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A Theory and Practice of Website Engagibility

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DUBLIN INSTITUTE of TECHNOLOGY
Institiúid Teicneolaíochta Bhaile Átha Cliath

A theory and practice of website engagibility

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PhD

A thesis submitted to the Dublin Institute of Technology
in fulfillment of the requirements for the degree of
Doctor of Philosophy

School of Computing,

Supervisor: **Professor Peter Smith** - Dean of School
Computing and Technology, University of Sunderland.

Supervisor: **Professor Brendan O'Shea** – Head of School
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Volume 1 of 2

Abstract

A theory and practice of website engagibility

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This thesis explores the domain of website quality. It presents a new study of website quality - an abstraction and synthesis, a measurement methodology, and analysis - and proposes metrics which can be used to quantify it.

The strategy employed involved revisiting software quality, modelling its broader perspectives and identifying quality factors which are specific to the World Wide Web (WWW). This resulted in a detailed set of elements which constitute website quality, a method for quantifying a quality measure, and demonstrating an approach to benchmarking eCommerce websites.

The thesis has two dimensions. The first is a contribution to the theory of software quality - specifically website quality.

The second dimension focuses on two perspectives of website quality - quality-of-product and quality-of-use - and uses them to present a new theory and methodology which are important first steps towards understanding metrics and their use when quantifying website quality. Once quantified, the websites can be benchmarked by evaluators and website owners for comparison with competitor sites.

The thesis presents a study of five mature eCommerce websites. The study involves identifying, defining and collecting data counts for 67 site-level criteria for each site. These counts are specific to website product quality and include criteria such as occurrences of hyperlinks and menus which underpin navigation, occurrences of activities which underpin interactivity, and counts relating to a site's eCommerce maturity. Lack of automated count collecting tools necessitated online visits to 537 HTML pages and performing manual counts.

The thesis formulates a new approach to measuring website quality, named Metric Ratio Analysis (MRA). The thesis demonstrates how one website quality factor - engagibility - can be quantified and used for website comparison analysis. The thesis proposes a detailed theoretical and empirical validation procedure for MRA.

I certify that this thesis which I now submit for examination for the award of *Doctor of Philosophy,* is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for an award in any other Institute or University.

The work reported on in this thesis conforms to the principles and requirements of the Institute's guidelines for ethics in research.

Institute has permission to keep, to lend or to copy this thesis in whole or in part, on condition that any such use of the material of the thesis be duly acknowledged.

Signature _________________________ Date _______________
Candidate

Acknowledgements

I would like to acknowledge the excellent advice given by the late Dr. Jenny Whitworth of Staffordshire University who first suggested that I continue my MSc towards a PhD award by publication. Although this has not been the route her advice encouraged me to start researching and writing for publication and most of the chapters in this thesis have associated published papers.

Thanks to Dr. Phyllis Murphy whose throwaway remark 'time flies' sustained me over the years. Knowing that sticking with the endeavour and regularly producing a deliverable could only result in a body of work, which would contribute to a final thesis.

Next I would like to express thanks to Professor Brendan O'Shea, Head of the School of Computing at Dublin Institute of Technology for his on-going support for my research. His recommendations, advice and encouragement as second supervisor were always greatly appreciated and appropriate to the high standard of a PhD research programme. I would especially like to acknowledge his vision in starting the School of Computing PhD programme.

Thanks to the Faculty of Science at Dublin Institute of Technology for financial support towards attendance at international conferences and other expenditure relating to the research. Thanks too to Professor Gordon Bull who confirmed the suitability of the thesis for submission.

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Thanks too to my family for 'putting up' with dad's preoccupation over the years and particularly, thanks to Marie. Without her support, encouragement, advice and wisdom, and especially her love and care in crisis of health I would never have had the opportunity to write this theory in *words in a form that has never been written before*.

Go raibh míle maith agaibh go léir.

Abbreviations

CIA	Competitive and Innovative Appeal
CoCoMo	Constructive Cost Model
CUPRIMDSO	capability [functionality], usability, performance, reliability, installability, maintainability, documentation, service and overall
DIS	Draft International Standard
EEC	European Economic Community
EFTA	European Free Trade Association
FDIS	Final Draft International Standard
FRA	Financial Ratio Analysis
FURPS	functionality, usability, reliability, performance and serviceability
GUFPIISMA	Italian Function Point User Group - Software Metrics Association
HCI	Human-Computer Interaction
HTML	HyperText Markup Language
IE	Information Economics
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFIP TC	International Federation for Information Processing Technical Committee
IRR	Internal Rate of Return
ISO	International Organisation for Standardisation
MRA	Metric Ratio Analysis
NAFTA	North American Free Trade Agreement
NPV	Net Present Value
P-CMM	People-Capability Maturity Model
RoI	Return on Investment
RSI	Repetitive Strain Injury
SEI	Software Engineering Institute
SIA	Special Interest Appeal
SMC	Software Measurement Committee

SMEF	Software Measurement European Forum
SNA	Special Needs Appeal
SPICE	Software Process Improvement and Capability dEtermination
SQ-SDM	Software Quality Strategic Driver Model
SQ-Star	Software Quality Star
SUMI	Software measurement Usability Inventory
SW-CMM	Software-Capability Maturity Model
URL	Universal Resource Locator
VCC	Visitor Contributed Content
VDT	Visual display terminal
W3C	World Wide Web Consortium
WQM	Web Quality Model
WRULDs	Work Related Upper Limb Disorders

Contents

Chapter 1 1
Introduction 1

Chapter 2 17
Total Software Quality and the Software Quality Star 17

Chapter 3 43
The strategic drivers of software quality 43

Chapter 4 61

Additional quality factors for the World Wide Web 61

Chapter 5 81

Website engagibility ratios, criteria and counts: Theory and practice 81

Chapter 6 112

Perspectives of software measurement 112

Chapter 7 138

Metric Ratio Analysis: An approach to measuring website quality 138

Illustrations

The theory and practice of website engagibility

List of Figures

List of Tables

Chapter 1

Introduction

> *This chapter provides a foundation for the thesis by introducing the core topics and explaining motivation, hypothesis and methodology.*

1.1 Background to the thesis

For website development to be considered as an engineering discipline there is a need to understand how website quality might be measured. There is also a need for models and formulae for use in that measurement. The derivation of such models and formulae are significant motivators for this thesis. The concept of applying software quality approaches to the domain of the World Wide Web (WWW) was also a motivator for this thesis. This research takes a step towards the maturity of the broader software quality discipline. It addresses the broader strategic perspectives of software quality, identifies quality factors for the World Wide Web and presents a new approach to measuring website quality.

The results of this research have been published in nine papers presented by the author at international conferences in the Americas, Europe and Asia/Pacific region. These publications are listed in Appendix E.

1.2 Introduction

The aim of this thesis is to report an investigation in the field of website quality. The investigation embraces academic thinking and professional practice in the domains of software quality, metrics and the WWW. The thesis also reports an eCommerce website study which demonstrates a new approach to measuring website quality through benchmark comparison.

The investigation and study are appropriate at this time because organizations are increasingly investing more in, and have a greater strategic reliance on, their Internet presence. There is a continuing need for quality eCommerce websites which satisfy their owner's broader perspective of quality of design and a visitor's perspective of quality of use. More particularly there is a need for website owners and designers to be able to specify what constitutes a website that will fully engage site visitors and consequently what needs to be designed into the website in order to ensure return on investment. The thesis addresses these issues and presents a measurement approach which will support website owners to ensure return on their investment through comparison with competitor websites. The findings will also support consultants to better specify the structure of a website.

The aim of this introductory chapter is to provide a foundation for the thesis by introducing core topics and explaining motivation and methodology. Section 1.3 provides an introductory overview of the domain of software quality. Section 1.4 sets out the intellectual challenge and the research aims and objectives. Section 1.5 explains the research methodology and Section 1.6 clarifies the research limits. Contributions to the body of knowledge and its dissemination through the research community are explained in Sections 1.7 and 1.8 respectively. Section 1.9 summarises the structure of the thesis.

1.3 The domain of software usability engineering

This section provides an introductory overview of the domains of software quality, usability, evolving domains like the WWW and measurement practice in the domain of the WWW.

1.3.1 The domain of software quality

Software quality is defined and categorised by McCall *et al.* (1977) and Boëhm (1978). The seminal publications from these researchers focus on the attributes of a software product and they typically refer to these attributes as quality factors. They explain that these factors are critical to designing a quality software product and critical to the use of that product.

In 1991 Ghezzi *et al.* suggested an alternative form of categorization. It was proposed that quality factors could be classified as internal quality factors and external quality factors. Internal quality factors relate to the technical excellence of the software product - matters that related to product development and maintenance - while external quality factors relate to the technical excellence of the user interface – matters that relate to the users' experience with the software product, i.e., usability.

There is a need for a review and evaluation based on three strands that now contribute to software quality. These three strands are:

- Advances in technology (especially new evolving domains, e.g. eLearning, semantic web).
- Compliance with statutory obligations.
- Advances in human-computer interaction.

By way of review, Fitzpatrick & Higgins (1998) consider the software quality factors defined by McCall *et al.* (1977) and present an analysis of how the above three strands influence these factors. The analysis of all three strands relies on seminal and authoritive research sources and on international standards. The full published review is included in Appendix B.

1.3.2 Strategic perspectives of software quality

The study of software quality has focused on product quality (McCall *et al.*, 1977; Boëhm, 1978; ISO/IEC 9126-1:2001). However, quality that is limited to product quality is referred to by Kaoru Ishikawa (the founding father of the Japanese Quality movement) as a narrow view of quality and he suggests that a broader view of quality is necessary (Ishikawa, 1985). It follows that limiting the study of software quality to the process by which the product is built and to its usability (as is the focus when studying the quality of conventional information processing systems) is too narrow a view and that there are a number of *perspectives* of quality, which merit further research. Typical of these perspectives are those of the Acquirer and Supplier whose roles are emphasized in standards from the International Organisation for Standardisation (ISO 12207, 1995). These perspectives are concerned with broader issues like return on investment and capability accreditation.

1.3.3 Quality perspectives in the domain of websites

The requirements of successful eCommerce websites further support Ishikawa's view and have precipitated a need to cater for the requirements of website visitors and owner organizations (Minocha *et al.*, 2003). While the site might be considered as the product, website owners and visitors also have a "quality" requirement. eCommerce sites have a sales focus and their quality is being driven by the sales and marketing professionals whose principal object is to attract and retain customers. The visitors' perspectives are described by (Minocha *et al.*, 2003) in terms of Total Customer Experience (TCE) which addresses the issues involved in attracting and retaining eCommerce customers. A full understanding of the issues involved is also important when determining work effort and cost of website development and for complying with the legal requirements of websites.

1.3.4 Measuring website quality

Website external quality research is not yet well established. Researchers addressing this issue include Stern (1995); Keeker (1997); Bevan (1998); Dreyfus (1998), Nielsen (1998) and Ivory (2001). Their work focuses mainly on usability issues. Their publications are focused on heuristics and lists of good practice relating to desirable usability features. However, website quality embraces much more than usability checklists. Additional quality issues, specific to the WWW, include the ease with which users can find a site, user trust and confidence in the website owner, and the extent to which knowledge is enhanced following a visit. Quality websites also need strategies for return-on-investment which include appeal and brand promotion - issues which encourage visitor loyalty. These issues are not addressed by traditional quality factors.

Heretofore, external metrics relating to websites are mainly concerned with analysing log files and examining visitor statistics. These metrics are specifically quality-of-use and rely on website traffic data and visitor statistics for their meaning. Because of the ease with which these statistics can be automatically collected they are core to the abundance of commercially available website analysis tools. Tools from companies like Webtrends are typical of this approach. The continuing study of eMetrics by Cutler & Sterne, (2003) is also focused on visitor statistics. An Online Business Intelligence website scanning software analytic tool from Maxamine Inc. partially addresses the issues but offers no separate measurement to distinguish quality-of product from quality-of-use (Maxamine, 2004). Here again, their focus is quality-of-use. So, all of these are focused mainly on use, which comes later in the life cycle.

In January 2004 the Italian Function Point User Group - Software Metrics Association (GUFPIISMA) Software Measurement Committee (SMC) published a Web Quality Model (WQM), focusing on the non-functional side of web measurement. The output from this model is a quality profile, as in the ISO/IEC 9126 standard, addressing 4 characteristics (proposed quality factors), 18 sub-characteristics and 34 metrics (Buglione *et al.*, 2004). This approach relies on ISO/IEC, IS 9126:1991, and this early version of the standard does not address recent advances in website quality factors. Furthermore, ISO 9126 (2001) explains that good feedback from product use (quality-of-use) will enhance product design and that enhanced product design (quality-of-product) will improve product use. The Italian Function Point User Group - Software Metrics Association's approach does not cover this. Recently Ivory (2001) has addressed the design quality of information-centric websites but does not address interactivity as is required by quality eCommerce and similar websites.

There is now a need for a new model to assist in the design of quality interactive websites. In keeping with engineering practice and in order to complete our understanding of the quality factors for the WWW this model must redefine and quantify website quality.

1.4 Intellectual challenge

The challenge addressed by this research is to investigate current understandings of software quality in the context of websites and specifically the measurement of a website visitor's engagement with the website. At a scholarly level the focus is the creation of new knowledge through original research. At a practical level, the focus is to apply the new knowledge and understanding of software quality to the specific context of websites. Emphasis is placed on defining a tailorable solution for measuring website quality. Simply expressed the research question is twofold: What constitutes website quality? and How can it be measured? The principal component parts of the problem are: definitions of website quality factors; a model for website quality measurement; and the validation, through a case study, of the definitions and the model using real-world data from a set of eCommerce websites.

1.4.1 Research hypothesis

The first hypothesis addressed in this thesis is:

Website engagibility is an important quality factor to be considered when designing a website and it is possible to derive formulae which use measures of website design elements to calculate metrics that are predictors of visitor engagibility.

A second hypothesis is:

A target-based website engagibility comparison can be developed, which sets a particular website within the context of marketplace custom and practice.

1.4.2 Aims and objectives

To complete the research, two complementary aims are addressed:

- To identify appropriate quality factors for the domain of the WWW.
- To focus on one particular website quality factor and derive metrics for benchmark comparison purposes.

To achieve these aims the research addresses the following objectives:

- To clarify the broader and strategic understanding of software quality.
- To create a new model of website quality.
- To propose new quality factors for the domain of the World Wide Web.
- To decompose the factors to their lowest measurement level and to clarify what criteria can be measured.
- To create a working model for the collection of website measurements.

- To use the working model in an eCommerce website study to guide the gathering of website measurements (counts) for a selection of websites.
- To develop formulae which use the collected counts to mathematically express the sub-characteristics of a typical website quality factor.
- To populate the formulae with a website's collected counts to calculate mathematical expressions for a website's quality factor.
- To perform benchmark comparisons of the sites in the eCommerce website study.
- To propose a procedure for validating the process.

1.5 Research methodology

The research employed in this thesis begins with a wide-ranging literature review. The findings of this review are synthesised to create conceptual models of website quality, which have been published by the author (Fitzpatrick, 2000a; Fitzpatrick, 2000b; Fitzpatrick 2003a; Fitzpatrick, 2003b; Fitzpatrick *et al.*, 2005). The research then proposes a new model for website quality measurement and applies this in an eCommerce website study. By way of evaluation the measurement model is applied in detail in the context of one website quality factor. These research methodology considerations are now explained in more detail.

1.5.1 Literature review

The thesis reports a structured literature review in order to establish current academic thinking and commercial practices. This study embraced software quality thinking; the broader perspective of quality; and strategic thinking appropriate to that perspective. The role of international standards was investigated during the literature review and these standards are contributors to the new model of software quality and to the measurement approach.

1.5.2 Conceptual models of website quality

Through a synthesis of the research findings the research creates a new model of software quality - the Software Quality Star. When creating this model, use is made of ISO 12207 (1995), as its principal motivator. Also created is a Taxonomy of additional quality factors for the WWW. Both models have been published by the author (Fitzpatrick, 2000b; Fitzpatrick, 2003b). These two models are combined and in turn are used to identify a set of complementary quality-of-product and quality-of-use measures.

1.5.3 A model of website quality measurement

The origins of the complementary quality-of-product and quality-of-use measures are influenced by the feedback philosophy of ISO 9126-1:2001. Using the philosophy of the Standard two sets of quantifiable elements of a quality characteristic are identified. These elements are named ratios. Using a methodical review and analysis of website structure, unique measurable data items specific to these ratios are identified. These data items are named criteria. A numeric measure of each data item is named a count which is determined using automatic tools or counted directly. Indirect values, formulae and calculated individual ratios are combined with these elements and modelled using a new generic structural model (which includes the goal of measurement, data gathering and statistical analysis) for approaching software measurement (Fenton, 1994; Kitchenham *et al.*, 1995).

1.5.4 An approach to implementing website quality measurement

The research devises a new 12-step website measurement approach and names it Metric Ratio Analysis (MRA). This new approach is based on acknowledged theory and practice. That is, Ratio Analysis from the financial world (Lev & Sunder, 1979; Salmi & Martikainem, 1994); and graph theory from Johnsonbaugh (2004a). Central to this new approach is the concept that a website's structural design elements can be combined to calculate individual values for website quality factors.

1.5.5 eCommerce website study

The research includes a study of a sample of online eCommerce websites. The study collects relevant website measurements (counts) appropriate to the structure of a website and uses them to calculate individual values for each website. These individual values are used for benchmark comparison of the websites in the study.

1.5.6 Website study methodology

A consistent methodology is ued to ensure measurement consistency across all websites in the study. The methodology has its own overriding philosophy and uses models and methods in conjunction with a commercial automatic measurement tool from Maxamine Inc. Practice and evaluation use a consistent format. The website study methodology is set out in Figure 1.1.

Philosophy	The philosophy underpinning the study is concerned with website quality, and specifically perspectives of quality as defined in the Software Quality Star. So, to name the study methodology it might be styled a ‘website perspectives methodology’.
Models	The conceptual models used are all derivatives of the published research. Were necessary, some of the derivatives are further synthesised or new models and vocabulary are defined.
Method	The study completes quantitative research relating to the eCommerce websites in order to fully understand the design structure of each website. This is achieved by gathering detailed counts of site criteria and it enables a thorough comparison of the study sites. The research devises a new method for measuring a website quality factor and uses it throughout the entire study.
Tools	The data gathering consistently relies on an automated software tool together with manual counting when necessary.
Practice	Data gathering follows a consistent and uniform practice which uses a 3-page dataform for recording counts. The research calculates eight different measures for each website which are analysed and evaluated through benchmark comparison (presented in Appendix D).

Figure 1.1 – *Website study methodology.*

The eCommerce website study uses a state-of-the art website scanning and analytic tool from online business intelligence specialists Maxamine Inc.

In collaboration with systems staff at the University of Sunderland a prototype scanning tool was created and used to spot check the measurements being generated by the Maxamine scanning tool.

1.5.7 Evaluation and validation

The theory presented in this thesis is demonstrated through the eCommerce website study. The study collects extensive data from online websites without reference to the site owners or developers and presents eight sets of results which consistently confirm the theory and practice of the research (Appendix D). Evaluation is also supported by the extent to which the research has presented itself for international peer review. Communications regarding technical clarifications were also conducted with experts in the USA and Europe.

The thesis also proposes a validation approach for the metrics which have been derived.

1.6 Limits of research scope

There are two issues that influence the limits of this thesis. These are:

- The website study avoids all issues relating to site usage which typically relies on log file statistics that relate to visitor use of a website.
- The study is specifically focused on how a website's design will support visitor engagement (engagibility) at a website.

1.7 Contributions to the body of knowledge

The overall contributions made by this thesis to the body of knowledge are:

1. **The Software Quality Star**, which is a conceptual model for presenting different perspectives of software quality. The model is based on the Acquirer and Supplier as defined in ISO/IEC 12207 (1995) and is used to guide the progression of the research.
2. **The Strategic Drivers of Software Quality**, which extends and builds on the Software Quality Star to fully clarify and model the strategic considerations that impact the Acquirer and Supplier of software products.
3. **The additional quality factors for the World Wide Web**, which constitute a set of five new quality factors specific to the World Wide Web.
4. **Website engagibility ratios**, which are a complementary set of quantifiable elements of website quality and are specific to a website's engagibility quality factor.

5. **Metric Ratio Analysis**, (MRA) which is a new approach specifically devised by the research in order to quantify website quality factors. This approach combines aspects of acknowledged measurement theory, the Financial Ratio Analysis approach and a graph theory approach.
6. **A strategy for website metric validation**, which describes parallel studies for empirically validating the MRA model and method using data collection and hypothesis testing.
7. **An eCommerce website study**, which demonstrates Metric Ratio Analysis applied to a set of eCommerce websites and completes their benchmark evaluation.
8. **A calculated engagibility index**, which represents a measure of one website quality factor.

1.8 Dissemination and continuing research

Research findings and deliverables have been disseminated by publication at international conferences. There are nine such publications as listed in Appendix E of this thesis. Research has also been presented at the 2003 and 2004 Dublin Institute of Technology School of Computing PhD Conference.

1.9 Synopsis of thesis Chapters 2 to 10

This section sets out the organisation of the remaining chapters in the thesis. A working diagram (Figure 1.2a and 1.2b) is included which illustrates the research progression and the deliverables - conceptual models and tools - that have been created during this work.

Chapter 2

Total Software Quality and the Software Quality Star

Motivated by the thinking of Kaoru Ishikawa, (Ishikawa, 1985) this chapter presents a broader view of software quality from the procurer, producer and product perspectives and creates a new conceptual model to reflect this broader view. The conceptual model is named the Software Quality Star and it is used as a framework throughout the thesis.

Chapter 3

The Strategic Drivers of Software Quality

Building on the broader view of software quality this chapter explores the producer organisation’s and the procurer organisation’s needs such as complying with new legislation, securing return on investment, achieving competitive support from their new software investments, qualification and certification, and quality management. This chapter addresses all of these issues and presents eleven issues, which it calls strategic drivers.

Chapter 4
Additional quality factors for the World Wide Web

The chapter builds on Chapter 3 (and Appendix A) and shows that, in addition to core and well understood quality factors, there is also a need for domain-specific quality factors for the WWW. The deliverable of this chapter is a set of five new quality factors appropriate to the WWW.

Chapter 5
Website engagibility ratios, criteria and counts: Theory and practice

Chapter 5 develops a conceptual model for website quality and uses that model during the data collection and documentation processes in an eCommerce website study. The model synthesises the Software Quality Star and the Taxonomy of additional quality factors for the WWW. The chapter sets the scope of the remaining research by focusing on one quality factor and one perspective, i.e., engagibility and quality-of-product.

Chapter 6
Perspectives of software measurement

This chapter provides a context and foundation for a proposed new website measurement approach that is presented in Chapter 7 and for a proposed new procedure for validating that approach in Chapter 9. The chapter addresses the scientific understanding of software measurement and reviews the history, derivation and validation of software metrics. The chapter considers models, methods and methodology of software measurement.

Chapter 7
Metric Ratio Analysis: An approach to measuring website quality

This chapter presents the formulation of a new generic approach to quantifying website quality. The approach uses acknowledged measurement theory and similarity graph theory. The approach derives a formula which can be used to calculate individual values for the sites in the eCommerce website study.

Chapter 8

Applying Metric Ratio Analysis to the navigation ratio

This chapter applies the Metric Ratio Analysis approach to one specific ratio: the navigation ratio.

