World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(Research Article)

Check for updates

Demonstration of quality evaluation for MDA-based web engineering methodologies using quality evaluation framework – WSDMDA case study

Mohammed Abdalla Osman Mukhtar [1,*], Ahmed Mohammed Elsawi [2] and Nisreen Beshir Osman [3]

[1] *Alzaiem Alazhari University, Faculty of Computer Science and Information Technology, Khartoum Bahri – SUDAN.*
[2] *Dubai Airports Corporation, Dubai – United Arab Emirates.*
[3] *Bayan University, Faculty of Computer Science and Information Technology, Khartoum – SUDAN.*

World Journal of Advanced Engineering Technology and Sciences, 2024, 12(02), 486–509

Publication history: Received on 08 June 2024; revised on 24 July 2024; accepted on 27 July 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.12.2.0305

Abstract

Model-Driven Architecture (MDA)-Based Web Engineering (MDWE) techniques are commonly used in the development of web applications. These methodologies enable the development of well-designed web applications, which in turn enable the automatic generation of high-level models into executable implementations. There are currently many MDWE methodologies available, therefore choosing one over the other is a crucial decision. Six evaluators participated in the asynchronous online focus groups technique utilized in this research study to collect qualitative data regarding the Web Site Design Method MDA-Based (WSDMDA), an MDA-based and Audience-Driven MDWE methodology, in order to complete the assessment process. Following that, the collected qualitative data was examined using the Quality Evaluation Framework (QuEF) to evaluate the WSDMDA methodology's quality of functionality, which consists of two features and six sub-characteristics. Because of one of initiator of NDT methodology has also participate in WSDMDA evaluation, the comparison has been conducted between NDA and WSDMDA. The findings demonstrate that WSDMDA has superior functionality with regard to Web Modeling feature and all Quality Sub-characteristics like Interoperability, Transformability, and Flexibility. This study significantly demonstrates how approaches can be methodically assessed to determine their advantages and disadvantages when applied to actual web development situations. This offers a structured approach to MDA-Based MDWE methodologies evaluation that not only helps developers choose the best procedures for their projects but also enhances the scholarly conversation.

Keywords: Model-Driven Web Engineering Methodology; Quality Evaluation Framework; Asynchronously Online Focus Group; Web Site Design Method MDA-Based (WSDMDA)

1. Introduction

Web applications are being developed these days for practically every field, including public administration, education, healthcare, and the economics. Furthermore, as noted in (Mesbah and Society 2012), a variety of complicated web applications have been created within each of these domains and can be classified as social, document-centric, collaborative, workflow-based, transactional, interactive, portal-oriented, or semantic, or as a combination of these categories. Despite the fact that these web application categories have many things in common, each domain still needs to be customized, necessitating the completion of a unique study for each web application development.

Web engineering, a relatively recent trend in software engineering, has gained traction despite some questioning the need to suggest unique web design techniques in comparison to more established "traditional" or "conventional" techniques. There are several ways to present and execute web site views in the field of web engineering. Various types of models, such as conceptual, navigation, and presentation models, can be used to present these viewpoints. Each of these approaches is free to define its own concepts or make use of pre-existing ones. The majority of them are limited

* Corresponding author: Mohammed Abdalla Osman Mukhtar

by platform and architectural requirements, which also have an impact on how they seem or are perceived in real life. The majority of these methods have already been developed depend on particular platforms (Aragón et al. 2013).

In terms of features that must be included in the website, choosing the right Model-Driven Web Engineering (MDWE) methodology as a tool to design web applications has become crucial. The Quality Evaluation Framework (QuEF) is specifically employed in this study endeavor to evaluate MDWE methodologies as well as other methodologies in general. It can be applied to evaluate a newly developed methodology or one that is already well-established. Six evaluators participated in an asynchronous online focus group to provide qualitative information about WSDMDA, as the QuEF requires this type of information to complete the evaluation process.

2. Web site design method MDA-based (WSDMDA)

The Web Site Design Method (WSDM), which is an old Web Engineering (WE) approach, has been improved by applying an MDA-based Web Engineering (MDWE) Mechanism to produce the methodology called Web Site Design Method MDA-Based (WSDMDA) (Pesic and Dahlgaard 2013). With the advent of WSDMDA, the traditional WSDM has transitioned from using non-standard modeling notation to an entirely MDA-based approach. As a result of this improvement process, the WSDM method is now a part of the MDWE methodologies rather than the standard WE methodology. Figure 1 shows the re-constructed WSDM and represents the new structure for WSDMDA methodology.

Interestingly, every dark area in Figure 1 corresponds to a component of the developed web engineering-based mechanism. The Mission Statement Specification phase and the Audience Modeling phase were the two stages that comprised the CIM component of the MDA technique in this general structure. The PSM of the MDA technique is represented by the Implementation Design phase, whereas the Design phase represents the PIM component. Furthermore, a notable automatic model conversion from PIM to PSM is facilitated by the web engineering process.

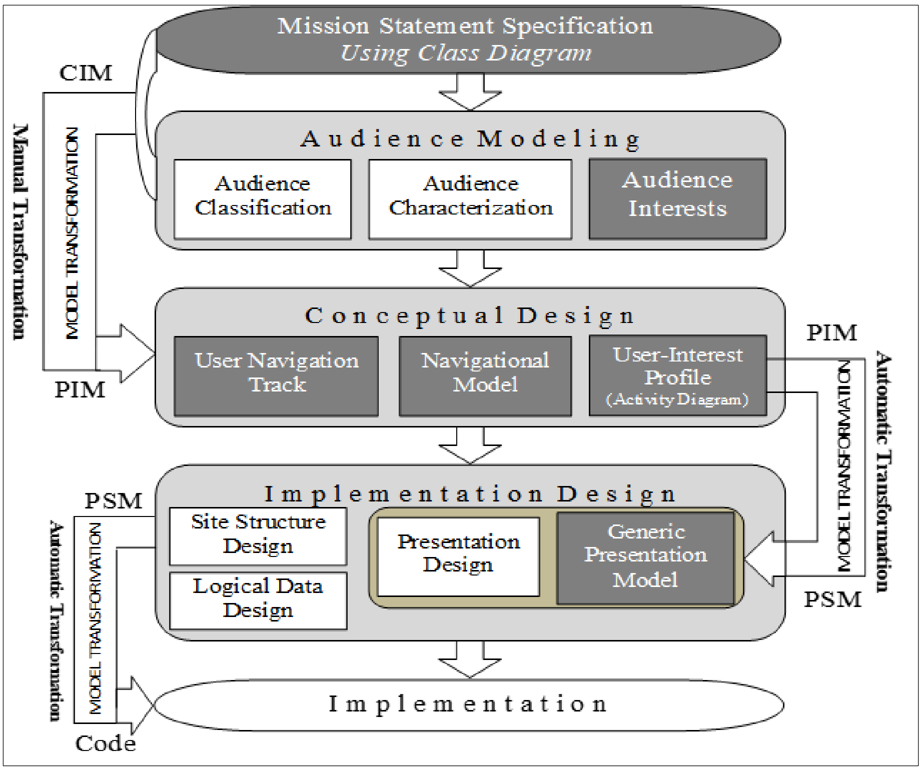

Figure 1 General Structure for WSDMDA Methodology

The relationships between the MDA framework's elements and the stages of WSDM are displayed in Table 1. In order to improve that phase, a corresponding element from the established MDA-based WE mechanism is added or substituted in the last column with the relevant WSDM phase, taking into consideration the model transformations and mapping specifications between phases.

Table 1 After Applying Web Engineering Mechanism into WSDM Structure - Comparison

WSDM Phase	Corresponding MDA Component	Corresponding Component from the Developed Mechanism
• Mission Statements Specification • Audience Modelling	CIM	• UML-based Generic CIM
• Conceptual Design	PIM	• User-Interest Profile • UML-based Conceptual Model • Activity Diagram, Class Diagram • State Transition Diagram
• Implementation Design	PSM	• UML-based Generic PSM
• Implementation	Code Generation	• N/A

3. Quality evaluation framework (QuEF)

There are a number of frameworks for evaluation that currently exist, including the Balanced Scorecard (Balaji et al. 2021), Total Quality Index (TQI) (Djekic et al. 2018), ISO/IEC 25010:2011 (System and Software Quality Models) (Panduwiyasa et al. 2021), Goal-Question-Metric (GQM) (McGinn et al. 2018), Non-Functional Requirements (NFR) framework (Rahman et al. 2024), and Web Quality Evaluation Methodology (WebQEM) (Singh 2016). Table 2 describes each framework individually and shows how it can be adapted to evaluate Model-Based Web Engineering (MBWE) methodologies.

Table 2 Description of Some Existing Evaluation Frameworks and Possibility of Applicability into MBWE

Framework	Description	Applicability into MBWE
Balanced Scorecard (Balaji et al. 2021)	This strategic planning and management system is used extensively in business to align business activities to the vision and strategy of the organization, improve internal and external communications, and monitor organization performance against strategic goals.	For MBWE methodologies, a balanced scorecard can be adapted to evaluate strategic alignment, process efficiency, customer satisfaction, and innovation.
Total Quality Index (TQI) (Djekic et al. 2018)	The TQI is a quantitative assessment system that provides a comprehensive picture of a methodology's quality by combining several quality metrics into a single index.	It can be used to measure and compare the overall effectiveness of different MBWE methodologies in producing high-quality web applications.
ISO/IEC 25010:2011 (Panduwiyasa et al. 2021)	This standard provides a comprehensive model for evaluating the quality of software and systems, which includes ten quality characteristics such as functionality, performance, compatibility, usability, reliability, security, maintainability, and portability.	While originally intended for software products, these criteria can be adapted to evaluate the outputs of MBWE methodologies, assessing how well the methodology supports the development of web applications that meet these quality standards.
Goal-Question-Metric (GQM) (McGinn et al. 2018)	The GQM approach involves defining specific goals, formulating questions that assess the achievement of these goals, and specifying metrics to answer the questions quantitatively. This methodology is adaptable and can be tailored to the specific goals of any MBWE methodology evaluation.	It can be used to measure various aspects of MBWE methodologies, such as process efficiency, model accuracy, and user satisfaction.

Non-Functional Requirements (NFR) (Rahman et al. 2024)	Originally developed by Chung et al.(Chung, Nixon, and Yu 1995), this framework focuses on specifying, operationalizing, and measuring non-functional requirements like performance, security, and scalability.	In the context of MBWE, the NFR framework can be used to evaluate how effectively a methodology addresses the non-functional requirements that are critical for web applications.
Web Quality Evaluation Methodology (WebQEM) (Singh 2016)	It integrates quantitative and qualitative assessment with a strong focus on user-centered metrics. WebQEM includes an evaluation matrix that combines quality characteristics with evaluation methods and techniques.	WebQEM is particularly useful in assessing user experience aspects of web applications developed through MBWE methodologies, focusing on usability, accessibility, and user satisfaction.

The researchers really examine more than the above-mentioned frameworks, including the INCAMI framework (Becker and Olsina 2010), the C-INCAMI framework (Becker and Olsina 2010), and the W-process framework (Punter et al. 2004) that are utilized to evaluate the MBWE. In summary, out of all the quality evaluation frameworks discussed above, QuEF is the only one that focuses especially on MDWE methodologies. As a result, QuEF has been chosen to evaluate the suggested WSDMDA methodology (Pesic and Dahlgaard 2013).

