency between elements (sub-criteria) of criterion (own cluster) appear as a loop connection and is drawn as an arc, feedback relationship appears as cycle and is drawn as a line with two arrows in dual directions (for example, the visualization of the decision problem as network graph in Fig. 3 for case study below). Nodes (sub-criteria) in cluster also may have relationship between themselves and other nodes in other clusters (influence and dependent) [23]–[25].

Fuzzy sets were used with MCDM methods like in AHP to reduce uncertainty. However, it does not solve this kind of problems in decision making. Saaty and et al. dose not support fuzzy-AHP because AHP is fuzzy by itself [26]. [27] Studies the correlation between the results of fuzzy-ANP and classical-ANP for software security assessment and proves
that they are highly correlated. That was a motivation to apply hybrid fuzzy-ANP-TOPSIS method to get better results in decision problems in case of the uncertain and imprecise information. In spite of fuzzy-ANP-TOPSIS results, but this study recommended that “for software security assessment issue, as it complex and dynamic task faced by both developers and users, there may be better MCDM symmetrical techniques rather than Hybrid fuzzy-ANP-TOPSIS”. As this issue is semi-similar with the ERP system evaluation issue that this paper handles, fuzzy-ANP or fuzzy-ANP-TOPSIS is not used. Neutrosophy is the origin of Neutrosophic which is care neutral (indeterminate/unknown) part as in philosophy. Its components are T, I, F. they are representing the membership (truth), indeterminacy (intermediate) and non-membership (false) values respectively. Each element in Neutrosophic set has three components which are considers a subset, contrary all other types of sets as in fuzzy set, its three component are numbers [28]. ANP with Neutrosophic set is used in [29] to overcome the problem of restricted knowledge or differences opinions of decision makers to specify deterministic values of comparison judgments. Neutrosophic set is more general than other set as fuzzy and thereby Saaty set. Neutrosophic set is more reliable in judgment and pairwise comparison for criteria and alternative especial in Multi-Criteria Group Decision Making (MCGDM). Neutrosophic is more suitable for dealing with high degree of imprecision and incomplete information. Neutrosophic set provides accurate values in decision rather than Saaty and fuzzy sets [23, 30–32]. The paper cares ANP with Neutrosophic set. The reasons of selecting Neutrosophic set are declared above and the cause of using ANP is declared below.

The selection of appropriate approach of decision making is very hard problem. There are many points can guide decision maker like size of problem (alternatives and criteria), relation between alternatives, complexity degree of problem (type of problem) and dependency and independency of criteria. Unfortunately, not all methods handle these points, but dependency and independency of criteria is addressed by ANP. As all methods cannot handle dependency between criteria especially correlation, like AHP, but ANP is able to work with Dependency or independency of criteria although it is a general form of AHP [26]. Where success factors of information system are much related together, like user satisfaction is achieved when system quality is exist. Also, one criterion may have many factors and these factors may be common with other sub-criteria of another criterion like reliability. Reliability is one of sub-criteria for both system quality and service quality criteria in D&M model [33]. Also, the multi-attribute utility theory method depends on using many factors in producing a total utility score for an alternative [24]. So, the proposed model adopts multi-criteria (criterion and its sub) to be accurate, sensible and handle many utility functions. In addition to, ANP more accurate and suitable with multi criteria rather than AHP. Furthermore, ANP is more rationality, flexibility and creditability rather than AHP which represents the problem in up-down hierarchy manner. It deals with weights of criteria and priority scores of alternatives as paired comparisons. AHP can’t handle feedback relations between criteria and alternatives, so the result is not representing the total value of alternatives [34], [35]. All of that are considered reasons of judging the decision problem by multi-criteria and ANP. Consequently, the proposed model adopts multi-criteria and ANP.

To help software consultant, system architect and enterprise (CEO, CFO, CHRO, GM, and marketing manager), this paper contributes in using Neutrosophic set and ANP approach in presenting a migration decision model for ERP system combining with a roadmap to help developer in executing the recommended decision. The second contribution is providing assessment criteria for evaluating the recent state of the current ERP system. The paper studied different evolution models, main factors, trends of evaluation criteria and critical success factors of ERP system and information system that mentioned in academic researchers from 1982 to (1) detect critical criteria that serve enterprise architecture, (2) describe characteristics of enterprise’s system that grantee successful factors of enterprise information system and architecture software. This is regarding a third critical contribution as there is lack in (evaluating) ERP system after implementation. This gap is mentioned in [33]. The proposed migration decision model with its two parts (assessment and transformation steps) can also help in avoiding migration problems as it listed in [9]. Where selection or transformation ERP system to non-suitable ERP system’s architecture is a disaster, the fourth contribution is providing a Benchmark of three different ERP systems. Each ERP system represents one of popular system architecture; monolith, service-oriented architecture and Microservices. The system architecture Benchmark is helpful for software consultant, system architect and enterprise. Benchmark makes software consultant, system architect, developers, enterprises and ERP vendors stay in synchronize with the development of ERP’s architecture. Accordingly, quality improvement, better performance, cost efficiency, stay relevant in the market and increasing productivity will achieve. Benchmark also helps decision makers in enterprise to select a suitable ERP’s architecture for ERP system if they want to purchase one rather than developing the current. Another contribution for presented Benchmark is containing a quality assessment for MSA. It fills gap in software engineering industry especially in architecture-based ERP like Microservices. Because there is a gap between academic and industry in Microservices in last few years [36].