Chapter 9

Validation

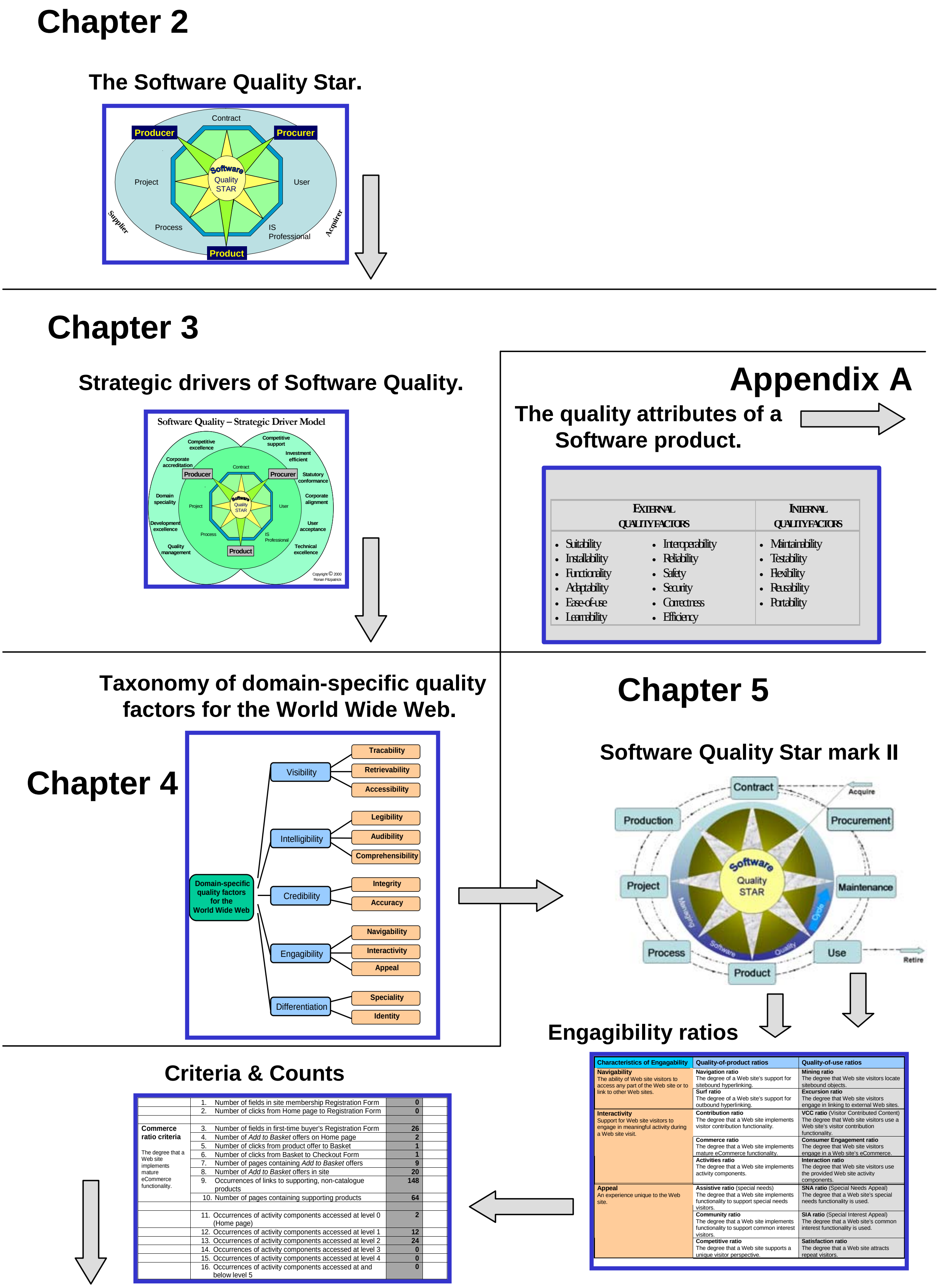
Chapter 9 proposes a procedure for the validation of Metric Ratio Analysis. The chapter considers both theoretical and empirical validation and proposes two parallel studies of data collection and hypothesis testing.

Chapter 10

Conclusion

This chapter presents a summary review and critique, research benefits, details of future challenges and a concluding statement.

Figures 1.2a and 1.2b illustrate the progressive nature of the chapters and show the chain of chapter deliverables. As the thesis progresses each chapter deliverable builds on deliverables for a previous chapter. The figures consist of thumbnail icons that represent the chapter deliverables and are included as a simple conceptual roadmap for guiding the reader. The icons are not intended to convey the information that is contained in the detailed figures in the individual chapters.



External Quality Factors		Internal Quality Factors
- Suitability	- Interoperability	- Maintainability
- Installability	- Reliability	- Testability
- Functionality	- Safety	- Flexibility
- Adaptability	- Security	- Reusability
- Ease-of-use	- Correctness	- Portability
- Learnability	- Efficiency	

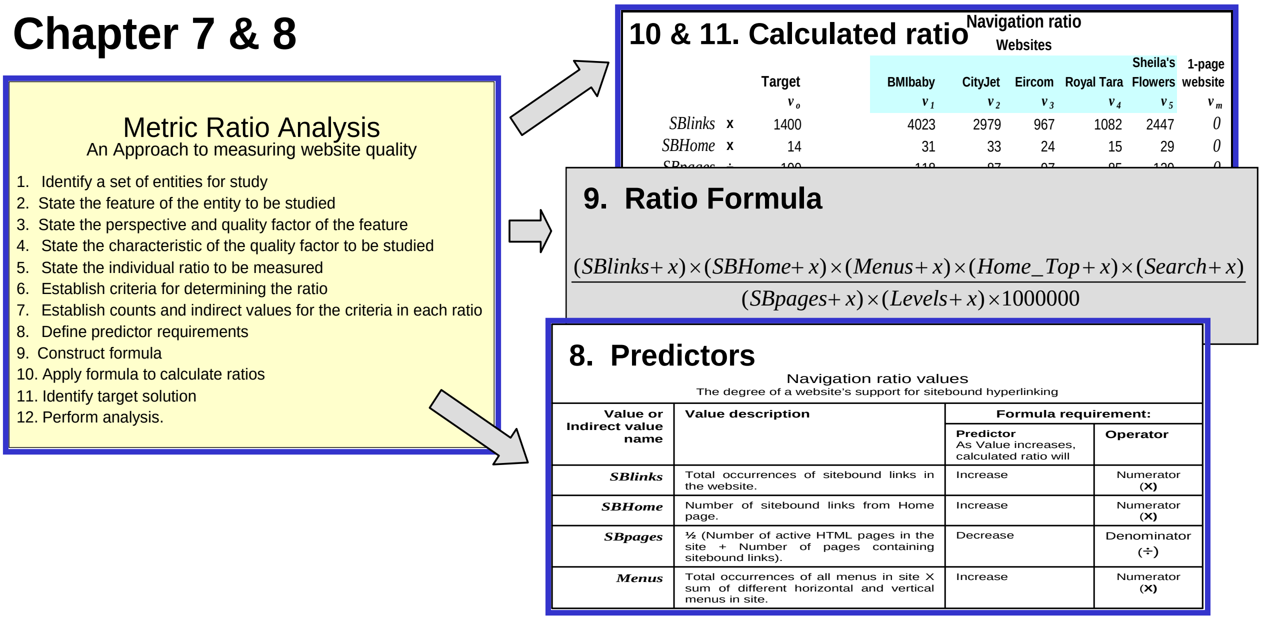
Characteristics of Engagability	Quality-of-product ratios	Quality-of-use ratios
Navigability The ability of Web site visitors to access any part of the Web site or to link to other Web sites.	**Navigation ratio** The degree of a Web site's support for sitebound hyperlinking.	**Mining ratio** The degree that Web site visitors locate sitebound objects.
	Surf ratio The degree of a Web site's support for outbound hyperlinking.	**Excursion ratio** The degree that Web site visitors engage in linking to external Web sites.
Interactivity Support for Web site visitors to engage in meaningful activity during a Web site visit.	**Contribution ratio** The degree that a Web site implements visitor contribution functionality.	**VCC ratio** (Visitor Contributed Content) The degree that Web site visitors use a Web site's visitor contribution functionality.
	Commerce ratio The degree that a Web site implements mature eCommerce functionality.	**Consumer Engagement ratio** The degree that Web site visitors engage in a Web site's eCommerce.
	Activities ratio The degree that a Web site implements activity components.	**Interaction ratio** The degree that Web site visitors use the provided Web site activity components.
Appeal An experience unique to the Web site.	**Assistive ratio** (special needs) The degree that a Web site implements functionality to support special needs visitors.	**SNA ratio** (Special Needs Appeal) The degree that a Web site's special needs functionality is used.
	Community ratio The degree that a Web site implements functionality to support common interest visitors.	**SIA ratio** (Special Interest Appeal) The degree that a Web site's common interest functionality is used.
	Competitive ratio The degree that a Web site supports a unique visitor perspective.	**Satisfaction ratio** The degree that a Web site attracts repeat visitors.

	1. Number of fields in site membership Registration Form	**0**	
	2. Number of clicks from Home page to Registration Form	**0**	
Commerce ratio criteria The degree that a Web site implements mature eCommerce functionality.	3. Number of fields in first-time buyer's Registration Form	**26**	
	4. Number of *Add to Basket* offers on Home page	**2**	
	5. Number of clicks from product offer to Basket	**1**	
	6. Number of clicks from Basket to Checkout Form	**1**	
	7. Number of pages containing *Add to Basket* offers	**9**	
	8. Number of *Add to Basket* offers in site	**20**	
	9. Occurrences of links to supporting, non-catalogue products	**148**	
	10. Number of pages containing supporting products	**64**	
	11. Occurrences of activity components accessed at level 0 (Home page)	**2**	
	12. Occurrences of activity components accessed at level 1	**12**	
	13. Occurrences of activity components accessed at level 2	**24**	
	14. Occurrences of activity components accessed at level 3	**0**	
	15. Occurrences of activity components accessed at level 4	**0**	
	16. Occurrences of activity components accessed at and below level 5	**0**	

Figure 1.2a – *Chain of Chapter Deliverables.*

Chapter 6 Perspectives of software measurement

Chapter 7 & 8



Metric Ratio Analysis
An Approach to measuring website quality

1. Identify a set of entities for study
2. State the feature of the entity to be studied
3. State the perspective and quality factor of the feature
4. State the characteristic of the quality factor to be studied
5. State the individual ratio to be measured
6. Establish criteria for determining the ratio
7. Establish counts and indirect values for the criteria in each ratio
8. Define predictor requirements
9. Construct formula
10. Apply formula to calculate ratios
11. Identify target solution
12. Perform analysis.

10 & 11. Calculated ratio

Navigation ratio

Websites

		Target	BMIbaby	CityJet	Eircom	Royal Tara	Sheila's Flowers	1-page website
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
SBlinks	x	1400	4023	2979	967	1082	2447	*0*
SBHome	x	14	31	33	24	15	29	*0*

9. Ratio Formula

$$\frac{(SBlinks+x)\times(SBHome+x)\times(Menus+x)\times(Home\_Top+x)\times(Search+x)}{(SBpages+x)\times(Levels+x)\times 1000000}$$

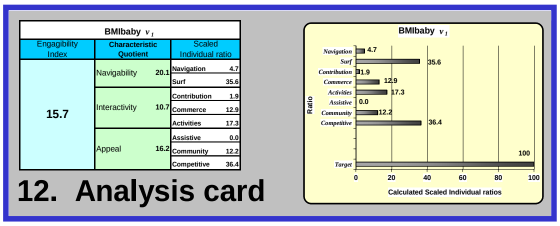
8. Predictors

Navigation ratio values
The degree of a website's support for sitebound hyperlinking

Value or Indirect value name	Value description	Formula requirement:	
		Predictor As Value increases, calculated ratio will	**Operator**
SBlinks	Total occurrences of sitebound links in the website.	Increase	Numerator (**X**)
SBHome	Number of sitebound links from Home page.	Increase	Numerator (**X**)
SBpages	½ (Number of active HTML pages in the site + Number of pages containing sitebound links).	Decrease	Denominator (÷)
Menus	Total occurrences of all menus in site X sum of different horizontal and vertical menus in site.	Increase	Numerator (**X**)

Appendix D

Website Engagibility Index card



BMIbaby v_1

Engagibility Index	Characteristic Quotient		Scaled Individual ratio	
15.7	Navigability	20.1	Navigation	4.7
			Surf	35.6
	Interactivity	10.7	Contribution	1.9
			Commerce	12.9
			Activities	17.3
	Appeal	16.2	Assistive	0.0
			Community	12.2
			Competitive	36.4

12. Analysis card

Chapter 9

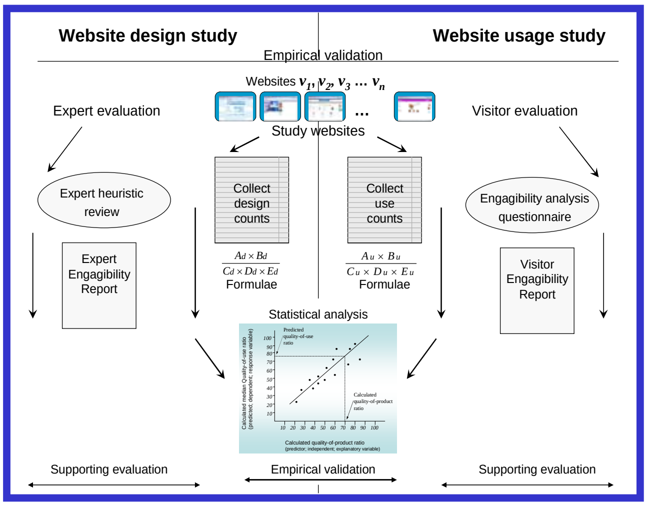


Figure 1.2b – *Chain of Chapter Deliverables.*

1.10 Conclusion

This chapter states the motivation for the research, introduces the domain of the thesis, and sets out the research hypothesis. It clarifies the intellectual challenge involved and how this has a practical dimension. The aims and objectives are clearly stated and the research methodology is explained. Scoping matters are clarified and contributions to the body of knowledge for this thesis are described. These deliverables are combined with a synopsis of the thesis chapters to form a 'map' of the thesis.

Chapter 2

Total Software Quality and the Software Quality Star

The aim of the chapter is to clarify how a broader interpretation of quality applies to software quality and to model different perspectives of software quality.

2.1 Background

The different perspectives of the various stakeholders involved have fragmented the study of software quality. Typically, these perspectives have been producer organisation focused, process focused or product focused. These are perspectives of specific interest to software suppliers. There is also a need to consider software quality for the acquirer's point of view, that is, the perspectives of the procurer, the IS professional charged with supporting and maintaining the software, and the perspective of the user. In particular there is a need to consider this perspective at strategic management level. This chapter proposes the Software Quality Star (Fitzpatrick, 2001) conceptual model which uses seven perspectives of quality (producer, project, process, product, procurer, IS professional and user) using ISO 12207 (1995) as a foundation. The chapter also considers the role of certification models such as the Capability Maturity Model in achieving software quality. In relation to the software product, the chapter discusses the subdivision of quality factors into external and internal quality factors and argues that these are insufficient. The chapter shows that there is also a need for strategic quality considerations.

The main deliverable of this chapter - the Software Quality Star - was first published by the author as the core of a second model in *Strategic Drivers of Software Quality: Beyond external and internal software quality*, (Fitzpatrick, 2001). More recently the Software Quality Star was published in *The Software Quality Star: A conceptual model for the software quality curriculum,* (Fitzpatrick, 2003b).

Chapter content was also published in *Software Quality Challenges*, (Fitzpatrick, Smith & O'Shea, 2004b).

2.2 Introduction

Organisations and researchers have addressed, and continue to address, the issue of software quality (McCall *et al.*, 1977; Boëhm, 1978; IEEE Standard 729, 1983; ISO/IEC 9126, 1991; Hewlett-Packard's FURPS, 1987 and IBM’s CUPRIMDSO, 1987, Paulk *et al.*, 1993b at the Software Engineering Institute (SEI); The SPICE project ISO/IEC 15504, Kasse & McQuaid, 2000; Harlev *et al.*, 2000, and Kim & Nam, 2000). The work is based on the concept that software is developed by an organisation that uses project management methods combined with some form of process to create a software product. This product is then purchased by procurers to be maintained by their technical staff and used by their operations staff. Some organisations and researchers (Paulk *et al.*, 1993b at the Software Engineering Institute (SEI); The SPICE project ISO/IEC 15504, Kasse & McQuaid, 2000; Harlev *et al.*, 2000, and Kim & Nam, 2000) have the view that if you are a world class organisation then you will, by definition, create quality products and they seek to have their organisation and the processes they employ certified as having achieved a suitable maturity level. Other organizations, for example, the National Standards Authority of Ireland, have the view that if you use well-defined processes then you will create quality software products, and they seek to have their processes ‘ISO 9000 certified’ to evidence attention to quality. Other researchers and organizations (McCall *et al.*, 1977; Boëhm, 1978; IEEE Standard 729, 1983; ISO/IEC 9126, 1991; Hewlett-Packard's FURPS, 1987 and IBM’s CUPRIMDSO, 1987) study a set of characteristics or attributes of the software product that constitute its quality and argue that if these are not addressed then organisation or process will have little impact on the software product. This chapter will show that acknowledged Japanese thinking based on a broader perspective of quality best illustrates how ‘total’ software quality might be achieved.

This chapter synthesises these software perspectives and views them in terms of the supplier and the acquirer as suggested by ISO Standard 12207 (1995). The aim of the chapter is to clarify how a broader interpretation of quality applies to software quality and to model these different perspectives. Section 2.3 considers appropriate definitions of quality and defines quality in its simplest terms. Section 2.4 explains software quality and introduces the Software Quality Star. Section 2.5 identifies the seven different perspectives (producer, project, process, product, procurer, IS professional and user) of software quality and clarifies them in the context of the Software Quality Star. Section 2.6 clarifies how the Software Quality Star can be used and Section 2.7 draws conclusions.

2.3 Definition of Quality

There are many different definitions of quality (Crosby, 1979; Deming, 1986; Feigenbaum, 1961; Ishikawa, 1985, 1986; Juran, 1989; Oakland, 1993; Shingo, 1987; Taguchi, 1987). It can be defined in terms of conformance to specification, fitness for purpose and minimum defects. International organisations (DIN - Deutsches Institut für Normung, ANSI – American National Standards Institute, IEEE – Institute of Electrical and Electronics Engineers and ISO – International Organisation for Standardisation) also define quality, and their definitions emphasise the characteristics of a product or process. Figure 2.1 shows a number of acknowledged definitions. The top section of the figure tabulates the definitions or interpretations of quality by world experts and strategic thinkers. The lower section of the figure tabulates definitions of quality by international standards bodies.

EXPERT	**EXPERT DEFINITION (INTERPRETATION)**
Crosby, 1984, p60	Conformance to requirements.
Deming, 2000, p168/9	Quality can be defined only in terms of the agent. Who is the judge of quality? Deming continues, "*The problems inherent in attempts to define quality of a product… were stated by the master Walter A Shewart (1986, Ch 4) viz, the difficulty in defining quality is to translate future needs of the user into measurable characteristics, so that the product can be designed and turned out to give satisfaction at a price that the user will pay*".
Feigenbaum, 1961, p13	The composite product characteristics of engineering and manufacture that determine the degree to which the product in use will meet the expectations of the customer.
Ishikawa, 1985, p44/5	In a series of definitions relating to quality control he refers to products which can "*satisfy the requirements of consumers*". This, he explains should be "*Narrowly interpreted to mean quality of products*". He continues "*that Broadly interpreted quality means quality of work, quality of service, quality of information, quality of process, quality of division, quality of people including workers, engineers, managers and executives, quality of system, quality of company, quality of objects etc. To control quality in its every manifestation is our basic approach*".
Juran, 1988, p11 1989, p15	Quality is product performance, quality is freedom from defects, quality is fitness for use.
Oakland, 1993, p4	Meeting customer's requirements.
Shingo, 1986, p11	Zero defects.
Taguchi *et al.*, 1987	Product quality is determined by the economic loss imposed upon society from the time a product is released for shipment.

STANDARDS BODY	**STANDARDS DEFINITION**
German Standard (DIN 55350 – 11, 1995)	Quality comprises all characteristics and significant features of a product or an activity which relate to the satisfying of given requirements.
ANSI Standard (ANSI/ASQC A3/1978)	Quality is the totality of features and characteristics of a product or a service that bears on its ability to satisfy the given needs.
ISO 8402, 1986 ISO 14598-1, 1999	The totality of characteristics of a [software] product or service that bear on its ability to satisfy stated or implied needs.
IEEE Standard (IEEE Std 729-1983)	**a** The totality of features and characteristics of a software product that bear on its ability to satisfy given needs: for example, conform to specifications. **b** The degree to which software possesses a desired combination of attributes. **c** The degree to which a customer or user perceives that software meets his or her composite expectations. **d** The composite characteristics of software that determine the degree to which the software in use will meet the expectations of the customer.
ISO/IEC 9126 (1991)	The totality of features and characteristics of a software product that bear on its ability to satisfy stated or implied needs.

Figure 2.1 - *Definitions of quality and software quality.*

ISO/IEC 12207 (1995) does not include a definition of software quality but it does refer its users to ISO standard ISO/IEC 9126 (1991) and for completeness that definition is included in Figure 2.1. However, it is appropriate to re-examine these definitions. When considering quality we refer to products and services in terms of poor quality or high quality. These expressions – poor and high – are simple terms for measures, poor indicating a low measure and high indicating excellence. So, it follows that quality is a measure of something about the product or service. That something is "excellence" and this chapter defines quality as the measure of excellence in each of the seven different perspectives. This measure of excellence is confirmed by the New Penguin English Dictionary (1986) which explains that quality is a degree of excellence. The same dictionary explains that excellence has to do with being outstandingly good.

2.4 Software quality and the Software Quality Star

Having defined quality as a measure of excellence it is now necessary to establish what it is that must be measured in the context of a quality software product. Some researchers are concerned with the ability of software producer organisations and are of the view that an organisation with a high, certified level of maturity will create a quality software product (Kasse & McQuaid, 2000; Harlev *et al.*, 2000). These researchers hold the view that, if an organisation uses a world class process to create its software then it will create quality software products (Kim & Nam, 2000). Another perspective is that a software product must embrace a set of quality factors and that it is the absence or presence of these quality factors that constitute a quality software product (McCall *et al.*, 1977; Boëhm, 1978). These measures tend to be issues of concern to the developer of the software.

A different set of perspectives is of concern to the purchaser. In the first instance, the purchaser is concerned to know that the developer is a high standard organisation with the expertise and skills to deliver a quality product. The purchaser needs to be confident that modern processes will be used to develop the software, especially if there is a substantial financial investment involved. The purchaser is also concerned to know that a full set of quality characteristics will be addressed as part of the requirements specification so that the product will be usable by users and supportable by IS professionals. So, from this we can see that the developer and the purchaser have different yet complementary perspectives and I have devised a suitable conceptual model in order to consider them further. My model is the Software Quality Star (Fitzpatrick, 2001) as illustrated in Figure 2.2.

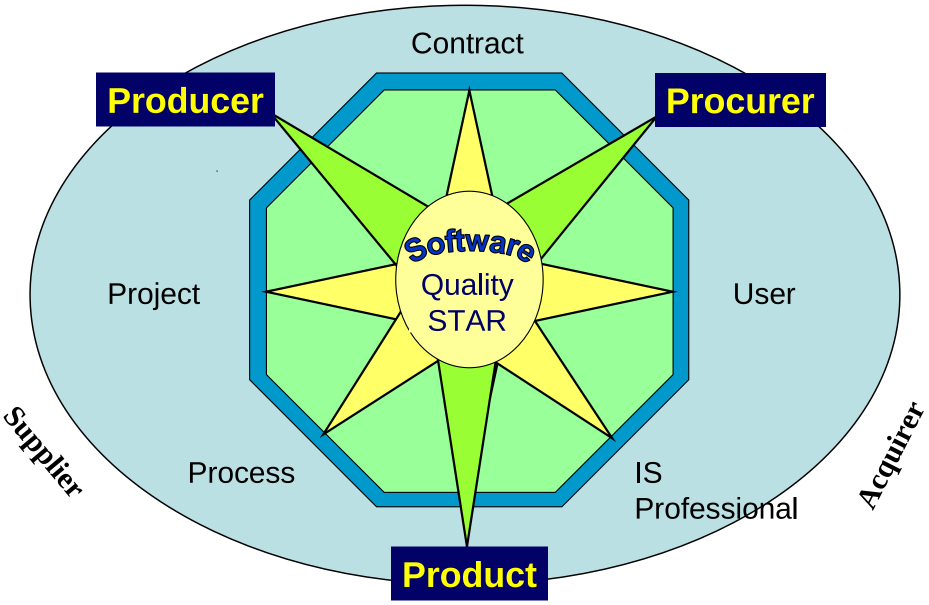


Figure 2.2 - *The Software Quality Star.*

The model is specifically designed to include the perspectives of both the developer and the purchaser. It originated as a simple, teaching aid triad of developer/purchaser/product. Use of the triad sought to exploit the term 'pro' in product such that the triad changed to producer/procurer/product. Over time as the model developed and as new elements were added emphasis was placed on the easy-to-remember 'pro' term and project, process and professional were incorporated. The model is also influenced by supplier/acquirer perspectives in ISO 12207, 1995 which contributes the contractual arrangement between them. The model considers supplier and producer to be one and the same. Similarly, acquirer and procurer are also one and the same and sometimes the terms are used interchangeably. For each entry on the Software Quality Star, there is a different perspective to the measure of excellence. These perspectives are examined in detail in the next section.

