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# QOS-AWARE EVALUATION CRITERIA FOR WEB SERVICE COMPOSITION

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**ABSTRACT**

Service composition is becoming increasingly pervasive, affecting the way service computing is utilized. Service composition has become an essential element of service deployment due to the fact that single services are unable to fulfill user requirements. Owing to the dramatic growth of services claiming similar functionalities, creating a value-added composite service from a number of candidate services to address the desired goals is a challenging task. To overcome this challenge, various Quality of Service (QoS) aware Web Service Composition (WSC) approaches have been implemented and have a significant impact on composition efficiency. However, there is a lack of knowledge on the impact of such approaches on service composition processes. Hence, this study is aimed to evaluate existing approaches based on QoS aspects. A mathematical-based QoS-aware evaluation framework is proposed and tested on the state-of-the-art approaches. The criteria used for evaluation are first identified from a comprehensive review of related literature. Multi Criteria Decision Making technique is applied in order to formulate a new QoS-aware evaluation method for Web Service Composition approaches based on the identified criteria. The approaches are evaluated using the proposed method to prove its applicability and correctness. The results demonstrate how a service composition approach addresses QoS aspects and assists researchers in outperforming their service composition solutions. The statistical results show the efficiency and correctness of the evaluation method.

**Keywords:** *Web Service Composition, Quality of Service, Comparative Evaluation*

## 1 INTRODUCTION

Web services have recently garnered a significant amount of attention as the dominant technology to realize Service Oriented Computing (SOC) [1]. They strongly support the development of low-cost, rapid, massive, evolvable, and interoperable distributed applications as the major goal of SOC through defined XML-based standards such as Web Service Description Language (WSDL) and Simple Object Access Protocol (SOAP). Furthermore, the emergence of recent SOC such as cloud computing, Software-as-a- Service (SaaS), and Web 2.0 are being grounded on Web services. Web services offer a significant advantage over former middleware, whereby such services provide simpler standards-based loosely coupled middleware to connect data, systems, and organizations. However, the real power of Web services cannot be realized unless service composition is employed efficiently. Ramakrishnan and Tomkins [2] stated that service composition has brought about a change in the Web from being a “read-only” repository of Web pages to a Web of services that can be enriched and composed. Nowadays, the number of services providing the same functionalities is escalating rapidly. Selection of the right service to compose or utilize is a demanding task. In order to address this issue, the parameters related to non-functional properties need to be considered along with functional properties. This leads to the emergence of the QoS concept in service computing. The numbers of criteria that should be accounted for can be taken as subset of QoS which comprises of a diverse range of properties from response time to security.

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The aim of implementing QoS in service deployment process is to enhanced and optimized service-oriented processes. This in turn, increases satisfaction and interaction between service providers and consumers. Indeed, QoS-aware SOC can achieve its full potential and authentic performance by fulfilling QoS criteria. Although qualifying Web services is a challenging task with respect to fulfilling QoS criteria, addressing these criteria for composite services is even more daunting. QoS-aware service composition is highly challenging due to its complicated nature whereby various services composed to create an added-value composite service. QoS-aware service composition is vital from two perspectives, namely, the service providers and service consumers. From the former viewpoint, it is highly crucial for service providers (composers) to select services which are most reliable and readily available to fulfill the desired criteria set by the consumers for composition. From the latter viewpoint, satisfying the required criteria by candidate services is also significant, regardless whether the service is single or composite. Although a bulk of research has been carried out on Web service composition in the industry and academia, there is a lack of research which is devoted on QoS-aware service composition.

Nonetheless, there is a lack of appropriate and comprehensive reviews on investigating the role of QoS in Web service composition. This study aims to present a novel mathematical-based evaluation method for service composition with respect to QoS. In this regard, a taxonomy of Web service composition solutions which is an extension of our previous work [3], is presented and the existing approaches are classified in their respective categories. A rigorous review on the existing literature is conducted, and the most relevant and updated literature are selected and analyzed in order to achieve this purpose. Following this, the evaluation criteria are identified with respect to service composition and QoS. These criteria are demonstrated mathematically by applying a decision-making technique, and a new QoS-aware evaluation formulation is introduced for service composition approaches. These approaches are evaluated based on the proposed formulation to prove its applicability and correctness. Finally, the results generated are used to demonstrate how existing service composition approaches address QoS.

This paper is organized as follows. The classification of the state-of-the-art Web service composition approaches are presented in Section 2. The evaluation criteria with regards to service composition and QoS are detailed in Section 3. Primary assessment of the approaches is described in Section 4. Section 5 demonstrates how the listed criteria can be transformed into mathematical-based criteria. A comparative evaluation of the approaches with respect to each mathematically defined criterion is described in Section 6, followed by statistical analysis. The results and discussion of this study are presented in Sections 7 and 8 respectively. Finally, the conclusions of this paper are presented in Section 9.

## 2 CLASSIFICATION OF STATE-OF-THE-ART WEB SERVICE COMPOSITION APPROACHES

In this section, a new classification on service composition approaches is introduced. The existing approaches are classified into four categories, namely, syntactic-based, semantic-based, AI-Planning based, and context-based. The hierarchical classification of the Web Service Composition (WSC) approaches is illustrated in Figure 1. A brief explanation of the approaches is provided for each category. It shall be noted that there are no predefined, strict boundaries between these four categories.

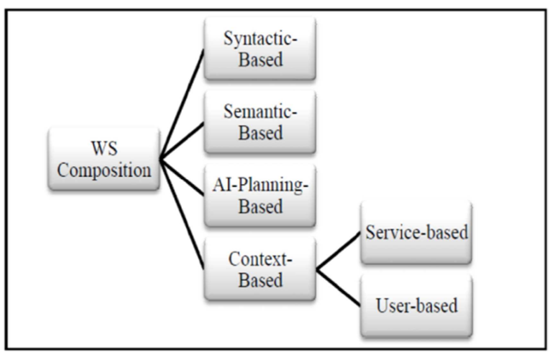


*Figure 1 Hierarchical Classification of WSC Approaches*

### 2.1 Syntactic-based Approaches

Approaches based on XML such as BPEL-based compositions are classified as syntactic-based approaches. There are two major approaches in the syntactic-based WSC realm, namely, WS orchestration and WS choreography. In the former approach, a central coordinator (orchestrator) is devised to invoke and combine the atomic activities and compose available WSs. In contrast, a central coordinator is substituted in the latter approach and complex tasks are defined through the definition of conversation in which each participant should undertake [4]. Web Service Business Process Execution Language (WS-BPEL) and Web Service

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Choreography Description Language (WS-CDL) are two representative languages commonly used for orchestration and choreography, respectively. The state-of-the-art approaches classified under this category are briefly discussed as follows. A Petri-net-based WSC approach is proposed in [5] through which visualization, creation, and verification of existing BPEL processes can be executed. A secure-based approach is proposed in [6] in order to design secure orchestration and choreography standards using formal foundation, which concerns specifically on orchestration and choreography security. However, the approach leverages formal methods to sustain correctness and reliability, and neglects other security criteria. A formal framework called SpiG4WSC has been proposed, which integrates Spi-calculus [7], secure global calculus [8], and adds a number of service syntaxes and operational semantics. A technique called Webπ which performs mapping from BPEL process to π-based calculus is proposed in [9]. The technique is concentrated on the transactional aspects of the BPEL language. An Improved Particle Swarm Optimization (IPSO) algorithm is proposed for WSC in [10]. In this model, WSs can be selected with respect to optimal QoS and composed into value-added composite service. The QoS characteristics in WSC are considered in [11], in which a QoS broker is proposed and complements UDDI via non-functional aspects.

### 2.2 Semantic-based Approaches

In XML documents, the definition of the included data cannot be described, and therefore it is considered as deficiency for XML. Lee et al. [12] states, "The current Web has evolved into a medium that can be interpreted primarily by humans rather than computers". In other words, automatization can be particularly challenging due to the absence of a well-defined definition for information, and manual intervention is required even for the simplest tasks. The semantic Web is created in order to address this issue, and provides additional machine-readable semantic descriptions. The semantic Web is a boon in computing, and it improves collaborations between people as well as automates service process [12, 13]. Several state-of-the-art approaches relevant to this field are summarized and presented as follows. A conversation-based Web service composition process is proposed in [14], whereby a generic composer agent can be generated automatically through the proposed approach. The user requirements are represented by a set of goal obligations which are used to direct the composer. Event Calculus (EC) formalism is selected to formalize obligations and their management. A model-driven approach is presented in [15] in order to specify semantic Web service composition. In this approach, UML, which is a specification language, is implemented and descriptions of composite processes are synthesized through XSLT transformation. OCL is utilized in [16] due to the fact that compositions may require various conditions which comprise of pre and post conditions on processes as well as conditions of control constructs. A variant of UML-based approach for semantic Web service composition has been proposed in [17]. The UML models for semantic WSC are transformed into a model-checking language called Promela. In this manner, the correctness of WSC can be verified using an automated verification tool known as SPIN. Kona et al. [18] proposed an automatic approach for semantic WSC, in which an agent-based technique is implemented to improve their work. Planning, discovery, and selection are carried out in an extended work [19] via intelligent agents without manual intervention. Consequently, automatic WSC can be managed by means of intelligent agents across decentralized repositories.

