

CHAPTER FOUR

WEB ACCESSIBILITY QUANTITATIVE METRIC

4.1 INTRODUCTION

This chapter seeks to answer the first research question, which is: “How can we formulate a mathematical metric that gives measurable weight to each barrier in order to rank them based on their influence and contribution to accessibility problems?”

The correction actions discussed earlier in Section 2.5.2, lack of clear mathematical model to determine severe barriers, since they are only based on limited experiments and surveys. Moreover, the metrics that were highlighted in Section 2.4 have different scope than this work’s metric since they are intended to measure websites’ accessibility level not to determine barriers severities. Thus, a mathematical based metric that aims at determining barriers severity by assigning measurable weight to each barrier based on severity is needed. WABS metric is different from the previous metrics, since it is more concerned about revealing the persistent barriers that limit the accessibility based on their severity rather than the total conformance to priority levels. Unlike the previous metric which based on WCAG 1.0, WABS is based on WCAG 2.0 which is the latest one from WAI and does not necessarily require human expert to assign scores and weights.

When carrying out large-scale studies, such metric would help accessibility evaluators to reveal the most persistent barriers they face when evaluating a specific set of websites. This will enable evaluators to further investigate these commonplace violations that Web

developers of intended websites keep making. Accordingly, Web developers can fix the determined severe barriers and avoid them in the future to increase the accessibility level of their websites.

The proposed metric (WABS) is designed to work with any evaluation technique that reveals the type and frequency of barriers for each website such as (automated tools, expert reviews, and lab studies). Yet, automated testing can help to reduce the time required for the evaluation process. Moreover, automated tools reduce the need for massive manual checking and allow large-scale assessment of aggregate websites. WABS metric will utilize the results of some automated tools which cover the WCAG 2.0 guidelines and assist Web developers to review violations in real time.

4.2 REQUIREMENTS AND ASSUMPTIONS

In this section, the requirements and assumptions for WABS metric are described, based on properties of a good web accessibility metric proposed by Zeng (2004) and Vigo et al. (2007). Later, this section shows how WABS metric abides by scientific research measurements.

Requirement 1: *Metric Results should be normalized.*

Assumption 1: The barriers must be measured in a quantitative score that provides a continuous range of values from perfectly major barriers to completely unimportant ones. A quantitative numerical score would allow assessment of barriers along groups of websites.

Assumption 2: The metric values must have a large discriminating power beyond simply major to minor. Instead of an absolute measure of accessibility barrier severity that

categorizes barriers only as important or not, an assessment using the metric would be able to answer the fundamental scientific question: More or less important, compared to what? (Tufté, 1997). A metric with good discriminating power would allow assessment of barriers affecting accessibility and show if there are significant differences among them. In order to rank barriers according to their severity, a weight with a positive value associated with each barrier is chosen so that values of the final metric are ranged from 0 to 1. The closer the result of the metric is to 0, the less severe the barrier is, and the closer to 1 it is, the more severe.

Requirement 2: *The metric should give a value to each barrier based on its influence on the priority level that it violates as well as to the whole dataset (the whole set of webpages being assessed)*

Assumption 1: Besides total frequency of errors for each barrier in the webpage, the metric should also take into account the total number of times each barrier has been tested. The metric should not be based on the absolute frequency of errors found for each barrier but in the relative number of found errors in relation to the number of tested cases, i.e. the ratio of errors and number of tested cases. In other words, the number of websites that contain the same type of barrier should be taken into account.

Assumption 2: The metric should be scalable in order to allow for large-scale web accessibility studies. Large-scale accessibility assessments require a metric that supports aggregation and allows statistical analysis in order to measure any significant difference among values.

Assumption 3: The priority of unfulfilled success criteria (barriers) should be reflected in the final result. Within WCAG 2.0, priority “A” SCs have more impact on the

accessibility level of a webpage than priority “AA” SCs, and so on. No matter the value assigned for each priority, it should reflect the differences between these priorities based on their importance. The unique restriction when selecting these weights is that:

$$1 > \text{priorityA_weight} > \text{priorityAA_weight} > \text{priorityAAA_weight} > 0$$

In this work, priorities weight suggested by (Vigo et al., 2007) were adopted. In their study, they conducted an experiment to assign weights to priorities. They chose the most appropriate weights that produce accessibility value similar to the failure rate on test files, the suggested weights were (priority “A”=0.8, priority “AA”=0.16, priority “AAA”=0.04).

Requirement 3: *The measurement should be normative.*

The metric should be derived from standard guidelines of web accessibility such as the WCAG.

Since the WCAG and Section 508 largely overlap—with WCAG being more comprehensive and the internationally accepted standard as well (WCAG, 2012)—WCAG2.0 is used as the foundation for WABS metric since it is the latest one from WAI.