2.5 Perspectives of Software Quality

This section examines software quality from the different perspectives of the entries on the Software Quality Star. Some of these perspectives are well researched and understood while for others the issues involved are not so well documented.

The supplier perspective is considered under the headings of producer, project and process. This is followed by a review of the product. The acquirer perspective is considered under the heading of procurer, IS professional and user. The contract between the supplier and the acquirer is also considered.

2.5.1 The Supplier (Producer)

ISO/IEC 12207 (1995) describes the supplier as:

> *"An organisation that enters into a contract with the acquirer for the supply of a system, software product or software service under the terms of the contract".*

The Software Quality Star considers that the supplier organisation is the producer who engages in a project using project management best practice and an appropriate process (or set of processes) in order to create a product. Producer, project and process are now considered in detail.

2.5.1.1 Producer

The producer's perspective is driven by the desire to be a quality organisation employing first-rate staff who engage in first-rate processes using first-rate tools and techniques to create quality software products. In keeping with the House of Quality model (Hauser & Clausing, 1988), the producer will be driven by an enlightened philosophy and leadership. This philosophy is underpinned by the belief that to achieve quality there must be political (organisational) stability and that there is a need for continuing education among the actors involved. The organisational ability will support organisational desire to create quality products and the education will support the ability to specify quality requirements. This is especially important for aligning the acquirer's corporate processes and their software requirements. The need to address software development strategies like developing re-usable code and software portability are significant issues for the producer organisation. These topics considerably impact the cost of creating software products but are not of direct interest to the acquirer. The accepted approach to successfully creating these first-rate software products is to engage in software project management and an expression often used to provide focus for the objective of project management is "*to complete the right project, on time and within budget*". Each of these elements is now addressed.

2.5.1.2 Project

Engaging in a project is a software industries approach to creating a software product and ISO/IEC 12207 (1995) gives project management guidance in Section 5.2 of the standard. Project management best practice is used in order to assure the successful delivery of the product and this employs planning, organising, controlling and directing throughout the development life cycle. It is through this best practice that the supplier demonstrates to the acquirer their standing and competence as a supplier organisation. ISO 12207 (1995) places the onus on the supplier to develop and document project management plans (Section 5.2.4.5) and continues that the supplier shall implement and execute the project management plans (Section 5.2.5.1). So, there are two critical aspects to the supplier's responsibility (develop and document AND implement and execute) and their level of competence in these is what the acquirer should evaluate. Both of these are now considered.

2.5.1.2.1 Develop and document project management plans

The standard sets out an extensive list of possible categories to be considered when developing and documenting project management plans. These are summarised in Figure 2.3:

1. Organisation and environment
2. Acquirer involvement
3. Acquirer requirements and quality characteristic
4. WBS, resources and contractors
5. Quality assurance/validation and verification
6. Risk management
7. Licensing, usage and ownership
8. Tracking, documenting and reporting
9. Personnel training

Figure 2.3 - *Project management planning issues.*

So, these are the issues that impact the project or project management perspective of software quality. The standard (ISO 12207) suggests that separate plans for quality may be developed. The reader will realise that the items in Figure 2.3 are all embracing and that items 3 and 5 are specifically related to quality. These two items are now considered further.

- **Acquirer requirements and quality characteristic**

  From a quality planning perspective, the real challenge for acquirers is to be able to clearly define their quality requirements and quantify the quality characteristics of the software product. To assist them they need their own well-defined set of strategic acquisition drivers for quality software products. Strategic quality drivers are addressed later in Chapter 3.

- **Quality assurance/validation and verification**

  According to ISO/IEC 12207 (1995) quality assurance involves quality assurance planning and quality control. Much of quality assurance concerns testing and according to the model suggested in ISO 9000-3 there are four classes of testing - item testing, integration testing, system testing and acceptance testing. A special discipline of testing concerns itself with usability testing. Usability and usability methods are discussed later in Section 2.5.3.3. During project planning the various quality assurance activities that will be performed during the project will be quantified, resources allocated and a timescale agreed for their completion. Test plans, test data and expected results will all be quantified.

2.5.1.2.2 Implement and execute the project management plans

This is where the quality and test plans are actioned, and the test data applied to completed work units. To implement and execute these plans resources are necessary as explained in Section 2.5.1.1. Addressing all of these issues will improve the potential of completing the right project as suggested in Section 2.5.1.1. The Software Engineering Institute at Carnegie Mellon University in Pennsylvania, USA, describes an organisation's project management capability in terms of mature and immature software organisations (Paulk *et al.,* 1993b). For a full discussion on all of the issues in Figure 2.3 the reader is referred to Ince (1994) and to the standard (ISO/IEC 12207, 1995).

- **On time**

  Time is the second consideration in the expression *"the right project, on time and within budget"*. Time is governed by milestone deadlines, which are critical events on the project critical path.

  Time is significant from the producer's perspective because failure to keep the project on time will result in cost overrun and consequently impact the profitability of the project. Failure to meet critical completion dates may have penalty consequences as defined in the contract. Failure to successfully deliver a project can seriously impact upon the competitive position of a producer organisation.

  Time is also significant to the procurer as the software might be needed to achieve a window of opportunity in the marketplace and failure to meet this opportunity might render the software product redundant.

- **Within budget**

  Budget is an issue that forms part of the contract negotiations. From the producer's perspective it is a profit consideration and from the procurer's it is a return on investment issue. These matters are outside the scope of this chapter.

- **People**

  For the purpose of this chapter, people include all of the project team, that is, the project manager, the QA manager, the IS development professionals, the configuration manager and anyone who has a role in the software creation process. Each of these has a different view of software quality, for example the project manager will maintain an overall perspective of creating the right product on time within budget and the QA manager will ensure that quality requirements are clearly stated in the contractual documents and will then plan and monitor the quality activities during the project life cycle. During the project, the IS development professional will be focusing on all of the quality factors, applying best practice to ensure that those specified in the requirements specification are being achieved.

  According to Curtis *et al.,* (1995) an important indicator of the maturity of an organisation is the capability of its staff. The Software Engineering Institute have devised a number of Capability Maturity Models (CMM) and one of these - P-CMM - relates to people (in Section 2.5.2.3 the Capability Maturity Model relating to software (SW-CMM) will be examined). P-CMM aims for an "*improvement path from ad hoc, inconsistently performed practices, to a mature, disciplined development of the knowledge, skills, and motivation of the work force*" (P-CMM). The five maturity levels of P-CMM are shown in Figure 2.4.

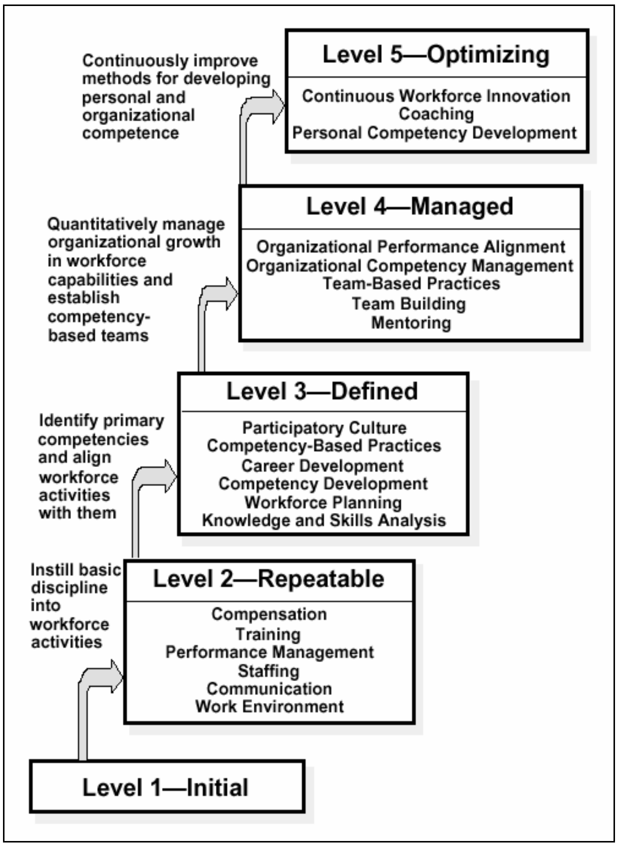


Figure 2.4 - *The five maturity levels of P-CMM.*

There are numerous reports of improved organisational maturity, and subsequently improved software quality, being achieved through the implementation of maturity models (Humphrey *et al.*, 1991; Diaz & Sligo, 1997; Herbsleb *et al.*, 1997).

The Software Engineering Institute have also developed the Capability Maturity Model for Software (Paulk *et al.*, 1993a). This model focuses on the processes that must be completed as part of a software project. In addition, there is a joint undertaking by the ISO and IEC called the Software Process Improvement and Capability dEtermination Project (SPICE). Both of these are examined in the next section.

2.5.1.3 Process

In this perspective the process for creating the software product is all-important. As part of the creation of software products, supplier organisations will engage in a set of processes. In the early days of software development these processes were established almost by trial and error and sets of standards evolved to suit developer understanding and practice. More recently, organisations like the International Organisation for Standardisation, the Software Engineering Institute and different developer companies have devised standards and models, which quantify full and comprehensive sets of processes. The philosophy behind this approach is that by addressing these comprehensive processes, supplier organisations will create quality software products. The International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC), have published ISO/IEC 12207 (1995) relating to software life cycle processes, the Software Engineering Institute has developed the Capability Maturity Model (Paulk *et al.*, 1993b) and ISO/IEC are developing the SPICE standard (ISO/IEC TR 15504:1998). The discussion in this chapter will be confined to these three approaches but the reader should be aware that there are other solutions, especially in the commercial sector.

2.5.1.3.1 ISO/IEC 12207

This International Standard provides a framework for the life cycle of software from conceptualisation through to retirement. It sets out a comprehensive set of processes, which are intended to be tailored, depending on the organisation, the application or project. The Standard views the software life cycle in terms of Primary life cycle processes, Supporting life cycle processes and Organisational life cycle processes. The structure of the standard is shown in Figure 2.5.

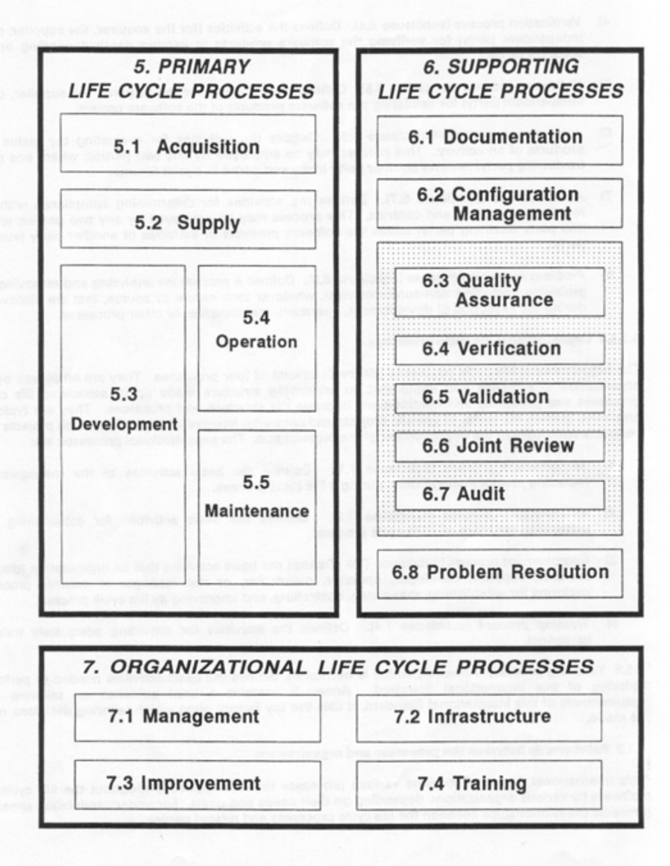


Figure 2.5 - *Life cycle processes per ISO/IEC 12207.*

The Primary life cycle processes are subdivided into three views, the contract view (acquisition and supply processes), the engineering view (development and maintenance processes) and the operating view (operation processes). The Supporting life processes address the documentation processes, configuration management processes and quality management processes. The Organisational life cycle processes address management processes, infrastructure processes, training processes and improvement processes.

Of particular interest is item 6.3 in the figure. The standard emphasises four quality assurance activities:

- **Process implementation** – requires that a quality assurance process tailored to the project should be established
- **Product assurance** – requires that plans and procedures be established to ensure that the software product meets the requirements specification

- **Process assurance** – requires that the life cycle processes used by the supplier organisation comply with the contract
- **Assurance of quality systems** – requires that the ISO 9001 quality management activities are assured.

Each of these processes is further divided into activities and tasks, which provide focus for the supplier and the acquirer during a contract.

2.5.1.3.2 Capability Maturity Model

The Capability Maturity Model for Software (SW-CMM) is a conceptual structure for managing and developing software products in a disciplined and consistent way (Paulk *et al.,* 1993b). It was developed by the Software Engineering Institute at Carnegie Mellon University in response to a need of the U.S. Department of Defense who required supporting techniques to enable them to evaluate and select competent software contractors. To support them with this evaluation and selection the model consists of five maturity levels each of which contains key process areas as illustrated in Figure 2.6.

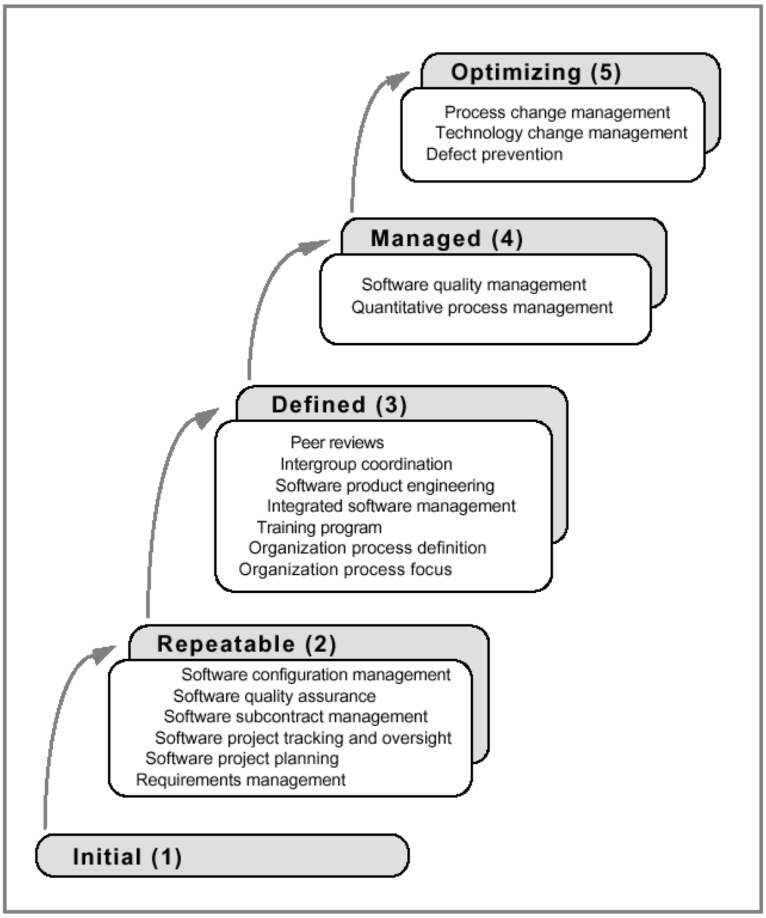


Figure 2.6 - *The CMM key process areas by maturity level (Paulk et al., 1993b).*

A **software process** is defined as a set of activities, methods, practices, and transformations that people use to develop and maintain software and the associated products (e.g., project plans, design documents, code, test cases, and user manuals).

The philosophy underpinning the model is that process improvement is achieved through a series of evolutionary steps, which are organised into the five maturity levels.

According to Paulk *et al.,* (1993a) The CMM can be used for:

- software process improvement in which an organsation plans, develops, and implements changes to its software process:
- software process assessments in which a trained team of software professionals determines the state of an organisation's current software process, determines the high-priority software process-related issues facing

an organisation, and obtains the organisational support for software process improvement: and

- software capability evaluations, in which a trained team of professionals identifies contractors who are qualified to perform the software work or monitors the state of the software process used on an existing software effort.

Note: In this model software quality assurance is a maturity requirement at level 2.

2.5.1.3.3 SPICE

The Software Process Improvement and Capability dEtermination Project is a joint undertaking by the ISO and IEC to support an international standard for software process assessment. At their dedicated website (http://www.sqi.gu.edu.au/spice/) they state their three aims as being:

- to develop a working draft for a standard for software process assessment
- to conduct industry trials of the emerging standard
- to promote the technology transfer of software process assessment into the software industry world-wide.

They list the benefits for the software industry as:

- software suppliers will submit to just one process assessment scheme (presently numerous schemes are used)
- software development organisations will have a tool to initiate and sustain a continuous process improvement
- programme managers will have a means to ensure that their software development is aligned with, and supports, the business *needs of the organisation.*

And, they list the benefit for purchasers of software as

- purchasers will be able to determine the capability of software suppliers and assess the risk involved in selecting one supplier over another.

The CMM and SPICE are international models, which are designed to enable the certification of the capability of supplier organisations to enter into software contracts and to predict their potential for success completion. So, it is desirable, and for some contracts essential, that tenderers should be able to demonstrate certification. At a national level, ISO 9000-3 certification is also available from the National Standards Authority of individual countries. All of these models can be further used by the supplier organisation as a foundation for building process improvement within their organisation.

That concludes the explanation of the three perspectives of the supplier (producer, project and process) as shown on the Software Quality Star. The measures of excellence that impact them are competitive excellence and certified maturity, development excellence and quality management.

In the next section the characteristics of a quality software product, from the joint perspectives of the acquirer and the supplier, are explained.

2.5.2 Product

From this perspective a software product is considered to be a quality product if it supports a set of quality factors or product characteristics. Software quality factors were first defined in the 1970's by researchers like McCall *et al.,* (1977) and Boëhm, (1978). Their research was later complemented by standards like IEEE Standard 729-1983 and ISO/IEC 9126 (1991). The McCall *et al.,* set of quality factors is typical of these and is:

- integrity
- reliability
- usability
- correctness
- efficiency
- interoperability
- maintainability
- testability
- flexibility
- reusability
- portability

Figure 2.7 – *Software quality factors by McCall et al., (1977)*

Twenty years after the publication of these quality factors, Fitzpatrick and Higgins (1998) conducted a methodical analysis and synthesis of three strands - quality (as explained by McCall *et al.,* and by Boëhm), statutory obligations, and human-computer interaction, which influence software quality. This established a comprehensive set of quality factors, and those factors that related to users, they called the attributes of a usable software product. The full study and analysis is included in Appendix A.

A significant issue arises in relation to this product-centred view of software quality. It is focused on traditional Information Systems software and takes no account of evolving domains such as the World Wide Web. This shortcoming is addressed by this thesis and Chapter 4 identifies a set of additional quality factors for the World Wide Web.

That concludes the explanation of the product perspectives as shown on the Software Quality Star. The measure of excellence in this case is focused on the characteristics of the software product.

In the next section the perspectives of the acquirer are explained.

2.5.3 The Acquirer (Procurer)

ISO/IEC 12207 (1995) describes the acquirer as:

> *"an organisation that acquirers or procures a system, software product or software service from a supplier".*

The Quality Star considers the acquirer as consisting of the procurer who is charged with the responsibility of procuring systems, products and services, that will be maintained and supported by the IS professional and used by the user. The procurer, IS professional and user are now considered in detail.

2.5.3.1 Procurer

In the context of software quality, the procurer organisation is obviously interested in knowing that the producer is a first-rate organisation, which uses first-rate processes to create software products that incorporate all of the most appropriate quality factors. However, there are also strategic issues, which the procurer must address. For example, the procurer will be interested to know that there is alignment between the software product and the organisation's business processes.

The procurer will also be concerned to know that the software product will be usable, that it contains the highest technical excellence and that the organisation can afford the software and secure a return on the investment. There are also legal considerations which the procurer must be satisfied that the software conforms to. Competitive advantage or competitive survival is also a procurer's concern. Typically, these are Strategic Quality Drivers which have been addressed by Fitzpatrick (2001) and for the benefit of the reader the full set of drivers is set out in Figure 2.8 and is explained later in detail in Chapter 3.

STRATEGIC QUALITY DRIVERS – PRODUCER	STRATEGIC QUALITY DRIVERS – PROCURER
Competitive excellence (Domination) **Corporate accreditation** (Certification) **Domain speciality** (Qualification) **Development excellence** (Organisation) **Quality management** (Direction).	**Competitive support** (Superiority) **Investment efficiency** (Affordability) **Statutory conformance** (Conformability) **Corporate alignment** (Alignability) **User acceptance** (Acceptability) **Technical excellence** (Supportability).

Figure 2.8 - *Strategic quality drivers - (Fitzpatrick, 2001)*

2.5.3.2 IS professional

For the purpose of this section the IS professionals being considered are the technical professionals of the acquirer organisation who have line responsibility for IS. Their role begins with advice to management regarding the specification, selection and acquisition processes and would typically address technical excellence, user empowerment, corporate alignment and investment efficiency together with supplier organisation profile. They have responsibility through to the retirement of the software at the end of its operational life.

During the specification, selection and acquisition processes they will identify the quality characteristics required of the software product and will ensure that contract documents address these issues.

During the operational stage they are responsible for supporting the users of the software and for servicing and maintaining the software during its operational life.

As part of their supporting role these IS Professionals are concerned with all of the quality factors as explained in Section 2.5.2 and Appendix A. For example, the installability of the software might be especially of interest to them, or, the reliability of the system might seriously impact their workload. From the time that a new system is delivered, technical support relies heavily on user and technical manuals. So, from the IS professional's perspective an essential requirement of a quality software product is a full and comprehensive set of these.

As part of the servicing role they will be addressing such quality issues as reinstalling sections of software where modules become corrupt and will require systems that support this type of servicing activity. As part of their maintenance role they are required to **adapt** software to suit changes such as government directives, changing rates like pay scales, tax rates and similar items. They will be required to **correct** any bugs or other errors that manifest themselves during the life of the product and they will be required to **perfect** the software especially by fine-tuning algorithms to improve their efficiency and to meet new user requirements. To assist them in these activities they will be especially interested to know that good designs, documentation and best programming practice has been used during the project phases when the software was being created.

In addition to supporting other users and maintaining systems, these professionals are often themselves the users of products like network operating systems and management tools, so, they too will be impacted by quality of use issues. While for some, the internal quality factors may be their primary interest they will also be concerned that the external quality factors fully support users.

2.5.3.3 User

The perspective here is usability. The traditional view of usability is that it is one of a set of the quality factors of a software product (McCall *et al.*, 1977; Boëhm, 1978). Fitzpatrick & Higgins (1998) argue that it is an all embracing measure of the software, which includes all aspects that impact on usage. In their view, *usability is of a higher order and includes all aspects of a software product (including its interface with hardware devices – the product-centred view) that impact on how an* *end-user uses the software (quality-of-use) and it involves all aspects that impact on the end-users attitude towards using the software in a specific context (context-of-use).* A consequence of this view is that it should be possible to measure the overall usability of a software product and quantify it with a usability quotient. Product-centred view, quality-of-use and context-of-use are terms used by Bevan and Macleod (1994, p136). They suggest that usability has to be viewed in different ways for different purposes, focusing on one or more of the following complementary views:

> "***a. the product-centred view of usability****: that the usability of a product is the attributes of the product which contribute towards the quality-of-use.*
> ***b. the context-of-use view of usability****: that usability depends on the nature of the user, product, task and environment.*
> ***c. the quality-of-use view of usability****: that usability is the outcome of interaction and can be measured by the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments*".
>
> Bevan and Macleod (1994, p136)

Software products are created to support the business processes of modern organisations. Quality-of-use is more easily achieved if the acquiring organisation has re-engineered its business processes to reflect these modern approaches.