### 2.3 AI-Planning based Approaches

Artificial Intelligence (AI) Planning is an important branch of software engineering and has been implemented successfully in service-oriented computing. In service composition, AI based approaches play a key role to identify which WSs should be used and how they can be composed to address functionality on the Web [20]. Excellent surveys relevant to AI-Planning approaches used for tackling WSC issues can be found in [3, 21]. A number of AI-Planning techniques have been utilized for service composition such as Situation Calculus, PDDL, HTN, and graph planning. In this section, two of these methods are briefly discussed.

### 2.4 Hierarchical Task Network (HTN)

HTN planning is one of the commonplace AI techniques, which has been widely used for service composition [22]. In this technique, atomic WSs are mapped to HTN operators while composite ones are mapped to HTN methods [3]. There is a wealth of research that justifies the implementation of HTN in addressing WSC issues and it is believed that HTN planner domains are capable of illustrating composite service descriptions. A couple of works [23, 24] highlighted that HTN planner poses higher efficiency compared to other planning languages such as Golog. Sirin [22] proposed an ideal HTN planner called SHOP2 which can be employed as

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grounding in order to integrate planning and external information resources, including Web-based resources. Integration of Description Logic (DL) with HTN is proposed by [22] in order to overcome limitations and support non-functional properties such as performance and correctness efficiently. Tabatabei et al. [25] proposed a hybrid algorithm with HTN-DL formalism in order to support automatic service. This approach integrates HTN planning, Description Logics (DL), and WSMO, and HTN-DL is selected as the AI-Planning technique since the technique is more optimized than HTN.

Tabatabei et al. [25] provide the following reasons in justifying the above claim: "Firstly, the hierarchical structure of HTN-DL domains can conveniently describe composite Web service descriptions and fit in well with the loosely coupled nature of Web services. Secondly, the components of the planning system, the OWL-DL reasoner Pellet and the API for OWL-S services are also released as standalone tools and have been incorporated in many systems". Sirin [22] stated that SHOP2 can be utilized in OWL-S Web Service descriptions and it is an algorithm that performs translation from OWL-S service descriptions to the SHOP2 domain. Hristoskova et al. [26] demonstrated another example of integrating OWL-S with HTN planner for automatic service composition. In this approach, composition is achieved while satisfying specific QoS requirements and constraints such as cost or execution time of the invoked WSs. A recovery mechanism has also been proposed to compensate for unavailable services rather than automatic composition. In such cases, the unavailable services are replaced with equivalent services or a new composition is carried out to achieve the required results.

Paik and Maruyama [27], however, proposed a framework to automate WSC using AI-Planning technique by integrating physical composition (Constraint Satisfaction Problem (CSP)) and logical combination (HTN). Real life planning and scheduling problems on the Web have been discussed as well.

## 2.5 Graph planning

The final AI-technique discussed in this section is Graph Planning, which was developed by Avrim Blum and Merrick Furst in order to automate planning in 1995. In this technique, a planning problem is expressed in STRIPS (Stanford Research Institute Problem Solver) and serves as the input whereas the sequence of operations used to achieve a goal state serves as the output. Feng and Kowalczyk [28] proposed an approach for distributed service composition, in which multiple agent services are contributed to create a composition collaboratively. The integration of Constraint Satisfaction Problem (CSP) and Graph Planning is the novelty of this approach, whereby composition of WS in distributed environments is solved automatically in a decentralized fashion.

## 2.6 Context-based Approaches

"Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves"[29]. Indeed, useful information on the environment where WSC occurs is provided in context, through which tracking is enabled for the whole composition process. Tracking requires the necessary information contained within the context such as triggering the appropriate policies and regulating the interactions between WSs in accordance to the current state of the environment [30]. In this regard, a semantic-based context-aware dynamic service composition framework is proposed in [31], wherein users are able to request for applications in natural language. The framework is capable of composing applications based on the context information of different users.

In addition, dynamic environments are adapted autonomously, whereby new applications are composed whenever there are alterations in user contexts. In an attempt to increase the efficiency of WSC, Zakaria et al. [30, 32] proposed an approach that accounts for the role of context and policies in service composition process, and their approaches is context-oriented and agent-based. They leveraged the interactions between WS agents to the level of conversations in order to achieve the desired efficiency. However, the challenges of WSC remain unresolved in pervasive computing environments. Mokhtar et al. [29] developed an approach in which OWL-S (Ontology Web Language for Services) is selected as a perfect framework for semantic Web service description and used to model contexts for user tasks. Mrissa et al. [33] employed a semantic context-based approach for WSC.

# 3 THE PROPOSED EVALUATION FRAMEWORK

The framework developed for QoS-aware evaluation is presented as follows. The framework consists of four steps, as shown in Figure 2.

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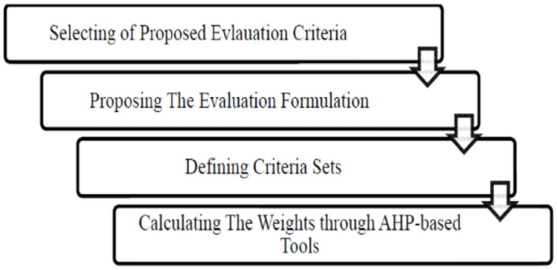


*Figure 2 Proposed Framework for QoS-aware Evaluation of Web Service Composition*

### 3.1 Evaluation Criteria

The first step of the framework involves identifying the evaluation criteria. In this section, the criteria used for comparing various WSC approaches are presented and briefly discussed in Table 1. From Table 1, several criteria are assigned with either the symbols "✓" or "×". The former symbol indicates that the criterion is either supported or improved by the stated approach. The latter symbol however, implies that the criterion is neither supported nor enhanced by the stated approach. Detailed description is provided for each criterion, as shown in Table 1. It shall be highlighted that several terms shown in Figure 5 such as "Model Driven", "Formal Method", and "Agent-Based" are explained in this section. Model Driven Architecture (MDA) is a software development approach which is centred on the creation of models rather than program code such as UML. One of the major goals of MDA is to separate design from architecture. According Dillon [34], "formal method manipulates a precise mathematical description of a software system for the purpose of establishing that the system does or does not exhibit some property, which is itself precisely defined". Agent-based refers to a piece of code that acts on behalf of the user with the authority to decide the best action for the user.

### 3.2 Mathematical Formulation

The second step involves constructing the mathematical formulation for the proposed evaluation framework. Multi Criteria Decision Making (MCDM) has a remarkable impact on scenarios involving various alternatives and decision criteria. MCDM technique is chosen in this study since the criteria consist of different values, which influence the evaluation process. The Analytical Hierarchical Process (AHP) proposed by Saaty (1994) is one of the well-known MCDM techniques and is selected for the evaluation process. This technique offers the capability of assigning different values, i.e. different weights for a particular criterion, and is therefore suitable for a systematic evaluation process. In order to evaluate WSC approaches, QoS-aware Service Composition (QSC) is introduced here, which is a metric used to measure the efficiency of service composition approaches based on the proposed criteria. The QSC values are computed based on the following equations:

$$\mathrm{QSC_k} = \mathrm{CoM_k} + \mathrm{QoS_k} \quad (1)$$

$$\mathrm{CoM_k} = \sum_{i=1}^{3} w_i * i \quad (2)$$

$$\mathrm{QoS_k} = \sum_{j=1}^{8} w_j * j \quad (3)$$

$$\mathrm{QSC_k} = \sum_{i=1}^{3} w_i * i + \sum_{j=1}^{8} w_j * j \quad (4)$$

$$\mathrm{CoM_k} = \{\mathrm{CL_k}, \mathrm{D_k}, \mathrm{A_k}\} \quad (5)$$

$$\mathrm{QoS_k} = \{\mathrm{SC_k}, \mathrm{R_k}, \mathrm{P_k}, \mathrm{C_k}, \mathrm{V_k}, \mathrm{PR_k}, \mathrm{AV_k}, \mathrm{SF_k}\} \quad (6)$$

Where $\mathrm{CoM_k}$ and $\mathrm{QoS_k}$ represents the composition and QoS criterion for approach k respectively, and form two important parts of the evaluation formula (Equations (1) and (4)). These parameters are computed based on the criteria presented in Equations (2) through (6). k represents the number of compared approaches, which equals to 19 in this study. i and j indicate the respective criterion, described as follows:

$$i = \begin{cases} CL_k & \text{if } i = 1 \\ D_k & \text{if } i = 2 \\ A_K & \text{if } i = 3 \end{cases}$$

$$j = \begin{cases} SC_k & \text{if } j = 1 \\ R_k & \text{if } j = 2 \\ P_K & \text{if } j = 3 \\ C_K & \text{if } j = 4 \\ V_K & \text{if } j = 5 \\ PR_K & \text{if } j = 6 \\ AV_K & \text{if } j = 7 \\ SF_K & \text{if } j = 8 \end{cases}$$

The next step in the evaluation framework involves defining the sets of criteria. For this purpose, the table 2 given by Chen et al. [37] is used to assign a value to each evaluation criterion considering various possible situations.