4. Evaluation process

Specifically, MDWE techniques and other methodologies in general can be evaluated using QuEF (Domínguez-mayo et al. 2012). It can be applied to assess a newly developed methodology or one that is already well-established. In order to obtain a deeper understanding and feedback from their respondents regarding two features (Web Modeling and MDE) and six sub-characteristics (Suitability, Interoperability, Compliance, Applicability, Flexibility, and Transformability), a very experienced group known as the Focus Group will be questioned to evaluate the WSDMDA methodology using QuEF in this paper. In accordance with this, the evaluation and assessment-related questions were drawn from the QuEF checklists (Domínguez Mayo 2013).

4.1. Asynchronously Online Focus Group

The purpose of the focus group is to acquire more in-depth understanding and feedback from the participants regarding a specific chosen topic (Fernandes et al. 2016). According to Liamputtong (Liamputtong 2011), by evaluating the pre-designed issues, the focus group's results might aid in the development of understanding about a certain topic.

Two forms of online focus groups can be used in this study: Synchronous Focus Groups, which are run in real time using chat or videoconference capabilities (Fox, Morris, and Rumsey 2007). Compared to Asynchronous Focus Groups, these tend to move more quickly, depending more on verbal processing and quick communication flow. Participants in asynchronous focus groups reply to discussion threads via email, bulletin boards, discussion boards, and listservs; these sessions don't happen in real time. Participants can attend asynchronous online focus groups whenever and wherever they'd like, making them convenient. Participants can think about their answers to questions or ideas and reflect on the group material without feeling pressed for time. By giving participants enough time to think over and react to focus group material, this type of data collection offers data depth and richness (Nicholas et al. 2010) – Thanks Asynchronous online focus groups.

An online evaluation form that was completed asynchronously was used to gather qualitative evaluation data for this study. Thankfully, six evaluators responded and took part in this focus group for the WSDMDA evaluation. In actuality, a large number of evaluators were extended invitations to do the evaluation; yet, a large number of them either declined politely or declined to respond at that specific moment. Following a month, there were six total responders, which fell within the allowed range. As a result, the QuEF calculations for the feature and quality sub-characteristic values could be started. Table 3 below provides a brief overview of the six evaluators:

Table 3 Details of Evaluators Participated in WSDMDA Methodology Evaluation Using QuEF

Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4	Evaluator 5	Evaluator 6
In 2012, he obtained his PhD from Multi-Media University (MMU), located in Malaysia. He began working as a	2011 saw him graduate from Universiti Teknologi Malaysia	He works as a software developer at the Swedish Scrum	In 2001, he graduated with a degree in computer science	Francisco is QuEF's primary developer. In 2013, he	He served as a system analyst, model-based software engineer, and consultant for

lecturer at Malaysia's Management and Science University (MSU) in 2011, and after earning his PhD, he eventually rose to the position of senior lecturer. He is currently an associate professor in Saudi Arabia at the University of Tabuk. His interesting research focuses on Model-Driven Architecture (MDA) and its industrial applications, Software Product Lines (SPL), and Software Engineering.	(UTM) with a PhD. He is an assistant professor at Saudi Arabia's King Faisal University (KFU) at the moment. His primary areas of interest in study are the relationship between the fields of Model-Driven Architecture (MDA) and Ontology Development. In addition, he participates to the OMG organization's Model-Driven development and Ontology group.	Master Company. Currently, he is interested in research in the following areas: Web Modeling, Model-Driven Engineering, Business Process Management (BPM), Software Engineering, and Quality Assurance. He leads Scrum Master's model-driven security techniques as well as the BPM division.	engineering from Linköping University in Sweden. He is currently employed in the Software Process Management industry working with Model-Driven techniques. He works as a researcher for the charity Towards Unity for Health (TUFH). His primary areas of interest in research are the industrial applications of software Process Improvement and Model-Driven Engineering. In addition, he collaborates to several societies' Web Engineering and Model-Driven Development groups.	graduated with a doctorate in software engineering from the University of Seville, Spain. Since 2005, he has worked as a researcher and lecturer at the University of Seville's Department of Computer Languages and Systems. His research interests lie in the fields of Web Engineering, Model-Driven Development, Software Engineering, and Software Quality. Additionally, he works on testing and software quality projects with both public and private companies. He is a part of the University of Seville's Web Engineering and Early Testing group (IWT2) www.iwt2.org	numerous oil and telecommunications companies for over a decade. Universiti Teknologi Malaysia (UTM) awarded him a PhD lately. His primary areas of interest in research are Model-Based Process Improvement, Information Modeling, and Model-Driven Architecture (MDA) technologies as he used for improving the code generation process.

4.2. QuEF Description

QuEF has two levels for Quality Properties and Characteristics. The Quality Characteristics and Sub-Characteristics can be used to first categorize the Quality Characteristics. Sub-Features and Features are the next divisions of the Properties. Comparably, different methodology designers have differing opinions about how attributes affect Quality Characteristics (Domínguez-mayo et al. 2012).

Features and Sub-Features weights values ($w_{f_{i,j_i}}$) are provided by QuEF. The Feature value (r_{F_i}) and Quality Sub-Characteristic value ($S_{q_{k,l_k}}$) for MDWE methodologies should be computed based on sub-feature weight values during the evaluation process.

4.2.1. Weigh (Importance) Value for Sub Features

Saaty (Saaty 1983) presents the Analytic Hierarchy Process (AHP) technique (Domínguez-Mayo, Espinilla, et al. 2011)(Domínguez-Mayo, Escalona, et al. 2011). It is used by methodology designers to create a Quality Model through many interpretations; typically, this process takes four steps to fully comprehend the significance of each Sub-Feature. As shown in Table 4, a quality hierarchy is created in the first stage. Based on a Systematic Literature Review (SLR) (Giraldo, Espana, and Pastor 2014), the components of a methodology used in a quality environment are presented in this table.

Table 4 Quality Model Hierarchy

Quality	Features	Sub-Features
X_0		f_{11} = Standard Definition
		f_{12} = Model-based Testing
	F_1 = MDE	f_{13} = Traces
		f_{14} = Levels of Abstraction
		f_{15} = Transformations
		f_{21} = Web Conceptual Levels
		f_{22} = Interfaces
		f_{23} = Content Modeling
	F_2 = Web Modelling	f_{24} = Presentation Modeling
		f_{25} = Navigation Modeling
		f_{26} = Development Process

The node that, in this research, reflects the methodology quality $\{X_0\}$ and the functionality of methodology is located at the top of the hierarchy. This attribute can be broken down into a number of Features, $F = \{F_i, i = 1,2, \ldots, t\}$ and each Feature, F_i includes a set of j_i Sub-Features, $F_i = \{F_{ij}, j = 1,2, \ldots, j_i\}$.

A detailed description of each of the AHP method's four steps may be found in (Domínguez-Mayo, Espinilla, et al. 2011). The importance (weight) of each feature and sub-feature will be decided by how these processes are implemented. The computed weights for Table 4's characteristics and sub-features are displayed in Table 5.

Table 5 The Importance (Weights) of Features and its Sub-Features

Features	Weights	Sub-Features	Weights
F_1 = MDE	$p_F = \begin{pmatrix} 0.10_{F_1} \\ 0.09_{F_2} \end{pmatrix}$	f_{11} = Standard Definition f_{12} = Model-based Testing f_{13} = Traces f_{14} = Levels of Abstraction f_{15} = Transformations	$p_{F_1} = \begin{pmatrix} 0.10_{f_{11}} \\ 0.09_{f_{12}} \\ 0.033_{f_{13}} \\ 0.17_{f_{14}} \\ 0.31_{f_{15}} \end{pmatrix}$
F_2 = Web Modeling		f_{21} = Web Conceptual Levels f_{22} = Interfaces f_{23} = Content Modeling f_{24} = Presentation Modeling f_{25} = Navigation Modeling f_{26} = Development Process	$p_{F_2} = \begin{pmatrix} 0.07_{f_{21}} \\ 0.38_{f_{22}} \\ 0.17_{f_{23}} \\ 0.10_{f_{24}} \\ 0.10_{f_{25}} \\ 0.10_{f_{26}} \end{pmatrix}$

4.2.2. How to Calculate Feature Value

Formula 1 is used to calculate the r_{F_i}, the value of Feature F_i for MDWE methodology using QuEF:

$$r_{F_i} = \frac{\sum_{j=1}^{j=n} w_{f_{i,j}} r_{f_{i,j}}}{m}$$ ………………. ***Formula 1*** (Domínguez-mayo et al. 2012)

Where:
$\mathbf{r_{F_i}}$: Feature value ***i***.
$\mathbf{w_{f_{i,j}}}$: weight of Sub-Feature $f_{i,j}$ for the Feature ***i*** (from Table 4).
$\mathbf{r_{f_{i,j}}}$: Sub-Feature value for the Feature ***i*** , this value will be calculated by using Checklists specified in Figure 2 (Dominguez-Mayo et al. 2010)(Domínguez Mayo 2013).
m : Number of Sub-Features associated with Feature ***i***.

4.2.3. Matrix of Influences (MoI)

The association ties between the current Features and Quality Characteristics are defined by the two-dimensional Matrix of Influences, or MoI. These associations between Features and their Sub-Features and Quality Characteristics and their Sub-Characteristics, as ascertained by the MoI matrix, are shown in Table 6.

The degree of influence represented by the MoI, which represents each Sub-Feature f_{i,j_i} on each Quality Sub-Characteristic q_{k,l_k} degree of influence, is the association link between the Sub-Features and Sub-Characteristics. This is essentially a qualitative value that needs to be converted into a quantitative value $v_{[f_{i,j_i}, q_{k,l_k}]}$ in the end. The influence of two valued scales, for example, can be expressed as Influence (√) or No Influence (×). Comparably, it might also establish the following four scale values: Moderate Influence (√), High Influence (√ ↑), Low Influence (√ ↓), and No Influence (×).

Table 6 Matrix of Influences between Features & Quality Characteristics

		$\boldsymbol{Q_1}$			$\boldsymbol{Q_2}$			⋯	$\boldsymbol{Q_k}$		
		$\boldsymbol{q_{1,1}}$	⋯	$\boldsymbol{q_{1,l_1}}$	$\boldsymbol{q_{2,1}}$	⋯	$\boldsymbol{q_{2,l_2}}$	⋯	$\boldsymbol{q_{k,1}}$	⋯	$\boldsymbol{q_{k,l_k}}$
F_1	$f_{1,1}$										
	⋯										
	f_{1,j_1}										
F_2	$f_{2,1}$										
	⋯										
	f_{2,j_2}					$v_{[f_{i,j_i}, q_{k,l_k}]}$					
⋯	⋯										
F_i	$f_{i,1}$										
	⋯										
	f_{i,j_i}										

4.2.4. How to Calculate Quality Sub-Characteristic Values?

Six Functionality Quality Sub-Characters will be evaluated throughout this research. Based on ISO/IEC 2500 (Czarnacka-Chrobot 2009), these quality sub-characteristics are defined and explained as follows:

- ***Suitability:*** The ability of an approach feature to offer a suitable function set for particular tasks and user goals.
- ***Interoperability:*** An approach feature's capacity to communicate with one or more particular approach features.
- ***Compliance:*** The ability of an approach feature to follow standards, guidelines, regulation, and various similar prescriptions.