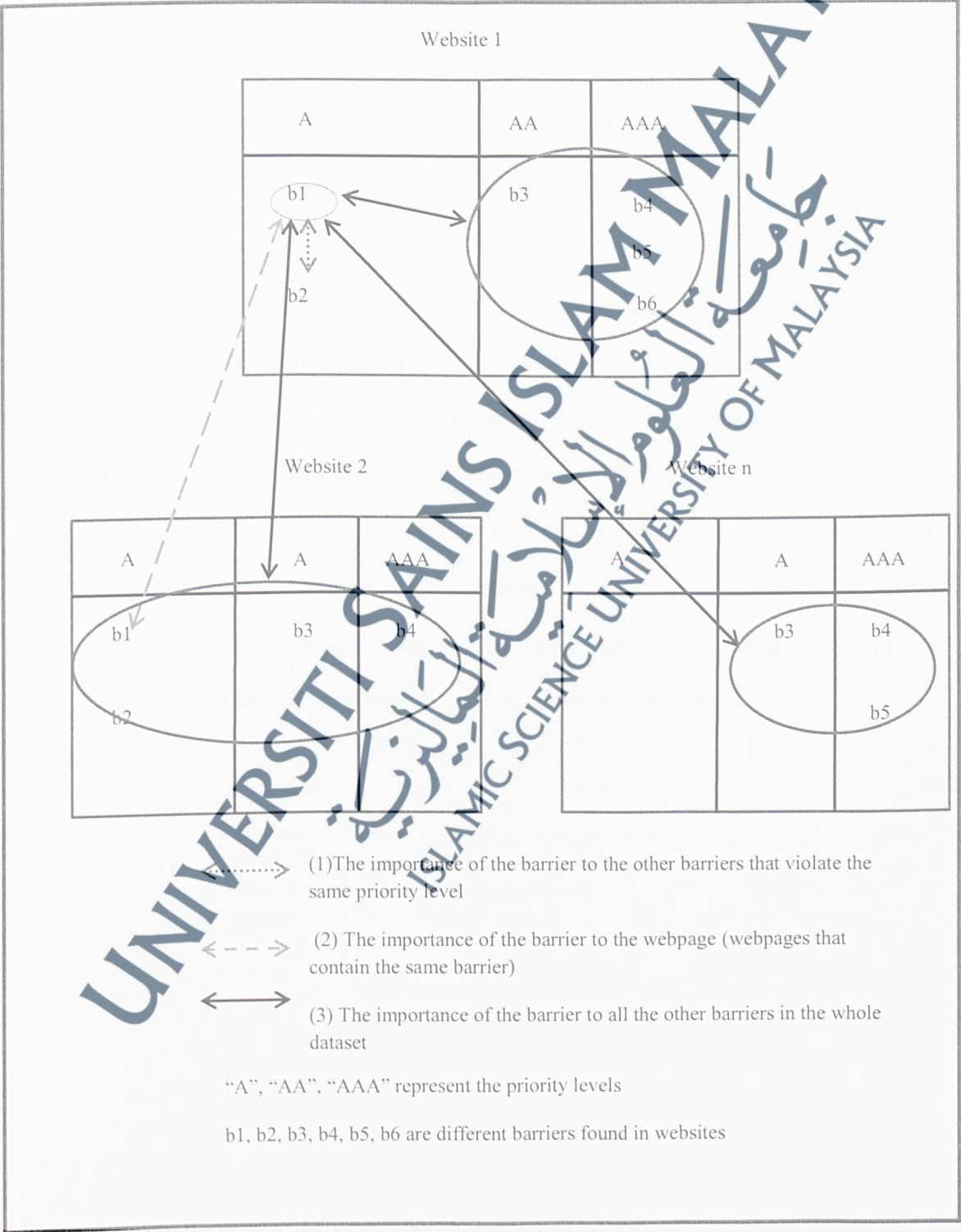
Requirement 4: *Problems that need human judgment should not have influence on the final metric.*

Theoretically, the metric can be used to calculate scores based on SCs in WCAG 2.0 priorities. Nevertheless, this work focuses only on barriers that can be checked automatically. Furthermore, when performing an automatic test, all webpages get the same report of generic problems that need manual review. Thus, a metric based on automatic evaluation should not take into account these generic problems.

4.3 METRIC FORMULATION

WABS metric is basically formed to meet the requirements of building a good metric as suggested by (Zeng, 2004; Vigo et al., 2007). Furthermore, it utilizes some parameters used by the metric proposed by (Zeng, 2004). Parameters such as barrier frequency and the priority level that has been violated as well as the concept of including the number of test cases, were used. The metric needs to take into consideration how a barrier weight can be affected by: other barriers that belong to the same priority level, other barriers that violate that same barrier's webpage and by all barriers across the whole documents. Thus, WABS needs different measurements for a scientific exploration which are: (1) The importance of the barrier to the other barriers that violate the same priority level; (2) The importance of the barrier to the webpage; and (3) The importance of the barrier to all the other barriers in the whole dataset (all websites). Figure 4.1 shows a simple demonstration of how a barrier weight is influenced by other barriers.