Usability is well researched and there are many established methods and techniques that can be used in order to measure the usability of a software product. Most authors would list observation, questionnaire, interview, empirical methods, user groups, cognitive walkthroughs, heuristics, review methods and model methods as being typical of the many methods that are available. Recently ISO published a new International Technical Report (ISO TR 16982:2000) to assist project managers to make informed decisions about the correct choice of usability methods. The specification provides an overview of existing usability methods, which can be used alone or in combination to support design and evaluation. The specification lists twelve usability methods and seven additional methods and techniques in its Annex C. These are shown in Figure 2.9.

USABILITY METHODS	
• Observation of users • Performance-related measurements • Critical incidents • Questionnaires • Interviews • Thinking aloud	• Collaborative design and evaluation • Creativity methods • Document-based methods • Model-based approaches • Expert evaluation • Automated evaluation
ADDITIONAL METHODS AND TECHNIQUES	
• Electronic surveys • Log files • Video capture • Scan converter	• Focus groups • Parallel design • Brainstorming

Figure 2.9 - *Usability methods as named by ISO/TR 16982.*

Each method is described in the Technical Report and the reader should refer to the document for fuller descriptions. These methods are referred to as generic usability methods and it is recommended that for best results a number of methods should be used together. Some of these methods have been commercialised and these solutions can be purchased as usability tools.

That concludes the explanation of the three perspectives of the acquirer (procurer, IS Professional and User) as shown on the Software Quality Star. The measures of excellence that impact them are a set of strategic quality drivers, technical excellence and usability.

However, it is also necessary to consider the contract, which is the instrument that connects the supplier and the acquirer. Because the contract is part of the acquisition process in ISO 12207 (1995) it is included in this section.

2.5.4 The contract

This model considers that the acquirer is the lead party in a contract. It can also be argued that a partnership arrangement between acquirer and supplier is a better solution and the contract between them becomes a vehicle for creating a quality software product. Before entering into a contract the acquirer will want to know the capability of the supplier (and other sub-contractors) to create a quality product. The acquirer will need to know that a full and comprehensive specification is in place and will also need assurance that essential critical schedule deadlines or milestones can be achieved and that the cost of the project is realistic. Contracts are legal documents so all of the legal contracting issues must be addressed. ISO/IEC 12207 (1995, Section 5.4.3.1) requires that the quality characteristics of the software should be specified. All contract documents including contract plans will be included. ISO/IEC 12207 (1995, Section 6.3.1.3) requires that these plans should include a quality assurance plan and the issues that should be addressed by that plan are set out in Figure 2.10.

- Quality standards, methodologies, procedures, and tools for performing the quality assurance activities (or their references in organisation's official documentation)
- Procedures for contract review and coordination thereof
- Procedures for identification, collection, filing, maintenance and disposition of quality records
- Resources, schedule, and responsibilities for conducting the quality assurance activities
- Selected activities and tasks from supporting processes, such as Verification (6.4), Validation (6.5), Joint Review (6.6), Audit (6.7), and problem Resolution (6.8).

Figure 2.10 - *Quality assurance planning per ISO/IEC 12207 (1995).*

At this stage it is appropriate to introduce the Quality assurance manager who will be responsible for quality. ISO/IEC 12207 (1995) also requires that

"*to be unbiased, quality assurance needs to have organisational freedom and authority from persons directly responsible for developing the software product or executing the process in the project*".

2.6 Using the Software Quality Star

The Software Quality Star continues to be used for the purpose that it was originally devised, i.e., a teaching aid. In this mode it is used as a conceptual model to clarify how the broader interpretation of quality applies to software quality for undergraduate and postgraduate students.

In this thesis it is further developed in the following chapters. First, in Chapter 3 it becomes the core of a new set of strategic considerations that are modelled as the Strategic Drivers of Software Quality. Second, in Chapter 6 an enhanced version of the model is used to underpin a strategy for measuring website quality.

2.7 Conclusion

This chapter presents a review of quality and software quality, and defines it as a measure of excellence.

The chapter synthesises seven different perspectives of software quality and for each perspective the focus of that measure of excellence is considered. The synthesis focuses on the supplier and the acquirer, as identified in ISO/IEC 12207, as stakeholders in the software life cycle process. To support the synthesis the Software Quality Star conceptual model is used. The three supplier perspectives are producer, project, and process and the three acquirer perspectives are procurer, IS professional and user. The joint perspective of a quality software product and the contractual agreement between them are also considered.

The chapter demonstrates for managers and IS professionals that quality software products are created through a combination of many different perspectives. So, it is appropriate to return to the definitions of quality set out in Section 2.3 and in particular to that of the founder of the Japanese quality movement, Kaoru Ishikawa (1985) and his thinking relating to quality of product, service, management, the company itself and the human being. This chapter clearly shows that in the software domain, researchers and those who are defining standards are embracing the all encompassing perspectives of the software product, the service of developing and maintaining that product, the management of acquisition and use of the product, the acquirer and supplier company perspectives and the human consideration of developers, maintainers and users.

The chapter has highlighted the need for additional research topics particularly in relation to:

- Software quality strategic drivers
- Strategic quality factors
- New quality factors for evolving technologies.

It would also be appropriate to revisit core software quality factors in order to establish if they should be reinterpreted in relation to these evolving technologies.

The next chapter addresses the strategic drivers of software quality. It extends the Software Quality Star by developing and explaining a set of formal strategic business considerations and presenting them in a new Software Quality Strategic Driver model. Additional quality factors for the World Wide Web are addressed in Chapter 4.

Chapter 3

The strategic drivers of software quality

> *The aim of the chapter is to investigate the producer and procurer perspectives in the producer/procurer/product triad in order to clarify the strategic quality considerations that influence their perspectives during the supply and acquisition of software products.*

3.1 Background

Software quality is often considered in terms of the contractual requirements between the producer and procurer as described in ISO/IEC 12207 (1995) and focuses on software life cycle processes. However, beyond these processes procurer organisations need to address other issues like complying with new legislation, securing return on investment, and achieving competitive support from their new software investments. Suppler organisations also have issues that they must manage. This chapter addresses these and proposes eleven issues, which it calls strategic drivers. Then, using the Software Quality Star, a new conceptual model is proposed where each strategic quality driver is defined and explained. Some of the basic ideas presented in this chapter were published in *Strategic Drivers of Software Quality: Beyond external and internal software quality*, (Fitzpatrick, 2001). Content from this chapter was also published in *Software Quality Challenges*, (Fitzpatrick, Smith & O'Shea, 2004b).

3.2 Introduction

Using ISO/IEC 12207 as a foundation, Chapter 2 presented the author’s Software Quality Star conceptual model, which explains software quality from the producer, procurer and product perspectives. Chapter 2 also highlighted the need for additional research particularly in relation to strategic quality drivers and new quality factors for evolving technologies. This chapter focuses on the first of these topics - strategic quality drivers – and builds on Chapter 2 by expanding the

Software Quality Star with a view to creating a new strategic driver conceptual model.

The study of software quality is often influenced by studies of particular factors (McCall *et al.,* 1977; Boëhm 1978) or by a desire to secure certification. The principal focus of the studies has been to create products which demonstrate high levels of usability and other technical excellence while the principal focus of certification has been to demonstrate maturity as a software development organisation. This in turn has provided confidence to the procurer community who need to enter into contracts with producer organisations. So, from the procurer's perspective software quality has been limited to usability excellence, technical excellence and to the producer organisation's ability to deliver this excellence. However, a number of developments are forcing a change in perspective. For example, as the Information Technology (IT) sector expands, new legislation has been introduced which software products must comply with. There is also an increasing awareness of the need to secure value for money from IT investments. The growth and demands of eCommerce are resulting in demands from software procurers for products that will support their competitive position. So, it is appropriate to review strategic considerations that influence software procurers in order to determine a broader understanding of what actually contributes to software quality. This is the focus of this chapter and to this end the chapter defines a set of strategic quality drivers. The aim of the chapter is to clarify for procurer organisations a new paradigm of software quality. Section 3.3 presents an overview of current procurer's perception of software quality, defines strategic drivers and identifies eleven new strategic quality drivers, which influence both the procurer and the producer. This section introduces a new *Software Quality – Strategic Driver Model* (*SQ-SDM*). Sections 3.4 and 3.5 define and explain each of the strategic drivers in the model and present summary tables from both the procurer and producer perspectives. Section 3.6 clarifies how the Software Quality Strategic Driver Model can be used. Section 3.7 draws conclusions.

3.3 Strategic drivers of software quality

From the software procurer's perspective, the quality characteristics of a software product are generally described in terms of external and internal quality factors (Ghezzi *et al.*, 1991). These can be mapped respectively to usability excellence and to technical excellence. In terms of the actors involved these relate to the quality perspectives of the users (external/usability) and to the quality perspectives of IS technical support and maintenance professionals (internal/technical). However, there is a third actor who contributes to this triad. This is the procurer (representing strategic management) who also has a perspective of software quality and which includes more than external and internal quality factors. In this new paradigm this chapter shows that all of the traditional external quality factors are collectively the usability of the software product while all of the internal quality factors are collectively the supportability of the software product. Typically that would be the extent of the study of software quality insofar as it applies to information systems. However, this chapter demonstrates that there are other issues.

Software quality is a measure of excellence, which, is achieved through a number of strategic quality drivers. Strategic drivers are defined in this chapter as:

> *a set of interrelated issues, which must be managed (planned, organised, controlled and directed) in order to achieve success in a specific domain in a specified context.*

For the purpose of this chapter the specific domain is software quality and the specified context is Information Systems (IS) acquisition. In this chapter, these strategic quality drivers present a new paradigm for software quality and provide a strategic focus for software procurers. They are of a higher, all embracing, order than traditional product quality factors and focus on strategic business excellence in addition to product technical excellence. They have been derived from a literature review of IT strategy considerations, using an abstraction technique known as PEST (or PESTLE) analysis. This technique is used to evaluate an organisation in the six categories of Political, Economic, Socio-cultural, Technological, Legal and

Environmental (America *et al.*, 2004). The terminology used to describe them involved the matching of their semantics with the natural meaning and shared understanding of what they address.

This chapter first presents a set of six strategic quality drivers which impact the procurer of software (a second set of five drivers which impact the producer will also be explained, thus making a total of eleven drivers in all) – see Fitzpatrick, 2001. These first six relate to ensuring that the software is supportable and maintainable by IS technical professionals: to ensuring that the software is usable by the workforce; to aligning the software product and the organisation's business processes; to being satisfied that the software product complies with the organisation's legal obligations; to securing value for money; and, to assisting the organisation to sustain its competitive position. The procurer strategic quality drivers are:

- **Technical excellence** (Supportability),
- **User acceptance** (Acceptability),
- **Corporate alignment** (Alignability),
- **Statutory conformance** (Conformability),
- **Investment efficiency** (Affordability),
- **Competitive support** (Superiority).

Fitzpatrick (2001)

The second set of five strategic quality drivers which impact the producer of software relate to ensuring that the procurer's quality requirements are managed at all phases of the evolving software product, best quality assurance development standards and practice, the producer organisation's knowledge and expertise of the procurer organisation's business processes, certification of the producer organisation's capability of creating quality software and to the competitive standing of a software producer compared with competitor software organisations. The procurer strategic quality drivers are:

- **Quality management** (Direction)
- **Development excellence** (Organisation)
- **Domain speciality** (Qualification)
- **Corporate accreditation** (Certification)
- **Competitive excellence** (Domination).

Fitzpatrick (2001)

All of the strategic quality drivers are illustrated in Figure 3.1.

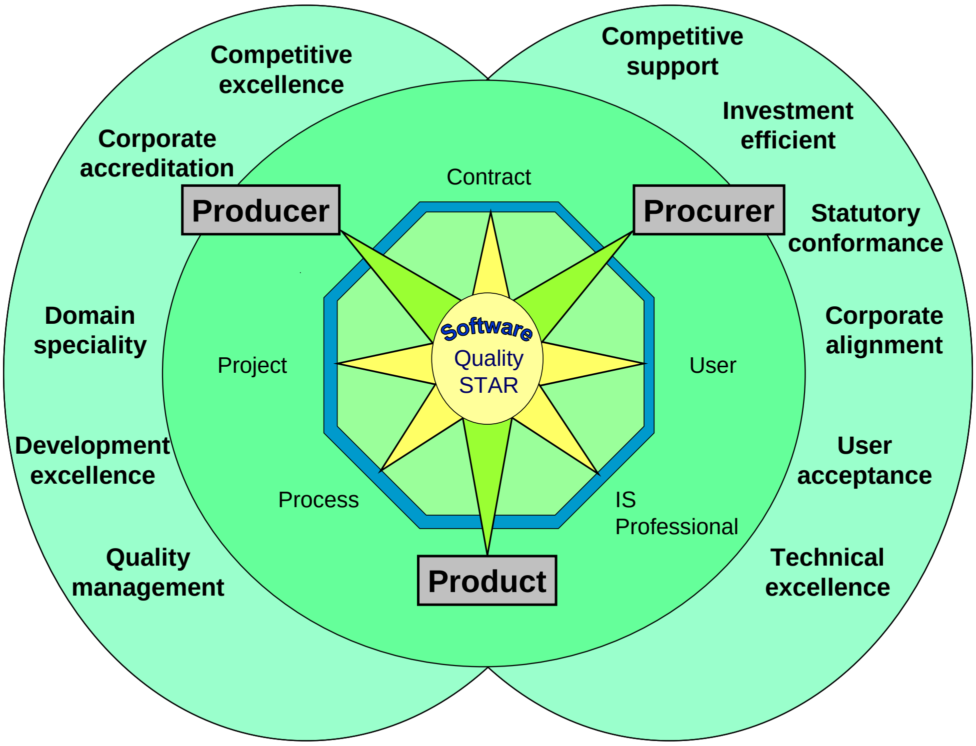


Figure 3.1- *Software Quality – Strategic Driver Model* (*SQ-SDM*)

Most of these issues have been well researched although they are not normally perceived as strategic quality drivers. Neither are they normally perceived as being interrelated. Industry understanding of some of these drivers like, statutory conformance is only now being researched as a result of national governments introducing legislation. This chapter identifies and names these strategic drivers and presents them in one model so that the perspectives of the procurer and the producer can be focused in order to achieve software products of the highest quality.

3.4 Procurer software quality strategic drivers explained

The six strategic quality drivers, which provide focus for forming a procurer's perspective of software quality, are explained in this section. The explanations include a description and definition of each strategic quality driver and indicate the quality considerations, which are appropriate to that strategic driver.

3.4.1 Technical excellence (Supportability)

Technical excellence is concerned with ensuring that the software is serviceable and maintainable by IS professionals and is defined as the strategic quality driver for excellence in software product support. It embraces all of the quality factors of the software product (external and internal as fully explained in Appendix A) and the ability of the IS professional to support users in their use of the product. In keeping with ISO/IEC 12207 (1995) the software product consists of all designs, programs, procedures, supporting documentation and data. Hewlett-Packard in their FURPS quality factors model consider serviceability to combine the ability to extend the program, adapt and service it. Ghezzi *et al.*, (1991) divide maintenance into three categories: corrective, adaptive and perfective. The model combines these two - service and maintenance – under the term supportability.

3.4.2 User acceptance (Acceptability)

User acceptance is concerned with ensuring that software is acceptable to the user community and that it is usable by them. It is defined as the strategic quality driver for excellence at the user interface and has two focuses. First, this strategic quality driver embraces all of the factors that have heretofore been described as external quality factors, that is, those factors that impact the user. According to Fitzpatrick & Higgins (1998) these include, suitability, installability, functionality, adaptability, ease-of-use, learnability, interoperability, reliability, safety, security, correctness and efficiency. Second, it embraces the extent to which the corporate alignment of business processes addressed by the software empowers the user. The combination of these two - external quality factors and business processes - influences user acceptance of the software and as a procurer's strategic quality driver they are collectively termed acceptability.

3.4.3 Corporate alignment (Alignability)

Corporate alignment is concerned with aligning the software product and the organisation's business strategy. There is a broad range of research literature relating to alignment where the principal authors are Henderson & Venkatraman (1989). The expression *strategic* is normally used to describe alignment. Henderson & Venkatraman emphasise that alignment is achieved through the strategic integration of the IT domain with the business domain. For the IT domain, applications, data, the user interface and communications all have to be harmonised with the business. For the business domain, both business strategy (external integration) and organisational infrastructure and processes (internal integration) must be addressed. This alignment will include functional alignment of the different corporate functions. The reader will appreciate that alignment must embrace all levels (strategic, tactical and operational) and all functions of the organisational pyramid. For example, at a strategic level, Eardley (2000) states that a strategic vision and the organisation's current position must be considered. He continues that the alignment strategy should be sufficiently flexibile to accommodate changes in both domains.

3.4.4 Statutory conformance (Conformability)

Statutory conformance (Conformability) is concerned with being satisfied that the software product complies with the organisation's legal obligations and is defined as the strategic quality driver for excellence with legal compliance. Conformability is about ensuring that the quality of the software (e.g., adaptability, safety, learnability and security) conforms to national and international law. Typically, the laws include the EU legal directive for display screen equipment, the Data Protection Act and Intellectual Property Rights legislation, especially patent, copyright, trademarks and look and feel. Conformability is not to be confused with business processes like VAT returns, social security deductions or national pension plan deductions that comply with government directives or statutory instruments. Business processes like these are part of alignability – Section 3.4.3.

3.4.5 Investment efficiency (Affordability)

Investment efficiency (Affordability) is the strategic driver that focuses on securing value for money. Establishing the efficiency of IT investments is the responsibility of accounting and investment professionals. Early IT investments relied on traditional evaluation techniques like Return on Investment (RoI), Net Present Value (NPV) and Internal Rate of Return (IRR) but research has shown these techniques to be inappropriate for the special nature of IT investments. According to Weill & Olson (1989) management began to ask questions like "Are the computerised systems contributing in a manner that was originally intended?", "Have they secured value for money?", "What is the business value of computers?" and "What is the impact of the level of investment in IT on a firm's performance?" More recently, what have become known as contemporary techniques, and which focus on a set of IT evaluation criteria, have proven more appropriate. According to Bennett (1998) popular contemporary techniques include Information Economics (IE), Return on management (ROM), The Kobler Unit approach, SESAME and The Application Transfer Team (ATT). Typical of the management criteria which address the IT focus that are evaluated by these contemporary techniques are Tangible Benefit, Intangible Benefit, Knock-on Benefit, Life Span, IT Risk, Strategic Match, IS Match and Portfolio. Affordability is the strategic quality driver for excellence in IT investment.

3.4.6 Competitive support (Superiority)

Competitive support relates to the software's ability to assist the procurer organisation to sustain its competitive position and is defined as the strategic quality driver for competitive support. This quality driver focuses the procurer's attention on the "*opportunity for improved profitability*" that the new software product presents. This view is supported by Robson (1994) who states, in relation to competitive advantage,

> "*So, what good does come about? Competitive advantage, no, but improved profitability, yes*".

She continues that competitive advantage might not be achieved but competitive disadvantage will follow if proactive approaches are not employed. For this reason, competitive support is more descriptive of this Strategic Quality Driver. Opportunities for improved profitability are available throughout Porter's entire Value-Chain (Porter, 1980, 1985) and every procurer organisation will need to complete its own industry specific analysis in order to identify the opportunities unique to them. Based on Robson (1994, p187), typical of the categories that might be analysed are: supplier to customer relationships, distribution channels, production economies and product life cycles, and value-added services. The procurer organisation also needs to be conscious of their customer's perception of them if they do not embrace IT solutions. They also need to be aware of the importance of empowering employees through IT. For some interesting examples under the headings of proprietary advantage, one step ahead, discontinuity, and implementation the reader is referred to Robson (1994, p199).

That concludes the review of the procurer's perception of strategic quality drivers. Figure 3.2 tabulates them with the quality focus that is relevant to each.

Strategic Driver	Description and Definition	Quality Focus
Competitive support Superiority	The software's ability to assist the organisation to sustain its competitive position and is defined as the strategic quality driver for competitive support.	• Value-chain quality benefits
Investment efficiency Affordability	Securing value for money. Affordability is the strategic quality driver for excellence in IT Investment.	• Contemporary techniques to evaluate IT investment
Statutory conformance Conformability	Being satisfied that the software product complies with the organisation's legal obligations and is defined as the strategic quality driver for excellence with legal compliance.	• EU Display screen directive • Data Protection Act • Intellectual property rights
Corporate alignment Alignability	Aligning the software product and the organisation's business strategy. Defined as the strategic quality driver for IT excellence in business practice.	• Aligning the IT domain and the business domain
User acceptance Acceptability	Ensuring that the software is acceptable to the user community and that it is usable by them. It is defined as the strategic quality driver for excellence at the user interface.	• Usability attributes of the software product • Process alignment
Technical excellence Supportability	Supportability is concerned with ensuring that the software is serviceable and maintainable by IS professionals and is defined as the strategic quality driver for excellence in software product support.	• Complete set of software quality factors

Figure 3.2 - *Strategic Quality Drivers defined – Procurer.*

3.5 Producer software quality strategic drivers explained

The five strategic quality drivers, which provide focus for forming a producer's perspective of software quality, are explained in this section. The explanations include a description and definition of each strategic quality driver and indicate the quality considerations, which are appropriate to that strategic driver. The reader will understand that these strategic quality drivers are also of interest to the procurer and will form the basis of evaluating the producer's capability of creating a quality software product. This set of strategic quality drivers is also of critical importance to producer organisation when defining their quality vision and philosophy.

3.5.1 Quality management (Direction)

Quality management is concerned with ensuring that the procurer's quality requirements are incorporated at all phases of the evolving software product. It is defined as the strategic quality driver for excellence in assuring software quality and includes quality assurance planning and quality control.

3.5.1.1 Quality assurance planning

According to ISO/IEC 12207 (1995), quality assurance planning involves:

- Quality standards, methodologies, procedures, and tools for performing the quality assurance activities (or their references in organisation's official documentation)
- Procedures for contract review and coordination thereof
- Procedures for identification, collection, filing, maintenance and disposition of quality records
- Resources, schedule, and responsibilities for conducting the quality assurance activities
- Selected activities and tasks from supporting processes, such as Verification, Validation, Joint Review, Audit, and problem Resolution.

3.5.1.2 Quality control

Quality control is the proactive cyclical revisiting of all of the planned quality assurance activities in order to ensure that quality requirements are being achieved. The quality characteristics that must be assured by this process are originally specified under clause 5.3.4.1 of ISO/IEC 12207 (1995).

Quality management is the role of the quality manager and ISO/IEC 12207 (1995) requires that

"to be unbiased, quality assurance needs to have organisational freedom and authority from persons directly responsible for developing the software product or executing the process in the project".

3.5.2 Development excellence (Organisation)

Development excellence is concerned with ensuring that the software product is created in accordance with best management standards and practice. It is defined as the strategic quality driver for excellence during the project life cycle and includes project management excellence, technical competence and continuous process improvement.

3.5.2.1 Project management excellence

It is through the application of management techniques like planning and control that the procurer is reassured of the ability of the producer to deliver a quality software product. According to ISO/IEC 12207 (1995) the onus is on the supplier *to develop and document project management plans (Section 5.2.4.5) and the supplier shall implement and execute the project management plans (Section 5.2.5.1).* The standard recommends that project management planning should address issues like organisation and environment, procurer involvement, procurer requirements and quality characteristic, WBS, resources and contractors, quality assurance/validation and verification, risk management, licensing, usage and ownership, tracking, documenting and reporting, and personnel training. Project control is the cyclical revisiting of these issues to ensure that they are progressing according to plan.

3.5.2.2 Technical competence

The technical ability of the IS professionals available to the producer organisation (employed by, contract hired or outsourced) will significantly impact the producer’s ability to create quality software products and deliver them on time and within budget. Typically, technical competence will address IS professional staff qualifications and their experience relevant to the project. To a limited extent the staffs’ understanding of the business processes being addressed by the new software product is also important in order that they can correctly interpret the requirements specification.