Eventually, the proposed model addresses: (1) when current ERP system’s architecture migrate to another one and (2) steps of migration decision which is made by Neutrosophic-ANP approach. The proposed migration decision model has two main parts; firstly, evaluation the performance state of the current system by using the proposed criteria and factors, then applying Neutrosophic-ANP to decide a suitable architecture fit business enterprises’ needs and vision. Secondly the model explains the migration steps.
from current architecture to the recommended architecture. The steps of applying the two main components of proposed model are:

1. First part (making decision): Evaluate the current ERP system’s architecture by using assessment form in Fig. 2, criteria and sub-criteria is valued by linguistic expression that declared in table 4.
2. Convert linguistic expression to estimated values of Neutrosophic set.
3. Then, decision is made by applying ANP steps with Neutrosophic set which is used as a reference in pairwise comparison judgment. steps are:
   a. create unweight super matrix for pairwise comparisons and priority vectors at nodes level (sub-criteria level),
   b. create weighted super matrix at clusters levels,
   c. create limit matrix,
   d. Finally get the recommended decision.
4. Now, Second part (applying the decision): Based on decision, the developers detect the start point and follow the flowchart steps of migration from current architecture to recommended architecture.

By providing a full roadmap for migration decision model and by answering two questions; (1) what are parameters that play role to judge on software architecture whereupon ERP system is to succeed? To get answer, the state of the system must be study well; otherwise the system causes a disaster”. That is the paper’s concern.

The start point of migration is answering the question “is migration essential?” To get answer, the state of the system must be study will. The current state is a guide enterprise to trust on migration decision. However, knowing the migration is a critical step or not. “How to evaluate the current system?” must be answered at first to detect the essential level of migration step. This section studies the previous evaluation models and listed criteria that is used.

Most of the existing literature in this context is related to the selection of ERP software and critical success factors (CSFs), which is not concerned with the ERP systems implementation measurement of performance after a system’s implementation. Because of this, some researchers have begun to study what possible criteria could be used to evaluate the final outcomes of an ERP system implementation [33]. The goal is to build model tradeoffs among criteria (like competing attributes, quality characteristics) and alternatives.

The structure of paper is: Section 2 provides a literature review. Section 3.1 handles a proposed migration architecture decision model, while section 4 addresses applying the proposed roadmap and numerical steps of Neutrosophic-ANP approach in case study. aforementioned, there is a gap between academic and industry in Microservices in last few years, this paper tries to fill this gap by creating a Benchmark for three different ERPs that are built based on three different architectures in section 3.2. The discussion section 3.3 comments on the relation between applying a proposed migration decision model and results of performance test for systems which are built based on these architectures. Section 6 is the conclusion of this study.

II. LITERATURE REVIEW

“The Business isomorphism with architecture” is the idea that the business and the design of systems must adopt. Many industries adopt Microservices such as Netflix, Twitter, Facebook, eBay, Uber, Spotify, Adrian Cockcroft, Google, Comcast Cable, Karma, Groupon, Gift, Hailo, Zalando, Lending Club, AutoScout24, and many several companies seek to migrate their systems to Microservices. Amazon started with a huge database then moved to a SOA. Wikipedia and IBM also use SOA [11], [13], [37]–[39]. Although many companies have invested in SOA aligned IT transformations, they did not harvest what it promised to provide [9], [20], [40], [41]. That emphasizes that “the migration decision must be making carefully and study well; otherwise the system causes a disaster” . That is the paper’s concern.

The start point of migration is answering the question “is migration essential?” To get answer, the state of the system must be study will. The current state is a guide enterprise to trust on migration decision. However, knowing the migration is a critical step or not. “How to evaluate the current system?” must be answered at first to detect the essential level of migration step. This section studies the previous evaluation models and listed criteria that is used.

Most of the existing literature in this context is related to the selection of ERP software and critical success factors (CSFs), which is not concerned with the ERP systems implementation measurement of performance after a system’s implementation. Because of this, some researchers have begun to study what possible criteria could be used to evaluate the final outcomes of an ERP system implementation [33]. The goal is to build model tradeoffs among criteria (like competing attributes, quality characteristics) and alternatives. Then, this model has a software tool that ranks possible alternatives [30]. The static (structural) analysis and the dynamic (behavior) analysis techniques have not been applied yet in migration process to the reengineering Microservices. Thereby, analysis techniques are one of drawbacks of architecture migration. Although these analysis effects on the software structure and the modernization processes, there is still a gap in the area of correlating structural and behavioral analysis [41]. Where, Critical success factors (CSF) are defined as ‘An area where an organization must perform well if it is to succeed’. That means these factors enable enterprises to achieve its goals. CSF targets things that affect quality, customer satisfaction, increase revenues, decrease cost and market share. Effective performance measures help in monitoring performance to detect whether it is meeting enterprise’s goals, how well system is doing, degree of customer’s satisfaction, and finally orient enterprise to take action that improve performance and efficiency [42]. The measurement is observation and quantification while evaluation is a paired measurement with an observation of what would be desired and comparison is putting two evaluations against each other [43]. Although performance measurement and evaluation are ensuring the successful implementation of information systems, also ERP model consists of data models.
Critical Success Factor (CSF) models and phase models [44], evaluation ERP solutions in post-implementation phase is under-research [33]. In [30], [45] previewed some researches that discussed the relation between criteria of ERP selection and enterprise’s size and concluded that the size does not significantly affect criteria selection, but only on the judgment importance assigned in comparisons. For example, flexibility and supplier support are two first selection criteria in large-sized enterprise, however cost and adoptability are the most important criteria for small-medium sized enterprises. In [30] use AHP to measure nine criteria for small-size enterprise are concluded from seven selection criteria models.