FIGURE 4.1: A Demo of How a Barrier Weight is influenced by Other Barriers in a Dataset of Websites



The metric formulation is inspired by the vector space model which is part of Information Retrieval field. The vector space includes three stages (Salton et al., 1975). First, document indexing; second, term weighting which consists of term frequency factor, collection frequency factor and length normalization factor; and third, weights ranking. The same idea was applied to WABS since each document will be indexed by the barriers, then each barrier will be assigned a weight that will take into account the barrier importance to a priority level, to the webpage being tested and to the whole dataset, and finally the barriers will be ranked based on their weights. Two principals were used from vector space model. The first one is the extension of Pythagorean Theorem (Weisstein, 2014), which is used to measure barrier length in different contexts (this principle covers the first and third measurements of the metric). The second principle is TF-IDF (Sparck Jones, 1972) which was adjusted to meet the second measurement of the metric (The importance of the barrier to the webpage). Formula (4.1) represents WABS metric. WABS is applied to each barrier separately to calculate its weight. Subsequently, the barriers' severity can be ranked once each barrier weight is found.

$$\frac{\sqrt{\sum_{d=1}^k freq(bi)^2}}{\sqrt{\sum_{d=1}^k b(pc)^2}} * \frac{n(bi)}{N} * \frac{pc}{\sqrt{\sum_{d=1}^k (b)^2}} \quad (4.1)$$

Variables, constants and how the metric is formulated are discussed in this section. In order to demonstrate how the final metric (formula (4.1)) is built; the researcher broke it down into three main sub equations namely, formula (4.1.1), (4.1.2) and (4.1.3). Equations cover the measurements which relates to the importance of a barrier to its priority level, its webpage and to the whole evaluation dataset. Figure 4.2 demonstrate the final metric (WABS) after aggregating the sub formulas. Besides, it displays how the sub formulas are connected to the extension of Pythagorean Theorem and TF-IDF principles.

FIGURE 4.2: Sub-Equations that Formulate WABS Metric and Covers Different Measurements

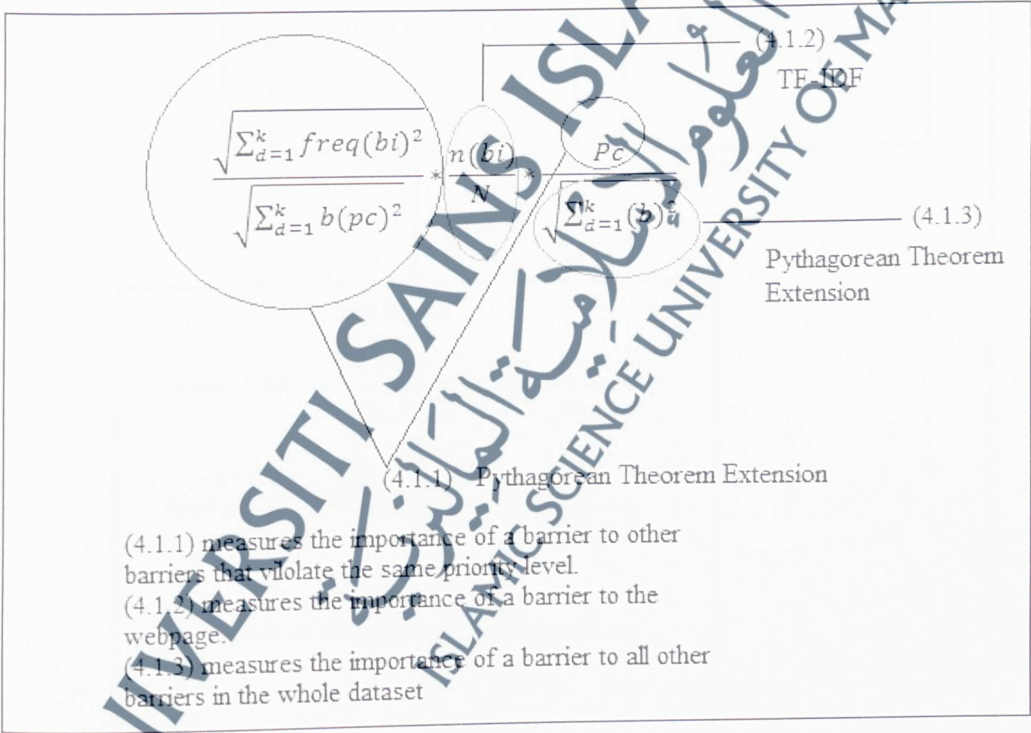
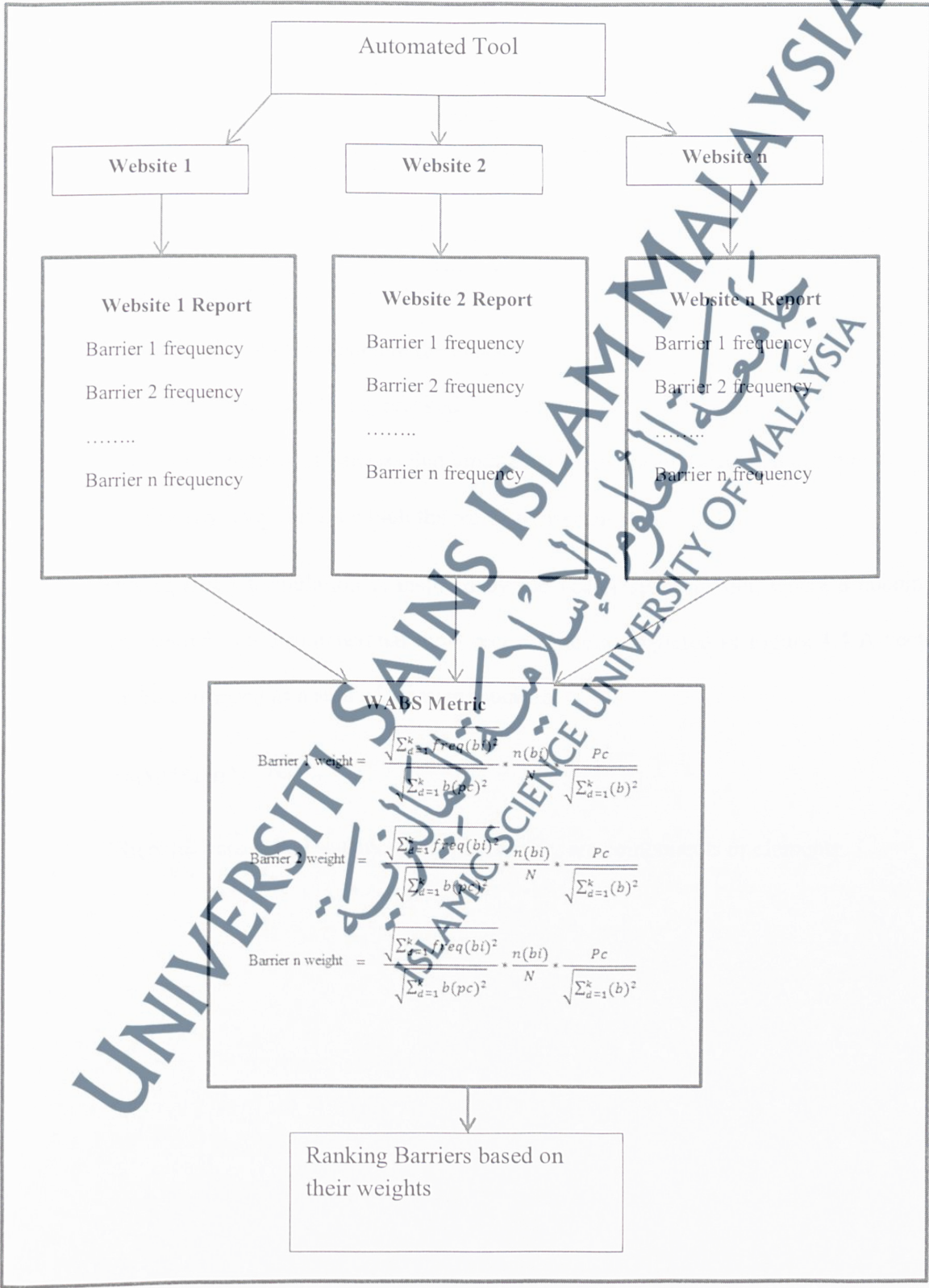