3.5.2.3 Continuous process improvement

From a development perspective, this is concerned with the review of how a producer organisation creates quality software products in order to identify shortcomings in their practice. Having identified any shortcomings the producer organisation will initiate procedures, which improve the original practice with a view to improving the quality of the software product.

3.5.3 Domain speciality (Qualification)

Domain speciality relates to the producer organisation's knowledge and expertise of the procurer organisation's business processes. It is defined as the strategic quality driver for excellent business process understanding.

In order to demonstrate excellence in this software quality driver, the producer organisation must number among its employees consultants who fully understand the theory and professional practice of the procurer's business processes. Input from these consultants into the creation of the software product will begin at contract tender stage and will continue through the life of the project to beyond final handover.

3.5.4 Corporate accreditation (Certification)

Corporate accreditation relates to the independent certification of the producer organisation's capability of creating quality software products. It is defined as the strategic quality driver of contractor maturity and includes Capability Maturity Model certification, ISO 9000 certification, and similar accreditations.

3.5.4.1 Capability Maturity Model certification (CMM)

The Capability Maturity Model for Software (SW-CMM) is a conceptual structure for managing and developing software products in a disciplined and consistent way (Paulk *et al.*, 1993b). It was developed by the Software Engineering Institute at Carnegie Mellon University in response to a need of the U.S. Department of Defense who required supporting techniques to enable them to evaluate and select competent software contractors. It consists of five maturity levels – Initial, Repeatable, Defined, Managed and Optimizing – each of which contains key process. Organisations are certified as being of a certain level in this model – the higher their level, the higher their maturity.

3.5.4.2 ISO 9000 certification

The International Organisation for Standardisation (ISO) have published ISO Standard 9001 (1994) and ISO 9000-3 (1997) which provide guidelines for best practice for software developer organisations. The national representative organisations of ISO are approved to review and evaluate a software developer's practice and to grant ISO certification if that practice is of a required standard. Those who are certified are allowed to display a Quality Mark on the promotional literature. In the United Kingdom, TickIT, is the expression used to express this type of certification (www.TickIT.org).

These are the principal categories of certification. However, representative organisations offer similar accreditations which certify their members ability to complete software projects and it is advisable to establish local practice in this regard. There are extensive practitioner reports of how accreditation policies have contributed to improved software quality. For a recent selection of these the reader is referred to the Proceedings of the Second World Congress for Software Quality (2WCSQ, 2000).

3.5.5 Competitive excellence (Domination)

Competitive excellence relates to the competitive standing or rating of a software producer compared with rival software organisations. It is defined as the strategic quality driver for selecting a suitable producer.

As part of the acquisition process it is normal for a procurer to identify a number of potential producers and to invite them to tender for the software contract. No two potential producers will have identical profile. They will have different strengths and weaknesses, so, competitive excellence profile includes regional affiliation, financial capacity, and experience.

3.5.5.1 Regional affiliation

Regional affiliation is concerned with national, regional and international trading agreements or partnerships like the North American Free Trade Agreement (NAFTA) and the single market of the European Union, which is achieved through the European Free Trade Association (EFTA). These agreements provide protection for organisations in member states and quite often require tendering organisations to be fully registered and resident in a partner country.

3.5.5.2 Financial capacity

Financial capacity relates to the producer's capability to fund their commitments to the project. For example, projects, especially large scale or safety-critical projects, may require the producer to have independent access to financial resources to ensure that the project does not fail during payment milestones.

3.5.5.3 Experience

Experience is concerned with the producer's past performance with similar types of projects. Even though a tenderer may have achieved a high level rating on a maturity model, some of the other tenderers, who have the same maturity rating, may have more experience of successfully completing a greater number of similar projects.

Competitive excellence is the last of the strategic drivers presented in the *SQ-SDM* and it is the one which best illustrates how some drivers are relevant to more than one perspective. For example, competitive excellence must be worked for, achieved and maintained by the producer yet it is the procurer who may use competitive excellence as the influencing strategic driver when selecting a suitable producer.

That concludes the explanation of the producer's five strategic quality drivers. Figure 3.3 tabulates them with the Quality focus that is relevant to each.

Strategic Driver	Description and Definition	Quality Focus
Competitive excellence Domination	The competitive standing or rating of a software producer compared with rival software organisations. Defined as the strategic quality driver for selecting a suitable contractor.	• Regional affiliation • Financial capacity • Experience
Corporate accreditation Certification	The independent certification of the producer organisation's capability of creating quality software products. Defined as the strategic quality driver of contractor maturity.	• CMM certification • ISO certification
Domain speciality Qualification	The producer organisation's knowledge and expertise of the procurer organisation's business processes. Defined as the strategic quality driver for excellent business process understanding.	• Business process consultant expertise
Development excellence Organisation	Ensuring that the software product is created in accordance with best management standards and practice. Defined as the strategic quality driver for excellence during the project life cycle.	• Project management excellence • Technical competence • Continuous process improvement
Quality management Direction	Ensuring that the procurer's quality requirements are incorporated at all phases of the evolving software product. Defined as the strategic quality driver for excellence in assuring software quality.	• Quality manager • Quality planning and control

Figure 3.3 - *Strategic quality drivers defined – Producer.*

3.6 Using the Software Quality Strategic Driver Model

The Software Quality Strategic Driver Model can be used in different ways as follows:

- The producer organisation, especially those engaging in a strategy of maturity certification, can use the drivers to create organisational awareness of the strategic issues that must be addressed as part of their maturity certification strategy.

- The procurer organisation can use the drivers during a selection and evaluation process at request for proposal and invitation to tender stages of software acquisition. They can also use them to create organisational awareness of their specific needs (for example, return on investment and statutory conformance) when devising their systems strategies.
- The drivers can be used by both producer and procurer to better understand the strategic issues that impact each other when they are engaging in a software contract.
- In addition to its importance to producers and procurers of software products, the Software Quality – Strategic Driver Model *(SQ–SDM)* presented in this chapter can be used in conjunction with the Software Quality Star as an excellent model in the academic syllabus for the study of software quality.

While devised and explained in relation to software quality the foundation of the model is generic and it might be easily adapted to any specific domain in a specified context. In these domains and contexts it might be used by management to identify and manage the strategic drivers of interest to their selected domain.

3.7 Conclusion

This chapter has presented the Software Quality – Strategic Driver Model *(SQ–SDM)* and has explained the different drivers that impact the procurer and producer of software products. While some of the Strategic Drivers are already well researched, others are relatively new so this chapter presents a comprehensive set and model based on the contractual processes of ISO/IEC 12207. The set is presented as those of interest to the procurer and the producer and are:

- **Technical excellence** (Supportability)
- **User acceptance** (Acceptability)
- **Corporate alignment** (Alignability)
- **Statutory conformance** (Conformability)
- **Investment efficiency** (Affordability)
- **Competitive support** (Superiority)
- **Quality management** (Direction)
- **Development excellence** (Organisation)
- **Domain speciality** (Qualification)
- **Corporate accreditation** (Certification)
- **Competitive excellence** (Domination).

In order to narrow the scope of the thesis and because user engagement is significant to website engagibility, user acceptance (Acceptability) will be a topic of focus in Chapter 4 in order to clarify new quality factors for the World Wide Web and in Chapter 5 in order to address engagibility measurement.

That completes the producer and procurer perspectives in the producer/procurer/product triad. The product perspective as set out in the Software Quality Star in Chapter 2 was part of previous MSc research and is included as Appendix A.

Chapter 4

Additional quality factors for the World Wide Web

The aim of the chapter is to further investigate the product perspective in the producer/procurer/product triad. This chapter identifies additional quality factors for the World Wide Web.

4.1 Background

Website development needs to mature from the enthusiastic experimental practice of recent years to a more professional discipline, catering for the needs of website visitors and owner organisations. Quality is central to this maturity. In particular it is necessary to have a full understanding of the meaning of quality in the context of the ever changing Web. This chapter builds on the product perspective (Appendix A) and shows that, in addition to core and well understood quality factors, there is also a need for domain-specific quality factors for the evolving World Wide Web (WWW). The deliverable of this chapter is a set of new quality factors appropriate to the WWW, as published in *Additional Quality Factors for the World Wide Web*, (Fitzpatrick, 2000b). Content from the chapter was also published in *Interpreting quality factors for the World Wide Web*, (Fitzpatrick, 2000a) and in *Software Quality Challenges*, (Fitzpatrick, Smith & O'Shea, 2004b)

4.2 Introduction

This chapter aims to further investigate the product perspective in the producer/procurer/product triad in order to identify additional quality factors for the WWW for the benefit of website owners, specifiers, designers, developers, evaluators and the user community. It is based on literature research and on informal observations of student web users. Through a synthesis and abstraction process, the chapter identifies new quality factors for the WWW. These quality factors (visibility, intelligibility, credibility, engagibility and differentiation), together with their characteristics, are explained and presented in a new taxonomy. A second chapter deliverable is a checklist of enablers for these new quality factors. Section 4.3 presents a review of current web site developments. Section 4.4 presents a summary review of software quality factors. Section 4.5 introduces web site quality requirements and Section 4.6 reviews current research. Section 4.7 identifies the special quality requirements for websites and explains these requirements in detail. Section 4.8 prioritises and categorises the new factors and Section 4.9 considers their usage. Section 4.10 draws conclusions.

4.3 Current web site development focus

According to Bevan (1998) "*websites provide a unique opportunity for inexperienced information providers to create a new generation of difficult to use systems*". It is frequently the norm to visit a website which has been difficult to find, is poorly structured, is difficult to navigate and is difficult to read because of improper use of grammar, syntax and text colour combinations. Other sites contain spelling and punctuation errors, while the language used is often inappropriate for the target users. Some sites take so long to download that users become impatient and leave. In many instances these sites are developed by enthusiastic beginners who have gained some experience of HTML authoring. Their perception of a quality site is one that is all singing, all dancing with bells and whistles and which demonstrates the latest multimedia and animation effects. These beginners are not yet experienced in user-centred requirements for quality systems (INUSE, 1998; De Troyer, 1999). The rush to secure a presence on the WWW takes precedence over the need for quality. Very little attention is paid to usability measures like effectiveness, efficiency and satisfaction (ISO/DIS 9241-11, 1995; and update to effectiveness, productivity, safety and satisfaction by Bevan, 1999 and in ISO/IEC 9126-1, 2001). Neither is there any corporate website strategy which offers website owners a return on their investment. All too often the result is failure as described by Bevan. Consequently, the users' sense of satisfaction with the site is low and organisations that require a Web presence do not obtain a quality site. Lessons learned in relation to system quality over the past two decades need to be relearned in relation to website development.

On the Stages of Growth Model (Nolan, 1979), website development is still only at the Contagion stage and is now ready for IS professionals to progress it to the Control stage in order that it can mature and advance to the final stages of the Model. In order to do this, principles and other determinants (Gehrke & Turban, 1999) for successful website design must evolve. Among these principles will be quality requirements. This chapter starts to address these quality requirements.

4.4 Summary review of software quality factors

Software quality was first defined in the late 1970's by researches like (McCall *et al.,* 1977 and Boëhm, 1978). Their research was later complemented by International standards like IEEE (1989), ISO/IEC 9126 (1991) and ISO 9000-3 (1997). Legislation initiated by the European Community (Council Directive, 1990) has also contributed to organisational obligations in relation to software quality. More recently, Fitzpatrick & Higgins (1998) conducted a methodical analysis and synthesis of three strands that influence software quality. These strands relate to:

- Software quality (as explained by McCall *et al.*, and by Boëhm)
- Statutory obligations
- Human-computer interaction.

The three strands rely on a number of well regarded sources which include the European Council Directive on minimum safety and health requirements for work with display screen equipment (Council Directive, 1990), ISO 9241-10 (ISO, 1993) and ISO 9000-3 (ISO, 1997). These strands were analysed to produce a comprehensive set of quality factors – see Figure 4.1. All of these quality factors should be considered as part of a website development strategy. However, they were devised prior to the commercialisation of the Internet and their focus is traditional data processing and information retrieval. With the introduction of the WWW new opportunities and challenges for user and organisation are presented, so, there is a need for reconsideration and expansion.

SOFTWARE QUALITY	
PRODUCT QUALITY FACTORS	
INTERNAL	EXTERNAL
• Maintainability • Testability • Flexibility • Reusability • Portability	• Suitability • Installability • Functionality • Adaptability • Ease-of-use • Learnability • Interoperability • Reliability • Safety • Security • Correctness • Efficiency

Figure 4.1 - *Software quality factors – (Fitzpatrick & Higgins, 1998).*

4.5 Website quality requirements

In order to understand the quality requirements of a website, it is appropriate to consider the purpose of website software. From a users perspective there is a substantial range of "need-to-include" features. For example, websites need to be easy-to-find, easy-to-download and easy-to-understand. Users need to be confident with the website content and with the website owner's objectives. To support visitor engagement, websites need to be interactive and need to incorporate a range of navigational aids. From an organisational perspective, websites need to communicate an organisational image and message, to inform site visitors, to support access to information and knowledge and to support the sale of products and services through eCommerce (Bevan, 1998; Dreyfus, 1998). These objectives for website applications are different to those of traditional applications, which perform data processing and data management. Consequently, websites have different quality considerations.

4.6 Current research

Researchers are addressing these issues (Stern, 1995; Keeker, 1997; Bevan, 1998; Dreyfus, 1998; Nielsen, 1998a). The topics of research include visual appearance, access, navigation, appeal or excitement, quality content, interactivity, trust, multimedia and download speed. The various considerations are being addressed by highly respected researchers and authors. These include, Lavine & Nielsen of Sun Microsystems, Bevan of Serco, Lynch & Horton who are associated with the Yale Style Guide, Instone of Argus Associates, Trower from the Microsoft Corporation and IBM’s Web publication relating to the WWW. However, the research is generally being described under the single heading of “usability” or “ease-of-use”. An analysis of these considerations clearly illustrates the concentration on web pages and the principal focus of this concentration is page content, consistency and style. In this respect they are excellent guides for page developers but offer little guidance on quality issues to site designers. Some sponsors do address site design but closer examination reveals a concentration on page hierarchy and internal links. Consequently, not all issues that impact quality websites are yet being addressed.

The WWW Consortium (W3C, 1999) is also engaged in research initiatives relating to “accessibility for all”. The extent of the accessibility challenge becomes obvious when considering the many users that quality websites are designed for. An example of user profile description comes from the Attorney General's Department in New South Wales (Lawlink, 1999) who categorise them as people with disabilities, people lacking multimedia computer functions, people using non-current Web browsers and people from non-English speaking countries. To these must be added all those who are English-speakers, non-disabled, with full multimedia computer functions and using the latest Web browsers. W3C’s Guidelines includes a 45-item checklist each labelled ‘Required’ or ‘Recommended’. Those that are required are for “some group of users to access information on a page” and those that are recommended are to make “page[s] easier to understand and use”. So, these guidelines address ease-of-access, understandability and usability. Figure 4.2 summarises the various considerations.

Sponsor	**Considerations**		
SUN MICROSYSTEMS **RICK LAVINE** *Guide to Web style* (1995)	• Purpose • Audience • Links • Page length • Graphics	• Image maps • Navigation • Security • Quality • Netiquette	• Content • Selling • Language • Java
SUN MICROSYSTEMS **JAKOB NIELSEN** *Top ten mistakes in Web design* (1996)	• Using frames • Gratuitous use of bleeding-edge technology • Scrolling text, marquees, and constantly running animations • Complex URLs • Orphan pages	• Long scrolling pages • Lack of navigational support • Non-standard link colours • Outdated information • Overly long download times	
SUN MICROSYSTEMS **JAKOB NIELSEN** *Sun's New Web Design* (1998b)	• Increase download speed • Facilitate navigation • Provide a unified visual appearance	• Make search available from every page • Ensure high usability and a quality user experience • Replace the 1995 design	
SUN MICROSYSTEMS **JAKOB NIELSEN** *Usability Heuristics for the Web* (1998c)	• Visibility of system status • Match between system and the real world • User control and freedom • Consistency and standards • Error prevention • Recognition rather than recall	• Flexibility and efficiency of use • Aesthetic and minimalist design • Help users recognise, diagnose and recover from errors • Help and documentation	
SERCO **NIGEL BEVAN** *Usability issues in website design* (1998)	• Planning • Site Structure and Content • Support Navigation	• Page Design • Evaluation Methods • Management and Maintenance	
YALE STYLE GUIDE **LYNCH, P & HORTON, S.** *Web style guide: Basic Design Principles for Creating Web Sites* (1999)	Six principal sections • Philosophy • Interface design • Site design	• Page design • Web graphics • Web multimedia and animation	
ARGUS ASSOCIATES **KEITH INSTONE** *15 sub-topics or general issues that impact Web usability* (1999)	• Access • Animation • Value • Architecture • Content	• Graphics • Hypermedia • Intranet • Links • Multimedia	• Navigation • Searching • Speed • Users • eCommerce
MICROSOFT CORPORATION **TANDY TROWER** *The Human Factor: Guidelines for Designing Interactive HTML Documents* (1999)	• Consistency • Visual and aesthetic design • Using colour • Using fonts • Using graphics	• Using sound, video and animation • Page design • Sizing your page • Displaying update information	• Supporting downloads • Supporting printing • Designing navigation balance
IBM *The World Wide Web* (1999)	• User Analysis • Competitive and Market Analysis • Strategy • Content • Development Tools and Technology Schedule of Time and Resources	• Structure • Text • Visual Layout and Elements • Navigation Elements • Frames • Media • Preparation • Browser Compatibility	• Creating Images • Cascading Style Sheets • Final Testing • Rollout • Administration • Advertising Your Site • User Feedback

Figure 4.2 - *Considerations for Web design.*

The following section shows that it is more appropriate to group topics into domain-specific quality factors.

4.7 Website quality factors

Based on the analysis of current research as outlined in Section 4.6, It is proposed that website quality topics are now grouped together under five requirements headings:

- Communicating with websites (Visibility)
- Understanding the content (Intelligibility)
- Confidence in the content (Credibility)
- Engaging the visitor (Engagibility)
- Corporate matters (Differentation).

These five requirements headings have been formulated by the author through abstraction of knowledge from the literature review combined with experience.

This chapter discusses these requirements and proposes them as new quality factors, which are specific to the WWW. This research names them as visibility (easy-to-communicate with), intelligibility (easy-to-assimilate and interpret), credibility (level of user confidence), engagibility (extent of user experience) and differentiation (demonstration of corporate superiority) and presents them in Figure 4.3 as a Taxonomy of domain-specific quality factors for the World Wide Web.

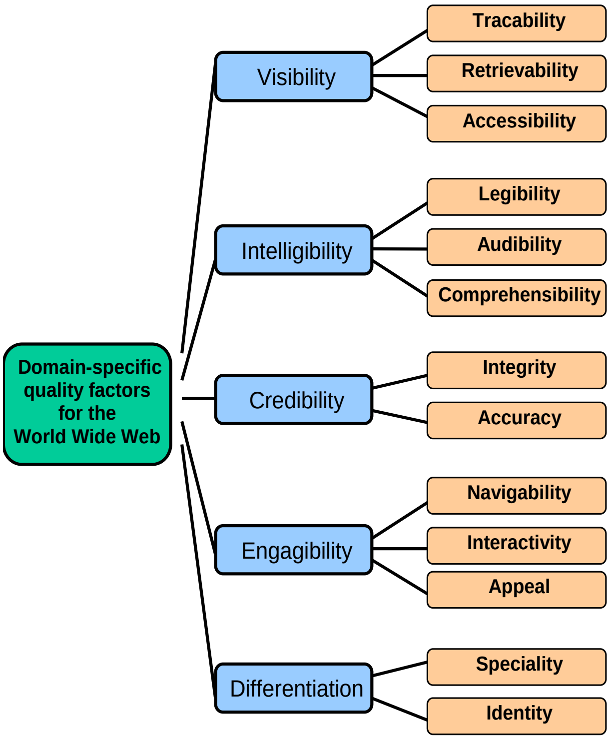


Figure 4.3 – *A proposed taxonomy of domain-specific quality factors for the World Wide Web.*

Each of the quality factors is now explained in detail. The explanation includes a rationale together with a definition for each quality factor. Also included are the characteristics of each quality factor and how it can be supported or enabled.

4.7.1 Communicating with websites (Visibility)

Websites are stored at unique locations and these locations have to be found by the visitor and by search engines. Finding a site can be time consuming and difficult to the point of frustration. The URL used to uniquely identify a site can be verbose, thereby resulting in an incorrectly typed address. Or, it can be so similar to another URL that it is mistyped and the wrong site is visited. Case-sensitive URLs are also a hindrance to users. URLs are addressed by Nielsen (1996).

There is a visitor expectation that once you are navigating the WWW all sites are contactable. All too often sites are closed or moved with no forward address.

Many site owners make extensive use of multimedia techniques. Sometimes these can be so overused that the download time for a site becomes extremely slow and visitors become impatient and move on. Download time is a significant concern for many researchers (Trower, 1999; Nielsen 1999c; Gehrke & Turban, 1999).

So, the first essential domain-specific quality factor for a website is that it must be easy-to-find, easy-to-download and easy-to-access (Webventures, 1999; Gehrke & Turban, 1999). This research names this quality factor, visibility.

Visibility is the ease with which users can visit a website and is concerned with traceability, retrievability and accessibility:

- Traceability supports potential visitors by enabling them to find and re-find a website. It is supported by a short and meaningful URL and by ensuring that servers are operational at all times. It is also supported by providing suitable feedback which indicates the new address after a site has been moved. Traceability is achieved by including appropriate key words (meta tags) or summary paragraphs in the website content in order that the site can be identified by search engines which support meta tags as well as those that don’t (Tillman, 1997).

- Retrievability addresses the download time associated with website activity. Download time has been extensively researched and is reported by Nielsen (1999) as the single-most important design consideration on the WWW. From a website quality perspective it is supported by keeping graphics, sound files and plug-ins to a minimum.

- Accessibility is the ease with which users can gain entry to the website and is supported by the welcoming philosophy of the website owner. For example, some website owners loose customers by insisting that first-time visitors complete a two or three page personal profile form before admitting them to the site. Ease-of-access may also be low if the website is password protected. The sophistication of the technology can also deny users access to a website. For example, not all browsers support frames and some users are still in text only mode (Serco, 1999; IBM, 1999).

4.7.2 Understanding the content (Intelligibility)

Many researchers are concerned with the challenge of designing Web pages to properly reflect the combination of best practice for text with best practice for multimedia (Nielsen, 1998; Bevan, 1999; Lynch & Horton, 1999; Trower, 1999). All researchers are concerned that websites should be easy-to-read and easy-to-understand (Keevil, 1999; Network Solutions, 1999). For completeness, this chapter adds that where sound is used it must be easy-to-hear and be relevant to the application. Researchers are also conscious that websites need to be presented in multiple languages and support cultural diversity. So, the second domain-specific quality factor for the WWW is that it should be easy-to-read, easy-to-hear and easy-to-understand. This research names this quality factor intelligibility.

Intelligibility is the ease with which users can assimilate and interpret the content of the website. It includes legibility, audibility and comprehensibility:

- Legibility is concerned with presentation and addresses text and colour management, screen layout management, language style and tone, spelling, grammar and punctuation (Bickerton *et al.,* 1996; Nielsen 1998a). This is best supported through an in-house standard which is used consistently.

- Audibility is concerned with the use of earcons and the appropriate use of the spoken word, sound and music.

- Comprehensibility is the manner in which all of the characteristics of intelligibility are crafted together into a framework of pages (Bevan, 1998 and IBM, 1999 consider this as part of site structure). These pages are then combined with graphics, animation and 3-dimensional effects in order to enhance the visitors understanding of the website. As part of comprehensibility, there is a need to address the user profile (skills, knowledge and personal attributes), in order to ensure that the website can be understood by as wide a population as possible. Because a website is visible to all nationalities, it is especially important to address culture, tradition and language as part of website comprehensibility.

4.7.3 Confidence in the content (Credibility)

Once a user has found a site, there is a need to trust the site owner of the site and the site content. An analogy is the option to rely on a research journal or a particular newspaper. In each instant the reader has a clear understanding of the different editorial policy. In addition, visitors to websites need to be confident that the content of the site is accurate. So, the third essential domain-specific quality factor for a website is that it must be easy-to-trust and the content must be accurate (Nielsen, 1996; Keevil, 1999). This research names this quality factor credibility.