[44] Mapped the critical success factors of ERP successful implementation articles since 2002 until 2016 and classified all these factors into four main classes: Organization-related, Customization of ERP, Project-related, and Individual-related. [46] Studied different roles and participations of ERP’s users with factors that effect on their missions via a comparison between four companies with different industrial fields used ERP to solve problems but unfortunately, they gained new problems. [47] Mentioned what CSF means, and all different CSF’s factors from 2003 to 2010. In [48] handles the classification of ERP implementation strategies (organization, technology and people), the context and conceptual model of ERP system implementation and separate between them. CSF is a factor that effect on context implementation model, while conceptual model addressed people, product, process and performance (4P). Also, it studies the user participation as a part of CSF in ERP implementation that was proposed for ten years. [48] Handled the user participation in ERP implementation since 1999 until 2010 where the system development in ERP implementation shifted from technical analysis and programming towards business process design and human elements, and [49] studied the existence of top 15 factors of CSFs that affects in successful ERP implementation in same time, and defines them briefly. It grouped the important and relative impact points of ERP system into six groups as following: Operational, Managerial, Strategic, Technology, Organizational, and Financial Benefits. It also proposed quality of system, information, and ERP as measurement of ERP quality success. The criteria of each measurement are as following: flexible, ease to use, reliable, data integration, efficient for system quality. Understandable, concise, relevant, usable, available, immediately are the criteria of information quality measurement. While ERP’s performance can be measured through: user satisfied of interaction with ERP system, worker’s participation improvement, simple &flexes functionality of company, improvement of individual productivity, customer satisfaction, and decision-making, finally organizational costs reducing.

According to [50], [51], they mentioned that Critical Success Factors of ERP are: Top Management Support and Commitment, Clear Goals and Objectives, Project Management, Change Management, and Selection ERP, BPR, minimum customization, suitability Hardware and Software, Communication and Cooperation, and ERP Vendors Support, Project Champion, User Involvement, User Training and Education, external Consultants, and Project Team Competence. While the five variables of ERP implementation success are: ERP Project Success (which can be measured in terms of time, cost and goals as usual information system contexts applied), User Satisfaction, System quality (flexible, ease to use, reliable, data integration, efficient attributes), Information Quality (understandable, concise, relevant, usable, available, immediately), ERP Performance (can measure through: improvement of worker’s participation, individual productivity, decision-making, customer satisfaction, reducing cost, flexes functionality. [52] Added Legacy systems, ERP strategy and Personnel Business process change and software configuration as a new measures to ERP’s implementation success model. Legacy systems, Business vision, ERP strategy, Project schedule/plans and Top management support are measures to strategic factor. Client consultation, Personnel, Business process change (BPC) & software configuration, Client acceptance, Monitoring and feedback, Communication and Troubleshooting are measures of tactical factor. Legacy system is measured as it used to determine the amount of IT and organizational changes that is required [52].

There are different models are produced to select and evaluate ERP systems. [45] Collected eight models from 1997 until 2006 and studied the dependency between selection criteria of ERP packages and ERP vendors. [31] Used the criteria of updated DeLone & McLean of success IS model, apply hybrid MCDM process (AHP and TOPSIS) on it to detect that service quality is a best criterion (with its sub-criteria: on time delivery, knowledge and competency, error network, availability, access, rate delay and reliability) for two different IS in banking and construction industry sector. [53] Proposed a criteria model based on two evaluation criteria model that proposed in Academic literatures in 1998 and 1999 for information system and ERP system in perpectively. Its criteria are: strategy-fit, technology, change management, risk, implement-ability, business functionality, vendor credentials, flexibility, cost and benefits. It used AHP to calculate relative priorities of various ERP systems to choose on each of proposed criteria. [33] after listed evaluation models from 1999 to 2011 it modified to updated D&M model in 2004, its proposed evaluation model became consist of system quality (reliability, efficiency, accuracy, user-friendliness etc.), information quality (timeliness, relevance, availability, understanding etc.), service quality (reliability, loyalty etc.), individual impact (productivity, ability to make decision etc.), workgroup impact (coordination, communication and productivity) and organization impact (measured by customer-services, decision making process etc.). It used CVR estimation to detect the effective criteria of ERP in post-implementation by 23 criteria and 111 experts ranked them with important, essential, important but not essential. [54] Defined seven performance measures of evaluation; quality assurance review, compliance audits, computer performance evaluation (include: evaluation measurements are made on actual throughput, percent uptime, and IO channel
TABLE 1. Summary of previous evaluation models from 1982 until 2004.

| Bailey and Pearson 1982                     | DeLone and McLean 1992                  | Pitt L, Watson R, Kavan B 1995 | Hitt L, Brynjolfsson E 1996 | Torkzadeh and Dol 1999 |
|--------------------------------------------|-----------------------------------------|--------------------------------|-----------------------------|------------------------|
| • Information system performance          | • Systems quality                       | • service quality              | • productivity              | • Task productivity    |
| • Information performance                 | • Information quality                   | • business profitability       | • business profitiability   | • task innovation      |
| • Information manipulation                | • Use                                   | • consumer surplus             | • consumer surplus          | • customer satisfaction|
| • User satisfaction                       | • User satisfaction                     |                                |                             | • Management control.  |
| • Individual influence                    | • Individual impact                     |                                |                             |                        |
| • Performance of services                 | • Organizational impact                 |                                |                             |                        |
| • Conflict resolution                     |                                        |                                |                             |                        |
| Martinsons et al 1999                     | Jiang and Klein 1999                    | Irami 2002                     | DeLone and McLean 2003      | Sadera et al., 2004   |
| • business value                          | • Performance issues                    | • strategic operational benefits| • Systems quality           | • Systems quality      |
| • user orientation                        | • decision quality                      | • Information quality          | • Information quality       | • Information quality  |
| • internal process                        | • personal impact                       | • Service quality              | • Service quality           | • Individual impact    |
| • future readiness                       | • organizational impact                 | • Individual impact            | • Workgroup impact          | • Organizational impact|
|                                            |                                        | • use                          | • Organizational impact     |                        |
|                                            |                                        | • System usage                 | • use                        |                        |
|                                            |                                        | • Net benefits                 | • System usage              |                        |
|                                            |                                        |                                |                             |                        |
utilization), service level monitoring (include: turnaround times, response times, user problems and requests for change, and error rate), budget performance review, personnel productivity measurement (include: time for development, time for data entry or operations), user attitude survey (include: timeliness, quality of service, and IT system-user communication), post installation review (PIR) (system meets the requirements definition) and cost/benefit analysis. It used two evaluation approaches: a summative approach that focus on outcomes or ends and formative approach that focus on process or mean, and classified performance measures to objective and subjective measures. [55] Studied only user interface and user interaction factors because long-term success of enterprise information system is heavily dependent on its use. Table 1 summarized the most popular evaluation model from 1982 until 2004.