From the values presented in Table 2, a designated set is generated for each criterion, as shown in Table 4. It shall be highlighted that these data sets are derived through an exhaustive literature review.

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*Table 1 Evaluation Criteria proposed for Web Service Composition Approaches*

| | Criteria | Description |
|---|---|---|
| Composition Criteria | Composition Language (CL) | There are several languages developed by several organizations such as BPEL4WS, OWL-S, and WSMO for service composition. |
| | Static/Dynamic Composition (S/D) | Static composition refers to constructing an abstract process model prior to the composition planning whereas, dynamic composition creates process model and selects atomic WSs automatically. |
| | Automatic Composition (A) | Automatic composition promises many improvements for service composition approaches including safer reusability, faster application development, and facilitating user interactions through complex service sets. |
| QoS Criteria | Security Constraints (SC) | Security constraints are specified to restrict the execution of activities for roles or users. |
| | Reliability (R) | This refers to the ability of a WS to perform its functions. Application of formal methods increases the reliability of WS applications [4]. |
| | Performance (P) | Performance represents how fast a Web Service request can be completed. In addition, implementing AI-Planning or agents in WS applications improves the performance of the process [22, 28]. |
| | Correctness (C) | Verification of correctness can be identified directly with regards to specifications of WSC [4]. Complex Web service systems may be formed through WSC, whereby correctness will be the main feature of such systems. Application of AI-Planning, UML, and formal methods can improve correctness of WSC [22, 35]. |
| | Privacy (PR) | Privacy refers to the fact that the identity and personal data of a client is not disclosed to non-authorized bodies. |
| | Availability (AV) | Availability is the probability that a WS is available at any given time, measured as the percentage of time that the WS is available over an extended period of time. According to [36], agent-based approaches increase WS availability. |
| | Validation (V) | This refers to verification of WSC at runtime. |
| | Stateless/Stateful (SL/SF) | Stateful systems are systems in which the status of the current state depends on the status of the system in past conditions. |

The final step of the evaluation framework involves computing the weights for each evaluation criterion. This step is based on a pairwise comparison of criteria dictated by the AHP methodology in order to determine the criteria weights. Thus, subjective assessments of relative importance are converted into numerical values (i.e. weights) and a matrix for evaluation of criteria importance is proposed, as depicted in Figure 3.

In the matrix, f refers to the number of criteria and the elements above the diagonal of the matrix are specified through an answer to the question, “how important is criterion Ci compared with criterion Cj?”. Each pairwise comparison is ranked according to an ascending order of importance with a value of 1 representing “equal importance of preference” and 9 representing “extreme importance of preference”, as shown in Table 3.

*Table 2 Values of QoS-aware Evaluation of Service Composition Criterion*

| *Qualitative Measure of Evaluation Criterion* | *Assigned Value* |
|---|---|
| Exceptionally Low (XL) | 0.045 |
| Extremely Low (EL) | 0.135 |
| Very Low (VL) | 0.255 |
| Low(L) | 0.335 |
| Below Average (BA) | 0.410 |
| Average (A) | 0.500 |
| Above Average (AA) | 0.590 |
| High (H) | 0.665 |
| Very High (VH) | 0.745 |
| Extremely High (EH) | 0.865 |
| Exceptionally High (XH) | 0.955 |

The elements on the diagonal are equal to 1 and the remaining elements are reciprocal. The weight for each criterion originates from this matrix.

*Table 3 Pair-wise Comparison Value*

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| Score | Response to the question, "How important significant is criterion $C_i$ compared with criterion $C_j$?" |
|---|---|
| 1 | Equal importance or preference |
| 2 | Equal to moderate importance or preference |
| 3 | Moderate importance or preference of one over another |
| 4 | Moderate to strong importance or preference |
| 5 | Strong or essential importance or preference |
| 6 | Strong to very strong importance or preference |
| 7 | Very strong or demonstrated importance or preference |
| 8 | Very strong to extreme importance or preference |
| 9 | Extreme importance or preference |

| Criteria | 1 | 2 | . . . | $f$ |
|---|---|---|---|---|
| 1 | 1 | $a_{12}$ | . . . | $a_{1f}$ |
| 2 | $a_{21}$ | 1 | . . . | $a_{2f}$ |
| . | . | . | | . |
| . | . | . | | . |
| $f$ | $a_{f1}$ | $a_{f2}$ | . . . | 1 |

*Figure 3 Matrix for Evaluation of Criteria Importance*

For this purpose, an AHP-based tool called "Expert Choice" is applied to determine the appropriate weight for each criterion with respect to the feedbacks received from experts. A number of experts and academicians are requested to provide feedback on the proposed evaluation attributes in order to generate the pair-wise comparison matrix. The geometrical mean of individual evaluations are computed using Equation (7) in order to attain accurate results. It shall be emphasized that the significance of the experts is considered to be equal. The weights for all criteria are presented in Figure 4 and the Consistency Ratio (CR) is equal to 0.1.

$$\bar{a}ij=\left(\prod_{k=1}^{N} a_{ij}^{(k)}\right)^{1/N} \qquad (7)$$

where

$a_{ij}^{(k)}$ is the kth expert's opinion to compare attribute i to attribute j
N is the number of involved experts

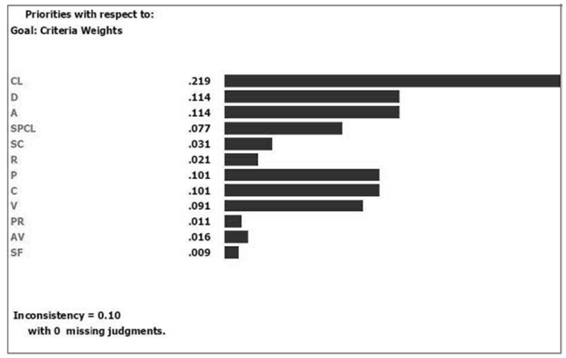


*Figure 4 Weight of Evaluation Attributes*

## 4 PRIMARY ASSESSMENT

The aforementioned approaches in Section 2 are evaluated comparatively with respect to the presented criteria in this section and the results are based upon information extracted from an extensive review, as illustrated in Figure 5. The assessment is focused on descriptive data derived from each approach. These data are coupled with the mathematical formulation detailed in Section 3 (i.e. Equations (4)) to evaluate the approaches. The procedure for assigning a number to each approach is presented in Appendix A.

## 5 MATHEMATICAL-BASED EVALUATION

The comparative table presented in Figure 5 is transformed from descriptive mode to mathematical-based style based on Table 2 and Table 4, as discussed in Section 3.2. Following this, a new diagram is produced (Figure 6), which displays the value of each criterion for each WSC approach. From the results presented in Figure 6 and the mathematical formulation developed in Section 3, it is evident that the comparative evaluation is carried out in a more systematic manner, whereby each approach is ranked in accordance to the results. The definitions of "Low", "Average", and "High" for each approach are inferred from the ranked values. From the definitions depicted in Figure 7, an approach is classified as "Low" if its achieved value (x) is less than 0.335 ($x \leq 0.335$). If the value is between 0.335 and 0.450 ($0.335 < x \leq 0.450$), the approach is classified as "Average". Likewise, an approach is classified as "High" if the value is found to exceed 0.450 ($x > 0.450$).

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| Work \ Criteria | | CL | S/D | A | QoS: SL/SF | R | P | C | AV | PR | V | SC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Syntactic -Based | [1] | BPEL | D/ Cp-net | Cp-net | SL | ✓Petri net | ✓formal method | ✓formal method | × | × | Program | × |
| | [2] | BPEL& WS-CDL | D/ Spi calculus+ Global calculus | Spi calculus+ Global calculus | SL | ✓Process Algebra | ✓ formal method | ✓ formal method | × | × | Program | × |
| | [3] | BPEL | D/ webπ∞ | webπ∞ | SL | ✓Process Algebra | ✓ formal method | ✓ formal method | × | × | × | × |
| | [4] | BPEL | D/ IPSO | IPSO | SL | × | ✓ AI Planning | ✓ AI Planning | × | × | Program | × |
| | [5] | BPEL | S | Agent | SL | × | ✓ Agent | × | ✓Agent | × | Program | × |
| Semantic-Based | [6] | OWL-S | D/ Semantic | Semantic/ Formal method/ agent | SL | Process Algebra: EC | ✓formal method | ✓formal method | × | × | Program | × |
| | [7] | OWL-S | D/ Semantic | Semantic/ agent | SL | × | ✓ Agent | × | ✓Agent | × | Program | × |
| | [8] | OWL-S | D / Semantic/ UML | Semantic | SL | ✓ Formal method | × | ✓UML | × | × | Formal method | × |
| | 9] | OWL-S | D / Semantic/ UML | Semantic OCL/ Model transformation | SL | × | × | ✓UML | × | × | × | × |
| AI-Planning Based | [10] | OWL-S | D/Semantic AI Planning | Semantic/ AI Planning : Graph Planning &DisCSP | SL | × | ✓ AI Planning | ✓ AI Planning | ✓ Agent | ✓ | × | × |
| | [11] | WSMO | D/Semantic AI Planning | Semantic / AI Planning: HTN-DL | SL | × | ✓ AI Planning | ✓ AI Planning | × | × | Program | × |
| | [12] | OWL-S | D/Semantic AI Planning | Semantic/AI Planning: HTN planner | SL | × | ✓ AI Planning | ✓ AI Planning | × | × | Program | × |
| | [13] | OWL-S | D/Semantic AI Planning | Semantic /AI Planning: HTN planner &CSP | SL | × | ✓ AI Planning | ✓ AI Planning | × | × | Program | × |
| | [14] | OWL-S | D/Semantic AI Planning | Semantic/AI Planning: HTN-DL | SL | × | ✓ AI Planning | ✓ AI Planning | × | × | Program | × |
| Context-Based / Service Centric | [15] | BPEL | S | ✓ Semantic /Agent | SL | × | ✓ Agent | × | ✓ Agent | × | × | maximum number of services that can be deployed at the same time |
| | [16] | BPEL | S | × | SL | × | Experiment | × | × | ✓ | Program | × |
| | [17] | OWL-S | D/Semantic | ✓Semantic | SL | × | × | × | × | × | × | × |
| Context-Based / User Centric | [18] | OWL-S | D/Semantic | ✓Semantic | SL | × | Experiment | × | × | × | Program | × |
| | [19] | OWL-S | D/Semantic /UML | Semantic /UML | SF | × | ✓ UML | ✓ UML | × | × | Program | × |