Credibility is the level of user confidence with the website and is concerned with the integrity of the owner and the accuracy of the content:

- Integrity is the extent to which a visitor can have confidence in the owner's motivations, qualifications and trustworthiness (Nielsen 1998). Tillman (1997) describes this in terms of the "viewpoint of the site" and suggests that the bias and authority of the authors must be clear. In the same way that email messages are impacted by issues of confidentiality, integrity, authentication and non-repudiation, so too are website owners responsible for the integrity and accuracy of the content which is contained in or can be accessed from their site. They must particularly concern themselves with these issues in the context of providing links to other websites.

- Accuracy is concerned with the correctness and currency of the content presented on the website (Nielsen, 1996). Content may be provided for different categories of users (e.g., social, academic and commercial) and credibility must be addressed for each of these categories. Inaccurate content has no value to the user and content that is out-of-date has a lower value than that which is current.

Users are unlikely to return to a site with a perceived low credibility. So, in the absence of an independent accreditation system or other quality index, website credibility must be established by the owner's efforts over a period of time.

4.7.4 Engaging the visitor (Engagibility)

For those who are charged with the responsibility of implementing successful electronic commerce (eCommerce) solutions there are other significant considerations. Gehrke & Turban (1999) explain that these are customer and marketing focused. From a customer focus, having enabled visitors to find the website, organisations need a strategy to keep these customers at the site for maximum benefit. Their strategy should also include mechanisms to attract visitors back to the site. They will also be concerned to ensure that they are not funding links to sites that they have no control over and which might, in turn, link to other sites with which they compete. Nor would they wish to be legally compromised by their outbound links. The concept of containing the boundaries of websites is already with us and is a quality consideration for website owners. Some website owners believe that a one-stop-shop which caters for a user's complete eCommerce, information, communication, education and entertainment needs is providing a quality Web service. Other website owners are of the view that to ensure the fullest return for their investment, their site should not be used as a surf station. Researchers are addressing these issues under the headings of navigation, interactivity and site appeal (Nielsen, 1998b; Instone, 1999; Keeker, 1997). This research names this quality factor engagibility and is the fourth domain-specific quality factor for a website.

Engagibility is the extent to which a website can fully engage a visitor by providing a complete and comprehensive website experience. Engagibility includes navigability, interactivity and appeal:

- Navigability is the ability of website visitors to access any part of the website or to link to other websites. It is typically supported through menu structures and page hierarchy, a site Home button, keyword search facilities or through internal and outbound hyperlinks. Navigability also includes aspects of signposting which indicate which parts of the site have already been visited and what options are still available. Some website hosts provide minimal or no outbound links and navigation is totally confined within the site. Their philosophy is that, since they have a substantial investment in their website, for maximum return-on-investment they must ensure that their site is not simply a surf station. Navigability has been a core consideration since the beginning of website development and standards are beginning to be suggested. For example, Nielsen (1999) has proposed that the site Home button should always be positioned in the top left-hand corner of every page.

- Interactivity addresses the engagement of website visitors and enables them in the completion of whatever process or experience is offered by the site. For example, this interactivity might include a site registration process, data retrieval, conducting online purchases or defining user-preferred outbound links. Wilson (1996) suggests that interactivity also includes facilities for visitors to make email contact with the site owner, a user comments forum, chat rooms if appropriate and question and answer bulletin boards.

- Appeal is addressed by Keeker (1997) who suggests that it can be achieved under five headings viz. Provide relevant, high-quality content; make it easy to use; promote effectively, both on the site and in other media; make the experience unique to the medium; evoke emotion.

4.7.5 Corporate matters (Differentiation)

From a marketing focus, corporate image and product branding are important considerations for organisations. So, it is natural that organisations are concerned to know that their investments in websites have the correct corporate influence and marketing impact on visiting customers. While their corporate image is extremely important and needs to demonstrate a modern, professional and progressive image, preoccupation with button-bars, graphic decorations and animation effects is less significant. This is confirmed by Bevan (1998) who explains that a quality website needs to portray a strong organisational image or brand which demonstrates organisational superiority. This research names this quality factor, differentiation. This is the fifth quality factor for a website and is concerned with product speciality together with corporate identity:

- Speciality is associated with product (or service). Typical examples of speciality would be bookstore sites or domain name registration sites that specialise in their chosen product or service. In these examples the website owner strives to make the website, in the minds of the entire Internet community, the number one website world-wide for that product or service.

- Identity is the way an organisation wishes to position itself and its product (Kotler, 1997). According to de Villiers (1999) "*a brand identity is relatively easy to implement but the real opportunity, and also the easiest to neglect, is the ongoing process of maximizing exposure opportunities. Every pixel-byte systematically creates a positive impression and awareness to the viewer - hard to quantify, but very real in terms of a Brand's wellbeing. Ultimately this does translate into increased revenues*".

> A typical example of identity associated with corporate superiority is Microsoft's free email site at Hotmail which has a distinctive login screen instantly identifiable by almost every college student. However, as more free email sites enter the marketplace these could use a corporate logo, brand identity or symbol (a new one designed specifically for the WWW or an already dominant commercial brand) to attract and retain customers.

Differentiation is not widely addressed by current software quality researchers and authors. Bevan (1998) mentions branding, and Ginsburg & Kambil (1999) mention competitive differentiation. However, most researchers are concerned with usability and accessibility considerations. Differentiation is of more interest to strategic management whose quality measures also include return-on-investment and potential to attract visitors (website hits).

Figure 4.4 concludes this investigation of the five quality requirement headings and their associated quality factors. Each of the quality factor definitions is tabulated together with a summary of its characteristics and combined with a summary checklist of enablers for each factor. These enablers are a simple set of considerations that influence each quality factor and have been derived from the literature review.

QUALITY FACTOR	CHARACTERISTICS	ENABLERS
Visibility The ease with which a user can visit a website.	• Traceability • Retrievability • Accessibility	☐ Appropriate URL ☐ Search Engine registration ☐ Efficient hosting servers ☐ Site forwarding ☐ Meta tags ☐ Summary paragraphs ☐ Efficient multimedia usage ☐ Minimal access registration ☐ Minimal password ☐ Multiple browser support
Intelligibility The ease with which a user can assimilate and interpret website content.	• Legibility • Audibility • Comprehensibility	☐ Style standards ☐ GUI standards ☐ Effective use of sound ☐ Effective multimedia usage ☐ Culture/Tradition issues ☐ International languages ☐ Audience profile
Credibility The level of user confidence with the content of the website.	• Integrity • Accuracy	☐ Owner's identity ☐ Owner's motivations ☐ Owner's qualifications ☐ Owners trustworthiness ☐ Accurate content ☐ Current content
Engagibility The extent to which a visitor achieves a complete experience at a website.	• Navigability • Interactivity • Appeal	☐ Menu structure ☐ Home ☐ Keyword search ☐ Hyperlinks ☐ Signposting ☐ Data retrieval ☐ Online eCommerce ☐ User-defined preferences ☐ Email communication ☐ Comments forum ☐ Chat room ☐ Questions Bulletin Board ☐ Offer a Unique experience ☐ Evoke emotion
Differentiation The extent to which a website demonstrates corporate superiority.	• Speciality • Identity	☐ Dominant product/service ☐ Corporate logo ☐ Brand symbol

Figure 4.4 – *Domain-specific quality factor definitions, characteristics and enablers.*

4.8 Prioritising and categorising the new quality factors

As recommended by Ghezzi *et al.,* (1991) and Daily (1992) it is appropriate to prioritise these new quality factors. If a website cannot be found then there is little value in considering the other factors. Therefore, visibility is first in order of importance in these factors. Intelligibility is next. If you cannot comprehend the contents of the site then you will receive no benefit for having visited. Furthermore, this comprehension is necessary in order to establish whether the site content is credible or not. So, credibility is third. If users are unable to trust the sources and the content then they are unlikely to take the site seriously and are also unlikely to make return visits. Engagibility is fourth in the list. These four quality factors – visibility, intelligibility, credibility and engagibility - can be categorised under the all-embracing terms of usability or accessibility quality factors, and being user-focused are, by definition (Fitzpatrick & Higgins, 1998), external quality factors.

Differentiation is the last of the domain-specific quality factors. However, differentiation fits into a new category of quality factor as it is principally of interest to marketing and financial management. This is closer to the procurer perspective explained in Chapter 3. This is different to the traditional internal and external categorisation of quality factors as illustrated in Figure 4.1. In these categories the emphasis is on usability (external quality), which is principally of interest to the user, and on technical excellence (internal quality) which is principally of interest to IS professionals (Fitzpatrick & Higgins, 1998).

All of this is illustrated in Figure 4.5, which enhances Figure 4.1 by first incorporating additional columns in order to reflect the strategic driver considerations. The strategic drivers are shown at the higher level and the producer and procurer drivers are listed. Below these the product quality factors are shown and a third category – strategic – is added to the internal and external categories shown in Figure 4.1. The original set of factors from Figure 4.1 are categorised as Core factors which are appropriate to all software applications.

The domain-specific quality factors for the WWW are shown separately. Visibility, intelligibility, credibility and engagibility are shown as external factors and differentiation is shown as a strategic driver.

<table>
<tr><td rowspan="6"></td><td colspan="4">SOFTWARE QUALITY</td></tr>
<tr><td colspan="4">STRATEGIC DRIVERS</td></tr>
<tr><td colspan="2">PRODUCER</td><td colspan="2">PROCURER</td></tr>
<tr><td colspan="2">• Domination
• Certification
• Qualification
• Organisation
• Direction</td><td colspan="2">• Superiority
• Affordability
• Conformability
• Alignability
• Acceptability
• Supportability</td></tr>
<tr><td colspan="4">PRODUCT QUALITY FACTORS</td></tr>
<tr><td>INTERNAL</td><td colspan="2">EXTERNAL</td><td>STRATEGIC</td></tr>
<tr><td>CORE FACTORS</td><td>• Maintainability
• Testability
• Flexibility
• Reusability
• Portability</td><td colspan="2">• Suitability
• Installability
• Functionality
• Adaptability
• Ease-of-use
• Learnability
• Interoperability
• Reliability
• Safety
• Security
• Correctness
• Efficiency</td><td></td></tr>
<tr><td>DOMAIN-SPECIFIC FOR THE WWW</td><td></td><td colspan="2">• Visibility
• Intelligibility
• Credibility
• Engagibility</td><td>• Differentiation</td></tr>
</table>

Figure 4.5 - *Software quality factors including factors for the World Wide Web.*

4.9 Using the domain-specific quality factors

As organisations engage in eCommerce, they will need assurance that their investment in websites will not be wasted. So, the domain-specific quality factors identified in this chapter can be used to focus their website design and evaluation in search of high return-on-investment and site usage.

The domain-specific quality factors and their enablers (Figure 4.3 and 4.4) when combined with the Core quality factors (Figure 4.5) can be used as key components by specifiers, designers, developers, users and evaluators as essential issues which must be addressed in order to create quality websites.

In Chapter 5 these domain-specific quality factors and the Software Quality Star are combined in order to provide a sound foundation for modelling further stages of the research.

4.10 Conclusion

This chapter explains the manner in which websites are currently developed without reference to quality considerations. The chapter addresses these quality considerations and focuses on new quality factors specific to websites. Five new quality factors - visibility, intelligibility, credibility, engagibility and differentiation, are identified and presented in a taxonomy. This taxonomy includes a set of characteristics for each quality factor together with a checklist of enablers which support the development of quality websites.

These quality factors are then combined with long established core quality factors. It is appropriate for IS professionals to consider all of the quality factors shown in Figure 4.5. For example, it is appropriate to consider the impact of advertisements on efficiency. And, it is also appropriate to consider the impact of unrestricted access on suitability.

This chapter has shown that as new domains evolve and are understood there is a need to review our interpretation of quality in those new domains and where appropriate new domain-specific quality factors identified.

Future research should address software tools and techniques, which support the successful achievement of these new quality factors. For example, vendors are supplying tools which support statistical analysis of visitor activity (page hits and the paths visitors follow). As part of this research it will be necessary to establish metrics for the new quality factors addressed in this chapter. And further research should address the quality evaluation of websites.

At this point the thesis has addressed the first aim. That is:

- To identify appropriate quality factors for the domain of the WWW.

As the thesis progresses it addresses the second aim, i.e.,

- To focus on one particular website quality factor and derive metrics for benchmark comparison purposes.

Having identified additional quality factors for the WWW the research now focuses on measurement. To do this, engagibility is selected as a quality factor (to address all five is beyond the scope of this thesis) and it is fully explored in the remainder of the thesis.

Specifically, the following chapters seek to:

- clarify what items should and can be measured
- propose a metric based on these
- analyse results of a benchmark comparison.

The next chapter addresses website engagibility ratios, criteria and counts.

Chapter 5

Website engagibility ratios, criteria and counts: Theory and practice

The aim of the chapter is to focus on one quality factor - website engagibility - and to sub-divide it to its lowest level so that its design data can be collected.

5.1 Background

Website measurement is typically driven by interest in site navigation patterns, search engine optimisation and pay-per-click opportunities. These measurements are mainly of interest to marketers who are interested in attracting more visitors to the website and in improving return on investment. They are measurements that rely on the existence of the artefact, that is, the website, and Fenton (1994) describes this as assessment measurement. They are specifically statistics that assess the quality of the site in use. This research names this quality-of-use.

An alternative form of measurement relates to the quality of the design of the website product and this research names this quality-of-product. To measure quality-of-product this chapter conducts an online study of selected eCommerce websites. The results are used later in the thesis during comparison of the sites. Following that the results can be used for predictive measurement (of artefacts and trends) with a view to designing quality websites. Content from this chapter has been published in *Software Quality Revisited*, (Fitzpatrick, Smith & O'Shea, 2004a) and in *Web site engagibility: A step beyond usability*, (Fitzpatrick, Smith & O'Shea, 2005).

5.2 Introduction

The aim of this chapter is to show how the quality factors identified in Chapter 4 can be quantified. This chapter begins by defining what needs to be measured in order to quantify a website quality factor and then completing the data collection process. The scope of the research is limited to just one of the new quality factors – engagibility. However, the model for data collection devised by the research is repeatable for the remaining quality factors. Website engagibility has been selected for further study because this thesis considers it to be a step beyond the usability focus of previous MSc research, and is in keeping with the product perspective of the Software Quality Star.

The chapter adapts the conceptual models from previous chapters - 'The Software Quality Star' and the 'domain-specific quality factors for the WWW' - in order to provide a sound foundation for data collection. This introduces the concept of ratios and for each ratio criteria that must be measured. Typically these criteria are statements that begin with 'Number of …', for example 'Number of active html pages in website' or 'Number of different vertical menus in site' or 'Number of sitebound links from Home page'. Counts are collected for the engagibility quality factor of five eCommerce websites. These counts have been partially collected automatically using a commercial website measurement and analysis tool and partially collected manually by physically visiting online each page in the five study websites and performing the counts.

This chapter produces four deliverables. These are:

- A model of quality-of-product and quality-of-use perspectives of engagibility
- A taxonomy of quality-of-product and quality-of-use engagibility ratios
- A set of criteria presented in a standard dataform which can be used for documenting a set of counts
- Five documented sets of counts – one for each site in the eCommerce website study.

Section 5.3 shows how earlier research is now combined to create a conceptual model for quantifying a website quality factor. Using this model Section 5.4 identifies a set of ratios which can be quantified. Section 5.5 uses these ratios to identify the criteria or text descriptions of what will be measured and presents a dataform for recording the counts for 67 quality-of-product engagibility criteria. Section 5.6 reports the collection of counts for the eCommerce website study. Section 5.7 draws conclusions.

5.3 Research strategy

This section first develops a vocabulary and then incorporates it into a conceptual model which will underpin the research from this point forward. It begins by recalling the Software Quality Star (Chapter 2; Fitzpatrick, 2003) and the Taxonomy of domain-specific quality factors for the WWW (Chapter 4; Fitzpatrick, 2000) and continues by explaining the various elements of sub-division that are appropriate to the study of website quality. This results in a vocabulary of clear unambiguous terms for later use in the chapter. All three of these (star, taxonomy and vocabulary) are then combined to form a ‘Model of perspectives’.

5.3.1 The Software Quality Star mark II *(SQ-StarII)*

The software quality Star (Fitzpatrick, 2003) is explained in Chapter 2. This update *(SQ-StarII)* is an enhanced version of the original model. The motivation for the original Star was to illustrate the principal points of focus in ISO/IEC 12207 (1995) which relate to software life cycle processes. The *SQ-StarII* is enhanced to incorporate end-to-end perspectives together with domains like the WWW which are additional to and different from the Management Information Systems domain. The *SQ-StarII* now incorporates thinking from ISO 9126 (2001) and ISO 13407 (1999) and focuses on eight perspectives of quality in the life cycle. The eight perspectives are:

- Quality-of-procurement
- Quality-of-contract
- Quality-of-production
- Quality-of-project
- Quality-of-process

- Quality-of-product
- Quality-of-use
- Quality-of-maintenance.

The *SQ-StarII* is illustrated in Figure 5.1.

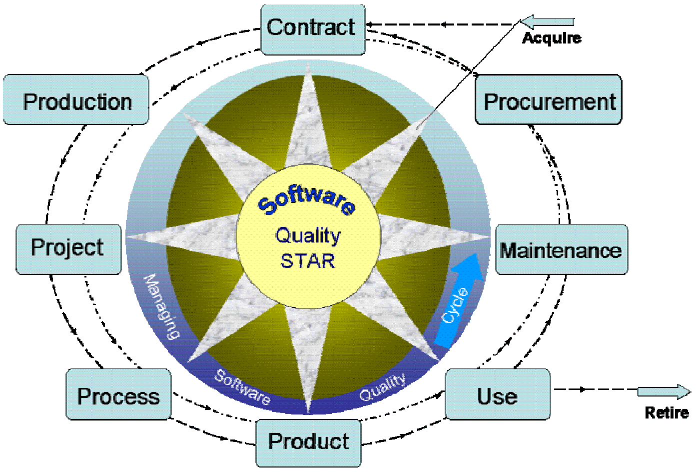


Figure 5.1 - *The Software Quality Star mark II (SQ-StarII)*

The updated model rewords the producer/procurer expressions to production/procurement to better reflect product life cycle processes and can be used as a complement to the original star which emphasised the life cycle stakeholder's perspectives. It also better reflects the use and retire sequence which occurs at a point when no further maintenance is appropriate. The application of the Star to different domains such as traditional management and business IT systems and newer domains like the WWW is indicated by the alternative dotted cyclical lines which commence at acquire and cease at retire. For further explanation of the enhanced Software Quality Star readers are referred to Fitzpatrick *et al.*, (2004a). In this chapter the *SQ-StarII* provides the foundation for quality-of-product and quality-of-use perspectives which are now the focus of the study.

5.3.2 Domain-specific quality factors for the WWW

While the Software Quality Star has been enhanced since it was first developed, the Taxonomy of domain-specific quality factors for the WWW (Chapter 4) is unchanged and is used in this section of the study in that unchanged format. The focus of this study is engagibility, so, the study combines engagibility in the taxonomy with the Software Quality Star as shown in Figure 5.2.

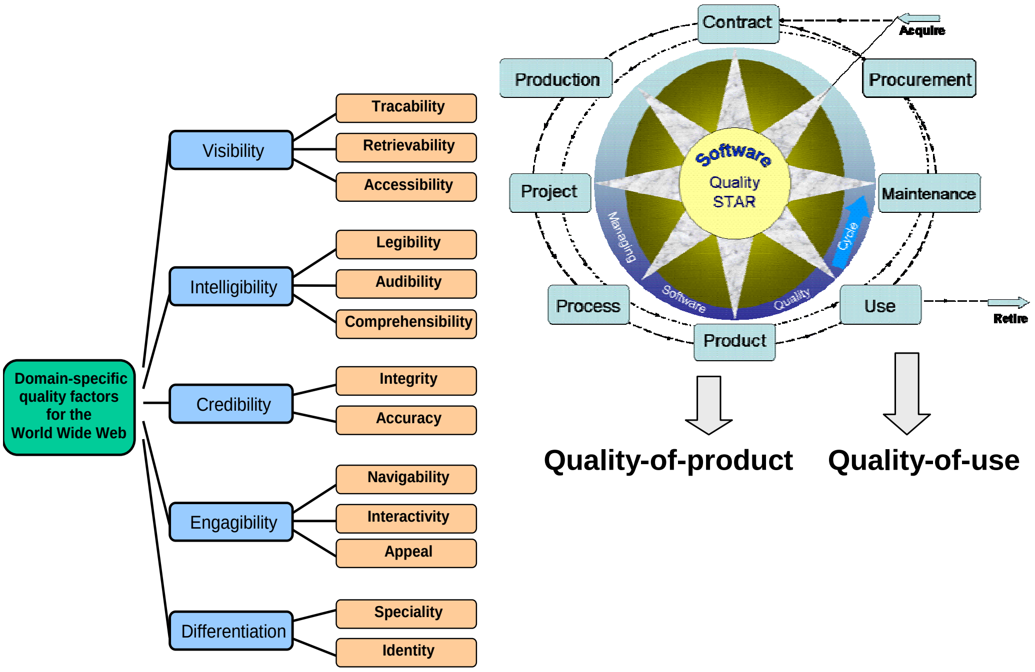


Figure 5.2 –*Taxonomy of domain-specific quality factors for the World Wide Web and the SQ-StarII combined.*

Because the study is concerned with artefacts (websites) the study is focused on quality-of-product. Conscious of the feedback philosophy of ISO 9126, quality-of-product is combined with quality-of-use such that the characteristics of engagibility (navigability, interactivity and appeal) are considered with regard to both quality-of-product and quality-of-use. However, it is first necessary to clarify the vocabulary that is used when combining them.

5.3.3 Defining a vocabulary

This section clarifies a set of terms and combines them with the two perspectives of engagibility. Named the 'Elements of website quality', the set is illustrated in Figure 5.3 which also indicates simple relations between them. The new terms used in the elements of website quality are included here to add clarity because terms currently used in the domain are often confusing. For example, the term measure is used as both a verb and a noun, which is not helpful. The term metric is defined as a number, or it can be a description or it can be "the defined measurement method and the measurement scale". The figure also shows a generic set of terms beginning with (Entity) and ending with (Value). These terms are used in the software sector; by international bodies; and by Kitchenham *et al.*, (1995) but not to the same level of detail.

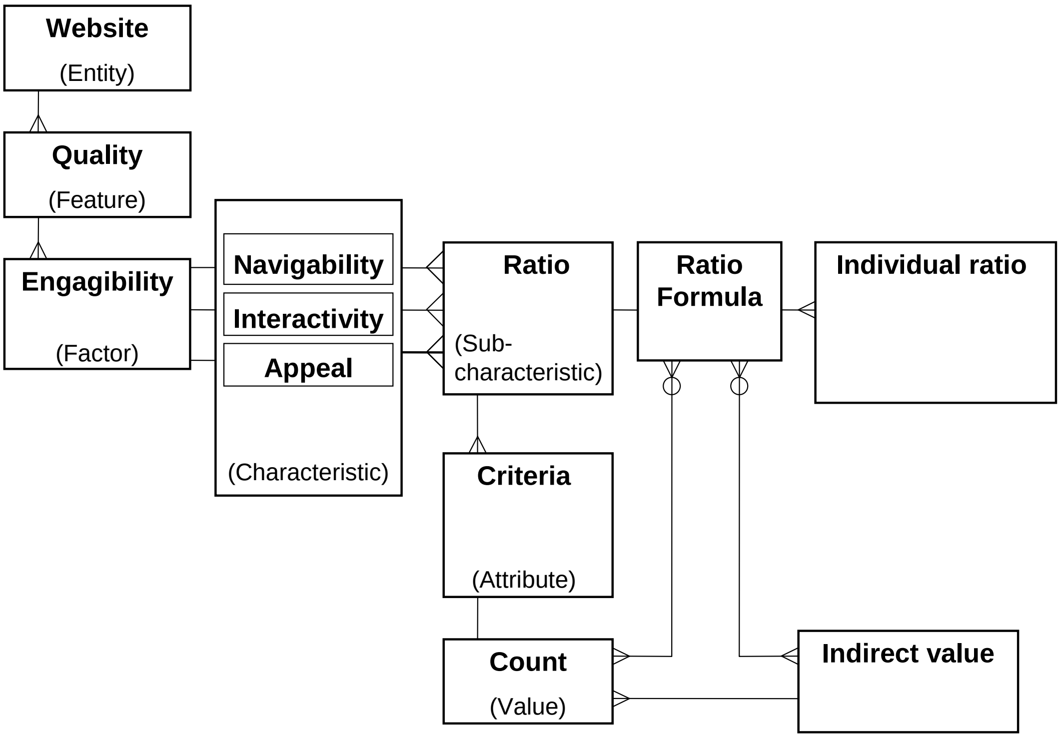


Figure 5.3 – *Elements of website quality.*

The term website is a starting point from which new research (from this study) has been published and for completeness this section briefly reminds readers of the terms (quality and engagibility and its characteristics). Also, the terms on the right of the figure – ratio, ratio formula, individual ratio, criteria, count, and indirect value are new and are defined and fully explained in this section.