The main factors and trends of evaluation model of systems that mentioned in academic researchers from 1982 is ranked by experts, or applied hybrid MCDM process. Based on these studies, the paper proposed a full roadmap of migration. The proposed migration-decision model consists of evaluation criteria form to evaluate performance state of the current system and answer “is the migration is essential?” Then, it proposed using Neutrosophic-ANP to answer the question “which architecture is adopted?”

III. PROPOSED ROADMAP FOR MIGRATION SYSTEM-ARCHITECTURE

A. PROPOSED MIGRATION DECISION MODEL FOR ERPS

The vision of any enterprise is modernizing their existing systems and services to maintain market share and improve its business agility. Research studies have proposed migrating functions and services to use features provided by cloud computing and Internet-of-things (IOT). It is hard to adopt legacy system Cloud computing or IOT. Because of Adopting new frameworks or technologies are very difficult, the main drawback keys of Monolithic applications related to the maintenance, upgrade and scale. The more reliable architectures than monolith (restricted architecture) are service-oriented architecture and Microservices architecture. Advantages that enterprise can be having after upgrading the current architecture are listed in table 3. Furthermore, Features of Monolith architecture, SOA and MSA is briefed in table 2 and its percentages are concluded from [4], [8]–[13], [37], [39], [56]–[63]. These features are regarding
as advantages that ERP systems are continuously developed to have.

Table 2 and Table 3 are a Proposed Preliminary Attempt to make decision of selecting a suitable architecture to achieve enterprise’s vision and goals. Although Table 2 contains all features that meet main enterprise’s goals and advantages of three architectures in percentage. Also, Table 3 provides decision-based reasons, but the decision is some time is confused. Because percentages of MSA and SOA are close or identical in most features as reusability and parallel development or percentages are not cleared as modularity and innovation. This is a problem face the decision of development and migration. Moreover, the decision makers check tables 2 and 3 to compare with what they desired for enterprise and advantages of migration to specific architectures. But the decision is very fuzzy if the current system’s architecture is SOA, as the enterprise has many pros of SOA and share with MSA, enterprise can’t detect the reason of defect so it can’t decide upgrade architecture or purchase a new system from another vendor.

As a Proposed Preliminary Attempt cares “comparison” and regards semi-helpful, the idea is developed to include “evaluation” and “measurement” principles. The measurement is observation and quantification while evaluation is a paired measurement with an observation of what would be desired and comparison is putting two evaluations against each other [43]. Consequently, the paper proposes evaluation criteria form, a full roadmap serve decision making and implementation. The full roadmap proposes migration decision model and flowchart of architecture migration.

A proposed roadmap is illustrated in Fig. 1. It previews a migration decision model supported with multi-criteria

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**TABLE 2. A comparison between features of the three architectures.**

| Feature                  | Monolithic Ar. | SOA | MSA |
|--------------------------|----------------|-----|-----|
| Reliability (debug&test) | √              | 80% | √   | 90% |
| Fault-tolerance          | √              | 75% | √   | 80% |
| Loosely coupled          | ×              | 70% | √   | 90% |
| independent              | ×              | 70% | √   | 100% |
| Scalability              | Only easier with small code file | √ | 80% | √ | 90% |
| Technical platform       | √              | 85% | √   | 95% |
| ACID transaction         | √              |     |     |
| Relational DB            | √              |     |     |
| Ease of deployment       | Only easier with small code file | √ | 60% | √ | 80% |
| Speed of deployment      | High with small code file | √ | 50% | √ | 80% |
| Frequent deployment      | Only with small code file | √ |     |     |
| Continuous integration   | Only with small code file | √ |     |     |
| DevOps                   | ×              | 75% | √   | 100% |
| Adopt new technology     | ×              | 80% | √   | 85% |
| Reusability              | Only with small code file | √ | 80% | √ | 80% |
| Maintainability          | Only easier with small code file | √ |     |     |
| High cost                | If large file code | √ | 14% | √ | 30% |
| Investment cost          | ×              | 70% | √   | 60% |
| Availability             | Only with small code file | √ | 70% | √ | 60% |
| Distributed environment  | ×              | 80% | √   | 95% |
| Parallel development     | ×              | 80% | √   | 80% |
| Performance with overload| Very bad       | √ | 65% | √ | 75% |
| Complexity               | Low only with small code file | √ | 65% | √ | 90% |
| Serverless architecture  | ×              | 60% | √   | 80% |
| Coupled and cohesion     | ×              | 55% | √   | 85% |
| Granularity              | ×              | 50% | √   | 100% |
| Flexibility              | Only with small code file | √ | 70% | √ | 85% |
| Modularity               | ×              |     |     |
| Polyglot                 | ×              |     |     |
| Innovation               | ×              |     |     |
| Security                 | Only with small code file | √ | 70% | √ | 60% |
| Visibility               | Only with small code file | √ |     |     |
| Risk management          | ×              | 80% | √   | 85% |
| Support IOT              |               | 70% | √   | 85% |
decision approach (Neutrosophic-ANP) to grantee an accurate decision (in black dash part) and the rest of figure illustrates a flowchart of architecture transformation with steps of each architecture’s transformation based on each architecture’s lifecycle.