Figure 4.3 shows how WABS metric will be applied to each barrier that is detected by the automated tools within the websites dataset in order to be ranked based on their severity (weights).

FIGURE 4.3: Applying WABS to Barriers detected by the Automated Tools



A- The importance of the barrier to the other barriers that violate the same priority level

$$\frac{\sqrt{\sum_{d=1}^k freq(bi)^2}}{\sqrt{\sum_{d=1}^k b(pc)^2}} * Pc \quad (4.1.1)$$

Where,

d = document (webpage) being tested

k = last document to be tested in the dataset

bi = barrier (violation) being checked

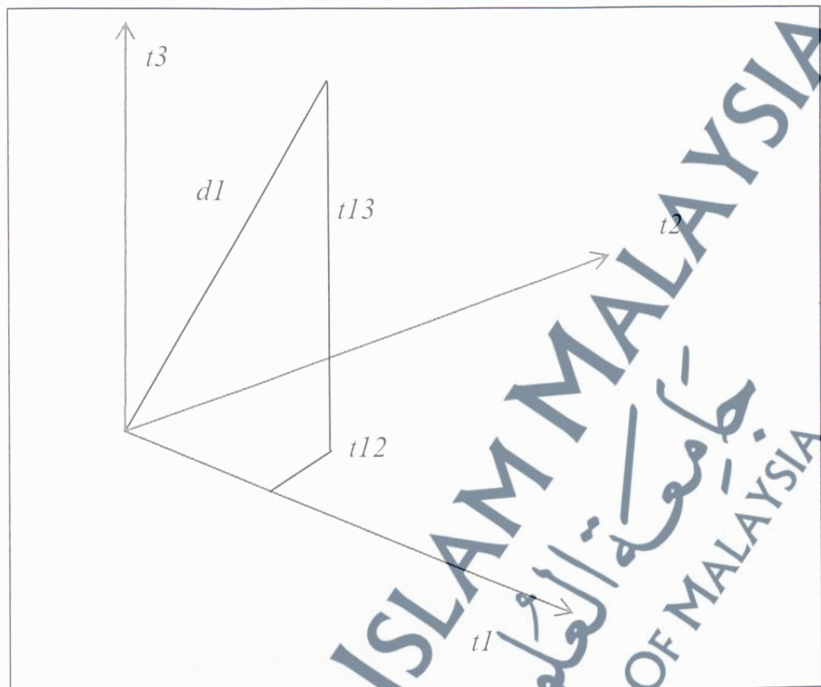
$b(pc)$ = total number of barriers that violate the same priority level in a document

Pc = priority level weight which the tested barrier violates

This equation formulation is inspired by the vector space model, where a document is represented in a 3-dimensional term vector space as depicted in Figure 4.4 A vector (v) can be expressed as a sum of elements such as,

$$v = a_1 v_{i1} + a_2 v_{i2} + \dots + a_n v_{in}$$

Where (a_n) are called scalars or weights and v_n are components or elements.