5.3.3.1 Website features and factors

An entity like a website has many features. Typically these might be its classification; its strategic significance; its quality; its compliance with statutory requirements, and the one of interest in this study, which is quality. In the software sector, quality is well understood to have many factors (McCall *et al.*, 1977; Boëhm, 1978; ISO/IEC 9126, 2001) and the quality factor that this research is concerned with is website engagibility (Fitzpatrick, 2000) which is an enhancement of traditional IT usability that is suitable to the WWW.

5.3.3.2 Website engagibility – a step beyond usability

End user interaction with a system is traditionally styled usability although ISO 9126-1 (2001) uses the synonym "quality in use" (defined in terms of effectiveness, productivity and satisfaction) as the term "usability" is already used in this standard in a different sense. These considerations impact the user but while using a system the user could not significantly influence the nature of the engagement that could occur. In the main, engagement was static and limited to the functionality provided by the system. The engagement was one way – system to user – and often limited to tailoring the interface to suit the user's preference.

Successful eCommerce is different and has additional requirements. Companies who have significant investment in their websites seek to retain visitors and to keep them fully engaged in order to secure increased sales. The strategy of this engagement is two way. In addition to the system engaging with the user or visitor, the visitor might also need to engage in exchanges with the website and in some instances with other website visitors. For example, visitors might need to contribute to the content of the website. This contribution might simply be through a Bulletin Board or mailing list where user generated messages become part of the archived content of the site. Or, the engagement might be the full posting of product for sale as in the auctioneer's portal model. Another example of website visitors having a more engaging visit is their ability to configure product that they wish to purchase to suit their own requirements. Visitors are further engaged through the quality of the navigation provided by the website and by the general maturity of the eCommerce functionality. Interactivity is impacted by the nature and extent of the activities provided, and the competitive ability of the site to attract visitors also contributes to the visitor's engagement. Readers will be aware that the quality of some websites can be negatively impacted by the ability of visitors to leave and surf to competitor sites. So, the website is not simply an artefact to be sold to a purchaser, it is now a strategic sales and marketing tool with different quality requirements. In the context of the World Wide Web the term usability limits the user's experience. What needs to be addressed is engagibility, which is a step beyond usability (Fitzpatrick *et al.*, 2004b). A study of website quality in general, and specifically engagibility, dictates that measurement (methods and metrics) needs to be revisited in relation to productivity, effort and cost estimation, quality assurance and engagibility evaluation.

5.3.3.3 Navigability, Interactivity and Appeal

In order to establish a numeric value for engagibility, the research returns to the already defined characteristics as shown in Figure 5.3 (navigability, interactivity and appeal) and calculates numeric values for each of them. Later, their individual calculations will be combined to calculate the engagibility value. In order to establish values for navigability, interactivity and appeal each is first decomposed to its lowest level of sub-division at which it can be measured. There are a number of subdivisions in this decomposition and these are named collectively as ratios. Each ratio is further described by a set of clearly defined measurable text descriptors named criteria. For each criteria there is one measurement which is named a count. A calculated result for any of the ratios is styled an individual ratio and a ratio formula (explained and fully illustrated in Chapters 7, 8 and Appendix D) is used to calculate the individual ratio for each sub-division. The ratio formula uses for its values the counts from each criteria. Sometimes it might be necessary to combine counts to obtain another value or indirect value for use in the ratio formula.

This section has introduced a number of new terms – ratio, ratio formula, individual ratio, criteria and count. These are clarified in the next section.

5.3.3.4 Engagibility sub-division and measurement terms

Section 5.3.3 has introduced new terms and this section now explains them in detail.

5.3.3.4.1 Ratio

This is the first of the new terms and is a sub-characteristic of a quality factor's characteristic. In order to quantify engagibility all three of its characteristics must be quantified. For example, navigation might mean a website owner's strategy of limiting visitors to linking to their pages only and denying onward surfing. Or, it might mean hyperlinking to other websites. Consider also interactivity. For interactivity to take place a website designer must design activity into the website. This activity might be visitors communicating with the website through email; or gaming; or similar interactive process. And, appeal will have many sub-divisions like support that appeals to individual needs or to community needs and similar visitor preferences. From this it can be seen that there are a number of sub-characteristics for each characteristic and in order to quantify each characteristic its sub-characteristics must first be quantified. This research names these sub-characteristics as ratios and the research challenge is to first calculate a numeric value for each. The research defines a ratio as 'a quantifiable element of a quality characteristic'.

A ratio is significantly influenced by the perspective of quality that is being measured. This research is measuring quality-of-product, so the research seeks to identify a set of ratios that influence the design of the product. This is important because the other perspectives in the Software Quality Star are different and have their own sets of ratios. In the quality-of-product perspective the artefact might not yet exist so it is website potential that is being established while in the quality-of-use perspective it would be visitor experience that is being measured. This implies that complementary sets of ratios need to be considered – one for each perspective - and two such complementary sets are considered in the chapter.

From this it can be seen that a characteristic has many ratios and this is illustrated as a one-to-many relation in Figure 5.3.

5.3.3.4.2 Ratio Formula

The definition of a ratio – ‘a quantifiable element of a quality characteristic’ – implies that some means of quantifying the ratio is needed and this research uses a formula to calculate it. The formula is named the ratio formula and is a unique mathematical expression which calculates a value which in turn is named an individual ratio. This is illustrated in Figure 5.3.

5.3.3.4.3 Individual ratio

The calculated output from a ratio formula is an individual ratio and is defined as ‘a calculated value which quantifies a ratio’.

The relation between a ratio and a ratio formula is one-to-one and between a ratio formula and an individual ratio is one-to-many as illustrated in Figure 5.4.

5.3.3.4.4 Criteria

Criteria is the next term. This addresses the need for a set of clear statements which describe what must be measured. These statements are the criteria, and are text descriptors each of which conveys a clear, unambiguous description of a numeric value. A criteria is a text label and should not be confused with the numeric value that it describes. Each criteria describes one value (data item) only. Typical examples of these text labels are: number of sitebound hyperlinks in the entire website or number of menus in the entire website. So, the research defines a criteria/criterion as ‘a text label description of a unique data item which is used to quantify a ratio’.

To quantify a ratio a number of values will be used in the ratio formula, and it follows that a number of criteria will also be needed. That is, a ratio has many criteria and in Figure 5.3 this is shown as a one-to-many relation.

5.3.3.4.5 Count

The data for calculating an individual ratio are numbers and this is the lowest level of sub-division that the research addresses. These numbers can be direct values, for example, the number of sitebound hyperlinks in the entire website or they can be the number of menus in the entire website. These numbers can be obtained by automatic process which counts them using a measurement instrument or they can be obtained through manual counting. Alternatively, the numbers can be indirect values (explained in the next section) where two or more of these direct values are combined in an equation. Also, numbers are used to quantify a ratio (calculated by the ratio formulae) so it is important to be able to properly label these three different numbers so that there is no ambiguity in the vocabulary and it is clear what each number refers to.

The description that is used in software measurement is the term metric. Pressman (1994: p581) explains that "*a quality metric is a number*", so it is correct to describe both direct and indirect values as metrics. And, as a number is also used to quantify a calculated individual ratio it too is properly described as a metric. This can cause confusion every time the word metric is used – what should the reader understand it to refer to? And, if the definition in ISO 9126-1 (2001) is considered there will be even more confusion as it defines metrics in terms of methods and scales.

The number calculated by a ratio formula is clearly named an individual ratio and the number calculated from a set of direct values is clearly named an indirect value. To ensure similar clarity, this research names direct values as counts – they can be automatically or manually counted and the research defines a count as 'a numeric measure of a unique data item'. There is just one count for each criteria and this is illustrated in Figure 5.3 as a one-to-one relation.

5.3.3.4.6 Indirect value

Counts are the primary values that are used in the ratio formula. However, in some instances the values might be calculated from a combination of counts. For example, the study uses a value named an Activity Occurrences Product which concerns the occurrences of activities at each level in the website. Such a calculated value is termed an indirect value. Indirect values are used by some ratio formula. For completeness an Indirect value is defined as a counts-based calculated value. The relation between an indirect value and a count is one-to-many and between an indirect value and a ratio formula is optional many-to-many. These new terms are summarised in Figure 5.4.

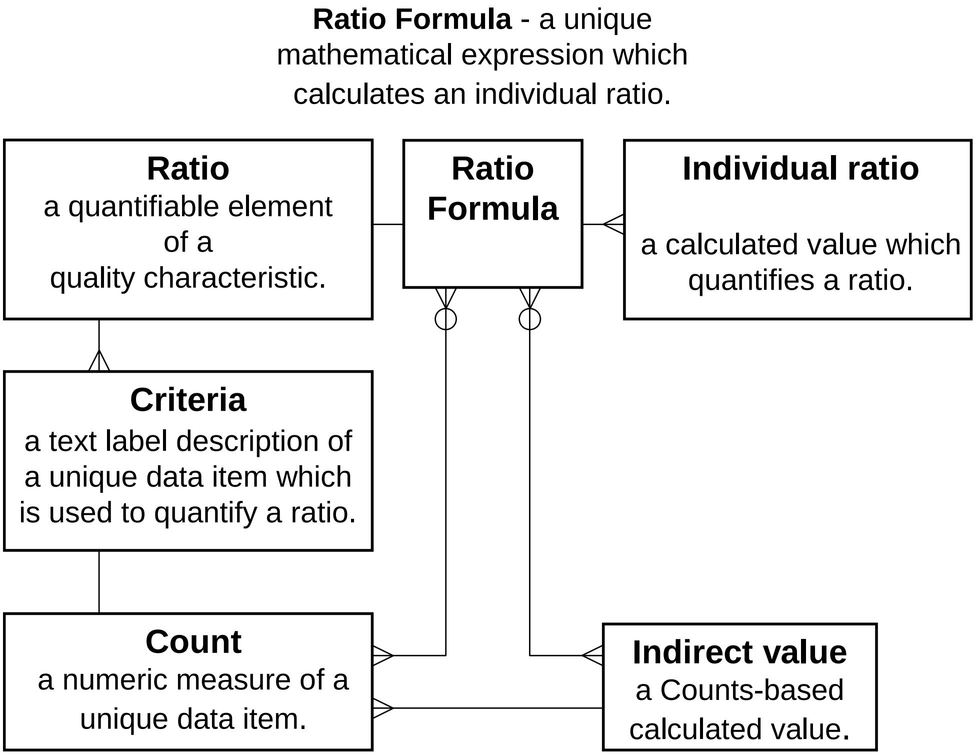


Figure 5.4 – *Definitions and relations of website quality elements.*

These terms resolve a difficulty surrounding the confusing usage of the term metric. In some instances you might read *'The metrics that need to be measured'*, where the context means *'The criteria that need to be measured'*. The context clearly means a set of text labels. In other instance it is clear that the term metric means *'number'*. However, it is clear from this research that 'number' is relevant to the counts, to indirect values; and to the calculated value of an individual ratio. So, at this stage the research avoids the word metric and instead uses well defined meaningful expressions. Use of these terms will also avoid the multiple and confusing use of the term measure as noun and verb. Later, the research will use the term metric in a more appropriate context. A composite model showing all of the vocabulary is illustrated in Figure 5.5.

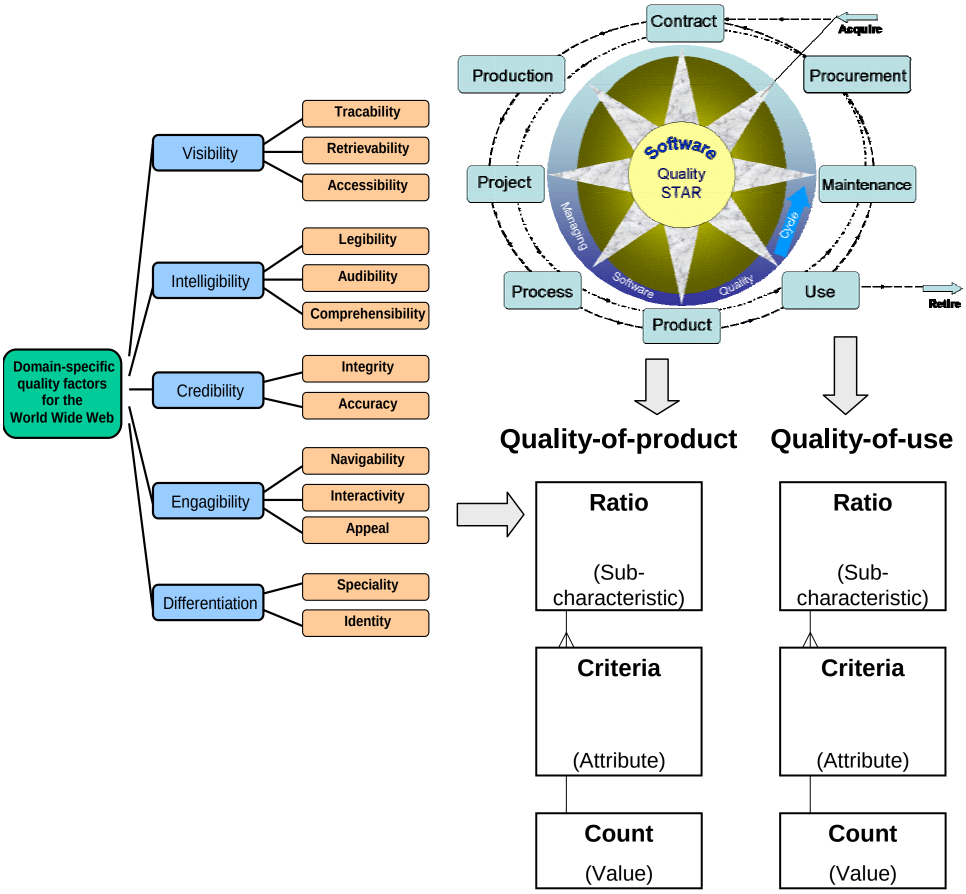


Figure 5.5 – *Model of quality-of-product and quality-of-use perspectives of engagibility*

It is necessary to identify and understand these ratios because this research considers them to be the lowest level to which a website should be decomposed before criteria can be identified and for which counts can be collected. So, as part of this section, typical criteria considerations are explained.

The theory is influenced by the philosophy that a quality product will support quality in use such that feedback from users will provide data which will enhance the product which in turn will result in enhanced use (ISO/IEC 9126, 2001). Consequently, the quality-of-product ratios need a complementary set of quality-of-use ratios, so, the research identifies two sets as illustrated in Figure 5.5.

5.3.4 Determining website engagibility ratios and criteria

The next stage in the research is to determine website engagibility ratios, and the criteria for mathematically expressing them. To do that the research first focused on three sources. These are:

- The previously-defined characteristics (navigability, interactivity and appeal) and definitions of engagibility
- The original literature review explained in Chapter 4, which partially suggests what might be measurable
- The published set of enablers shown in Chapter 4, Figure 4.4.

The process specifically concerned itself with:

- Ascertaining appropriate quantifiable elements for navigability, interactivity and appeal
- Creating complementary sets of these elements
- Defining each quantifiable element
- Naming each element.

To determine the criteria the research additionally focused on a selection of appropriate websites and through investigation and analysis extracted from them common structural components that can be counted. The objective was an attempt to prepare an exhaustive listing of these structural components. So, using abstraction and careful cross-referencing the process concerned itself with:

- Writing text labels for each countable structural component
- Understanding the impact of each component on a ratio formula.

From this the research proposes a general solution for website engagibility ratios and criteria. The solution consists of two supporting sets of engagibility ratios (one for quality-of-product and one for quality-of-use) and a dataform of clear text labels each of which is an engagibility criteria.

The following sections fully explain the ratios, the criteria, and report the collection of counts for the five sites in the eCommerce website study.

5.4 Quality-of-product and quality-of-use engagibility ratios

The theory underpinning the identification of engagibility ratios is conceptualised in Figure 5.5. This shows that quality-of-product and quality-of-use perspectives from the Software Quality Star are studied in relation to the characteristics of engagibility (navigability, interactivity and appeal) from the Taxonomy of domain-specific quality factors for the WWW. The ratio, criteria and count elements for quality-of-product and quality-of-use are represented in the figure. The complete figure illustrates the next stage in the research, that is, to determine website engagibility ratios and to collect data (counts) which are used for quantifying them. This section considers the ratios and the following sections address criteria and counts.

5.4.1 Navigability ratios

Navigability is defined in Chapter 4, Section 4.7.4 as the *ability of website visitors to access any part of the website or to link to other websites* (Fitzpatrick, 2000; Fitzpatrick, Smith & O'Shea, 2005). From this definition it consists of two ratios – 'access any part of the website' i.e., site navigation and 'link to other websites' i.e., website surfing. These two ratios are then named the Navigation ratio and the Surf ratio and are illustrated with their definitions in Figure 5.6.

Characteristic of Engagibility	**Quality-of-product ratios**	**Quality-of-use ratios**
Navigability The ability of website visitors to access any part of the website or to link to other websites.	**Navigation ratio** The degree of a website's support for sitebound hyperlinking.	**Mining ratio** The degree that website visitors locate sitebound objects.
	Surf ratio The degree of a website's support for outbound hyperlinking.	**Excursion ratio** The degree that website visitors engage in linking to external websites.

Figure 5.6 – *Corresponding quality-of-product and quality-of-use navigability ratios.*

5.4.1.1 Navigation ratio

The Navigation ratio is concerned with how the structure of the website will support movement within the website by linking to other pages in the site. Typically, it is supported by criteria like menus and the sitebound links within those menus and by sitebound links on the website pages. Links to Home, links to Top of page and a Site search facility are also criteria that support sitebound navigation. The number of pages and the levels in the site also impact navigation.

5.4.1.2 Surf ratio

The surf ratio is concerned with quantifying the website's support for exiting a website through links to external sites. This ratio too is supported by criteria like menus and the outbound links within those menus and by outbound links from the website pages to other websites. Pages and levels in the site also impact surfing.

To support these two ratios two corresponding quality-of-use ratios are also required and these are named the Mining ratio and the Excursion ratio as illustrated and defined in Figure 5.6. Both of these quality-of-use definitions are concerned with visitor usage of the sitebound and outbound hyperlinking in order to access objects within the website or link to other websites. Further research on these corresponding ratios is beyond the scope of this research.

5.4.2 Interactivity ratios

Interactivity is explained in Chapter 4, Section 4.7.4 as *the engagement of the website visitors and enables them in the completion of whatever process or experience is offered by the site*. It is a central tenet of this thesis that interactivity is different to navigability. Navigability relies on hyperlinking as explained by the Navigation and Surf ratios in Section 5.4.1. Interactivity is defined by Fitzpatrick, Smith & O'Shea (2005) as 'Support for website visitors to engage in meaningful activity during a website visit'. So, for interactivity to take place the website must contain activities which enable that interactivity. It is appropriate to note here that an ISO International standard currently at Committee Draft stage simply limits its clarification of interactivity to *manipulating data in the Web user interface* (ISO/CD 23973, 2004).

Following review and analysis the research now proposes three ratios which support interactivity. These are the Activities ratio, the Contribution ratio and the Commerce ratio and are defined in Figure 5.7.

Characteristic of Engagibility	**Quality-of-product ratios**	**Quality-of-use ratios**
Interactivity Support for website visitors to engage in meaningful activity during a website visit.	**Activities ratio** The degree that a website implements activity components.	**Interaction ratio** The degree that website visitors use the provided website activity components.
	Contribution ratio The degree that a website implements visitor contribution functionality.	**VCC ratio** (Visitor Contributed Content) The degree that website visitors use a website's visitor contribution functionality.
	Commerce ratio The degree that a website implements mature eCommerce functionality.	**Consumer Engagement ratio** The degree that website visitors engage in a website's eCommerce.

Figure 5.7 – *Corresponding quality-of-product and quality-of-use interactivity ratios.*

5.4.2.1 Activities ratio

For interaction to take place it is necessary for the website designer to provide activities in the website. So, in the quality-of-product perspective this is named the Activities ratio. Typical of the activities that might be included would be a simple 'Contact us' or a 'Survey feedback form'. Or, the criteria might be sophisticated activities like product configurators or conferencing activities.

5.4.2.2 Contribution ratio

Visitor contribution to a website's content is an important form of interactivity offered by some websites. This visitor content contribution can be created through email exchanges which are archived and become part of the site's content or it might be comprehensive property details which have been created and posted by an Auctioneer or House Agent on a 'Property for Sale' website. Support for a mailing list archive and for contributing property details are both examples of a website implementing functionality to engage visitors while they contribute website content.

5.4.2.3 Commerce ratio

Electronic Commerce is the third ratio which contributes to the interactivity of some websites and the design of an eCommerce solution can significantly impact a visitor's engagement. It is influenced by criteria like the number of fields in registration forms and purchaser or delivery forms. It is also influenced by the number of products offered for sale and by the proximity of those offers during a site visit. It can also be influenced by the number of supporting non-catalogue products that can be linked to from the site. The ease with which visitors can complete a transaction also contributes to the visitor's engagibility.

Corresponding quality-of-use ratios are required and these are named Interaction ratio, VCC ratio (Visitor Contributed Content) and Consumer Engagement ratio. Further research on these ratios is beyond the scope of this research.

5.4.3 Appeal ratios

The appeal ratios are concerned with establishing websites that appeal to visitors through some experience that is unique to the website (Keeker, 1997). These sites are concerned with providing appealing functionality which supports personal needs, community needs or some competitive/innovative functionality which appeals to visitors. The underlying motivation is to provide functionality which encourages visitors to re-visit the site. The study proposes three ratios which support these three experience needs. These are the Assistive ratio, the Community ratio and the Competitive ratio and they are illustrated and defined in Figure 5.8.

Characteristic of Engagibility	**Quality-of-product ratios**	**Quality-of-use ratios**
Appeal An experience unique to the website.	**Assistive ratio** (special needs) The degree that a website implements functionality to support the special needs of visitors.	**SNA ratio** (Special Needs Appeal) The degree that a website's special needs functionality is used.
	Community ratio The degree that a website implements functionality to support common interest visitors.	**SIA ratio** (Special Interest Appeal) The degree that a website's common interest functionality is used.
	Competitive ratio The degree that a website supports a unique visitor perspective.	**CIA ratio** (Competitive & Innovative Appeal) The degree that a website's competitive and innovative functionality is used.

Figure 5.8 – *Corresponding quality-of-product and quality-of-use appeal ratios.*

5.4.3.1 Assistive ratio

The assistive ratio is a measure of functionality which supports the special needs of a visitor. ‘Special needs’ is often associated with individuals who have a need for perhaps voice, vision and motor support. However, this ratio recognises that visitors who don’t have these special needs often have personal preferences when visiting a website. For example, myMSN which provides options for visitors to configure their own default home page. This ratio also addresses voice, vision and motor support by addressing voice enabled functionality, text and colour usage and support for touch enabled systems.