- ***Applicability:*** How distinctive, practical, and easy-to-apply an approach characteristic is for the target community.
- ***Flexibility:*** The degree to which an approach characteristic may be readily expanded upon, modified, and adapted in order to satisfy different requirements.
- ***Transformability:*** An approach feature's capacity to offer a suitable set of functions for converting models into other models or codes.

The calculation of the Quality Sub-Characteristic values $S_{q_{k,l_k}}$ is displayed in Formula 2. Every *Sub-Feature* value $r_{f_{i,j_i}}$ and *Feature* value F_i are taken into account in this calculation. Apart from $v_{[f_{i,j_i}, q_{k,l_k}]}$, which in the *MoI* (Table 6) represents a qualitative value converted to a quantitative value. Additionally, Table 4 provides the *Sub-Feature* weight value $w_{f_{i,j_i}}$.

$$S_{q_{k,l_k}} = \frac{\sum_{j=1}^{n} v_{[f_{i,j_i}, q_{k,l_k}]}\, r_{f_{i,j_i}}\, w_{f_{i,j_i}}}{n}$$ ………………… ***Formula 2*** (Domínguez-mayo et al. 2012)

Where:
$\boldsymbol{S_{q_{k,l_k}}}$**:** Defines the state achieved by a value ranging between ($0 \leq S_{q_{k,l_k}} \leq 1$), which is the Quality Sub-Characteristic value, hence it sees that it satisfies the required model (value = 1) or not.
$\boldsymbol{v_{[f_{i,j_i}, q_{k,l_k}]}}$**:** This defines the relationship between the Sub-Feature f_{i,j_i} and the Quality Sub-Characteristic q_{k,l_k} in MOI. It is a qualitative value that has to be changed into quantitative value ranging between ($0 \leq v_{[f_{i,j_i}, q_{k,l_k}]} \leq 1$).
$\boldsymbol{r_{f_{i,j_i}}}$**:** This is a sub-Feature value that ranges in between ($0 \leq r_{f_{i,j_i}} \leq 1$), which represents the state achieved by the given value, whether it satisfies the required model value of 1 or not.
$\boldsymbol{w_{f_{i,j_i}}}$**:** This defines the weight value of Sub-Feature f_{i,j_i} which ranges in between ($0 \leq w_{f_{i,j_i}} \leq 1$). This value defines the importance of Sub-Feature in the set of Sub-Features.
$\boldsymbol{n}$ **:** This value signifies the number of Sub-Feature values of Feature F_i. The degree of influence value $v_{[f_{i,j_i}, q_{k,l_k}]}$ in this case is not equal to 0 (Domínguez-mayo et al. 2012).

Formula 2 can be generalized to other formula 3 to calculate the value of Quality Sub-Characteristic in terms of different Features.

$$S_{q_{k,l_k}} = \frac{\sum_{j=1}^{n_1} v_{[f_{i,j_1}, q_{k,l_1}]}\, r_{f_{i,j_1}}\, w_{f_{i,j_1}} + \cdots + \sum_{j=1}^{n_t} v_{[f_{i,j_t}, q_{k,l_t}]}\, r_{f_{i,j_t}}\, w_{f_{i,j_t}}}{n_1 + \cdots + n_t}$$ ………. ***Formula 3*** (Domínguez-mayo et al. 2012)

Formula 1 should only be utilized in this study endeavor to evaluate the MDWE methodology (WSDMDA) employing MDE and Web Modeling characteristics. The online evaluation form will be too lengthy to include the other two elements (Tool Support and Experience) in the evaluation process. We are all aware that the evaluation process may get incredibly time-consuming and tedious. Furthermore, there is little correlation between MDWE features and the maturity of the WSDMDA methodology and its tool, the WSDMDA-tool. Similarly, formulas 2 and 3 will be utilized for evaluating six sub-characteristics.

Notably, the outcomes will be compared with the MDWE approach (NDT) with respect to six sub-characteristics, two features, and their sub-features. Although *Evaluator05* completed the QuEF-based NDT methodology evaluation procedure in (Domínguez Mayo 2013), the WSDMDA has already been evaluated by the same evaluator that completed the evaluations like the other five evaluators.

4.3. Description of WSDMDA Evaluation Process Using QuEF

The first step in the MDWE methodology evaluation procedure is to define a set of checklists, one for each sub-feature, which are taken from (Domínguez Mayo 2013). Sub-features must be used to arrange these checklists, and each sub-feature must consist of a collection of properties. Every property has a set of details linked to it that are specific to that sub-feature. These details give a description of the evaluated MDWE methodology with respect to a specific property, together with any sub-details that may exist. The checklists for the WSDMDA evaluation procedure are displayed in Figure 2.

Table 7 summarizes the various scale types for each property in the checklists with reference to property scaling and evaluation.

Table 7 The Property Scaling Specification

SC<ID>	Type	Range	Range Type	Value
<id value>	<Qualitative or Quantitative>	<range of possible values>	<range type>	<Normalized quantitative value>

Where:
SC<ID>: It stands for the scale type's identifying code;
Type: It is the kind of scale that has the potential to be quantitative or qualitative;
Range: It is used to specify the range of values that this scale can have;
Range Type: It is the range values' data type;
Value: In terms of range, it is a normalized quantitative number.

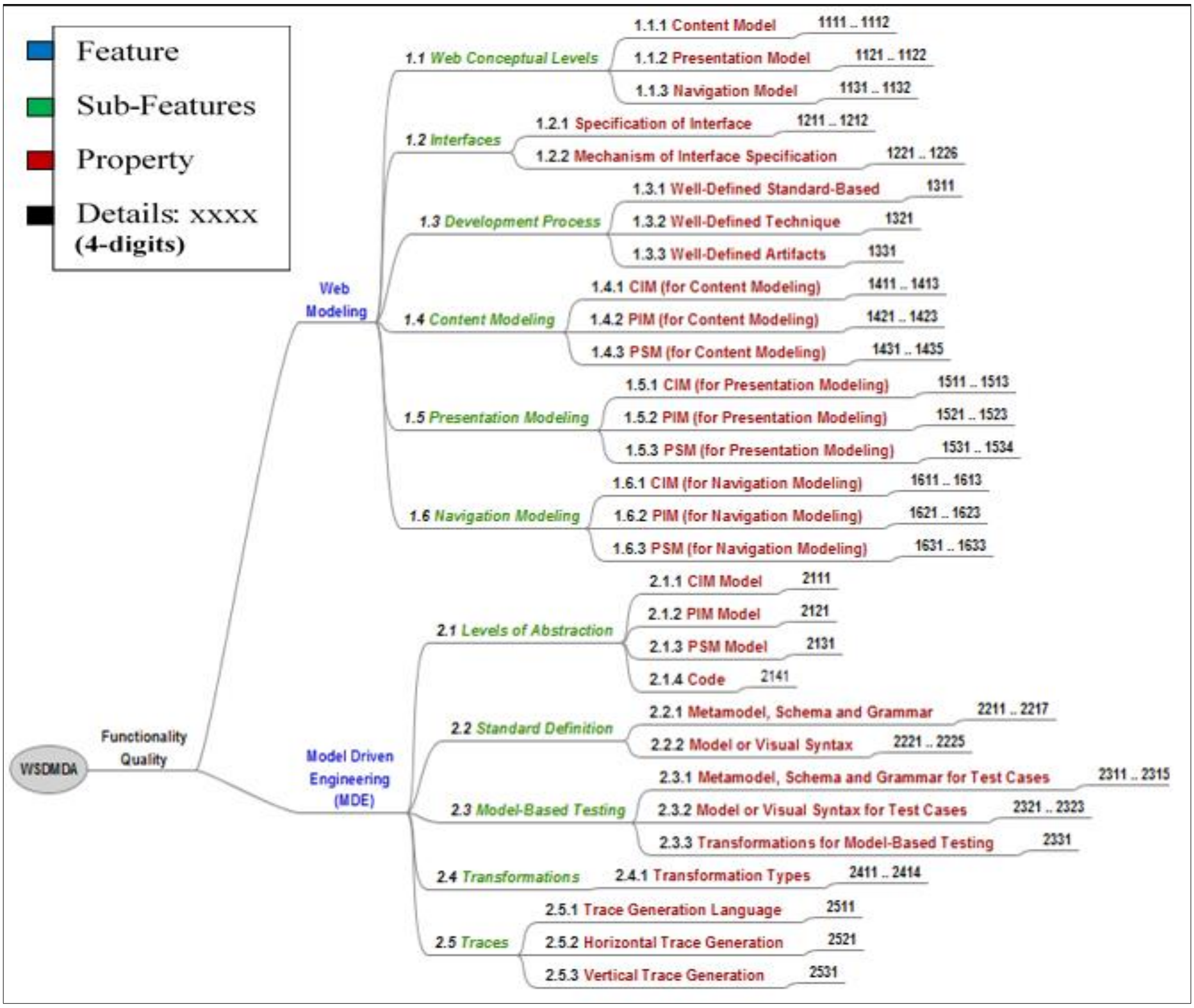

Figure 2 Checklists of Evaluation Process for WSDMDA Methodology

Scaling comes in two forms: SC<1> and SC<2>. Table 8 thus offers a range of values to be instantiated to the specified criteria of Table 6.

Table 8 The Property Scale's Potential Values

SC<ID>	Type	Range	Range Type	Value
1	Qualitative	{Not Supported, Partially Supported, Supported}	String	{0, 1/2 , 1}
2	Quantitative	{0-MAX}	Integer	$\frac{\text{Value in the range}}{\text{MAX value in the range}}$

Each detail's values for qualitative values, as specified by the scale **SC<1>**, can be classified as 'Supported', 'Partially Supported', or 'Not Supported'. If a property is supported, its value should be 1; if it is partially supported, it should be 1/2; and if it is not supported, it should be 0 (Dominguez-Mayo et al. 2010)(Domínguez Mayo 2013).

The arithmetic mean of all the sub-details should be taken when there are numerous sub-details connected to a specific main-detail. Similarly, if a given property has multiple details connected to it, the arithmetic mean needs to be determined.

A value in the range divided by the highest value in the same range should produce the property value for quantitative value as defined in the scale **SC<2>** (Dominguez-Mayo et al. 2010)(Domínguez Mayo 2013).

as the SC Code, which is divided into five sections that are explained as follows:

SC<ID> Code =

Feature	Sub-Feature	Property	Details	Sub Details

For instance, the sub-details scale code **<24123>** for NDT (in the brown cell) in Table 9 indicates:

- **2:** (MDE Feature) shows Feature ***i***.
- **4:** (Transformations Sub-Feature) shows Sub-Feature ***j*** connected to Feature ***i***.
- **1:** (Transformations Types Property) shows Property ***k*** connected to Sub-Feature ***j***.
- **2:** (automatic transformation types) shows Details ***m*** connected to Property ***k***.
- **3:** (Model2Document) shows ***optional*** Sub-Details ***n*** connected to Details ***m***.