FIGURE 4.4: Document's Representation in a Vector Space

In order to calculate the document length in a vector space, the extension of Pythagorean Theorem (Weisstein, 2014) is being used as follows:

$d = (x_1, x_2, x_3, \dots, x_n)$ is a vector in an n -dimensional vector space. Length of x is given by (extension of Pythagoras's theorem):

$$|d|^2 = x_1^2 + x_2^2 + x_3^2 + \dots + x_n^2$$

$$|d| = (x_1^2 + x_2^2 + x_3^2 + \dots + x_n^2)^{1/2}$$

The webpages in a collection can be viewed as a set of vectors in vector space in which there is one axis for every barrier. Each webpage in the dataset has a different type and frequency of errors (barriers). As a result, webpages length is different and should be measured based on barriers' impact on priority level.

The only problem with this assumption is that a webpage cannot be treated as a document of terms. The severity of barriers is not only affected by a webpage in the dataset since many factors are controlling the severity, such as other barriers in the dataset and the priority level that has been violated. So, the vector length formula is adjusted to measure the severity of barriers that violate a priority level across the whole dataset.

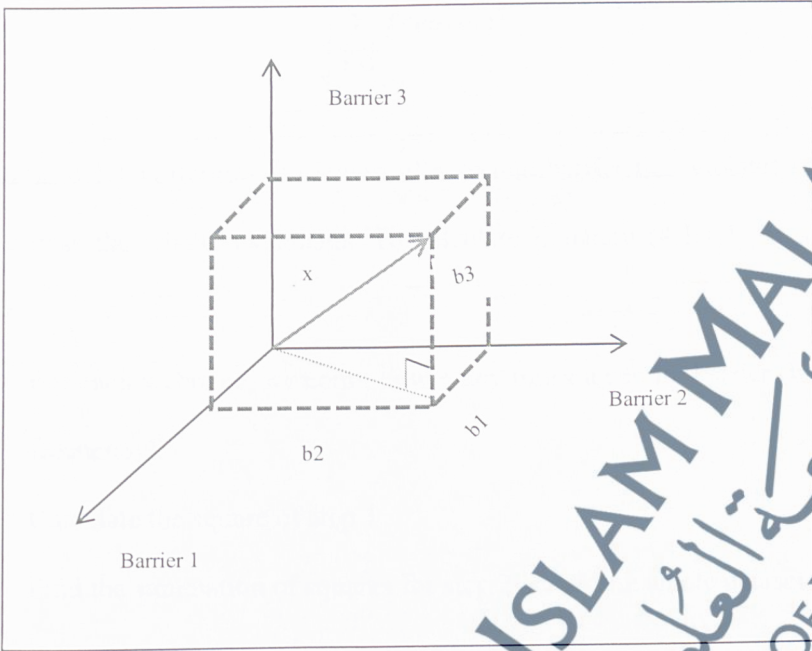
Let x be the length of all barriers that violate the same priority level across the whole dataset as illustrated in Figure 4.5. Then,

$$|x|^2 = b_1^2 + b_2^2 + b_3^2 + \dots + b_n^2$$

$$|x| = (b_1^2 + b_2^2 + b_3^2 + \dots + b_n^2)^{1/2}$$

The same idea is applied for a certain barrier length across the whole dataset as well as the total length of barriers across the dataset.

FIGURE 4.5: Web Accessibility Barriers Representation in a Vector Space for a Priority Level



Since all the values cannot be negative, there is no need for the absolute value. This leads to equation (4.1.1) formulation. For simplicity, equation (4.1.1) is refined into formula (4.1.1.1) and (4.1.1.2). Where, formula (4.1.1.1) represents the numerator in equation (4.1.1), while (4.1.1.2) represents the denominator. These formulas are discussed later in this section.

Eq. (4.1.1) steps:

1. Divide the result of formula (4.1.1.1) by the result of formula (4.1.1.2)
2. Multiply the result of step 1 by the weight of the priority level which the barrier (bi) violates. Where (Priority “A”=0.8, priority “AA”=0.16, priority “AAA”=0.04)

$$\sqrt{\sum_{d=1}^k freq(b_i)^2} \quad (4.1.1.1)$$

Equation (4.1.1.1) defines the length of a certain barrier that violates a specific priority level across the whole documents. To calculate Equation (4.1.1.1), we follow the steps below:

1. For each webpage, we count how many times a certain barrier (b_i) appears in (i.e. frequency).
2. Calculate the square of step 1
3. Find the summation of squares for step 2 across the whole dataset
4. Calculate the square root for step 3 final results

$$\sqrt{\sum_{d=1}^k b(pc)^2} \quad (4.1.1.2)$$

Eq. (4.1.1.2) calculates the length of all barriers across the whole documents that violate the same barrier's priority level. Note that this formula's result will be fixed for each set of barriers that violate the same priority level. Steps are described hereunder:

1. For each webpage, find the total number of barriers that belong to the same priority level (check first against priority "A")
2. Find the square of step 1
3. Repeat the previous steps for the whole dataset (all webpages)
4. Sum up the results of step 3 (the summation of barriers squares)

5. Find the square root for the final result (step 4)
6. Repeat the previous steps for the remained priority levels (“AA” and “AAA”)

B- The Importance of the barrier to the webpage

$$\frac{n(bi)}{N} \quad (4.1.2)$$

Where,

$n(bi)$ = the number of different documents (webpages) the barrier (bi) appears in

N = the total number of documents

This formula shows the ratio of documents that the barrier appears in to the total number of documents in the dataset.

This formula is inspired by a principle in Information Retrieval known as TF-IDF (Sparck Jones, 1972). TF-IDF assesses a document's word importance by counting its frequency. The term frequency (TF) is simply the number of times a given term appears in a specific document. The inverse document frequency (IDF) is a measure of the general importance of the term which means the terms which appear in many documents are not very useful for distinguishing a relevant document from irrelevant ones. However, in WABS metric, a barrier which appears in many webpages indicates how significant the barrier is to the whole set of webpages. Roughly speaking, WABS is more concerned about measuring how common a barrier is across an entire collection of webpages. Thus, the TF-IDF is adjusted to fit the metric goal.

Formula (4.1.2) steps are described below:

1. Calculate how many times a certain barrier (bi) appears in a different document.
2. Divide step 1 over the total number of documents (Fixed across the documents).

C- The Importance of the barrier to all the other barriers in the whole dataset (the whole tested webpages)

$$\sqrt{\sum_{d=1}^k (b)^2} \quad (4.1.3)$$

Where,

b = total number of barriers that appear in document d

Eq. (4.1.3) is fixed for all the documents and calculated once. It calculates the total lengths of all barriers across the whole documents. The steps are as follows:

1. For each document, find the summation of barriers that appear in it
2. Find the square of step 1
3. Repeat the first two steps for all documents.
4. Sum up the result of step 3
5. Find the square root of step 4

4.4 METRIC ATTRIBUTES' EVALUATION

Freire et al. (2008) discussed how to evaluate web metric based on its attributes. Hence, this section adopted some attributes that can be applied to WABS metric. It evaluates WABS by showing how the applicable attributes were addressed and mapped into the proposed metric; the attributes are presented as follows:

- 1) **Guidelines set:** set of guidelines used for the metric, such as WCAG, self-defined guidelines set or customized set of guidelines. WABS metric utilizes WCAG 2.0 as basis for metric computation.
- 2) **Coupling level with guidelines:** show how coupled the metric is with the guidelines set and whether if it is easy or not to change the guidelines set. WABS is strongly linked to WCAG 2.0 guidelines and priority levels to define barriers weights.
- 3) **Type of evaluation:** type of the accessibility evaluation methods (AEM) that a metric is supposed to support, such as automatic testing, manual inspections or user testing. WABS is designed to work with any evaluation technique that enumerates the type and the frequency of barriers for the tested webpage. Nonetheless, this work will only analyze the results obtained by automated tools to conduct large-scale assessment.
- 4) **Consideration of site complexity:** the metric considers the complexity and size of the site, usually related to number of pages. The main goal of WABS is not website evaluation but rather 'barriers' severity evaluation. As a consequence, WABS considers the size and the complexity of each webpage in the dataset, related to the influence of the number and type of barriers in that webpage.
- 5) **Type of barriers weights coefficients:** the metric makes use of predefined coefficients based on the priority of barriers in a given set of guidelines, user-derived coefficients or other approaches. WABS considers weights based on WCAG 2.0 barriers.

- 6) **Default coefficients:** default values for barriers weights coefficients. WABS uses fixed values related to the priority of each success criteria in WCAG 2.0 as suggested by (Vigo et al., 2007), (priority “A”=0.8, priority “AA”=0.16, priority “AAA”=0.04).
- 7) **Automated tool:** use of an automated tool for metric computation, if any. WABS is used in the context of automatic evaluation. In this research, the metric is associated with two automated tools, namely: A-Checker and TAW.
- 8) **Use in large scale:** use of a metric in large-scale evaluations. The next chapter will conduct a large-scale assessment to demonstrate the metric.

4.5 METRIC CALCULATIONS

This section provides a simplified hypothetical example to demonstrate WABS metric’s mechanism. Suppose that we want to find the severity weight for each barrier in a dataset composed of 5 webpages. Assume that only three different types of barriers are found namely: (1.1.1), (1.2.2) and (1.4.9). Table 4.1 shows how many times each barrier appears in each webpage, as well as other necessary data for the metric.