*Figure 5 Primary Assessment of Web Service Composition Approaches*

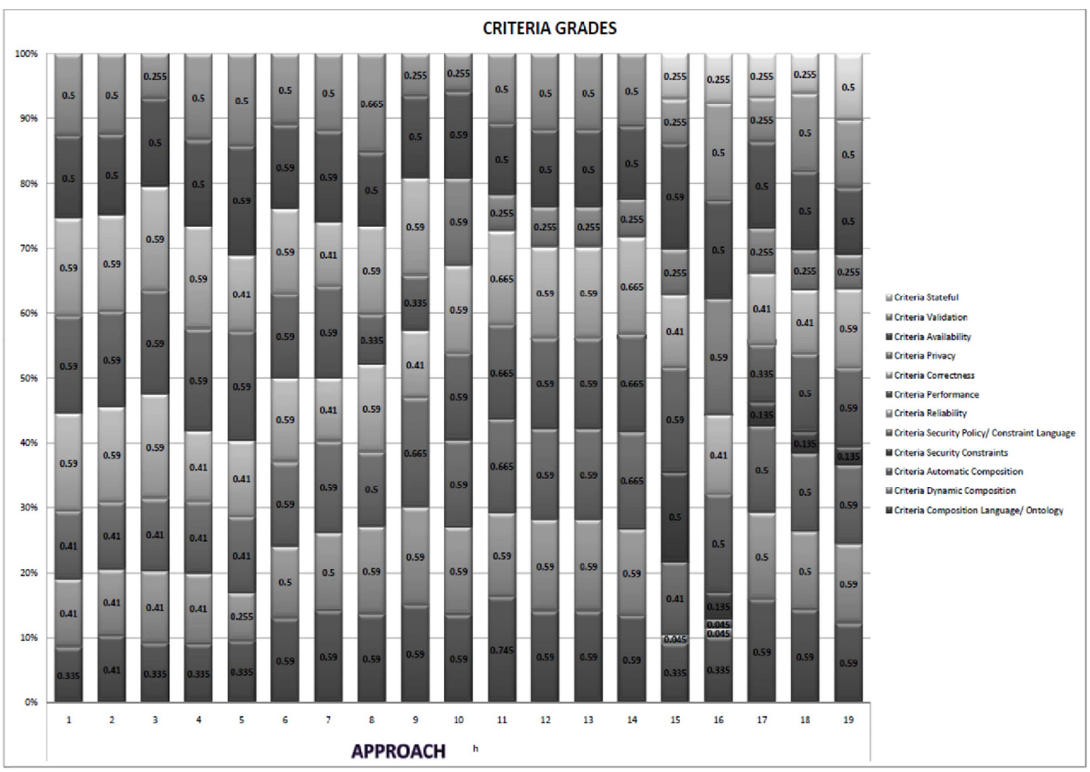


*Figure 6 Mathematical-based Evaluation of Web Service Composition Approaches*

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*Table 4 Regulated Data Set for Evaluation Criteria*

| Derived Regulations to Assign Data Set to Evalaution Criteria | | | | | References |
|---|---|---|---|---|---|
| $CL_k=$ | 0.255 | VL | if | Has not been applied composition language | [4,5,6,20,23,26,29,45,46] |
| | 0.335 | L | if | Language = BPEL4WS | |
| | 0.410 | BA | if | Language = BPEL4WS + WSDL | |
| | 0.500 | A | if | Language = BPEL4WS + AO4BPEL (an engine) | |
| | 0.590 | AA | if | Language = OWL-S | |
| | 0.745 | VH | if | Language = WSMO | |
| $A_k=$ | 0.045 | XL | if | The approach is not automatic | [4,15,16,23,38,39,47] |
| | 0.410 | BA | if | The approach is automatic because of applying factors support automation along with BPEL such as agent/formal method/AI Planning/Intelligent Service/UML | |
| | 0.500 | A | if | The approach supports automation owing to use of semantic | |
| | 0.590 | AA | if | The approach supports automation due to using factors support automation along with semantic | |
| | 0.665 | H | if | The approach supports automation because of applying UML and OCL with semantic or applies HTN along with DL | |
| $D_k=$ | 0.045 | XL | if | The approach is not dynamic | [4,38,47] |
| | 0.410 | BA | if | The approach supports dynamism because of applying factors support dynamism along with BPEL such as UML/AI Planning /Formal method/ intelligent Service | |
| | 0.500 | A | if | The approach supports dynamism owing to use of semantic | |
| | 0.590 | AA | if | The approach supports dynamism due to applying factors support dynamism along with semantic | |
| $SC_k=$ | 0.135 | EL | if | It is not proposed security constraint | [29,37] |
| | 0.500 | A | if | The proposed security constraints consider only service provider or requester or web service side | |
| | 0.590 | AA | if | The proposed security constraints consider only two of service provider or requester or web service sides | |
| | 0.665 | H | if | The proposed security constraints consider all three of service provider or requester or web service sides | |
| $P_k=$ | 0.335 | L | if | in case of no points with regards to the performance in the approach | [23,28,39,41,42] |
| | 0.410 | BA | if | The approach just claims to increase performance but no offers validation | |
| | 0.500 | A | if | The approach validates its claimed performance improvement | |
| | 0.590 | AA | if | The approach applies formal method /agent/AI Planning/UML technique to improve its performance | |
| | 0.665 | H | if | The approach applies AI Planning along with DL to improve its performance | |
| $AV_k =$ | 0.500 | VL | if | There is no applied standards or methods to improve availability | [42,48] |
| | 0.590 | AA | if | The approach applies agent-based technique to improve availability | |
| $PR_k =$ | 0.255 | VL | if | There is no applied standards or methods to address privacy | Proposed by authots |
| | 0.590 | AA | if | The approach applies standards or methods to address privacy | |
| $C_k =$ | 0.410 | BA | if | The Proposed approach is semantic or syntactic based without applying techniques to improve correctness | [4,16,17,44] |
| | 0.590 | AA | if | The Proposed approach is applied techniques to improve correctness such as AI-planning, formal method, and UML | |
| | 0.665 | H | if | The Proposed approach is applied AI-planning with DL to improve correctness | |
| $V_k =$ | 0.255 | VL | if | The approach proposes no implementation for its claim | Proposed by authots |
| | 0.500 | A | if | The approach employs programming as a implementation | |
| | 0.665 | H | if | The approach applies mathematical technique to implement its claim | |
| $SF_k =$ | 0.255 | VL | if | The approach support no stateful aspect | Proposed by authots |
| | 0.500 | A | if | The approach supports stateful aspect | |
| $R_k =$ | 0.410 | BA | if | Formal Method is not applied in the approach | [4] |
| | 0.590 | AA | if | Formal Method is applied in the approach | |