The Motivation reasons of developing the current system by migrating its architecture to another (for example, SOA or MSA) are determined after assessment the current system’s state and trade-off between (1) what enterprise want to gain, and (2) which architecture able to achieve these needs and

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**TABLE 3. Transformation reasons to different architecture.**

| Monolith to SOA | Monolith to MSA | SOA to MSA |
|-----------------|-----------------|------------|
| • Support all kind of scalability  |
| • Agility  |
| • Cost-effectively  |
| • Support technical platform  | • Build based on bounded-context | • Independent DB |

**FIGURE 1.** A roadmap of transformation ERP system’s architecture with its three main parts: (assessment form, Migration decision model with Neutrosophic-ANP Model and flowchart of implementing the decision.)

- **Stay with SOA if:**
  - System has complex operations.
  - Don’t care with aligning services to business objectives
  - Don’t care with Lacking the necessary skills, DevOps, and automation
  - Don’t care with low performance in a distributed application

- **Start with monolith if:**
  - Startup with small application and small resource base.
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enterprise capability’s costs (migration’s cost are architecture’s limitations, money, resources and time). The proposed critical criteria evaluation form that triggered migration architecture decision is previewed in Fig. 2. The Critical criteria evaluation form is listed in Fig. 1 as a file sample connected with evaluate system process. The critical criteria evaluation form and flowchart are a recipe of evaluation and transformation any IT-system.

The third part of a proposed migration roadmap is Neutrosophic-ANP. Fig. 3 declare the network of the migration-system architecture decision problem. The distinguishing of ANP is declaring the actual relationships between criteria, alternatives and between sub-criteria whatever in same cluster or not. The inner dependency between elements (sub-criteria) of criterion (own cluster) appear as a loop connection and is drawn as an arc (blue half circle in figure below), feedback relationship appears as cycle and is drawn as a line with two arrows in dual directions. Nodes (sub-criteria) in cluster also may have relationship between themselves and other nodes in other clusters (influence and dependent). Critical evaluation criteria that are used in evaluating current systems will be used as an index of

![FIGURE 2. A critical criteria evaluation form.](image)

![FIGURE 3. Analytical network for migration decision.](image)
The proposed migration model that supported with Neutrosophic-ANP approach is applied to make decision to choose a suitable architecture. Suppose that the architecture of current system is monolith. Unfortunately, the current system needs to be developed to keep its high performance under enterprise’s scalability and increasing its activities and its sleekness to the agility. Hence, this is required applying a Neutrosophic-ANP approach. Steps of applying Neutrosophic-ANP approach to make decision to choose a suitable architecture are:

1. Create unweighted super matrix: Compare sub-criteria and alternatives based on the nature of relationship based on neutrosophic Scale set for Saaty’s linguistic trade-off in Table 4, by using equation 1 [29].

\[
s(r_{ji}) = \left( l_{ij} \times m_{ij} \times u_{ij} \right)^{\frac{T_{ij} + I_{ij} + F_{ij}}{3}}
\]  

2. Create weighted super matrix
3. Create limit matrix
4. Analysis

Briefly, the proposed full roadmap of migration consists of three main phases: assessment by critical criteria evaluation form, make decision and migration. Each phase has many steps. They are:

1. Assessment phase: asset the current system state by evaluation form in Fig. 2.
2. Decision phase: The decision may be changing the current architecture to another or keep it without exchange. If current system is not satisfying, decision maker can use architecture’s features in tables 2 and table 4 to choose a suitable architecture for his trade-off. If decision is inconsistent, then, using a Neutrosophic-ANP approach is helpful. Neutrosophic-ANP approach steps are illustrated in the right part of Fig. 1 and the decision problem (criteria-alternative) network is declared in Fig. 3. the use-case section handles in details and with numeric steps.

3. Migration phase: after a recommended architecture is decided, steps of transformation from monolith to SOA or MSA or transformation from SOA to MSA are applied. Steps are listed as a flowchart in un-dashed section of Fig. 1.

### B. QUALITY ASSESSMENT OF ERP’S ARCHITECTURES

Parameters of system architecture evaluation combine operational, technical and computational sides. The most critical parameters that are proposed are time to the market, future proof, stability, cost, security and maintainability. As security assessment has many aspects and very vital and important requirement, it is not measured in this paper. This paper evaluates the most used architectures in enterprise resource planning systems; monolithic, service-oriented and Microservices based on these proposed parameters. Openbravo, Odoo 12 and Metasfresh 5.144 are chosen as representative for monolithic, SOA and MSA. Apache JMeter is an open-source tool used for testing. The test is done by version 5.2.1 of JMeter and on Ubuntu 18.04 as a unified open-source operating system for three servers.

Load and stress test are types of performance profiling, performance test are measured because it is one of the most important non-functional requirements for ERPs and most valuable distinguish parameter of architecture design. Further, performance is one of the major factors of adopting Microservices [36]. The transaction per second (TPS), byte throughput over time, response latencies over time, code response (response code of HTTP requests, like 200 for success, 404 if server fail) and byte that sent and received are checked to assess communications between different components of architecture (layers or services), and architecture’s performance for transactions execution. These measurements regard as a pointer to different parameters as time to the market, future proof, stability, cost and maintainability. The test simulates 13 main transactions done by more than 200 concurrent users. Software configuration is done based on recommendations of each ERP system needs. Odoo12 Server’s requirements are python 2.7.17, PostgreSQL 9.4, while...
openBravo server are oracle 12c, Java SE 11 OpenJDK and Oracle JDK, PostgreSQL 9.4, apache Tomcat8.5, apache HTTP server 2.2 and apache Ant 1.10.6. Requirements of metasfresh 5.14 server are Docker server engine 19.03.12, WebUI server, PostgreSQL 9.5, Apache2, OpenJDK-8 RabbitMQ, and Elasticsearch. Hardware configurations for all are processor: Intel Xeon X5660-3.2 Ghz, RAM: 32GB DDR3R, 128GB SSD and 1TB western digital hard for data store.