TABLE 4.1: Metric Simulation for a Dataset of Five Websites

Webpage ID	Each barrier frequency in each webpage		
	1.1.1	1.2.2	1.4.9
1	3	6	1
2	15	10	5
3	7	0	0
4	0	4	4
5	5	4	4

A- Equation (4.1.1.1) Calculations

$$\sum_{d=1}^k freq(bi)^2$$

(4.1.1.1)

Table 4.2 includes the necessary data to calculate equation 4.1.1.1

TABLE 4.2: Equation (4.1.1.1) Data and Calculations

Webpage ID	Barrier ID	Priority Level	Barrier Frequency in each webpage (bi)	(bi) ²
1	1.1.1	A	3	9
	1.2.2	A	6	36
	1.4.9	AAA	1	1
2	1.1.1	A	15	225
	1.2.2	A	10	100
	1.4.9	AAA	5	25
3	1.1.1	A	7	49
	1.2.2	A	0	0
	1.4.9	AAA	0	0
4	1.1.1	A	0	0
	1.2.2	A	4	16
	1.4.9	AAA	4	16
5	1.1.1	A	5	25
	1.2.2	A	11	121
	1.4.9	AAA	4	16
Sum square of (1.1.1) across the whole dataset, $\sum_{n=1}^k freq b(i)$				9+225+49+0+25=308
Sum square of (1.2.2) across the whole dataset				36+100+0+16+121= 273
Sum square of (1.4.9) across the whole dataset				1+25+0+16+16=58

The final results for each barrier for equation 4.1.1.1 based on Table 4.2 are:

- Root of sum squares for (1.1.1): $\sqrt{\sum_{d=1}^5 freq(b(1.1.1))^2} = \sqrt{308} = 17.5499$
- Root of sum squares for (1.2.2): $\sqrt{\sum_{d=1}^5 freq(b(1.2.2))^2} = \sqrt{273} = 16.52271$
- Root of sum squares for (1.4.9): $\sqrt{\sum_{d=1}^5 freq(b(1.4.9))^2} = \sqrt{58} = 7.61577$

B- Equation (4.1.1.2) Calculations

$$\sqrt{\sum_{d=1}^k b(pc)^2} \quad (4.1.1.2)$$

This formula's result will be fixed for each set of barriers that violate the same priority level. Spars Matrix 4.3 shows the sum square for barriers that violate the same priority level. The required data and calculations are also presented.

TABLE 4.3: Equation (4.1.1.2) Data and Calculations

Webpage ID	Barrier ID	Priority Level	Barrier Frequency in each webpage (bi)	Total number of barriers that violate the same priority level b(pc) in each webpage	b(pc) ²
1	1.1.1	A	3		
	1.2.2	A	6		
	1.4.9	AAA	1		
	Priority A			3+6=9	9^2=81
	Priority AA			0	0^2=0
	Priority AAA			1	1^2=1
2	1.1.1	A	15		
	1.2.2	A	10		
	1.4.9	AAA	5		
	Priority A			15+10=25	25^2=625
	Priority AA			0	0^2=0
	Priority AAA			5	5^2=25
3	1.1.1	A	7		
	1.2.2	A	0		
	1.4.9	AAA	0		
	Priority A			7+0=7	7^2=49
	Priority AA			0	0^2=0
	Priority AAA			0	0^2=0
4	1.1.1	A	0		
	1.2.2	A	4		
	1.4.9	AAA	4		
	Priority A			0+4=4	4^2=16
	Priority AA			0	0
	Priority AAA			4	4^2=16
5	1.1.1	A	5		
	1.2.2	A	11		
	1.4.9	AAA	4		
	Priority A			5+11=16	16^2=256
	Priority AA			0	0^2=0
	Priority AAA			4	4^2=16
Total sum squares for barriers that violate priority "A" across the whole dataset ($\sum_{i=1}^k b(pc)^2$)				81+625+49+16+256=1027	
Total sum squares for barriers that violate priority "AA" across the whole dataset				0+0+0+0+0=0	
Total sum squares for barriers that violate priority "AAA" across the whole dataset				1+25+0+16+16=58	

- Root of sum squares for Priority A: $\sqrt{\sum_{d=1}^5 b(pA)^2} = \sqrt{1027} = 32.0468$
(barrier 1.1.1 and 1.2.2 violate priority A)
- Root of sum squares for Priority AA: $\sqrt{\sum_{d=1}^5 b(pAA)^2} = \sqrt{0} = 0$ (No barrier violates priority AA)
- Root of sum squares for Priority AAA: $\sqrt{\sum_{d=1}^5 b(pAAA)^2} = \sqrt{58} = 7.61577$
(barrier 1.4.9 violate priority AAA)

C- Equation (4.1.1) Calculations

$$\frac{\sqrt{\sum_{d=1}^k freq(bi)^2}}{\sqrt{\sum_{d=1}^k b(pc)^2}} * Pc \quad (4.1.1)$$

Now that the results for equation 4.1.1.1 and 4.1.1.2 are found, it is possible to aggregate them together in order to find the results for Equation 4.1.1, by dividing the result of formula (4.1.1.1) by the result of formula (4.1.1.2). Following, multiplying the result of step 1 by the weight of the priority level which the barrier (bi) violates.