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*Table 5 Mathematical Evaluation of Web Service Composition Approaches*

| Work \ Criteria | | | CL | D/S | A | QoS: SF/SL | QoS: R | QoS: P | QoS: C | QoS: AV | QoS: PR | QoS: V | SC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Syntactic -Based | | [1] | 0.335 | 0.410 | 0.410 | 0.255 | 0.590 | 0.590 | 0.590 | 0.500 | 0.255 | 0.500 | 0.135 |
| | | [2] | 0.410 | 0.410 | 0.410 | 0.255 | 0.410 | 0.590 | 0.590 | 0.500 | 0.255 | 0.500 | 0.135 |
| | | [3] | 0.335 | 0.410 | 0.410 | 0.255 | 0.410 | 0.590 | 0.590 | 0.500 | 0.255 | 0.255 | 0.135 |
| | | [4] | 0.335 | 0.410 | 0.410 | 0.255 | 0.410 | 0.590 | 0.590 | 0.500 | 0.255 | 0.500 | 0.135 |
| | | [5] | 0.335 | 0.045 | 0.410 | 0.255 | 0.410 | 0.590 | 0.410 | 0.590 | 0.255 | 0.500 | 0.135 |
| Semantic-Based | | [6] | 0.590 | 0.500 | 0.590 | 0.255 | 0.590 | 0.590 | 0.590 | 0.590 | 0.255 | 0.500 | 0.135 |
| | | [7] | 0.590 | 0.500 | 0.590 | 0.255 | 0.410 | 0.590 | 0.410 | 0.590 | 0.255 | 0.500 | 0.135 |
| | | [8] | 0.590 | 0.590 | 0.500 | 0.255 | 0.590 | 0.335 | 0.590 | 0.500 | 0.255 | 0.665 | 0.135 |
| | | [9] | 0.590 | 0.590 | 0.665 | 0.255 | 0.410 | 0.335 | 0.590 | 0.500 | 0.255 | 0.255 | 0.135 |
| AI-Planning Based | | [10] | 0.590 | 0.590 | 0.590 | 0.255 | 0.410 | 0.590 | 0.590 | 0.590 | 0.255 | 0.255 | 0.135 |
| | | [11] | 0.745 | 0.590 | 0.665 | 0.255 | 0.410 | 0.665 | 0.665 | 0.500 | 0.255 | 0.500 | 0.135 |
| | | [12] | 0.590 | 0.590 | 0.590 | 0.255 | 0.410 | 0.590 | 0.590 | 0.500 | 0.255 | 0.500 | 0.135 |
| | | [13] | 0.590 | 0.590 | 0.590 | 0.255 | 0.410 | 0.590 | 0.590 | 0.500 | 0.255 | 0.500 | 0.135 |
| | | [14] | 0.590 | 0.590 | 0.665 | 0.255 | 0.410 | 0.665 | 0.665 | 0.500 | 0.255 | 0.500 | 0.135 |
| Context-Based | Service Centric | [15] | 0.335 | 0.045 | 0.410 | 0.255 | 0.410 | 0.590 | 0.410 | 0.590 | 0.255 | 0.255 | 0.500 |
| | | [16] | 0.335 | 0.045 | 0.045 | 0.255 | 0.410 | 0.500 | 0.410 | 0.500 | 0.590 | 0.500 | 0.135 |
| | | [17] | 0.590 | 0.500 | 0.500 | 0.255 | 0.410 | 0.335 | 0.410 | 0.500 | 0.255 | 0.255 | 0.135 |
| | User Centric | [18] | 0.590 | 0.500 | 0.500 | 0.255 | 0.410 | 0.500 | 0.410 | 0.500 | 0.255 | 0.500 | 0.135 |
| | | [19] | 0.590 | 0.590 | 0.590 | 0.500 | 0.410 | 0.590 | 0.590 | 0.500 | 0.255 | 0.500 | 0.135 |

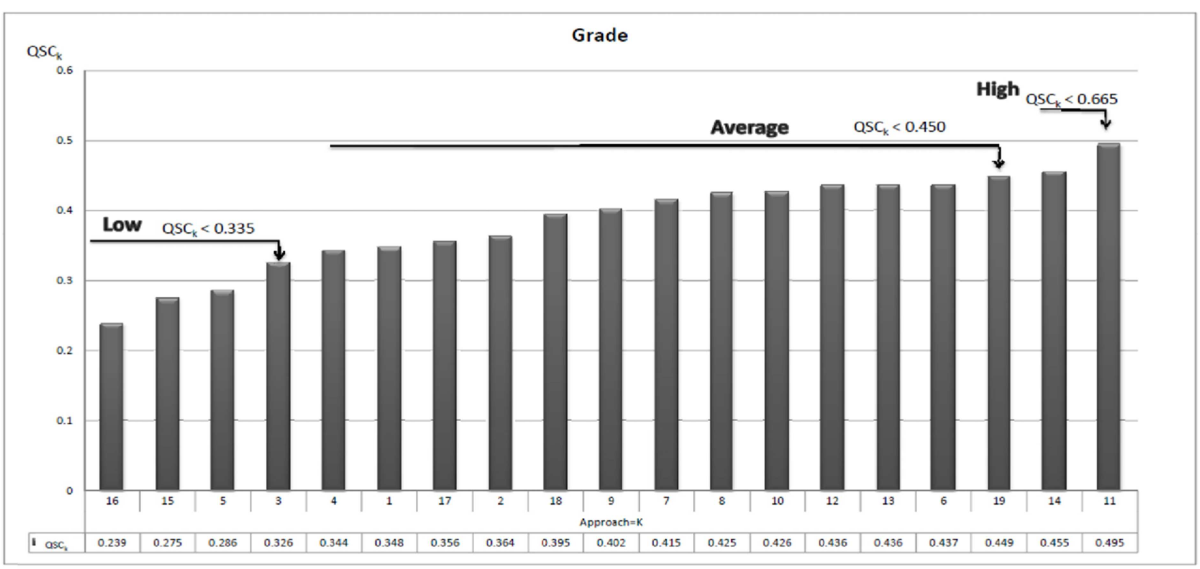


*Figure 7 QoS-Aware Web Service Composition Ranking*

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## 6 RESULT AND ANALYSIS

Analysis and discussion of the results are presented in this section, with regards to each category of WSC approaches. A comparative evaluation of the state-of-the-art approaches are shown in Table 5. This table represents a mathematical version of Figure 5, which is demonstrated as a primary assessment. A detailed discussion on the comparative evaluations of syntactic-based, semantic-based, AI-Planning based, and context-based approaches is presented in subsequent sub-sections.

### 6.1 Comparative Evaluation of Syntactic-based Approaches

In the syntactic-based category, approaches [5],[6] and [10] are evaluated as “Average” whereas the remaining approaches are marked as “Low”. From the composition language viewpoint, approach [6] integrates BPEL and WS-CDL to support orchestration and choreography of service composition (i.e. conservations between services and clients) while other approaches solely implement BPEL to specify WSC concerning orchestration. Although BPEL-based approaches are inherently static [4], all approaches with the exception of approach proposed in [11], address this limitation using complementary techniques such as formal methods and intelligent algorithms, and are evaluated as dynamic approaches. Since semantic characteristics are unsupported in BPEL, BPEL-based approaches are unable to provide automatic service composition by themselves [4, 38].

However, the existing approaches presented in this comparative evaluation address this limitation using formal methods, intelligent algorithms and agent-based techniques, as well as offer automatic service composition. When it comes to reliability criterion, approaches [5], [6] and [9] offer reliability for WSC owing to the implementation of formal methods [4]. These approaches as well as approach [10], are evaluated as “Above Average” with respect to correctness due to the utilization of formal methods and intelligent algorithms respectively. Approach [11] is marked as “Below Average” with regards to correctness criterion. With regards to the performance criterion, it can be observed that service composition performance is improved for approach [11] due to the implementation of an agent based technique. Similarly, WSC performance is also enhanced by approach [9], which is attributed to the application of webπ as the formal method. It shall be highlighted that webπ is equipped with an explicit mechanism to overcome the challenges of time during composition, such as timeout handling and time elapse [39]. In addition, approach [11] increases the availability of services in WSC due to the application of an agent-based technique. Petri nets are also considered to be more favourable compared to Process Algebra [40]. Hence, approach [5], which is based on CP nets (an extended version of Petri nets), is generally preferable compared to approaches [6] and [9] which are based on Spi Calculus and webπ (a variant of Process Algebra). Finally, from the validation viewpoint, all approaches with the exception of approach [9] that proposes a prototype, are evaluated as “Average”. Approach [9] offers no proof for its validation and is therefore marked as “Low”. It can be clearly seen from this evaluation that none of the approaches addresses the security criterion and is therefore considered as limitation.

### 6.2 Comparative Evaluation of Semantic-based Approaches

All approaches in the semantic-based category are indicated as “Average”. The approaches utilized OWL-S as the composition language. Since semantic-based approaches are considered as dynamic and automatic service compositions [3, 4], the approaches are all dynamic and automated. However, the levels of dynamism and automatization may vary from one approach to another. For instance, approaches [15] and [17] have higher dynamism compared to others due to the use of UML, which is suitable for ontology languages in order to improve dynamic composition [25, 41]. The approach proposed by Timm and Gannod [15] provides higher automatization due to the implementation of OCL as the formal language in expressing constraints, as well as XSLT as the model transformation which facilitates automatic construction of OWL-S specifications from UML language. The integration of OCL and UML enables the generation of programming codes in an automatic and platform-independent manner, and OCL expressions are used to specify invariant conditions for the system being modelled [15].

Approaches [14] and [19] support automatization of service composition due to the application of formal and agent-based methods. UML has been shown to improve dynamism of the composition process as well as increase correctness of dynamic composition process [17, 41]. Hence, the approaches developed by Timm and Gannod [15] and Zhengdong et al. [17] are evaluated as

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"Above Average" in terms of correctness criterion. The correctness of the approach by Gutierrez-Garcia et al. [14] is qualified as "Above Average", which is attributed to the use of Process Algebra as the formal method. The reliability of the approach is improved since formal methods increase the reliability of WS applications [4]. Approaches [14] and [19] are found to improve the performance and availability criteria for compositions in which agents are applied. When it comes to validation criterion, approach [17] utilizes an automated verification tool called SPIN to verify the correctness and reliability of WSC and thus the approach is evaluated as "High". Approaches in [14] and [19] are evaluated as "Average" due to the use of prototype verification tools. Finally, since no validation has been carried out in [15] for verifying WSC correctness, its validation is evaluated as "Very Low". None of the approaches address the security criterion, and is therefore considered as deficiency.