The scenario test is combined more than two integrated modules and more than two relational tables in DB of ERPs. Based on three Benchmark components and consistency of performance test in mimicking what happens in realistic cases by real users in peak hour, the test script reflects critical sessions that contains the site’s critical transactions. The main steps of this scenario test are done by virtual clients and virtual inner users as accountants, store man and managers. Their main transactions are: browsing products on website, filtering product by offer/variant, purchasing multi-items with different quantities, then address and needed data are inserted, logging, checking and confirming the order. Other transactions are done by employee in background to make client’s order like logging each one as his authority, check quantity in store, creating invoices, finally making reports about sales and customers. Tests are applied many times with different numbers of concurrent virtual clients and employees for three systems. All these transactions are distributed into sales, quotation, purchasing, web site, invoicing, products and CRM modules. Names of modules may seem different from system to another but they share in functionalities. All scenario tests that have been tracked for three architectures are applied and illustrated.

Response time is the elapsed time between an inquiry and its response, so it used as a measurement of system software performance. Figs. 4, 5, 6 illustrate response time in MSA, SOA and monolith respectively with 1500 concurrent virtual users. High values for response time mean high delay time. Low response time refer to successful computing. Based on these figures, MSA has a low response time rather than SOA and monolith which are semi-similar measurements in some transactions. (Note: each color in diagram represents different business transaction; colored lines are not representing the same transaction in three figures).
Throughput is amount of data (requests) that handled between servers and inner users’ terminals and clients’ devices during the performance test execution, where latency determines how fast the transformed data from client or users to server. Fig. 7 represents throughput for three architectures for same response time at 1500 concurrent users. SOA excels monolith in some transactions and resembles in the other, but MSA exceed them.

Latency for MSA at 1600 and 1000 of users is illustrated in Fig. 8 and Fig. 9 in respectively. It is noted that there is not a huge different between two measures. While Fig. 10 shows latency of SOA at 600 users and it approximates latency of MSA at 1000 users.

Load Testing is a type of performance testing to evaluate the system behavior under load and stress tests. Network load traffic is one parameter of system behavior evaluation, and it implicitly reflects response time, so Response code of transactions is used as a reference to architecture’s stability. Fig. 11 showed the code response at 2500 users for monolith ERP, where Fig. 12 and 13 are captured at 4000 and 4600 users of SOA ERP and MSA ERP respectively. These numbers of users is not the maximum number of users for architecture’s stability.

C. DISCUSSION

Based on load test and all measurement that are illustrated in figures 4 to 13, Latencies on MSA excels latencies of SOA where latencies of MSA with 1600 and 1000 users regards approximated while SOA with 600 users close to 1000 of MSA. Also, response time and throughput of MSA is better than measurements of SOA and Monolith at same number of concurrent users. Containerization also helps in increase availability and reliability of MSA rather than SOA and monolith. MSA hold out number of concurrent different
users (client, manager, employee) more than both SOA and monolith and achieved the highest response in code 200 (success), less response in codes 302 (temporarily redirecting) and 304 (using cached version of response) also in code 408 (idle connection by server). Although MSA get less response with code 500 (internal server error) but it has not got any response with code 404 (not found) that SOA had got it at number of concurrent users 4000 less than MSA’s users. MSA excels in stability with 4500 users rather than SOA that handles 4000 users and monolith with 2500 users.

Micro-services units are deployed on container images that run on Docker, these containers provide load balance and
auto-scaling if any node fail, another instance image will be created automatically and speedy. But if container is used in monolith, the results are not the same because, whole system is deployed on one container not one unit as in MSA. Cloud services do not serve functionality as container do, which appears in huge system as ERPS because of differences between virtual machine and container.

Easy access to market and future proof are beside polyglot rather than unified technology. So future proof of Microservices is slop-up more than SOA because it adopts double polyglot - programming language and persistence- and each micro-service has own database while SOA has centralized database for whole system. MSA and SOA excel on monolith in future proof. Although up-slope of time to the market and future proof for MSA, the same reason of that adds complexity for MSA rather than rest architectures.

Where time to the market and future proof are implicitly referring to maintainability, MSA is more excel than SOA and monolith excel than SOA and MSA provided that small code, but in ERP case it is a nightmare in maintainability and has a low rate in time to the market and future proof.

Briefly, the low latency, low response time and high throughput represent the ideal measurement for software performance. Based on measurements of these three elements and previous figures of three architectures, MSA is exceeding SOA and performance of SOA sometimes likes Monolith in handling many transactions. MSA can handle more requests than SOA, under current conditions. Consequently,
IV. AN EMPIRICAL APPLICATION—CASE STUDY

The following case study is a real application for the paper’s cores. ‘Hitac’ is a profit enterprise for import and export services. It is a moderate-sized enterprise in Egypt. It imports from neighbouring countries to sell in Egyptian market, also export to Jordan and Saudi Arabia. Unfortunately, COVID-19 adds many changes in trade not only at health level. COVID-19 changes trade patterns, trade trajectories and thereby customer’s manner [64], [65]. Because of the negative effects of COVID-19 on marine navigation, road transport and air traffic prohibition, the enterprise seeks to have branch and two stores in Saudi Arabia kingdom. One is in the eastern region, Dammam, to cover middle and east zones; the other one is in the western region, Jeddah, to cover west, north and south zones. This expansion on marketing and customer services grantees decreases damages caused by the closure of airports and ports. Saudi Arabia branch and stores will regard the distribution centre for the rest of the Gulf countries and will open a new market in the Middle East. About shipping and transportation in Kingdom, the enterprise will depend on road transport, Dammam and Jeddah ports. Enterprise seeks to start its branch and stores in the middle of 2021. The current modules of ERP system that running are Human Resource, Sales and Marketing, Inventory, Finance and Accounting and Customer Relationship Management (CRM). The architecture of current ERP system is SOA. The enterprise adopted ERP system handling a huge data of agents, suppliers, customers and employee. Inevitably, the size of data and operations will multiply after the expansion. Consequently, the enterprise is forced to make upgrading CRM decision and adopting a new supply chain management (SCM).