Table 9 Sub-Feature of *Transformations* Values (Quantitatively) for NDT (Domínguez Mayo 2013)

Properties	**Checklist Details**		**Qualitative Value**	**Quantitative Value**		
	Main Details	**Sub-Details**				
<241> Transformations Types	<2411> It uses a standard language for defining transformation rules (i.e. providing ATL, QVT or Graph transformations).		Support			1
	<2412> It defines automatic transformation types from models into other models or into code and documentation such as:	<24121> Mod2Mod	Supported	1		1
		<24122> Mod2Code	Supported	1		
		<24123> Mod2Doc	Supported	1		
	<2413> It provides mapping functions or automatic transformations such as:	<24131> CIM2CIM	Part.Supported	1/2		2/3
		<24132> CIM2PIM	Supported	1		
		<24133> PIM2PIM	Part.Supported	1/2		

		<24134> PIM2PSM	Supported	1		
		<24135> PIM2Code	Part.Supported	1/2		
		<24136> PSM2Code	Part.Supported	1/2		
	<2414> It provides a separate model for describing the transformation such the separate Platform-Description Model: Platform-Description Model from (PIM2PSM)		NotSupported			0

The arithmetic mean of the **3** sub-details (<24121>, <24122>, and <24123>) is calculated in the following way to determine the result for Main Details <2412>:

Quantitative Value of Main Details **<2412>** = $\frac{1+1+1}{3} = 1$

Similar to the above, the arithmetic mean of **6** Sub-Details (<24131>, <24132>, <24133>, <24134>, <24135>, and <24136>) is calculated to get the value for Main Details <2413>:

Quantitative Value of Main Details **<2413>** = $\frac{1/2+1+1/2+1+1/2+1/2}{6} = 2/3$

Next, the arithmetic mean of the **4** Main Details (<2411>, <2412>, <2413>, and <2414>) is calculated in order to determine the overall value for Property <241>:

Quantitative Value of Property **<241>** = $\frac{1+1+2/3+0}{4} = 0.665$

It is possible to think of the value of each sub-feature as the average of the set of property values divided by the total number of properties associated to that specific sub-feature (Domínguez-mayo et al. 2012). The sub-feature value computation is defined by Formula 4 in the following:

$$sF = \frac{1}{n}\sum_{i=1}^{n} p_i$$ ……………...... ***Formula 4*** (Domínguez-mayo et al. 2012)

Where *n* is the total number of properties associated with the specific sub-feature, ***i*** is the property index, *p* is the related properties with the sub-feature, and *sF* is the sub-feature's total value.

Because of this, the sub-feature value computation yields a fractional number between 0 and 1. The evaluation framework dictates that numbers containing floating points are not permitted in QuEF. As a result, the calculated fraction's mathematical ceiling is determined. Lastly, the number of sub-features associated to the specific feature must be the denominator of the calculated sub-feature value (Dominguez-Mayo et al. 2010)(Domínguez Mayo 2013).

As a result, Formula 4 will be used to get the total value for the Transformations sub-feature in Table 8. The denominator must be fixed at **5** due to the fact that the MDE feature includes 5 associated sub-features (Standard Definition, Model-Based Testing, Traces, Levels of Abstraction, and Transformations). The nearest fraction (ceiling or grounding) will be used for the resultant number.

Quantitative Value of Sub-Feature **<24>** (for NDT) = $\frac{0.665}{1} = 0.665 \cong 3/5$

Because there are **6** sub-features related to the Web Modeling feature (Web Conceptual Levels, Interfaces, Development Process, Content Modeling, Presentation Modeling, and Navigation Modeling), the denominator of the calculated sub-feature values linked with this feature must be fixed at 6.

5. Results and discussion

The final values for all calculations, which were previously covered in the preceding section, are contained in the following subsections after evaluation data was gathered through an asynchronous online focus group. Additionally, the authors of this research computed all of the values used in this section for the WSDMDA technique using mathematical formulas 1, 2, 3, and 4, whereas the values used for the NDT methodology were taken from the author of the research in (Dominguez-Mayo et al. 2010)(Domínguez Mayo 2013). First, there will be a calculation, presentation, comparison, and discussion of Features and its Sub-Features. In a comparable manner, the authors of this research will handle each Quality Sub-Characteristic using the same process.

5.1. Evaluation of WSDMDA Features

As previously seen in the Evaluation Process Description using Formula 1 example, Table 10 displays the sub-feature values that each evaluator determined using QuEF. Figures 3 and 4 show these values separately for the Web Modeling Feature and the MDE Feature, respectively. By multiplying the data from Table 9 by 100, a scaling is used in those figures to facilitate the comparison process.

Table 10 Values of Every Sub-Feature Computed for Six Evaluators

F	No	Sub Features	Evaluator (1)	Evaluator (2)	Evaluator (3)	Evaluator (4)	Evaluator (5)	Evaluator (6)
Web Modeling	1	Web Conceptual Levels	1	5/6	5/6	4/6	1	1
	2	Interfaces	5/6	5/6	4/6	4/6	5/6	5/6
	3	Development Process	1	1	5/6	3/6	1	1
	4	Content Modeling	5/6	5/6	4/6	4/6	5/6	5/6
	5	Presentation Modeling	4/6	4/6	4/6	3/6	4/6	3/6
	6	Navigation Modeling	5/6	5/6	4/6	4/6	5/6	4/6
M D E	1	Levels of Abstraction	4/5	4/5	3/5	4/5	4/5	4/5
	2	Standard Definition	3/5	3/5	3/5	3/5	4/5	3/5
	3	Model-based Testing	2/5	2/5	2/5	3/5	3/5	3/5
	4	Transformations	3/5	3/5	2/5	4/5	3/5	3/5
	5	Traces	3/5	3/5	4/5	4/5	3/5	4/5

Similarly, Table 11 displays the equivalent estimated feature values for each evaluator using QuEF, as determined by Formula 1. The clustered column chart in Figure 5 displays these results. The data from Table 10 are scaled by 1000 to facilitate the comparison.

Table 11 Values of Every Feature Calculated for Six Evaluators

	Web Modeling	Model-Driven Engineering (MDE)	Global Properties
Evaluator (1)	0.1297	0.0876	0.0102
Evaluator (2)	0.1278	0.0876	0.0101
Evaluator (3)	0.1069	0.0697	0.0083
Evaluator (4)	0.0967	0.1049	0.0096
Evaluator (5)	0.1287	0.0948	0.0105
Evaluator (6)	0.1242	0.0925	0.0102

5.2. Comparison Between WSDMDA and NDT Features Evaluation

The overall quantitative sub-feature values of MDE Feature for the enhanced MDWE methodology WSDMDA, as determined by the research authors, are now displayed in Table 12 in comparison to NDT, which has been evaluated in (Domínguez Mayo 2013). Figure 6 compares the NDT methodology and the enhanced WSDMDA methodology graphically using a clustered column chart. A scale is used by multiplying the Web Modeling Feature sub-feature values from Table 11 by 100 in order to simplify the comparison.