### 6.3 Comparative Evaluation of AI-Planning Based Approaches

In AI-Planning based category, approaches [25] and [42] are marked as "High" while the remaining approaches are evaluated as "Average". From the perspective of composition language, all approaches are based on OWL-S except [25], in which WSMO is used. WSMO is generally preferable to support non-functional properties in compositions. All approaches classified in this category support automatic and dynamic service compositions owing to the use of ontologies [4]. It is also noteworthy that all approaches in this category improve the automation levels of WSC by the application of AI-Planning techniques [26]. The approaches utilize HTN planning with the exception of the approach developed by Feng and Kowalczyk [28], which uses graph planning. HTN planning has higher efficiency compared to other planning languages [23]. According to Tabatabaei et al. [39], the implementation of HTN planning on its own poses several limitations for WSC. In this regard, approach [27] recommends the use of HTN and CSP (Calculus of Sequential Processes) to address the issue whereby functions are unavailable to cover additional scheduling information.

However, HTN-DL proposed by Sirin [42] and Tabatabaei et al. [25] addresses a majority of the aforementioned limitations. All approaches are evaluated as "High" with respect to correctness criterion except for approaches [22, 25]. When it comes to performance criterion, the approaches enhance service composition performance due to the application of AI- Planning techniques [28]. In addition, approaches [25] and [42] which implements HTN-DL exhibits higher performance and correctness over other approaches. The availability and performance of WSC is improved in [28] due to the fact that agent-based method is known to improve such criteria [33, 36]. It is also claimed that the privacy of users is provided in the approach. In terms of validation, all approaches are evaluated as "Average" since a prototype is proposed in these approaches, excluding approach [28].

### 6.4 Comparative Evaluation of Context Based Approaches

In the context-based category, approaches [30] and [32] are evaluated as "Low", while other approaches are marked as "Average". Most of the existed approaches in context-aware systems can be classified from two different aspects, namely Service-Centric and User Centric [29]. The former approach refers to approaches which promote service adaptability with respect to context changes whereas the latter approach refers to mobile applications in which user preferences are accounted for accordingly [31]. With regards to composition language, approaches [30] and [32] utilize BPEL, while the remaining approaches employ OWL-S. Unlike ontology based approaches, the BPEL-based approaches employed in [30] and [32] are less suitable and less useful for context-based systems [29]. This is due to the fact that contexts change frequently in context-aware systems, which in turn require alterations in access control policies. This is a cumbersome process in BPEL approaches as the access control policies need to be written manually for all possible instantiations of the context [43]. Furthermore, approaches [30] and [32] do not support dynamism as they are static-based WSC approaches.

In contrast, the remaining approaches support dynamism due to the implementation of ontologies [4]. Approach [31] offers higher dynamism among all dynamic-based approaches due to UML. From an automatization viewpoint, all approaches support automatic service composition due to BPEL, except approach [32]. It is noteworthy that approach [31] does not offer model transformation in assisting automatic construction of OWL-S specifications from UML diagrams [15]. When it comes to correctness criterion, all approaches are evaluated as "Below Average", with the exception of approach [31]. Approach [31] is marked as "Above Average" due to the application of UML, which ensures the correctness of dynamic composition process [17]. Mokhtar et al. [29], Maamar et al. [32] and Fujii and Suda [31]

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measured the performance of their approaches and claimed that they provide acceptable performance for service composition process. The performance of [30] can be potentially improved since agent-based solution is employed for WSC. With respect to stateless or stateful criterion, the approach developed by Fujii and Suda [31] is evaluated as stateful since it stores the history of users. It shall be noted that statefulness affects the security and efficiency of Web services. The availability of approach [30] is also improved since agent-based solution is employed [19, 36].

Although approach [32] claims that it offers privacy of contexts, there are no explicit directions in providing this attribute. From the security constraint viewpoint, even though approach [30] provides several security constraints in order to improve security of Web services, no languages have been identified to specify the constraints. Approaches [29], [32] and [31] are evaluated as "Average" in terms of validation due to the prototype proposed in these approaches. In contrast, the approaches implemented by Maamar et al. [30] and Mrissa et al. [33] are indicated as "Very Low" due to lack of validation. Finally, development of a language which is similar to OWL-S is required since semantic context-based services will greatly facilitate Web service interoperability and improve tracking [44].

## 7 STATISTICAL APPROACH TO STUDY QOS-AWARE WEB SERVICE COMPOSITION

The results derived from statistical analysis based on existing data are described in this section. The mean of 11 characteristics presented in Table 6, with respect to syntactic-based, semantic-based, AI-Planning based, and context-based approaches. Statistical analysis is carried out for all approaches using One-Way Analysis of Variance (one-way ANOVA). The results of the statistical test are shown in Table 7, which indicate a significant difference in mean scores for Composition Language (CL), Automatic Composition (A), and Correctness (C) criteria at 0.05 level of significance. However, the remaining criteria do not exhibit a significant difference between approaches, whereby P-value > 0.05. It can be observed from Figure 8 that AI-Planning based approaches have values which are significantly higher compared to other approaches with respect to these three criteria (i.e. CL, C, and A). It shall be noted that three criteria, namely, Security Constraint (SC), Privacy (PR), and being Stateful or Stateless (SF/SL) are not normally distributed and the Kruskal-Wallis test is performed to check their level of significance. However, there is no significant difference between the mean values for these criteria.

*Table 7 ANOVA Table*

| Criterion | Mean Square | F | Sig. |
|---|---|---|---|
| CL | 0.073 | 10.691 | 0.001 |
| DS | 0.088 | 3.265 | 0.051 |
| A | 0.061 | 4.539 | 0.019 |
| R | 0.008 | 2.018 | 0.155 |
| P | 0.025 | 3.218 | 0.053 |
| C | 0.026 | 4.659 | 0.017 |
| AV | 0.001 | 0.418 | 0.743 |
| V | 0.005 | 0.286 | 0.835 |

The second statistical analysis utilized in this work is factor analysis. Factor analysis plays a role in describing the variability between observed and correlated variables, considering unobserved latent variables called factors.

*Table 6 Mean of Criteria for approaches*

| Criteria / Category | CL | DS | A | SFSL | R | P | C | AV | PR | V | SC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Syntactic - Based | 0.35 | 0.337 | 0.41 | 0.255 | 0.446 | 0.59 | 0.554 | 0.518 | 0.255 | 0.451 | 0.135 |
| Semantic-Based | 0.59 | 0.545 | 0.5862 | 0.255 | 0.5 | 0.4625 | 0.545 | 0.545 | 0.255 | 0.48 | 0.135 |
| AI-Planning Based | 0.621 | 0.59 | 0.62 | 0.255 | 0.41 | 0.62 | 0.62 | 0.518 | 0.255 | 0.451 | 0.135 |
| Context-Based | 0.488 | 0.336 | 0.409 | 0.304 | 0.41 | 0.503 | 0.446 | 0.518 | 0.322 | 0.402 | 0.208 |

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The 11 QoS-based criteria used to evaluate service composition approaches are reduced to 4 linear functions, whereby the parameters are classified in four dimensions based on similarity and co-linearity. Varimax rotation is applied to clear all dimensions. Examination of the Kaiser-Meyerin measure of sampling adequacy reveals that the sample is factorable. The initial Eigen values demonstrate that the first factor explains 29.854% of the variance while the second, third, and fourth factor explains 18.439%, 13.482% and 12.222% of the variance, respectively. From Table 8, it is evident that "Automatization & Dynamism" is the most important factor, which explains 29.854% of the variance. Each factor is described briefly as follows.

*Table 8 Total Variance Explained*

| Rotation Sums of Squared Loadings | | | |
|---|---|---|---|
| Latent Variable (Component) | Total | % of Variance | Cumulative % |
| 1 | 3.636 | 29.854 | 29.854 |
| 2 | 1.899 | 18.439 | 48.293 |
| 3 | 1.348 | 13.482 | 61.775 |
| 4 | 1.256 | 12.222 | 73.997 |

Extraction Method: Principal Component Analysis

Firstly, four criteria are loaded into Factor 1, which is labelled as "Automatization & Dynamism". It can be clearly seen from Table 9 that these four items are related to automatic and dynamic composition, composition language and privacy level. Two criteria are loaded into the second factor labelled as "Accessibility", which relates to the level of availability and defined security constraints in a service composition approach. The two criteria loaded into Factor 3 are related to the reliability level and validation of the approach. Factor 3 is labelled as "Credibility". Finally, the criterion loaded into the fourth factor relates to the level of performance in an approach and this factor is labelled as "Productivity". The rotated component matrix depicted in Table 9 reveals that the most significant factor in QoS evaluation of service composition is "Automatization & Dynamism", comprising of Automatic Composition (A), Dynamic/Static Composition (D/S), Composition Language (CL) and Privacy (PR) parameters. It can be deduced that the 11 criteria categorized in these four factors (dimensions) described 73.997% of the variance, which affects approximately 74% of the QoS evaluation. This implies that there are other important factors that influence QoS evaluation which are unknown to in this study.