The proposed model and Benchmark will help enterprise to keep its high performance under enterprise’s scalability and increasing its customers and activities by providing an accurate decision of choosing a suitable architecture to move to it.
The first part of proposed migration roadmap that visualized in Fig. 1 is the migration decision model. The migration decision model steps are: assessment the current system’s architecture by using the evaluation form in Fig. 2. If decision is easy to make, use the second part of the proposed migration roadmap; flowchart, as declared in Fig. 14. But...
TABLE 5. Numerical steps of applying Neutrosophic-ANP.

Step 1: Create unweighted super matrix

Unweighted super matrix is done at nodes level (sub-criteria level).

- Using Neutrosophic-ANP steps to get weights/eigenvectors for matrix.
  - Compare sub-criteria and alternatives based on the nature of relationship.
  - Using this equation Eq. 1 to convert Neutrosophic values to crisp. After that, calculate column summation; divide crisp values by this summation. The final criteria weight is estimated by calculating row average of previous.
  - The judgment of alternatives for criteria and is sub must be respect to the nature and size of current system that want to make transformation decision for it (goal). Because the monolithic architecture is a best choice only if the code file is small size, otherwise, this architecture will be a nightmare for developers and enterprise at all levels of management and users (client, employee, manager and etc.).

- Table 4 is used by experts in their judgment in pairwise comparison.

- Weights are set in unweighted super matrix based on the nature of relationship (dependency or influence) between nodes in criteria and alternatives. For arrows out from criteria cluster to alternative cluster, weights are set in position of alternatives (influence) on row and criteria on column (depend). Arrows out from alternative cluster to criteria cluster, weights are set in position of criteria (influence) on row and alternatives on column (depend). For inner dependent (loop), set 1 at diagonal for sub-criteria in same criteria group. These relationships are illustrated in Fig. 3.

- The easy way to set pairwise comparison value in correct position in matrix based on relationship directions is setting influence in column and depend on row.

- Unweighted super matrix is illustrated in Fig. A1: (note: the abbreviations of sub-criteria is the first letter of its words)

| Goal | system quality | criteria | service quality | alternatives |
|------|----------------|----------|----------------|--------------|
| FL1  | 0.00             | 0        | 0              | 0            |
| FL2  | 0.09             | 1        | 0              | 0            |
| FL3  | 0.00             | 0        | 0              | 0            |
| FL4  | 0.11             | 0        | 0              | 0            |
| FL5  | 0.00             | 0        | 0              | 0            |
| FL6  | 0.00             | 0        | 0              | 0            |
| FL7  | 0.00             | 0        | 0              | 0            |
| FL8  | 0.00             | 0        | 0              | 0            |
| FL9  | 0.00             | 0        | 0              | 0            |
| FL10 | 0.00             | 0        | 0              | 0            |

Figure A1: Unweighted super matrix

Step 2: create weighted super matrix

- Repeat all sub-steps in first step, but judgments are done at clusters levels (not nodes as previous).
  - The weights at 1st level cluster is listed below in Fig. B, (note: the abbreviations of criteria is the first letter of its words).

| Goal | SQ | IQ | US | S | SQ |
|------|----|----|----|---|----|
| FL1  | 0  |    |    |   | 0  |
| FL2  | 0.29 |    |    |   | 0.29 |
| FL3  | 0.11 |    |    |   | 0.11 |
| FL4  | 0.132 |    |    |   | 0.132 |
| FL5  | 0.199 |    |    |   | 0.199 |
| FL6  | 0.277 |    |    |   | 0.277 |

Figure B: Weighted matrix at cluster level

- Multiply the cluster weight in its corresponding sub from unweighted super matrix (above matrix in Fig. B and unweighted super matrix from step1 in Fig. A). The result of this multiplication is illustrated in Fig. C.
TABLE 5. (Continued.) Numerical steps of applying Neutrosophic-ANP.

- Normalize the produced matrix is summation values of column is greater than 1. The normalization is done by divide the product weight on column’s summation.

- Where The Consistency Ratio (CR) is the ratio between two averages which are the Consistency Index (CI) and the Random Index (RI), CI is the average of sum of errors when the eigenvector method is used. The RI is the average of the sum of random errors generated by simulation. The CR for all 69 pairwise comparisons that calculated with Neutrosophic set after corresponding to average of experts’ evaluation has values 0.003, 0.03, 0.04, 0.08, 0.08 or -00.05. That means that experts’ evaluation for the system and architectures respect to proposed criteria is optimum.

- All columns summation are calculated more than one. So matrix in Fig. C need to be normalized. Fig. D is the weighted super matrix.

Figure C: The output of multiply unweighted matrix in weights at cluster level

Step 3: create limit matrix

- Multiply weighted super matrix with itself until get the same value for all cells at row level. Where, the weighted super matrix is raised to a significantly large power in order to have the converged or stable values. Some literatures set value of power equal to 
\[ (2K - 1) \] where K is random number. After many trials the weighted super matrix is raised to power equal to number of clusters in ANP model (criteria and alternatives). In this case study, six is the number of clusters, the limit matrix is gained after 6 times of multiplication (64 is value of power).

- Limit matrix is illustrated in Fig. E.
TABLE 5. (Continued.) Numerical steps of applying Neutrosophic-ANP.

| Numerical steps of applying Neutrosophic-ANP. |
|-----------------------------------------------|

The decision rank for each alternative are: 6% for monolithic architecture, 13% for SOA and 21% for MSA.
So the MSA is a suitable architecture for this system which enterprise can get desired performance by it, and it is the recommended decision.