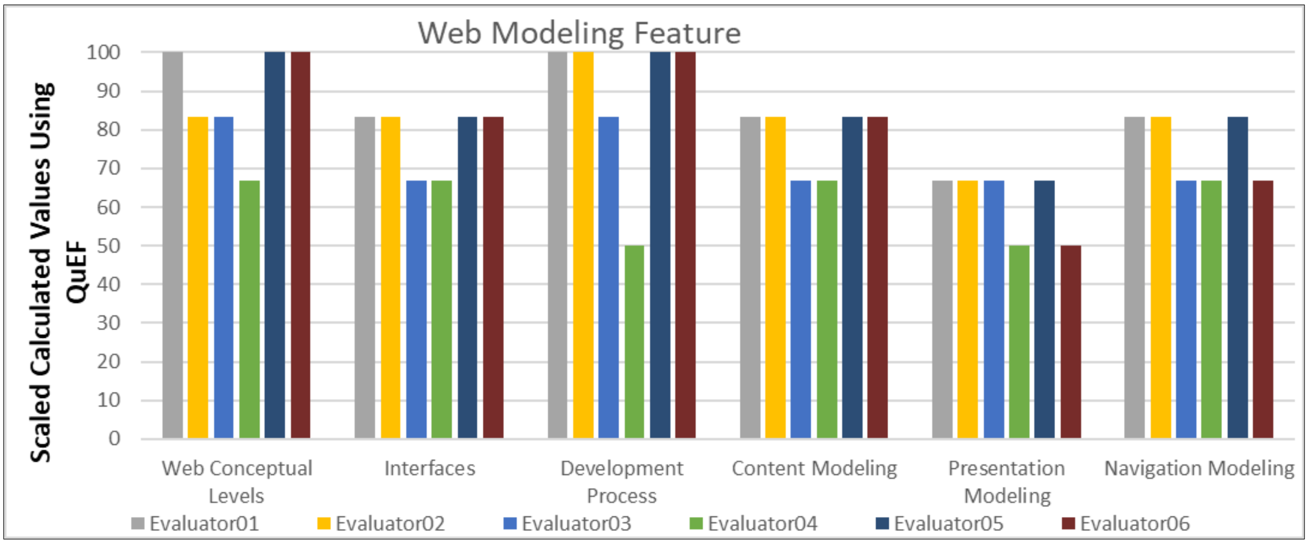

Figure 3 Sub-Feature Values of Web Modeling Calculated for Six Evaluators

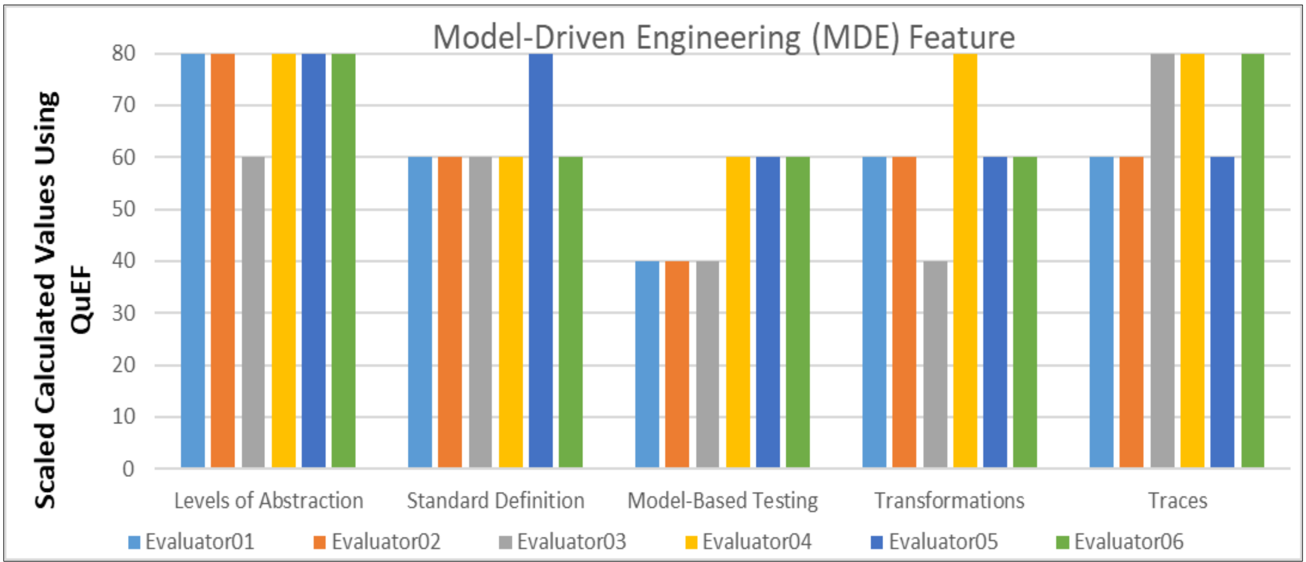

Figure 4 Sub-Feature Values of MDE Calculated for Six Evaluators

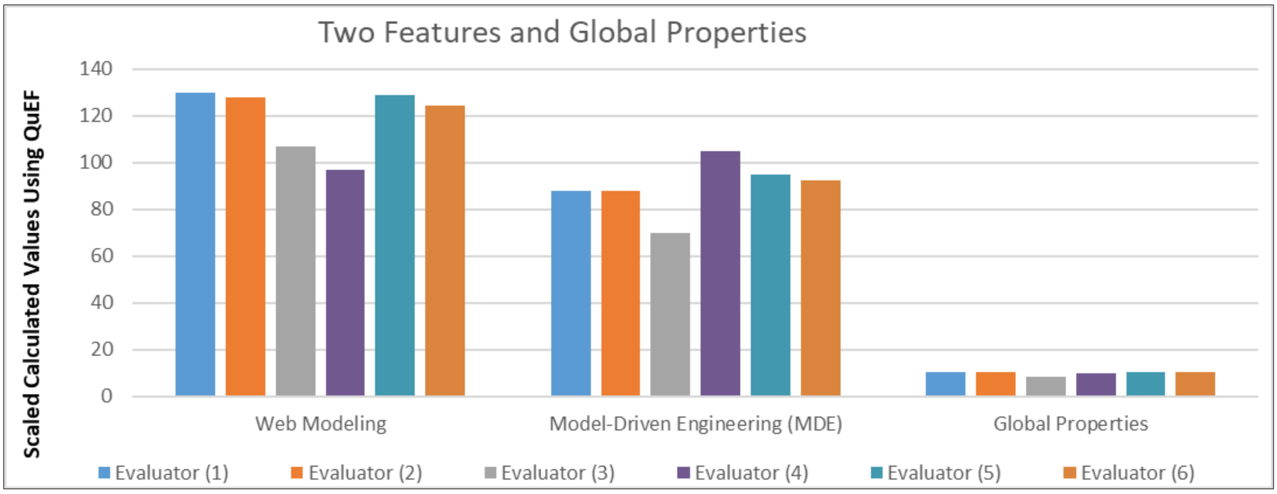

Figure 5 Values of Two Features Calculated for Six Evaluators

Table 12 Comparison Sub-Feature Values of MDE Feature between NDA & WSDMDA

F_1	Sub-Feature	NDT	WSDMDA
M D E	f_{14} = Levels of Abstraction	1	4/5 ↓
	f_{11} = Standard Definition	3/5	4/5 ↑
	f_{12} = Model-based Testing	1	3/5 ↓
	f_{15} = Transformations	3/5	3/5 √
	f_{13} = Traces	1	3/5 ↓

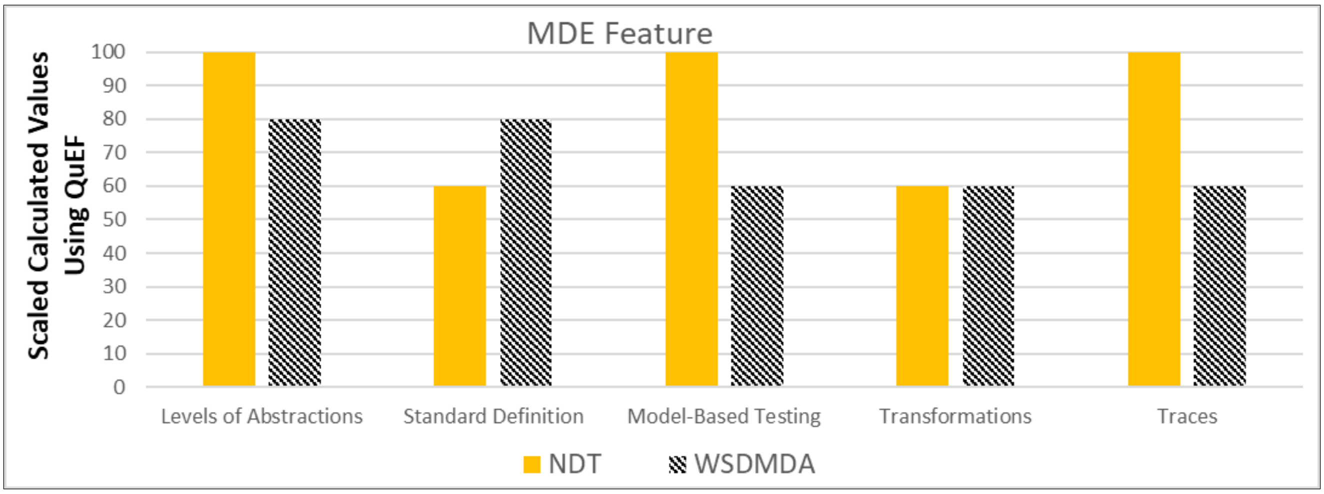

Figure 6 Comparison Sub-Feature Values of MDE Feature between NDA & WSDMDA

Using the quantitative values of the sub-features (Levels of Abstraction, Standard Definition, Model-based Testing, Transformations, and Traces), Formula 1 will be used to determine the value of the MDE feature. Furthermore, Table 4's computed weights for each sub-feature must be remembered.

$$r_{F_1} = \frac{0.8 * 0.17 + 0.8 * 0.10 + 0.6 * 0.09 + 0.6 * 0.31 + 0.6 * 0.033}{5} = 0.095$$

Comparing the authors' calculation of the total quantitative sub-feature values of Web Modeling Feature for the enhanced MDWE methodology WSDMDA to NDT, which is evaluated in (Domínguez Mayo 2013). Table 13 displays the results. Visually, the enhanced WSDMDA and NDT methodology are compared in a clustered column chart in Figure 7. The Web Modeling Feature's sub-feature values from Table 12 are multiplied by 100 to ease comparison.

Table 13 Comparison Sub-Feature Values of Web Modeling Feature between NDA & WSDMDA

F_2	Sub-Feature	NDT	WSDMDA
Web Modeling	f_{21} = Web Conceptual Levels	5/6	1 ↑
	f_{22} = Interfaces	4/6	5/6 ↑
	f_{23} = Development Process	1	1 √
	f_{24} = Content Modeling	4/6	5/6 ↑
	f_{25} = Presentation Modeling	4/6	4/6 √
	f_{26} = Navigation Modeling	5/6	5/6 √

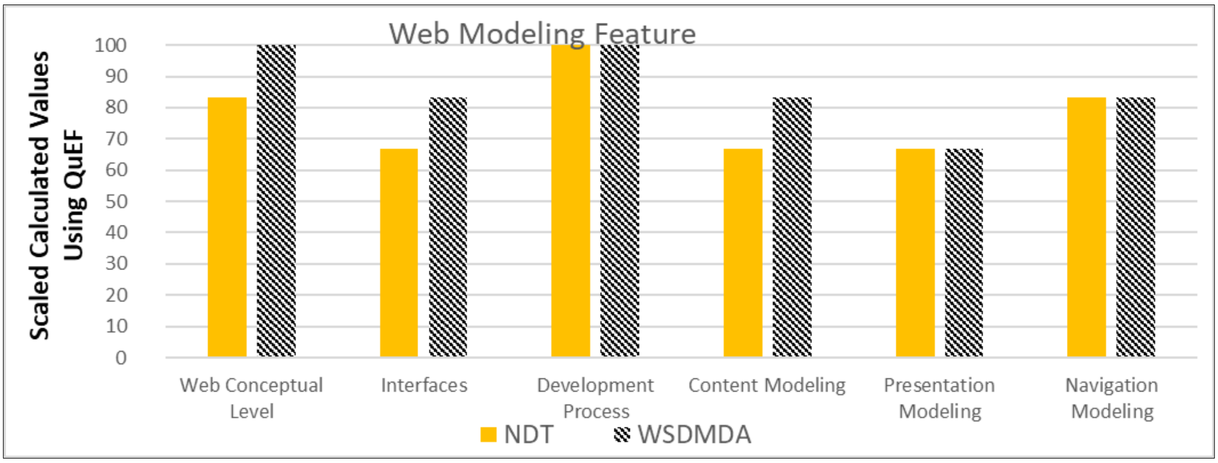

Figure 7 Comparison Sub-Feature Values of Web Modeling Feature between NDA & WSDMDA

Using the quantitative values of the sub-features (Web Conceptual Levels, Interfaces, Development Process, Content Modeling, Presentation Modeling, and Navigation Modeling), Formula 1 will be used to calculate the Web Modeling Feature value. It is necessary to recall the weights for every sub-feature from Table 4.

$$r_{F_2} = \frac{1 * 0.07 + 0.83 * 0.38 + 1 * 0.10 + 0.83 * 0.17 + 0.67 * 0.10 + 0.83 * 0.10}{6} = 0.129$$

Generally, using the feature weights listed in Table 4, Formula 1 can be used to determine the global properties value for WSDMDA in terms of two features (Web Modeling and MDE). The values that have been computed in this section for the recommendation on WSDMDA vs. NDT characteristics and their sub-features are concluded and summarized in Table 13.

$$\mathrm{r_F} = \frac{0.095 * 0.10 + 0.129 * 0.09}{2} = 0.01056$$

The Functionality Quality Characteristic values are displayed in Figure 8 according to the Global Properties Value and two Features (MDE and Web Modeling). The results of Domínguez-Mayo et al (Domínguez-mayo et al. 2012)(Domínguez Mayo 2013) are described by the values of the NDT. On the other hand, the results that the authors of this research work calculated are described by the values of the WSDMDA. The values of MDE, Web Modeling, and Global Properties Value from Table 14 are multiplied by 1000 to ease comparison.

Table 14 A comparison of two features between NDT and WSDMDA

Features	Sub-Features	Weights	Total Values		WSDMDA vs NDT
			NDT	WSDMDA	
MDE	f_{11} = Standard Definition	0.10	3/5	4/5	*Better*
	f_{12} = Model-based Testing	0.09	1	3/5	*Less*
	f_{13} = Traces	0.033	1	3/5	*Less*
	f_{14} = Levels of Abstraction	0.17	1	4/5	*Less*
	f_{15} = Transformations	0.31	3/5	3/5	*Equal*
Web Modeling	f_{21} = Web Conceptual Levels	0.07	5/6	1	*Better*
	f_{22} = Interfaces	0.38	4/6	5/6	*Better*
	f_{23} = Development Process	0.10	1	1	*Equal*
	f_{24} = Content Modeling	0.17	4/6	5/6	*Better*
	f_{25} = Presentation Modeling	0.10	4/6	4/6	*Equal*
	f_{26} = Navigation Modeling	0.10	5/6	5/6	*Equal*
r_{F_1} = Model-Driven Engineering (MDE)		W_{F_1} = 0.10	0.108	0.095	*Less*
r_{F_2} = Web Modeling		W_{F_2} = 0.09	0.113	0.129	*Better*
r_F = Global Properties Value			0.01049	0.01056	*Better*