## 8 COMPLEMENTARY DISCUSSION

A comparative evaluation of state-of-the-art QoS-aware WSC approaches with respect to various categories of WSC taxonomy is proposed in this study. The most salient advantages and strengths of the evaluated approaches are highlighted in this section with the aim of providing a guideline to researchers in assessing various approaches for WSC.

*Table 9 Rotated Component Matrix*

| | | Component | | | |
|---|---|---|---|---|---|
| | | Automatization & Dynamism | Accessibility | Credibility | Productivity |
| Criteria | A | 0.973 | | | |
| | D/S | 0.862 | | | |
| | CL | 0.789 | | | |
| | PR | -0.78 | | | |
| | AV | | -0.843 | | |
| | SC | | -0.714 | | |
| | R | | | 0.879 | |
| | V | | | 0.694 | |
| | P | | | | 0.903 |
| | SF/SL | | | | |
| | C | | | | |

Extraction Method: Principal Component Analysis

Rotation Method: Varimax with Kaiser Normalization

Rotation converges in 9 iterations

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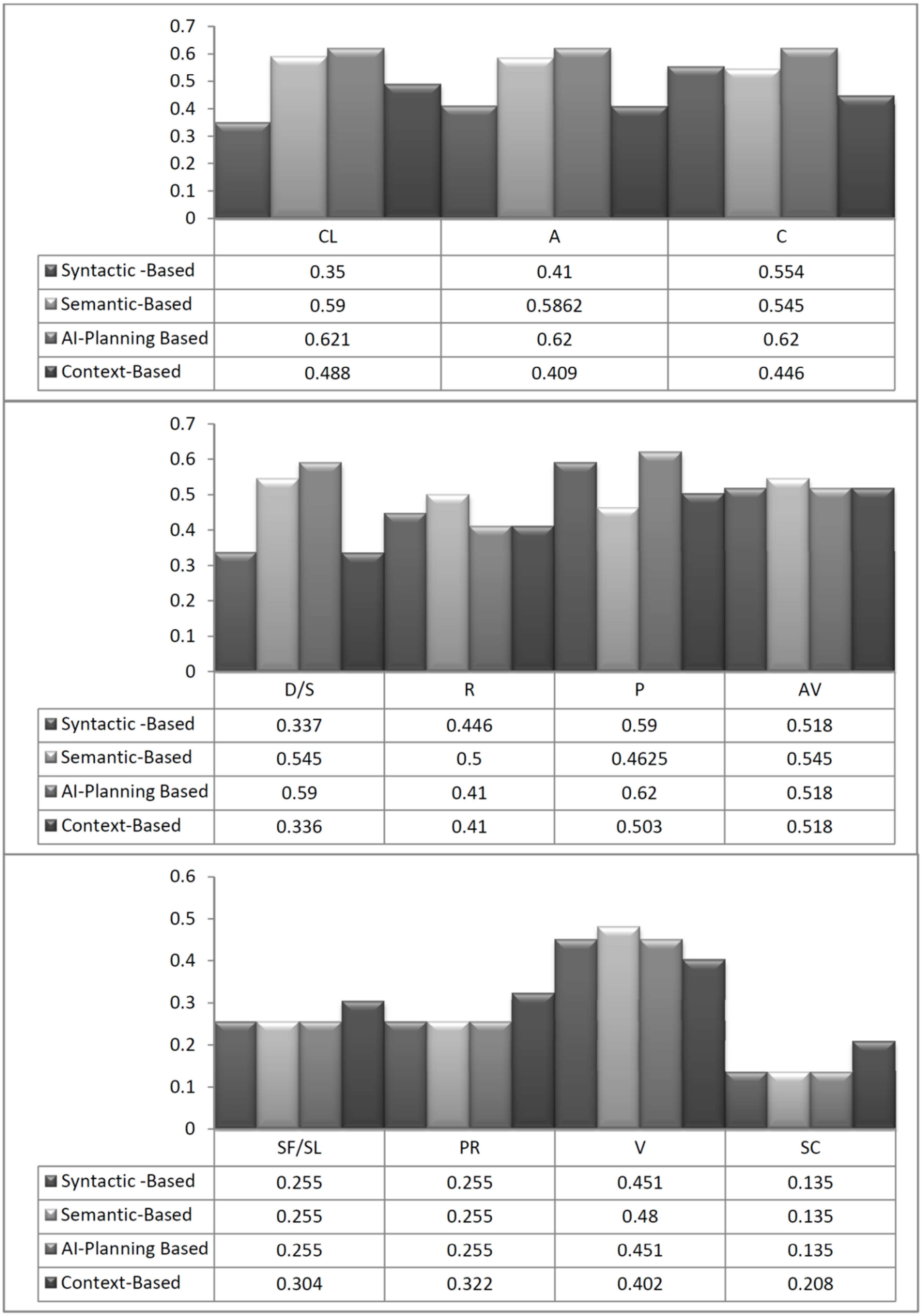

| | CL | A | C |
|---|---|---|---|
| Syntactic -Based | 0.35 | 0.41 | 0.554 |
| Semantic-Based | 0.59 | 0.5862 | 0.545 |
| AI-Planning Based | 0.621 | 0.62 | 0.62 |
| Context-Based | 0.488 | 0.409 | 0.446 |

| | D/S | R | P | AV |
|---|---|---|---|---|
| Syntactic -Based | 0.337 | 0.446 | 0.59 | 0.518 |
| Semantic-Based | 0.545 | 0.5 | 0.4625 | 0.545 |
| AI-Planning Based | 0.59 | 0.41 | 0.62 | 0.518 |
| Context-Based | 0.336 | 0.41 | 0.503 | 0.518 |

| | SF/SL | PR | V | SC |
|---|---|---|---|---|
| Syntactic -Based | 0.255 | 0.255 | 0.451 | 0.135 |
| Semantic-Based | 0.255 | 0.255 | 0.48 | 0.135 |
| AI-Planning Based | 0.255 | 0.255 | 0.451 | 0.135 |
| Context-Based | 0.304 | 0.322 | 0.402 | 0.208 |

*Figure 8 Difference Level of Means between Four Groups*

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The evaluation method presented in this study may be used to enhance the strengths and eliminate the weaknesses of a specific WSC approach. Approaches with the highest achieved rank are selected as the best representatives for each category of WSC approaches. The approaches proposed by Xu et al. [6], Gutierrez-Garcia et al. [14], Tabatabaei et al. [25] and Fujii and Suda [31] are chosen as the best representative of syntactic-based, semantic-based, AI-Planning based, and context-based approach, respectively. Base on the results, it can be deduced that ontologies have a significant impact on automatization and dynamism of an approach, such as [3], [31] and [14]. Consequently, syntactic-based approaches such as [6] which are lacking in semantics do not support automatic and dynamic service composition. However, syntactic-based approaches can partially counteract this limitation with the aid of AI-Planning, formal method and UML- based techniques (e.g. [6]). Implementation of formal methods in service composition offers several advantages. For instance, formal methods enhance the correctness and reliability of service compositions regardless whether the approach is syntactic or semantic. In addition, formal methods improve automatization and dynamism (e.g. [14]) and provide strong validation for service composition as the methods are intrinsically mathematical (e.g. [31]). AI-Planning techniques also outperform service composition performance (Tabatabaei et al. [25]). As discussed previously, HTN-DL is the most preferable AI-Planning based technique since it significantly improves the correctness and performance of service composition. Utilizing UML-based techniques in service composition leads to higher levels of correctness and performance (e.g. [31]). It is recommended that orchestration and choreography should be coupled in composition language for WSC, such as that proposed by Xu et al [6] and Tabatabaei et al. [25]. Tabatabaei et al. [25] use WSMO as semantic solution to solve this issue whereas Xu et al. [6] employ BPEL with WS-CDL.

## 9 CONCLUSION

Web service composition has gained significant amount of interests since the advent of service computing. The primary issue associated with WSC user requirements are not fulfilled by a single service. Hence, new value-added services are required fulfil the variety of requests from service consumers. The rationale behind WSC is to address such issues. In recent years, the number of services increases dramatically, resulting in new challenges for WSC. Selection of candidate services for composition is a challenging task, particularly for QoS-aware services. At present, there is a lack of a comprehensive review on the role of QoS in WSC. The relation to this, this paper presents a comparative evaluation on the state-of-the-art approaches implemented in QoS-aware service compositions. The approaches are classified into four categories, namely, syntactic-based, semantic-based, AI-Planning based, and context-based approaches, and described in details. A new QoS-aware evaluation method is proposed in this study, whereby the evaluation criteria for QoS-aware service composition are first identified and the evaluation method is formulated mathematically into a decision making technique. The classified approaches are evaluated as “Low”, “Average” and “High” with respect to the criteria. The results prove the applicability of the evaluation method, and hence the proposed methodology can be implemented by researchers and practitioners to evaluate QoS-aware service composition approaches. Four factors have been identified with respect to 11 criteria, which account for 74% of the QoS evaluation. Future work may involve examining other non-functional aspects of WSC such as security and trust for the evaluation method.