If the decision is ambiguous, the role of Neutrosophic-ANP is clearly visible. Its steps of applying, to make decision of choice a suitable architecture, are showed in Fig. 15 and its network is in Fig. 3. The numerical steps are mentioned in table 5 and the Neutrosophic set for linguistic trade-off of Saaty is mentioned in table 4. The decision rank for each
alternative is: 6% for monolithic architecture, 13% for SOA and 21% for MSA. So, the MSA is a suitable architecture for enterprise’s demands which enterprise can get desired performance by it, and it is the recommended decision. The current CRM’s architecture will upgrade to MSA.

As for the SCM system, Benchmark is very helpful because it provides a quality estimation and performance study. It saves time that is consumed to choose a suitable decision. Also, there are many aspects of less the cost, but the essential aspect is the cost of adopting non-suitable architecture. Under COVID problems, nature of SCM’s operations (shipping optimization, reducing overhead costs, cash flow and risk mitigation improvement), error like that is not acceptable. It may cause destroying an enterprise’s reputation technically. Adopting MSA for SCM is the recommended system by Benchmark because it fit enterprise’s goal of expansion, expected customers and trade operations from the Arabian Gulf countries at first years.

A. DISCUSSION

The measurement of Benchmark provides a high-quality performance for MSA in many aspects especially in stress-test which is grant a distinguish advantage in scalability and reliability. So, it is a recommended architecture provides high performance for heavy usage. For the expansion plan of the enterprise in this case study and heavy expected data and operations, the Migration decision model with Neutrosophic-ANP recommend MSA as a suitable architecture for ERP system. Thereby, there is a convergence between decision of migration decision model Neutrosophic-ANP Model and Quality assessment Benchmark. That adds a value and consistency for a proposed migration decision model. Furthermore, the proposed critical system transform architecture criteria are close with parameters of performance test that are measured for QOS. Evaluation of system architecture agrees with system software evaluation. This means that selection system architecture is very vital and critical step for developing system software.

V. CONCLUSION

Developing any enterprise system based on choosing a suitable architecture that support agility, productivity, achieving the both short-term and strategic goals and using modern IT trends such as containers, cloud computing and DevOps. Most researches handled architecture migration for running system, not addressed how chooses a suitable architecture at first time. Most evaluation models that provided before used one dimension of criteria, while in real practice, criterion may has sub-criteria or factors to grantee precision of assessment. Moreover, these evaluated models did not handle all factors that judge on all system aspects. Furthermore, architecture testing is not less important than software testing. Benchmark of architecture is as a pointer for building software system in respect of industry criteria and constrains of test environment. Measurement of QOS for architecture is helpful for performance analyst, software architecture consultant, system analyst, system and network administrators and decision maker. Acquaintance of architecture Benchmark and its QOS measurement before building system or in development current system will save costs, consuming time of diagnosis and manipulation and also reduce threats to a business and opportunities of following “fire-fighting” approach (monitoring QOS of system and reacting it when problems arise). Aforementioned, MSA appeared since a few years, its Benchmark is not more available like SOA and monolith. QOS for ERP system based on it is not full and available easily. There are commercial comparisons between different ERPs that are provided by its own vendors or by competitors but it is not enough for developers or any IT members as it is not covering technical sides that they care.

This paper supports decision of developing a system’s architecture and also provides a guide of adopting system’s architecture by proposing a migration decision model and a Benchmark in respective. As process of evaluation is more accurate, the paper provides an assessment form with multi-dimension of evaluation criteria. The paper used ANP decision approach that produces accurate measures for sub-criteria rather than others such as AHP. The pairwise comparison that applied for ANP is Neutrosophic set.

In case study the decision makers in enterprise decided upgrade the current CRM as COVID’s effect on trade and customer manner, enterprise’s expansion plan, keep current customer’s loyalty and acquire new, improving customer service under new arguments of constrains and risks, keep consistence reliability, increase employee productivity. As it is a critical matter, enterprise does more studies. Enterprise also decides not purchasing a new CRM because of familiarity, not need to migrate data, its integration with legacy system and the cost. However, enterprise can’t decide which system architecture supports their needs. The proposed roadmap of migration with its two main components serves this purpose. Where the first part applies migration decision model via Neutrosophic-ANP to make migration decision, the second part, flowchart of migration steps, helps in decision execution. AS paper interests in providing an integrated help, it provides a quality assessment for same three architectures which are subject of study. The quality assessment (Benchmark) also helps in case study. The Benchmark is more help than comparisons between three architectures that is addressed in table 2. Because the Benchmark provides a visualized comparison for real running systems. This Benchmark helps enterprise in case study to make purchasing decision easily. This Benchmark also help enterprise case study in saves time, cost and experience error exposure.

The case study proves that “A convergence between decision of migration decision model Neutrosophic-ANP Model and Quality assessment Benchmark assure that Neutrosophic-ANP approach and evaluation criteria that are proposed for migration decision model decision model is accurate”. This model is qualified for applying for any information system whether for assessment or development. The analysis step in Neutrosophic-ANP model showed that:
the security control, relevance, system interface are control criteria for monolithic architecture. While response time is control criterion for SOA, Reusability and DB independency are control criteria for MSA. Usability, standardization and support scalability are common control criterion for both SOA and MSA.

Most published papers and literatures about Microservices are not empirical. Further, there is a gap between academic research and industry practices in Microservices. The main paper’s result is filling this gap by one of the empirical aspects with an academic study support. However, security is one of MSA challenge, so Measuring and evaluating security, DB consistency and virtualization and network with its related services such as cloud and containerization of MSA are the most future work are needed in Benchmark industry and ERPs industry.

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