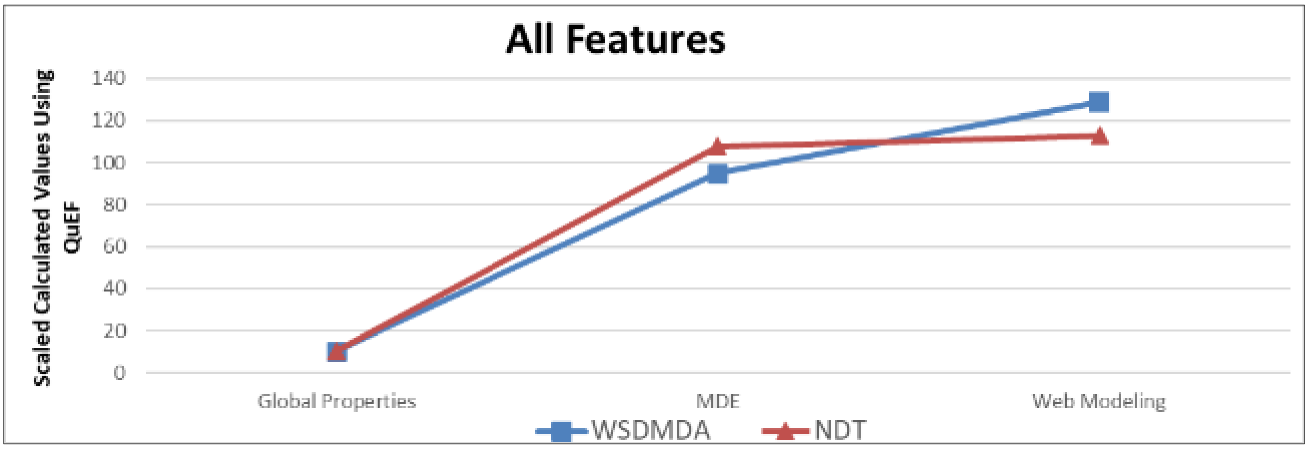

Figure 8 A comparison of two features between NDT and WSDMDA

5.3. Discussion for Functionality of WSDMDA for Two Features

The application of *Formula1* for calculating the feature value r_{F_i} provided a structured approach to quantifying the evaluators' scores, thereby allowing a robust comparison across different sub-features within each feature. The computed feature values for MDE and Web Modeling were instrumental in identifying performance discrepancies and areas requiring enhancement.

The evaluation data gathered from the six independent evaluators using an online asynchronous focus group was used to determine the obtained values. A benchmarking study was carried out to compare the assessment data from the six evaluators individually or to compare evaluation of *Evaluator05* for the WSDMDA and NDT. Based solely on QuEF's Functionality Quality attribute, benchmarking has been developed. Since it won't be impacted by the maturity of the evaluated MDWE methodology, only this quality has been examined (Domiguez-Mayo et al. 2014).

Two Features comprise this Functionality Quality Characteristic. As a result, 11 Sub-Features comprise these Features. Each of these Sub-Features produced a different set of values and yielded a different number for each Feature. Therefore, Figures 6 and 7 illustrate the differences between WSDMDA and NDT in terms of the two features, MDE and Web Modeling, respectively.

The MDA technology, which is regarded as the primary manifestation of MDE and Web Modeling features, is the primary focus of this research. Because of this, Figure 8 illustrates that the enhanced WSDMDA exhibits a better Web Modeling Feature value in comparison to the NDT methodology. This shows that by including all MDA technology components (CIM, PIM, PSM, Mapping Specification, and Model Transformations) into the framework of the WSDM web modeling method, the WSDMDA methodology has achieved its stated objective.

The comparison of the evaluators' responds for the WSDMDA web modeling feature is shown in Figure 3. Three-quarters of the evaluation panels' responses ranged from an estimated 66.67 to a score of 100, while 50% ranged with a value equal to 83.33. In terms of the web modeling components, this indicates that the WSDMDA has met the requirements with an average satisfaction rate of 81%.

Similar to the aforementioned, Figure 4 shows that 50% of the evaluators' answers for the WSDMDA's model-driven engineering (MDE) feature equal 60. Of the responses, 30% equal 80 and 20% equal 40. In conclusion, this indicates that, in terms of the model-driven engineering (MDE) feature, an average of 62% of the evaluation panels' requirements have been met.

Notably, Figures 3 and 4 in particular highlight the sub-features for the two features (MDE and Web Modeling). The total values of the same features, which are derived from their sub-features, are typically the main focus of Figure 5. In terms of the related sub-features in Figures 3 and 4, the feature values in Figure 5 are aligned with the same features, according to the results obtained from computing the evaluation data that was collected. Conversely, the six evaluators' WSDMDA global properties have been impaired because this evaluation process has utilized just two features.

It is evident that, in terms of Web Modeling Feature, the enhanced WSDMDA methodology performs better than NDT. Web developers can utilize the Web Modeling Feature to shorten the time it takes to design a system, and they will gain from MDA's model conformance in terms of transforming the models from one abstract level to another. Therefore, web developers could use the model transformations process in MDA technology as a catalyst to include this technology into their development processes.

Because of its maturity, which has a direct impact on the overall value for these sub-features, the NDT technique has the highest value for the sub-features of Traces and Model-based Testing in Figure 6. Despite being in its early stages of development, WSDMDA has outperformed NDT in the Standard Definition sub-feature and is on par with NDT in the Transformation sub-feature. Additionally, even though WSDMDA does not yet have a code generation component of MDA, it has achieved a very similar outcome to NDT for the Levels of Abstractions sub-feature.

The overall findings suggest that the WSDMDA methodology, which is based on the UML modeling language and implements its phases utilizing MDA technique components, can be considered to be an enhanced version of the WSDM method. Better evaluation findings using QuEF have been found by benchmarking compared to the de-facto MDWE methodology, specifically NDT, particularly in the Web Modeling Feature.

5.4. Evaluation of WSDMDA Sub-Characteristics

To illustrate the relationship between each Sub-Feature's influence on each Quality Sub-Characteristic, the matrix of influence (MoI) of Table 6 will be filled in for the quality sub-characteristics. The qualitative values (×) representing the non-influential degree and (√) representing the influential degree will be converted to values of 0 and 1, respectively, based on the QuEF description. The MoI matrix for the Functionality Quality Characteristic is displayed in Table 15 (Domínguez-mayo et al. 2012).

Six Quality Sub-Characteristics will be used to evaluate the enhanced MDWE methodology WSDMDA using the MoI matrix in Table 15. Then are going to calculate the Quality Sub-Characteristics values using Formulas 2 and 3. The weight of each Sub-Feature p_{f_i}, which may be found in Table 5 or 14, and the Sub-Feature value $r_{f_{ij}}$, which was previously calculated (in Tables 13 and 14), should be utilized in this calculation.

Table 15 MoI matrix between Sub-Features and Quality Sub-Characteristics (Domínguez-mayo et al. 2012)

			Q_1 = ***Functionality***					
		Sub-Feature	q_{11} **Suitability**	q_{12} **Interoperability**	q_{13} **Compliance**	q_{14} **Applicability**	q_{15} **Flexibility**	q_{16} **Transformability**
F E A T U E R S	**F_1 = MDE**	f_{11} = Standard Definition	1	1	1	1	1	1
		f_{12} = Model-based Testing	1	0	0	0	0	0
		f_{13} = Traces	1	0	0	0	0	0
		f_{14} = Levels of Abstraction	1	1	1	1	1	0
		f_{15} = Transformations	1	1	0	1	0	1
	F_2 = Web Modeling	f_{21} = Web Conceptual Levels	1	1	1	1	1	0
		f_{22} = Interfaces	1	1	1	1	1	1
		f_{23} = Development Process	1	1	1	1	1	0
		f_{24} = Content Modeling	1	1	1	1	0	0
		f_{25} = Presentation Modeling	1	1	1	1	0	0
		f_{26} = Navigation Modeling	1	1	1	1	0	0

Following the collection of evaluation data using asynchronous online focus groups, Table 16 displays the derived quality sub-characteristics values from each evaluator using QuEF, as demonstrated in the preceding subsection. This is achieved by utilizing Formulas 2 and 3. Figure 9 provides a comprehensive representation of these values. Figure 10 shows the evaluators' individual responses for each sub-characteristic. The calculated values are multiplied by 1000 to create a scaling that makes the comparison in these figures easier.

Table 16 Values of All Sub-Characteristic Calculated for Six Evaluators

	Quality Sub-Characteristics	**Evaluator (1)**	**Evaluator (2)**	**Evaluator (3)**	**Evaluator (4)**	**Evaluator (5)**	**Evaluator (6)**
Quality of Functionality	Suitability	0.1105	0.1096	0.0900	0.1004	0.1145	0.1097
	Interoperability	0.1289	0.1277	0.1031	0.1138	0.1311	0.1252
	Compliance	0.1218	0.1204	0.1005	0.0970	0.1250	0.1176
	Applicability	0.1289	0.1277	0.1031	0.1138	0.1311	0.1252
	Flexibility	0.1366	0.1342	0.1114	0.1092	0.1420	0.1366
	Transformability	0.1877	0.1877	0.1457	0.1870	0.1967	0.1877