1. Divide the result of formula (4.1.1.1) by the result of formula (4.1.1.2)

- $b(1.1.1): 17.5499 / 32.0468 = 0.54763346106$
- $b(1.2.2): 16.52271 / 32.0468 = 0.5155806508$
- $b(1.4.9): 7.61577 / 7.61577 = 1$

2. Multiply the result of step 1 by the weight of the priority level which the barrier (bi) violates. Where (Priority “A”=0.8, priority “AA”=0.16, priority “AAA”=0.04)

- $b(1.1.1): 0.54763346106 \times 0.8 = 0.438106768850556$ (belongs to priority “A”)
- $b(1.2.2): 0.5155806508 \times 0.8 = 0.412464520638566$ (belongs to priority “A”)
- $b(1.4.9): 1 \times 0.04 = 0.04$ (belongs to priority “AAA”)

D- Equation (4.1.2) Calculations

$$\frac{n(bi)}{N} \quad (4.1.2)$$

The total number of documents is (5) and in this example each barrier appears in 4 different webpages. So the result for this formula will be as follows:

- The total number of documents in which barrier (1.1.1) in is: $4/5 = 0.8$ (it appears in all documents except document 4, see Table 4.1)
- The total number of documents in which barrier (1.2.2) in is: $4/5 = 0.8$ (it appears in all documents except document 3)
- The total number of documents in which barrier (1.4.9) in is: $4/5 = 0.8$ (it appears in all documents except document 3)

E- Equation (4.1.3) Calculations

$$\sqrt{\sum_{d=1}^k (b)^2} \tag{3}$$

This equation is fixed for all the documents and calculated once. Using the data presented previously in Table 4.2, we should find the total sum squares of all barriers across the whole dataset as demonstrated in Table 4.4.

TABLE 4.4: Equation (4.1.3) Data and Calculations

Webpage ID	Barrier ID	Priority Level	Barrier Frequency in each webpage (bi)	Total sum of barriers in each webpage (b)	(b) ²
1	1.1.1	A	3	3+6+1=10	10 ² =100
	1.2.2	A	6		
	1.4.9	AAA	1		
2	1.1.1	A	15	15+10+5=30	30 ² =900
	1.2.2	A	10		
	1.4.9	AAA	5		
3	1.1.1	A	7	7+0+0=7	7 ² =49
	1.2.2	A	0		
	1.4.9	AAA	0		
4	1.1.1	A	0	0+4+4=8	8 ² =64
	1.2.2	A	4		
	1.4.9	AAA	4		
5	1.1.1	A	5	5+11+4=20	20 ² =400
	1.2.2	A	11		
	1.4.9	AAA	4		

- The sum squares for all barriers across the whole dataset is:
 $\sum_{d=1}^5 (b)^2 = 100 + 900 + 49 + 64 + 400 = 1513$
- The root of sum squares: $\sqrt{\sum_{d=1}^5 (b)^2} = \text{Sqrt}(1513) = 38.8973$

Now back to the final metric in order to calculate the weight for each barrier.

F- Final metric (4.1)

The following formula represents the WABS metric after aggregating equations 4.1.1, 4.1.2 and 4.1.3 discussed previously.

$$\frac{\sqrt{\sum_{d=1}^k freq(bi)^2}}{\sqrt{\sum_{d=1}^k b(pc)^2}} * \frac{n(bi)}{N} * \frac{Pc}{\sqrt{\sum_{d=1}^k (b)^2}} \quad (4.1)$$

WABS is calculated for each barrier to determine its final weight as follows:

$$w(bi) = (\text{Equation (4.1.1)} * \text{Equation (4.1.2)}) / \text{Equation (4.1.3)}$$

Where w refers to barrier's weight

- $w(1.1.1) = (0.582475035 * 0.8) / 38.8973 = 0.01197975$
- $w(1.2.2) = (0.548382959 * 0.8) / 38.8973 = 0.0112786$
- $w(1.4.9) = (0.04 * 0.8) / 38.8973 = 0.000823$

After finding each barrier weight, the barriers can be ranked accordingly; the higher the weight, the more severe it is, so the most severe barrier is (1.1.1), followed by (1.2.2), and finally (1.4.9).

4.6 CHAPTER SUMMARY

The present chapter illustrates the need for web accessibility metric to determine barriers severity. The requirements to build a good metric and the assumptions are described. Four main requirements should be met which are: (1) Metric Results should be normalized; (2) The metric should give a value to each barrier based on its influence on the priority level that it violates as well as to the whole dataset; (3) Problems that need human judgment should not have influence on the final metric; and (4) The measurement should be normative. WABS metric utilizes some parameters used by metric proposed by (Zeng, 2004) such as barrier frequency, priority level that has been violated and the number of webpages that have been tested. The metric measurements cover: (1) The importance of the barrier to the other barriers that violate the same priority level; (2) The importance of the barrier to the webpage; and (3) The importance of the barrier to all the other barriers in the whole dataset (all websites). The metric formulation is inspired by the vector space model in terms of barriers weighting and ranking. Two principals are used from vector space model. The first one is the extension of Pythagorean Theorem (Weisstein, 2014), which is used to measure barrier length in different context (this principle covers the first and third measurements). The second principle is TF-IDF (Sparck Jones, 1972) which is adjusted to meet the second measurement. WABS Formulation steps are explained in details to cover the measurements and finally an example to demonstrate metric calculations is presented.