**Appendix A.** Assigned numbers to investigate Approaches in Figure 5

| ID | Reference |
|---|---|
| [1] | [5] |
| [2] | [6] |
| [3] | [9] |
| [4] | [10] |
| [5] | [11] |
| [6] | [14] |
| [7] | [19] |
| [8] | [17] |
| [9] | [15] |
| [10] | [28] |
| [11] | [25] |
| [12] | [41] |
| [13] | [27] |
| [14] | [42] |
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## REFERENCE

[1]. Papazoglou, M., et al., Service-oriented computing: State of the art and research challenges. Computer, 2007. 40(11): p. 38-45.

[2]. Ramakrishnan, R. and A. Tomkins, Toward a PeopleWeb. Computer, 2007. 40(8): p. 63-72.

[3]. Tabatabaei, S., W. Kadir, and S. Ibrahim. A Comparative Evaluation of State-of-the-Art Approaches for Web Service Composition. in Software Engineering Advances, 2008. ICSEA '08. The Third International Conference on. 2008.

[4]. Ter Beek, M., A. Bucchiarone, and S. Gnesi. Web Service Composition Approaches: From Industrial Standards to Formal Methods. in Internet and Web Applications and Services, 2007. ICIW '07. Second International Conference on. 2007.

[5]. Xiaochuan, Y. and K.J. Kochut. A CP-nets-based design and verification framework for Web services composition. in Web Services, 2004. Proceedings. IEEE International Conference on. 2004.

[6]. Xu, D.H., et al., A novel formal framework for secure dynamic services composition. 2008 Ieee 8th International Conference on Computer and Information Technology, Vols 1 and 2. 2008. 694-699.

[7]. Murata, T., Petri nets: Properties, analysis and applications. Proceedings of the IEEE, 2002. 77(4): p. 541-580.

[8]. Jensen, K., Coloured Petri nets: basic concepts, analysis methods and practical use: volume 1. 1997: Springer-Verlag.

[9]. Lucchi, R. and M. Mazzara, A pi-calculus based semantics for WS-BPEL. Journal of Logic and Algebraic Programming, 2007. 70(1): p. 96-118.

[10]. Yi, L. and X. YingYuan. An Efficient Web Service Composition Approach Based on improved Particle Swarm Optimization Model. in Management and Service Science, 2009. MASS '09. International Conference on. 2009.

[11]. Thissen, D. and P. Wesnarat. Considering QoS Aspects in Web Service Composition. in Computers and Communications, 2006. ISCC '06. Proceedings. 11th IEEE Symposium on. 2006.

[12]. Lee, T., J. Hendler, and O. Lassila, The semantic web. Scientific American, 2001. 284(5): p. 34-43.

[13]. Timm, J., A model-driven framework for the specification, grounding, and execution of semantic Web services. 2008.

[14]. Gutierrez-Garcia, J.O., et al. Obligation-Based Agent Conversations for Semantic Web Service Composition. in Web Intelligence and Intelligent Agent Technologies, 2009. WI-IAT '09. IEEE/WIC/ACM International Joint Conferences on. 2009.

[15]. Timm, J.T.E. and G.C. Gannod. Specifying Semantic Web Service Compositions using UML and OCL. in Web Services, 2007. ICWS 2007. IEEE International Conference on. 2007.

[16]. Foerster, T., J. Morales, and J. Stoter, A classification of generalization operators formalised in OCL. Proceedings of the 6th Geographic Information Days, 2008. 32: p. 141–156.

[17]. Zhengdong, Z., et al. Describing and Verifying Semantic Web Service Composition with MDA. in E-Business and Information System Security, 2009. EBISS '09. International Conference on. 2009.

[18]. Kona, S., et al. Automatic composition of semantic web services. 2007.

[19]. Bansal, A., et al. An Agent-Based Approach for Composition of Semantic Web Services. in Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, 2008. WETICE '08. IEEE 17th. 2008.

[20]. Kuter, U. and J. Golbeck, Semantic Web Service Composition in Social Environments. Semantic Web - Iswc 2009, Proceedings, 2009. 5823: p. 344-358.

[21]. Oh, S.-C., D. Lee, and S.R.T. Kumara, A comparative illustration of AI planning-based web services composition. SIGecom Exch., 2006. 5(5): p. 1-10.

[22]. Sirin, E., Combining Description Logic Reasoning with Ai Planning for Composition of Web Services, 2006, University of Maryland at College Park, College Park, MD, USA.

[23]. Rao, J. and X. Su, A survey of automated web service composition methods. Semantic Web Services and Web Process Composition, 2005: p. 43-54.

[24]. Evren, D., et al. Automatic Web Services Composition Using SHOP2. 2003.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[25]. Tabatabaei, S.G.H., W.M.N. Kadir, and S. Ibrahim. Semantic Web Service Discovery and Composition Based on AI Planning and Web Service Modeling Ontology. in Asia-Pacific Services Computing Conference, 2008. APSCC '08. IEEE. 2008.

[26]. Hristoskova, A., B. Volckaert, and F. De Turck. Dynamic Composition of Semantically Annotated Web Services through QoS-Aware HTN Planning Algorithms. in Internet and Web Applications and Services, 2009. ICIW '09. Fourth International Conference on. 2009.

[27]. Paik, I. and D. Maruyama. Automatic Web Services Composition Using Combining HTN and CSP. in Computer and Information Technology, 2007. CIT 2007. 7th IEEE International Conference on. 2007.

[28]. Jian Feng, Z. and R. Kowalczyk. Agent-based Dis-graph Planning Algorithm for Web Service Composition. in Computational Intelligence for Modelling, Control and Automation, 2006 and International Conference on Intelligent Agents, Web Technologies and Internet Commerce, International Conference on. 2006.

[29]. Mokhtar, S., et al., Context-aware service composition in pervasive computing environments. Rapid Integration of Software Engineering Techniques, 2006: p. 129-144.

[30]. Maamar, Z., S.K. Mostefaoui, and H. Yahyaoui, Toward an agent-based and context-oriented approach for Web services composition. Ieee Transactions on Knowledge and Data Engineering, 2005. 17(5): p. 686-697.

[31]. Fujii, K. and T. Suda, Semantics-based context-aware dynamic service composition. ACM Trans. Auton. Adapt. Syst., 2009. 4(2): p. 1-31.

[32]. Maamar, Z., et al., Towards a context-based multi-type policy approach for Web services composition. Data & Knowledge Engineering, 2007. 62(2): p. 327-351.

[33]. Mrissa, M., et al., Towards a semantic-and context-based approach for composing web services. International Journal of Web and Grid Services, 2005. 1(3): p. 268-286.

[34]. Dillon, L.K., Special issue on formal methods in software practice. 1997. 25(5).

[35]. Gilmore, S., et al., Non-functional properties in the model-driven development of service-oriented systems. Software and Systems Modeling, 2010: p. 1-25.

[36]. Chafle, G., et al., Orchestrating composite web services under data flow constraints. 2005 IEEE International Conference on Web Services, Vols 1 and 2, Proceedings. 2005. 211-218.

[37]. Chen, S.J.J., et al., Fuzzy multiple attribute decision making: methods and applications. 1992: Springer-Verlag New York, Inc.

[38]. Dersingh, A., R. Liscano, and A. Jost, Context-aware access control using semantic policies. Ubiquitous Computing And Communication Journal (UBICC) Special Issue on Autonomic Computing Systems and Applications, 2008. 3: p. 19-32.

[39]. Tabatabaei, S., et al., Security conscious AI-planning-based composition of semantic web services. International Journal of Web Information Systems, 2010. 6(3): p. 203-229.

[40]. van der Aalst, W., Pi calculus versus petri nets: Let us eat" humble pie" rather than further inflate the" pi hype". BPTrends, 2005. 3(5): p. 1-11.

[41]. Sirin, E., et al., HTN planning for web service composition using SHOP2. Web Semantics: Science, Services and Agents on the World Wide Web, 2004. 1(4): p. 377-396.

[42]. Sirin, E., Combining description logic reasoning with ai planning for composition of web services. 2006.

[43]. Dersingh, A., et al., Context-aware access control using semantic policies. Ubiquitous Computing And Communication Journal (UBICC) Special Issue on Autonomic Computing Systems and Applications, 2008. 3: p. 19-32.

[44]. Maamar, Z., N.C. Narendra, and S. Sattanathan, Towards an ontology-based approach for specifying and securing Web services. Information and Software Technology, 2006. 48(7): p. 441-455.

[45]. Charfi, A. and M. Mezini, Ao4bpel: An aspect-oriented extension to bpel. World Wide Web, 2007. 10(3): p. 309-344.

[46]. Rouached, M. and C. Godart. Reasoning about Events to Specify Authorization Policies forWeb Services Composition. in Web Services, 2007. ICWS 2007. IEEE International Conference on. 2007.

[47]. Sivasubramanian, S.P., E. Ilavarasan, and G. Vadivelou. Dynamic Web Service Composition: Challenges and techniques. in Intelligent Agent & Multi-Agent Systems, 2009. IAMA 2009. International Conference on. 2009.

[48]. Timm, J. and G. Gannod. A model-driven approach for specifying semantic web services. 2005. IEEE.