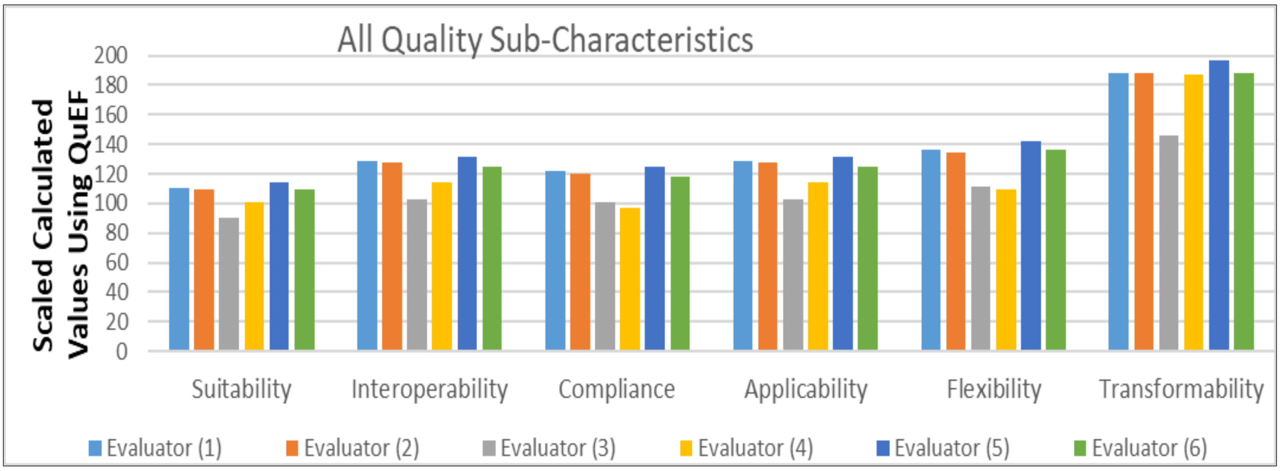

Figure 9 Values of All Sub-Characteristic Calculated for Six Evaluators

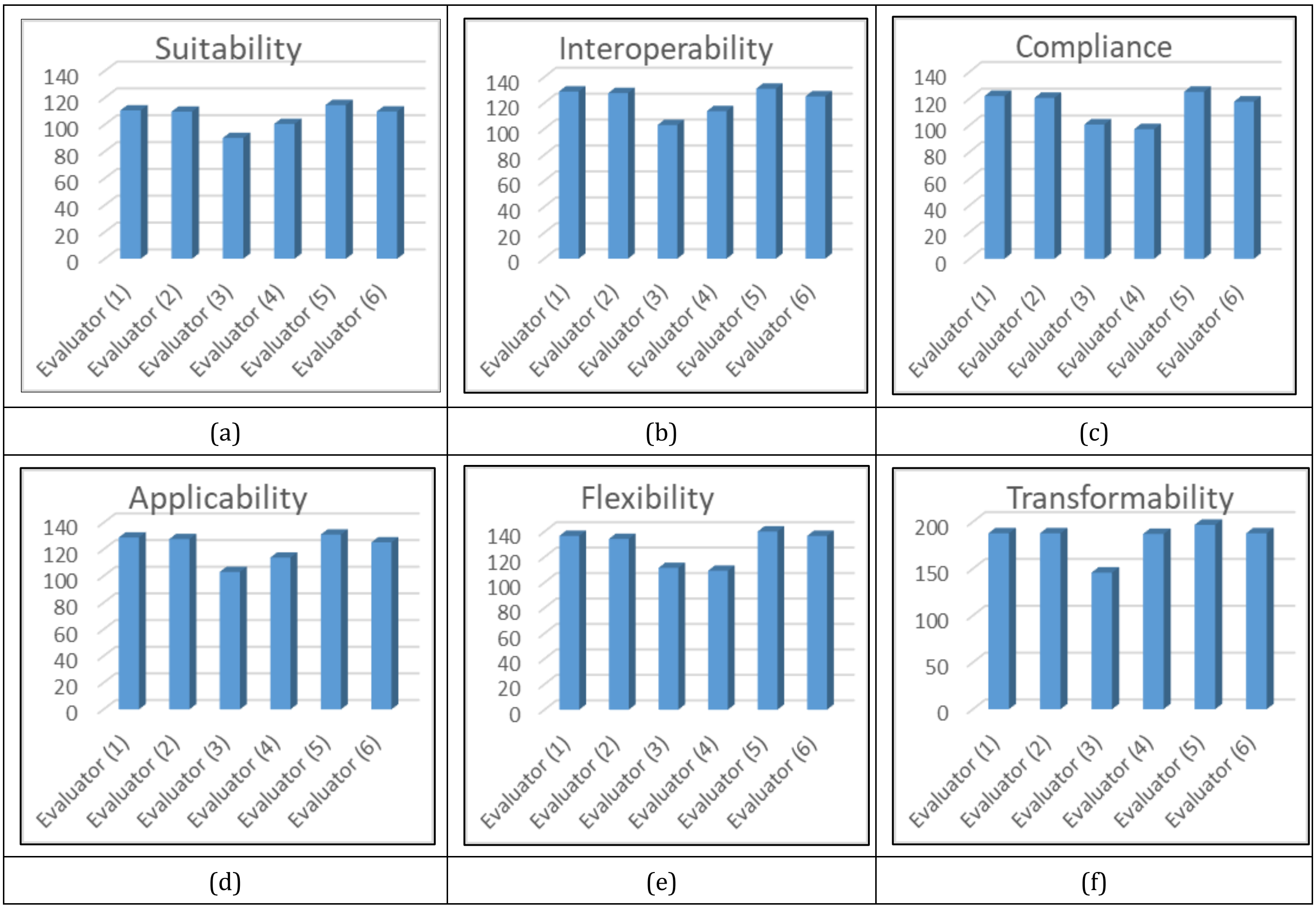

Figure 10 Individual Values of Each Sub-Characteristic Calculated for Six Evaluators

5.5. Comparison Between WSDMDA and NDT Sub-Characteristics Evaluation

Based on the six Quality Sub-Characteristics, a comparison of the Functionality Quality Characteristics of the NDT methodology and the enhanced WSDMDA methodology has been executed. Table 17 shows the six Quality Sub-Characteristics along with the findings of Domínguez-Mayo et al. (Domínguez-mayo et al. 2012)(Domínguez Mayo 2013) for the values of the NDT methodology. The evaluation responses of Domínguez-Mayo, the same scholar who served as Evaluator05 in the asynchronous online focus group, were calculated and described using the values of the WSDMDA methodology. The calculated values are multiplied by 1000 to facilitate the comparison. Figure 11 compares the WSDMDA methodology with the well-known MDWE methodology (NDT) graphically.

Table 17 A Comparison of All Quality Sub-Characteristics between NDT and WSDMDA

	Quality Sub-Characteristics	Total Values		WSDMDA vs NDT
		WSDMDA	NDT	
Functionality (Q_1)	q_{11} = Suitability	114.5	110.9	*Better*
	q_{12} = Interoperability	131.1	122.2	*Better*
	q_{13} = Compliance	125.0	113.8	*Better*
	q_{14} = Applicability	131.1	122.2	*Better*
	q_{15} = Flexibility	142.0	128.0	*Better*
	q_{16} = Transformability	196.7	170.0	*Better*

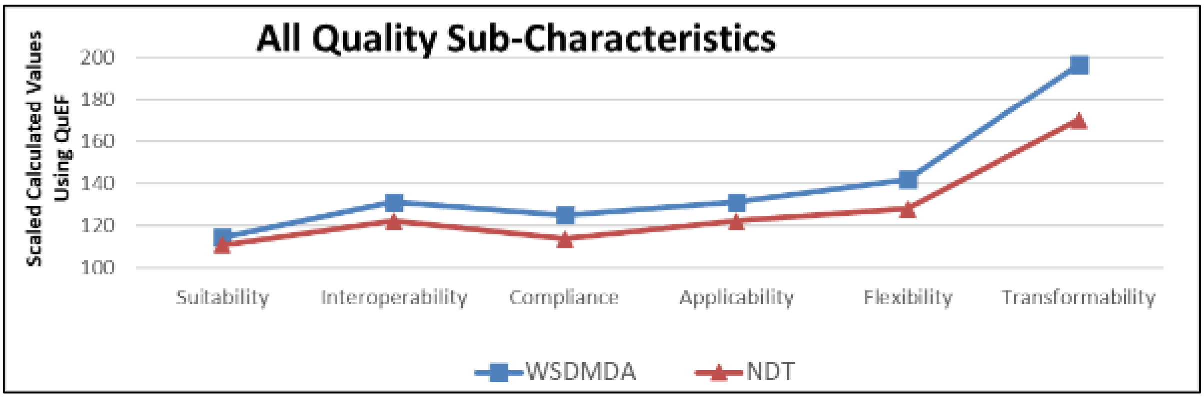

Figure 11 A Comparison of All Quality Sub-Characteristics between NDT and WSDMDA

5.6. Discussion for Functionality of WSDMDA for Six Sub-Characteristics

The study further broke down the evaluation into six quality sub-characteristics: Suitability, Interoperability, Compliance, Applicability, Flexibility, and Transformability. Each sub-characteristic was analyzed using *Formula2* and *Formula3*, facilitating a deep understanding of the methodology's functional capabilities:

Interoperability and Transformability scored exceptionally well, affirming the methodology's strong performance in integrating with diverse systems and adapting to varied modeling requirements.

Compliance and Flexibility received lower scores, highlighting potential areas for improvement in adhering to standards and adjusting to changing environments.

Through the use of an online asynchronous focus group, evaluation data from six independent evaluators was gathered, and the resulting values were calculated. The evaluation results from the six evaluators individually and the evaluation of *Evaluator05* for the WSDMDA and NDT combination have been benchmarked. Based on QuEF's Functionality Quality feature, the benchmarking was constructed. Because it is independent of the development level of the compared methodologies, the Functionality Quality Characteristic and its six quality sub-characteristics (Suitability, Interoperability, Compliance, Applicability, Flexibility, and Transformability) have been chosen (Domiguez-Mayo et al. 2014).

Two Features and six Quality Sub-Characteristics make up the Functionality Quality Characteristic. As a result, 11 Sub-Features comprise these Features. Each of these sub-features produced a distinct value and a different number for each quality sub-characteristic. Thus, Figure 11 presents the differences between WSDMDA and NDT.

Notably, as Figure 11 makes clearly evident, WSDMDA methodology outperformed NDT methodology in terms of all Quality Sub-Characteristics. The line that represents the evaluation of the enhanced WSDMDA methodology and the line that represents the evaluation of the NDT methodology are fairly comparable. This suggests that the WSDMDA methodology is headed toward popularity, much like NDT, and has the potential to be a popular and successful methodology in the near future.

Figure 9 shows that the Transformability sub-characteristic has received higher ratings from evaluation panels, however the Flexibility sub-characteristic has received lower ratings than Interoperability and Applicability. Therefore, the main objective of the WSDMDA methodology has been accomplished, namely to provide an enhanced MDWE methodology with excellent criteria for transformability, flexibility, and compatibility.

It is well known that web developers are encouraged to use MDA technology into their techniques because of the model transformations process. As a result, the WSDMDA methodology has concentrated on changing user navigation activities particularly during the interoperability process. As a result, the enhanced WSDMDA exhibits a better transformability Quality Sub-Characteristic in comparison to the other Quality Sub-Characteristics, as illustrated in Figure 11. It indicates that the WSDMDA methodology has achieved its original objective of enabling user requirements to be transformed from an early stage to a final stage during the process of interoperability between various MDWE methodologies.

Figure 10, a collection of six different figures, shows the outcomes of the calculated evaluation data gathered from six evaluators in terms of each sub-characteristic independently. These numbers clearly show that among all evaluation panels, the Transformability sub-characteristic had the greatest response. Interoperability and Applicability ranked third, while Flexibility and Suitability placed second. Ultimately, the sub-characteristic of Compliance came in lowest.

In comparison to the other WSDMDA Quality Sub-Characteristics, the enhanced WSDMDA methodology's values for Interoperability, Applicability, Flexibility, and Transformability achieved the greatest values. Furthermore, these figures confirm to the applicability and adaptability of WSDMDA in creating web applications in a straightforward way.

The total outcome shows that the WSDMDA methodology, which implements its phases entirely using MDA technology components and is based on the UML modeling language, can be considered as an enhanced MDWE methodology. The WSDMDA methodology has demonstrated a strong evaluation based on QuEF through comparison with other MDWE methodologies, particularly in the Interoperability, Flexibility, and Transformability Quality Sub-characteristics. This indicates that the enhanced methodology could significantly contribute on transforming user navigation activities during the interoperability process for different MDWE methodologies.

6. Conclusion

The detailed evaluation using QuEF underscores the WSDMDA methodology's potential as a leading framework in MDA-based web engineering. However, the identified gaps in testing and compliance present opportunities for further refinement. Future research should focus on enhancing these aspects and re-evaluating the methodology post-improvements to gauge their impact on the overall effectiveness of WSDMDA.

The WSDMDA methodology exhibits significant strengths in Web Modeling and MDE features, particularly excelling in conceptual design, user interface design, and standard definition. These strengths are critical for developing complex, user-centric web applications that require high levels of interoperability and adaptability.

The areas identified for improvement, such as Model-Based Testing and Compliance, suggest a need for the methodology to incorporate more rigorous testing frameworks and enhanced compliance measures. Addressing these areas could improve the reliability and standard adherence of the methodology, making it more robust and versatile.

The results of this study may direct future advancements in MDA-based techniques, which could ultimately result in web apps that are stronger, more effective, and easier to use. This work advances both the theoretical and practical understanding of web engineering and establishes a standard for future assessments and advancements in the field.

As conclusion, this research study applies the QuEF framework to evaluate the WSDMDA methodology, which offers a significant addition to the field of Model-Based Web Engineering (MBWE). The work might provide deeper insights and a stronger case by going into greater detail on the aforementioned points, which would increase its applicability and influence in both academic and professional contexts.

6.1. Future Works

This research work is significant as it provides a comprehensive evaluation of the Web Site Design Method MDA-Based (WSDMDA) using the Quality Evaluation Framework (QuEF). By rigorously assessing both Model-Driven Engineering (MDE) and Web Modeling features under the MDA framework, the study contributes substantially to the field of web engineering.

This research highlights how methodologies can be systematically evaluated to identify strengths and weaknesses in their application to real-world web development scenarios. This research doesn't only aids developers in selecting the most appropriate methodologies for their projects but also enriches the academic discourse by providing a structured approach to methodology evaluation.

The findings from this research have the potential to guide future improvements in MDA-based methodologies, ultimately leading to more robust, efficient, and user-friendly web applications. This study sets a precedent for future evaluations and developments in the domain, enhancing the theoretical and practical understanding of web engineering.

Some arguments could be said that the evaluation is totally based on the opinions and voting of a small group of evaluators. The results of the evaluation may be impacted by their own understanding and their own experiences. Although the fact that the evaluators are experts in their fields, the different of their understandability, familiarity, and degrees of experience with the QuEF may be reflected on the importance and consistency of the outcomes.

1. As a nature of focus group, six respondents is considering within the acceptable range when employing the online focus group approach. Carey et. al. (Carey and Asbury 2016) argued that "On average, the group should consist of 6 to 10 members. Therefore, it may be difficult to sustain a discussion if the number of participants is less than 6; and it may be difficult to control if the number of participants is more than 10". However, this number of evaluators can be increased in the future work to strengthen research outcomes. But it is important to know; the online questionnaire has been prepared to be totally dependent on the QuEF context, and the evaluators don't need to be familiar with it.

Some arguments could be also said that The evaluation and resulting outcomes are based on the only case study of the WSDMDA methodology. Unfortunately, these results cannot be generalized to other MDA-based methodologies without making additional critical adjustments and assessments. The specific characteristics of WSDMDA may respond differently to the evaluation framework compared to other methodologies, which could limit the broader application of the findings.

2. The selection of the most commonly used qualities and features that need to be evaluated is a very important issue for making the evaluation and resulting outcomes more fair and reflective. So, in future work, there must be a critical consideration for a carefully selection for the qualities and features of the methodologies under evaluation. If this selection has been done properly, generalizability can be granted.

Some reviewers could be argued that although the study utilizes a reliable quantitative approach to evaluate the methodology, the qualitative features such as user satisfaction, usability, and interface considerations of the development of web applications using WSDMDA have not yet been deeply examined. This drawback of qualitative evaluation could ignore some other but critical features of model-based web engineering. In addition, the evaluation process focuses on two features: MDE and Web Modeling. Despite the fact that they are critical components, other critical components like Tool Support and User Experience have not yet been reviewed. This limitation may result in an unsatisfactory evaluation of the methodology's overall selection potentiality and efficiency.

3. The theme of web applications is a qualitative theme in terms of qualities and features therefore it is important to address or evaluate these qualities and features by a qualitative framework. Hence, the QuEF is receiving qualitative data (like either Supported, Not Supported, or Partially Supported), as the QuEF framework basically has a special step to convert these qualitative feedback data to quantitative data. In the future, these quantitative data can be processed using standard statistical approaches to increase the understandability of evaluations and resulting outcomes. However, the QuEF already has many qualities (such as User Satisfaction, Usability, and Model-Based Testing) and other Features (such as Tool Support, Interface, and User Experience). In the near future, these qualitative aspects will be included to make the evaluation and selection of appropriate MBWE methodology is fair, efficient, and effective.

Compliance with ethical standards

Acknowledgement

We would like to express our sincere gratitude to Prof. Dr. Francisco Jose Dominguez Mayo for his invaluable support and assistance throughout this research, which is one of the contributors to this study, and he is the primary developer of QuEF as well. We also extend our appreciation to our Colleagues, Advisors, and Institutions for their insightful comments and encouragement. Finally, we are grateful to our families and friends for their unwavering support and understanding during this endeavor.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Aragón, G, M.J Escalona, M Lang, and J.R Hilera. 2013. An Analysis of Model-Driven Web Engineering Methodologies. International Journal of Innovative Computing, Information and Control 9 (1): 413–36. http://www.ijicic.org/ijicic-11-11012.pdf.

[2] Balaji, M., S. N. Dinesh, P. Manoj Kumar, and K. Hari Ram. 2021. Balanced Scorecard Approach in Deducing Supply Chain Performance. In Materials Today, 47:5217–22. Elsevier Ltd. https://doi.org/10.1016/j.matpr.2021.05.541.

[3] Becker, Pablo, and Luis Olsina. 2010. Towards Support Processes for Web Projects. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 6385 LNCS (6360): 102–13. https://doi.org/10.1007/978-3-642-16985-4_10.

[4] Carey, Martha Ann, and Jo-Ellen Asbury. 2016. Focus Group Research. Routledge.

[5] Chung, L, Brian a Nixon, and Eric S K Yu. 1995. Using Non-Functional Requirements to Systematically Select Among Alternatives in Architectural Design. In 1st International Workshop on Architectures for Software Systems - In Cooperation with the 17th International Conference on Software Engineering, ICSE 1995, 31–43. https://ics.uci.edu/~andre/ics223w2006/chungnixonyu.pdf.

[6] Czarnacka-Chrobot, Beata. 2009. The ISO/IEC Standards for the Software Processes and Products Measurement. In New Trends in Software Methodologies, Tools and Techniques: Proceedings of the Eighth SoMeT_09, 187–200. IOS Press. https://books.google.com/books?hl=en&lr=&id=Jqo-VbwUDGUC&pgis=1.

[7] Djekic, Ilija, Nikola Tomic, Siméon Bourdoux, Sara Spilimbergo, Nada Smigic, Bozidar Udovicki, Gerard Hofland, Frank Devlieghere, and Andreja Rajkovic. 2018. Comparison of Three Types of Drying (Supercritical CO2, Air and Freeze) on the Quality of Dried Apple – Quality Index Approach. LWT - Food Science and Technology 94 (November 2017): 64–72. https://doi.org/10.1016/j.lwt.2018.04.029.

[8] Domiguez-Mayo, F. J., M. J. Escalona, M. Mejias, M. Ross, and G. Staples. 2014. Towards a Homogeneous Characterization of The Model-Driven Web Development Methodologies. Journal of Web Engineering 13 (1–2): 129–59. http://cat.inist.fr/?aModele=afficheN&cpsidt=28345213.

[9] Dominguez-Mayo, F.J., María José Escalona, M. Mejias, and A.H. Torres. 2010. A Quality Model in a Quality Evaluation Framework for MDWE Methodologies. In IEEE Fourth International Conference on Research Challenges in Information Science (RCIS), 495–506. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5507323.

[10] Domínguez-Mayo, F.J., María José Escalona, Manuel Mejías, M. Ross, and G. Staples. 2011. A Method Based on AHP to Define the Quality Model of QuEF. In Knowledge Engineering and Management - Springer Berlin Heidelberg, 685–94. https://doi.org/10.1007/978-3-642-25661-5_85.

[11] Domínguez-Mayo, F.J., M Espinilla, M J Escalona, and M Mejías. 2011. A Weighted Quality Evaluation Framework by Applying the Analytic Hierarchy Process. In Nineteenth International Conference on Software Quality Management, Global Quality Issues, 55–66.

[12] Domínguez-mayo, F J, M J Escalona, M Mejías, M Ross, and G Staples. 2012. Quality Evaluation for Model-Driven Web Engineering Methodologies. Information and Software Technology - ELSEVIER 54 (11): 1265–82. https://doi.org/10.1016/j.infsof.2012.06.007.

[13] Domínguez Mayo, Francisco José. 2013. Thesis: A Framework to Evaluate Quality of Model-Driven Web Engineering Approaches. University of Seville.

[14] Fernandes, Telma Santos, Ângela Silva, Raquel Reis, and Celina Leão. 2016. Gathering Information Based on Focus Groups : Consumer ' s Involvement in the Use of Vending Machines. The Qualitative Report. Vol. 21. http://nsuworks.nova.edu/cgi/viewcontent.cgi?article=2608&context=tqr.

[15] Fox, Fiona E., Marianne Morris, and Nichola Rumsey. 2007. Doing Synchronous Online Focus Groups With Young People: Methodological Reflections. Qualitative Health Research 17 (4): 539–47. http://qhr.sagepub.com/content/17/4/539.short.

[16] Giraldo, Faber D., Sergio Espana, and Oscar Pastor. 2014. Analysing the Concept of Quality in Model-Driven Engineering Literature : A Systematic Review. In IEEE Eighth International Conference on Research Challenges in Information Science (RCIS), 1–12. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6861030.

[17] Liamputtong, Pranee. 2011. Focus Group Methodology. SAGE.

[18] McGinn, Conor, Eamonn Bourke, Tiarnan O'Kelly, and Michael F. Cullinan. 2018. Adapting the Goals/Questions/Metrics (GQM) Method for Applications in Robot Design. In IEEE International Conference on Robotics and Automation, 4746–51. IEEE. https://doi.org/10.1109/ICRA.2018.8460630.

[19] Mesbah, Ali, and Ieee Computer Society. 2012. Invariant-Based Automatic Testing of Modern Web Applications. IEEE Transactions on Software Engineering 38 (1): 35–53. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5728834.

[20] Nicholas, David B., Lucy Lach, Gillian King, Marjorie Scott, Katherine Boydell, Bonita Sawatzky, Joe Reisman, Erika Schippel, and Nancy L. Young. 2010. Contrasting Internet and Face-to-Face Focus Groups for Children with Chronic Health Conditions : Outcomes and Participant Experiences. International Journal of Qualitative Methods 9 (1): 105–22. https://doi.org/10.1177/160940691000900102.

[21] Panduwiyasa, H, M Saputra, Z F Azzahra, and A R Aniko. 2021. Accounting and Smart System: Functional Evaluation of ISO/IEC 25010:2011 Quality Model (a Case Study). In IOP Conference Series: Materials Science and Engineering, 1092:012065. https://doi.org/10.1088/1757-899x/1092/1/012065.

[22] Pesic, Marija Andjelkovic, and Jens J. Dahlgaard. 2013. Using the Balanced Scorecard and the European Foundation for Quality Management Excellence Model as A Combined Roadmap for Diagnosing and Attaining Excellence. Total Quality Management & Business Excellence 24 (5–6): 652–63.

[23] Punter, Teade, Rob Kusters, Jos Trienekens, Theo Bemelmans, and Aarnout Brombacher. 2004. The W-Process for Software Product Evaluation: A Method for Goal-Oriented Implementation of the ISO 14598 Standard. Software Quality Journal 12 (2): 137–58. https://doi.org/10.1023/B:SQJO.0000024060.32026.a2.

[24] Rahman, Kiramat, Anwar Ghani, Sanjay Misra, and Arif Ur Rahman. 2024. A Deep Learning Framework for Non-Functional Requirement Classification. Scientific Reports. Vol. 14. Nature Publishing Group UK. https://doi.org/10.1038/s41598-024-52802-0.

[25] Saaty, T.L. 1983. Introduction to a Modeling of Social Decision Process, Mathematics and Computers in Simulation. MacGraw-Hill, New York.

[26] Singh, K K. 2016. A Quantitative Method for Evaluation of Websites Quality Using WebQEM Tool. Journal of Global Research Computer Science and Technology (JGRCST), 1–11.