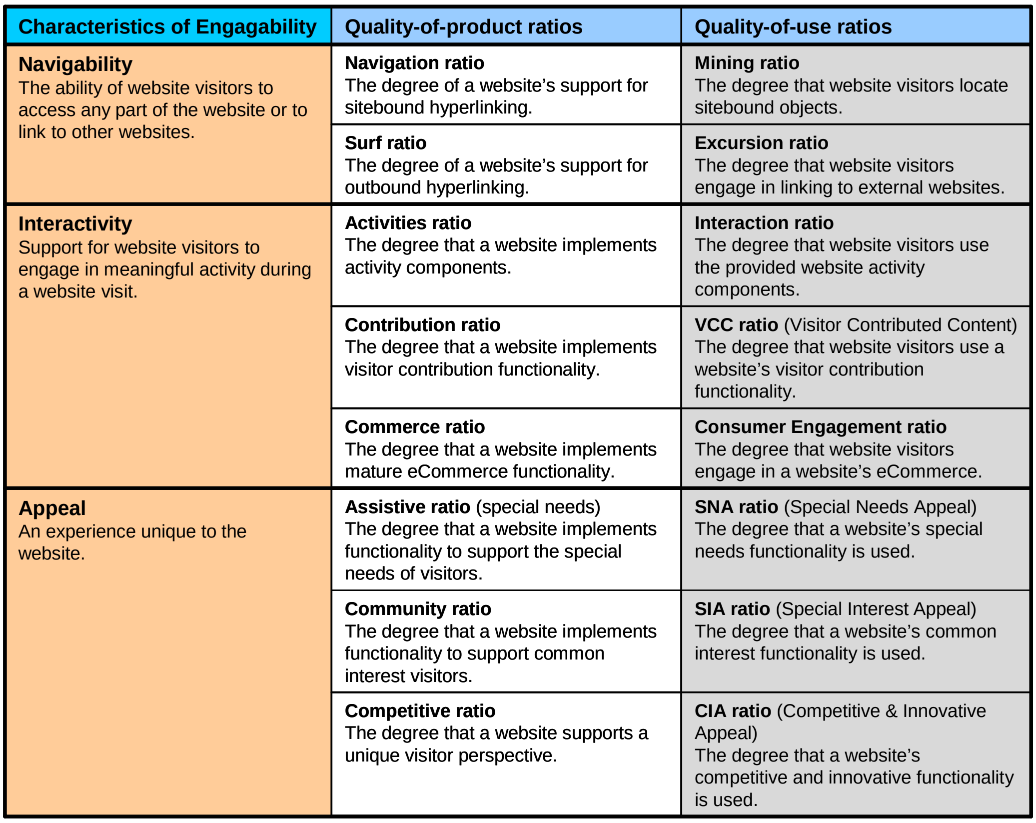
5.4.3.2 Community ratio

Website appeal is greatly influenced by a sense of belonging to a community of common interest visitors. So, the Community ratio seeks to measure the extent that common interest functionality is implemented in the website. Typical of this functionality is conferencing, an Intranet, community newsletter, and similar functionality. This sense of belonging further supports a sense of ownership, commitment, familiarity, and many similar appealing community facets.

5.4.3.3 Competitive ratio

As Internet usage develops as a tool for competitive advantage, website owners will increasingly seek opportunities to provide new competitive and innovative experiences for their visitors. Typically these might be eLearning or multi-lingual experiences, webcam and conferencing experiences. New solutions will evolve and in the main will be activities that uniquely engage visitors and consequently appeal to their preference and persuade them to return to the site again.

Corresponding quality-of-use ratios are also required and these are respectively named SNA ratio (Special Needs Appeal), SIA ratio (Special Interest Appeal) and CIA ratio (Competitive and Innovative Appeal). Further research on these corresponding ratios is beyond the scope of this research.



Characteristics of Engagability	Quality-of-product ratios	Quality-of-use ratios
Navigability The ability of website visitors to access any part of the website or to link to other websites.	**Navigation ratio** The degree of a website's support for sitebound hyperlinking.	**Mining ratio** The degree that website visitors locate sitebound objects.
	Surf ratio The degree of a website's support for outbound hyperlinking.	**Excursion ratio** The degree that website visitors engage in linking to external websites.
Interactivity Support for website visitors to engage in meaningful activity during a website visit.	**Activities ratio** The degree that a website implements activity components.	**Interaction ratio** The degree that website visitors use the provided website activity components.
	Contribution ratio The degree that a website implements visitor contribution functionality.	**VCC ratio** (Visitor Contributed Content) The degree that website visitors use a website's visitor contribution functionality.
	Commerce ratio The degree that a website implements mature eCommerce functionality.	**Consumer Engagement ratio** The degree that website visitors engage in a website's eCommerce.
Appeal An experience unique to the website.	**Assistive ratio** (special needs) The degree that a website implements functionality to support the special needs of visitors.	**SNA ratio** (Special Needs Appeal) The degree that a website's special needs functionality is used.
	Community ratio The degree that a website implements functionality to support common interest visitors.	**SIA ratio** (Special Interest Appeal) The degree that a website's common interest functionality is used.
	Competitive ratio The degree that a website supports a unique visitor perspective.	**CIA ratio** (Competitive & Innovative Appeal) The degree that a website's competitive and innovative functionality is used.

Figure 5.9 - *Taxonomy of quality-of-product and quality-of-use engagibility ratios* (Fitzpatrick, Smith & O'Shea, 2005)

The two final sets of ratios and their definitions are set out in a taxonomy of quality-of-product and quality-of-use engagibility ratios as shown in Figure 5.9.

The study recognizes that these sets will continue to evolve as knowledge and understanding of website measurement develops. This approach is accommodated when creating the ratio formula later in this study.

That ends the description and definition of the engagibility ratios. The chapter next identifies the criteria associated with the eight quality-of-product ratios.

5.5 Criteria for determining quality-of-product ratios

To provide a framework for identifying engagibility criteria, the research used the enablers of engagibility as identified and as explained at the end of Section 4.7 in Chapter 4 and in Fitzpatrick (2000). These were mapped to appropriate ratios in the set of quality-of-product ratios from Figure 5.9. Some of these enablers were already in the form such that composing criteria was straight forward. Others were not, and had to be further analysed in order to write suitable criteria for their measurement. By applying an understanding of website design, which has been gained from a continuing review of website development, observation of website usage, theory and practice from the domain of website quality, and commercial approaches to website measurement and metrics, further engagibility criteria were identified. This equates to the feedback philosophy of ISO 9126 (2001) in practice - quality-of-product ratio criteria being identified by reference to feedback from websites in use. During this stage the process was forever vigilant to ensure that no quality-of-use criteria were included. Also during this stage criteria that are common to more than one ratio were identified. Typical of these are Number of levels below Home page and Total occurrences of horizontal menus in site. Using this approach 57 criteria were identified and used in a pilot study of four academic websites belonging to staff at the School of Computing at DIT. Because of the nature of these sites the Contribution ratio, the Commerce ratio and the Competitive ratio were inappropriate to the pilot study. Consequently the pilot was focused on the Navigation ratio, the Surf ratio and the Activities ratio. At this time the counts related to approximately 25 criteria which were manually counted. The fact that these sites contained low numbers of HTML pages was a significant contributor to the success of this pilot study. Even within these constraints, this pilot study helped to confirm many of the criteria and also identified a need for better wording of the criteria – ambiguity was removed. Later when an automatic tool became available and using the improved wording the pilot study was extended to nine academic sites. This provided excellent experience with using the automatic tool and interpreting its reports. It also provided excellent understanding for an analysis of what the tool was measuring. This preliminary study ceased at this time. The study demonstrated that the planned, and more sophisticated, eCommerce website study was viable. These nine academic sites were also limited by the lack of any eCommerce functionality, so, the study turned to reviewing selected commercial sites. During this process the criteria first increased from 57 to 62 and later to 67.

During this investigation and review process a uniformity of website design substantiated earlier understanding of website menu usage. Typically, websites were structured using vertical and horizontal menus. The final 67 criteria are presented in a dataform which sets out a generic process for collecting and documenting website quality-of-product engagibility counts – see Figure 5.10.

Website quality-of-product engagibility criteria and counts

Classification

Website name ______________________________ ____________________

URL ____ **Date** _______________

Thank you in advance for taking the time to measure this set of criteria. Please return the completed sheets to:

Ronan Fitzpatrick
School of Computing
Dublin Institute of Technology
Kevin Street, Dublin 8, Ireland.
Tel: +353 1 4024835
Email: Ronan.Fitzpatrick@comp.dit.ie

How can I contact you?

Name
Address

Tel: ________________________________
Email:________________________________

	Criteria	Counts
Common criteria	1. Size of active website in KB. (html pages + images + other objects)	Semi-Automatic
	2. Number of active html pages in website	Automatic
	3. Number of levels below Home page	Semi-Automatic
	4. Number of html pages at level 0 (Home page)	Semi-Automatic
	5. Number of html pages at level 1	Semi-Automatic
	6. Number of html pages at level 2	Semi-Automatic
	7. Number of html pages at level 3	Semi-Automatic
	8. Number of html pages at level 4	Semi-Automatic
	9. Number of html pages at and below level 5.	Semi-Automatic
	10. Number of different horizontal menus in site	Manual
	11. Total occurrences of horizontal menus in site	Manual
	12. Number of different vertical menus in site	Manual
	13. Total occurrence of vertical menus in site	Manual
	14. Total scanned Web objects in active site	Automatic
Navigation ratio criteria	15. Number of sitebound links from Home page (including those in menus and links to Home)	Manual
	16. Total occurrences of sitebound links in website	Manual
	17. Number of pages containing sitebound links	Manual
	18. Total occurrences of sitebound links in horizontal menus	Manual
	19. Total occurrences of sitebound links in vertical menus	Manual
	20. Total occurrences of links to Home	Manual
	21. Total occurrences of links to Top	Manual
	22. Number of pages supporting site search engine	Manual
Surf ratio criteria	23. Number of outbound links from Home page (including those in menus)	Manual
	24. Total occurrences of outbound links in website	Manual
	25. Number of pages containing outbound links	Manual
	26. Total occurrences of outbound links in horizontal menus	Manual
	27. Total occurrences of outbound links in vertical menus	Manual

Activities ratio criteria	28. Number of core activity components (max. ten from the list of ten preferred activity components) - Contact us ☐, survey/feedback form ☐, mailing list/discussion forum ☐, site search ☐, bulletin board ☐, chat line ☐, newsletter ☐, e-mail this page ☐, archive retrieval ☐, site map ☐.	Manual
Contribution ratio criteria	29. Number of content contribution activity components (max five from the list of contribution activity components) – eg, Visitor Content management ☐, mailing list/Discussion forum ☐, other 1 ☐, other 2 ☐, other 3 ☐.	Manual
	30. Number of fields in site membership Registration Form	Manual
	31. Number of clicks from Home page to Registration Form	Manual
Commerce ratio criteria	32. Number of fields in first-time buyer's Registration Form	Manual
	33. Number of *Add to Basket* offers on Home page	Manual
	34. Number of clicks from product offer to Basket	Manual
	35. Number of clicks from Basket to Checkout Form	Manual
	36. Number of pages containing *Add to Basket* offers	Manual
	37. Number of *Add to Basket* offers in site	Manual
	38. Occurrences of links to supporting, non-catalogue products	Manual
	39. Number of pages containing supporting products	Manual
	40. Level below Home page containing first *Add to Basket* offers	Manual
	41. Level below Home page containing first link to supporting products	Manual
Assistive ratio criteria	42. Number of voice enabled html pages in website	Manual
	43. Number of voice enabled hyperlinks in website	Manual
	44. Number of voice enabled activity components in website	Manual
	45. Number of embedded images in website	Automatic
	46. Number of embedded images with alt tags	Automatic
	47. Number of background colours on Home page	Manual
	48. Number of text colours on Home page	Manual
	49. Number of font sizes on Home page	Manual
	50. Number of fonts on Home page	Manual
	51. Number of touch enabled html pages in website	Manual
	52. Number of touch enabled hyperlinks in website	Manual
	53. Number of touch enabled activity components in website	Manual
Community ratio criteria	54. Number of community activity components (max. ten from the list of ten preferred activity components) – Conferencing ☐, intranet ☐, mailing list/discussion forum ☐, chat line ☐, newsletter ☐, newsgroup ☐, diary ☐, gaming/quiz ☐, survey/feedback form ☐, guestbook ☐.	Manual
Competitive ratio criteria	55. Number of competitive activity components (max five from the list of competitive activity components) – eg, eCommerce ☐, eLearning ☐, Intranet ☐, multi-lingual options ☐, other sector-specific activity ☐.	Manual
	56. Number of innovative activity components provided by website (max. five from the list of innovative activity components) – eg, Product configurator ☐, conferencing ☐, personal preference Home page configurator ☐, Web cam ☐, other sector-specific innovative activity ☐.	Manual

Common Occurrences	57. Occurrences of activity components accessed at level 0 (Home page)	Manual
	58. Occurrences of activity components accessed at level 1	Manual
	59. Occurrences of activity components accessed at level 2	Manual
	60. Occurrences of activity components accessed at level 3	Manual
	61. Occurrences of activity components accessed at level 4	Manual
	62. Occurrences of activity components accessed at and below level 5	Manual
	63. Total occurrences of core activity components	Manual
	64. Total occurrences of the competitive activity components	Manual
	65. Total occurrences of community activity components	Manual
	66. Total occurrences of innovative activity components	Manual
	67. Total occurrences of contribution activity components	Manual
	68.	
	69.	
	70.	
	71.	
	72.	
	73.	
	74.	
	75.	

Figure 5.10 – *Website quality-of-product engagibility criteria*

In general, the content of the form is self explanatory although some of the content and how it is presented needs explanation. Criteria that are common to some of the ratios are grouped under a common heading at the beginning of the form. These are criteria 1 to 14 inclusive. For convenience, the remainder of the criteria are grouped with an appropriate ratio. For example, the Assistive ratio criteria are grouped at 42 to 53 inclusive. To support evaluators who might wish to add additional criteria, blank lines are provided at the end of the form. It is also appropriate to clarify the different meaning of the terms 'Number of' and 'Occurrences of'. Consider, for example, criteria 10 and 11 and that a website being studied consistently uses a horizontal menu at the head of every page and consistently uses a second horizontal menu at the foot of every page. In this case, Criteria 10 – Number of different horizontal menus in site - is 2. Now, if that website has say 100 HTML pages and 84 of those have the 2 menus (1 header and 1 footer) and the remaining pages have no menus then, criteria 11 – Total occurrences of horizontal menus in site – is 2 x 84 = 168. In criteria 28, 29 and 54 to 56 each activity that is included in the website is referred to as an 'activity component' and for the purposes of levelling the eCommerce website study, criteria counts are restricted to a maximum number. For example, criteria 56 - Number of innovative activity components provided by website is restricted to a maximum of five innovative ‘activity components’.

The meaning of Automatic, Semi-Automatic and Manual in the right-hand column will be clarified in the next section.

5.6 Data collection for the website study

Having identified appropriate criteria for quantifying website engagibility and prepared a dataform for documenting them the research next advances to collect data from a representative set of eCommerce websites. The aim of this study is to count the criteria for five eCommerce websites. These counts will be used later in the research in order to calculate individual ratios.

The original plan was to collect data from low cost airline company sites including Ryanair.com, Aerlingus.com and Cityjet.com. This plan had to be revised as will be explained in the next section.

For the purpose of gathering the counts the study was supported by Maxamine Inc. who are the proprietors of an online website analysis tool. This tool allows evaluators to scan any online URL and generates detailed reports of the scan. This scan can be completed without reference to the website owner and relies simply on being able to identify the website home page or index. The Maxamine scan tool was particularly useful because it returns some of the quality-of-product counts that the study requires. Some of the counts are generated by the automatic process and some are generated by a semi-automatic process. For example, the reports do not return a count of the number of pages at each site level, but they do return a listing of the pages at each level. So, a simple manual count of the items in this list is the required count of pages at that level. But, the majority of the counts are manually counted by visiting every HTML page in each website in the study. In this study that is 537 pages (118+96+104+89+130).

5.6.1 Practice and evaluation

This section explains how the sites for the study were selected and issues involved in collecting the counts.

5.6.1.1 Selecting the sites

The original plan to collect data from low cost airline sites had to be reconsidered when it was discovered that Ryanair.com had 3802 pages and Aerlingus.com had 885 pages. Attempting to manually collect counts for this size of website would have been inappropriate. This resulted in a survey of popular Irish eCommerce sites in order to gain an indication of size. The results of this survey are shown in Figure 5.11.

Website	**Page count**	**Description**
http://www.ryanair.com/	3802	Low cost airline online booking site
http://www.aerlingus.ie/	885	Low cost airline online booking site
http://www.bmibaby.com/bmibaby/	117	Low cost airline online booking site
http://www.cityjet.com/	96	Low cost airline online booking site
http://www.buy4now.ie/appleby/	438	Online jewellery retailer
http://www.buy4now.ie/arnotts/	7160	Online department store
http://www.buy4now.ie/atlantic/	637	Online DIY & homecare retailer
http://www.buy4now.ie/eircom/	104	Online telecoms gift store
http://www.royal-tara.com/	89	Online fine china gift store
http://www.buy4now.ie/Sheilasflowers/	130	Online Interflora florist
http://www.woodiesdiy.ie/woodies/	205	Online DIY & homecare retailer
Flybe		Low cost airline online booking site
Eason & son		Online bookstore
Kenny’s book shop, Galway		Online bookstore
Naughton Antiquarian & Secondhand Booksellers		Online bookstore
Superquinn		Online supermarket

Figure 5.11 – *Page counts of popular Irish websites.*

Also shown at the end of Figure 5.11 are sites that the study attempted to scan using the Maxamine tool. These sites were discounted because the scans proved unsuccessful.

From these, the sites belonging to BMIbaby, Cityjet, Eircom, Royal Tara and Sheila's Flowers were chosen for further study. An influencing factor in this choice had to be the number of pages. Approximately 100 pages were considered appropriate, considering that substantial manual measurement would be involved. A second influencing factor was that the sites were mature eCommerce sites.

5.6.1.2 Collecting the counts

The term Automatic, Semi-Automatic and Manual in the right-hand column in Figure 5.10 are the methods used by the study for collecting the counts. For example, criteria 2 is a count that is automatically returned by the Maxmine tool. Criteria 1 was collected semi-automatically by combining counts returned by the Maxamine scanning tool. Criteria 3-9 (counts that are specific to website levels) were also collected semi-automatically, by manually counting the hypertext pages in a list of all pages at each level in the site as automatically returned by Maxamine's scan.

Both the automatic and semi-automatic counts were established from the scan without need to further visit the online website. Manual collection however, required a visit to the online site so that the criteria could be individually counted. This manual process availed of the list of HTML pages in the Maxamine Page Proximity Report (identified paths between HTML pages). Using this report ensured that all HTML pages in the website were identified and included in the study. In some instances (e.g., criteria 34 -37) it was not possible to rely on any automatic tool, so each process was individually measured by performing the steps in the process on-line.

None of the sites offered any content contribution functionality, so the Contribution ratio will not be quantifiable for this study. There was also difficulty with criteria 53 to 66 - Assistive ratio. Criteria 56, 57 and 66 are automatically measured by the Maxamine tool. Commercially available assistive measurement tools like Lift (2004) and Bobby Online (Bobby, 2005) and the recently developed academic tool from Melody Ivory (Ivory, 2001) do not measure the counts required by this study. So, they had to be measured manually.

This measurement was substantially completed by October 2004. Since then, the sites have been revisited and as expected there is evidence of progressive maintenance (Fitzpatrick *et al*., 2004b) which includes updating changes to them. It the counts were to be collected now the results would be different. This confirms the need for completing a benchmarking study without undue delay.

In some instances of clarification where the automatic reports generated by the Maxamine scan tool indicate conflict, the proprietor's of the tool have confirmed that this study has highlighted functionality in their product that they have now re-visited and amended.

5.6.1.3 Deliverables

The dataform of 67 website quality-of-product engagibility criteria was used to document the counts for each of the five websites in the study.

Five sets of results have been fully documented and are presented in Appendix B.

In the continuing study criteria 1 - Size of active website in KB – is not used. This is because the size of a website can be can be disproportionately influenced by the number of object, and their size, which are included in the site. Furthermore, the study of the size of these objects is more appropriate to website visibility, particularly download speed which is a function of the bandwith connection being used by a website visitor. Consequently, this criteria is not research further at this time.

5.7 Conclusion

This chapter has set out the first steps towards numerically quantifying the additional quality factors of the WWW which were identified and published as part of earlier research. The Software Quality Star and the Taxonomy of additional quality factors for the WWW have been recalled. To these models have been added the Elements of website quality and a Taxonomy of quality-of-product and quality-of-use engagibility ratios. This has enabled the scope of the website study to be clearly defined and confined to the quality-of-product perspective of engagibility.

The chapter reports the collecting of counts which partially relied on the Maxamine online automatic measurement tool and partially on manual measurement. For documenting the counts the research developed its own tool - a dataform consisting of 67 criteria. This in turn has ensured a rigor during the practice of collecting and recording the counts.

The chapter has presented an end-to-end solution (from quality factor through count to individual ratio) which clearly and without ambiguity clarifies and illustrates how data for a website measurement evaluation study should be collected. Having collected appropriate data for five eCommerce websites, using them for analysis purpose is the focus of the remaining chapters of this thesis.

The outputs of this chapter are a taxonomy of quality-of-product and quality-of-use engagibility ratios, a set of criteria presented in a standard dataform suitable for documenting a set of counts, and five complete sets of counts for the sites in the eCommerce website study.

Having completed the research a number of observations can be made.

The taxonomy of ratios (Figure 5.9) is a working set and other ratios are possible. Evaluators can use the same methodology to create and tailor sets of ratios to their specific measurement needs.

This study concerns itself with two perspectives from the Software Quality Star (quality-of-product and quality-of-use) and one quality factor from the set of additional quality factors for the WWW (engagibility). Further studies might address other perspectives and other quality factors.

Having taken the first step toward numerically quantifying the additional quality factors of the WWW, the next chapter - Chapter 6 – reviews the theory and practice of software measurement with a view to positioning website engagibility measurement in relation to website research and measurement. This provides a foundation for Chapter 7 which introduces Metric Ratio Analysis (MRA). This is a new approach to measuring a website quality factor. The approach derives formulae and using the counts from the dataform calculates individual ratios.

Chapter 6

Perspectives of software measurement

> *The aim of this chapter is to provide on overview of the history of mainstream software metrics research, discuss how researchers have developed models, methods and methodologies for deriving, promoting and validating software measurement and to position website engagibility measurement in relation to website research and measurement.*

6.1 Background

Website engagibility is introduced in this thesis as a new quality factor for the WWW that could offer competitive advantage opportunities to website owners. Having a reliable method that can be used as a predictor of this engagibility would be a valuable tool for specifiers and designers of websites. Such a predictor is part of the study of the science of software measurement and there is a substantial history and body of knowledge relating to models, methods and methodologies from this science that can influence engagibility measurement. This thesis proposes a new approach to website measurement in Chapter 7 and a procedure for validating the measurement approach in Chapter 9. This chapter provides a context and foundation for those two proposals.

6.2 Introduction

Researchers and students in any field of scientific measurement might benefit from the insight of the statement attributed to Italian scientist Galileo Galilei:

> *"Measure what is measurable, and make measurable what is not so"*.

They may also be familiar with the statement from the Belfast-born scientist William Thomson (Lord Kelvin) who states:

> *"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of science, whatever the matter may be".*
>
> (Kelvin, 1883)

Tom DeMarco in the opening statement of his book (DeMarco, 1982; p3) states:

> *"You can't control what you can't measure".*

And to encourage researchers Fenton & Pfleeger (1996; p20) advise:

> *"We must be bold in our attempts at measurement. Just because no one has measured some attribute of interest does not mean that it cannot be measured satisfactorily".*

These statements show how measurement is a significant issue for scientific researchers. This chapter address measurement, specifically software measurement. Mainstream software measurement publications (Halstead, 1972; Wolverton, 1974; McCabe, 1976; Gilb, 1976; Halstead, 1977; McCall *et al.*, 1977, Boehm, 1976; 1978; Yin & Winchester, 1978; Benyon-Tinker, 1978; Albrecht, 1979; Boehm, 1981; Henry & Kafura, 1981; deMarco, 1982; Basili & Rombach, 1987; 1988; Ince & Shepperd, 1988; Symons, 1988; Shepperd, 1990; Chidamber & Kemerer, 1991; Schneidewind, 1992; Shepperd & Ince, 1993; Churcher & Shepperd, 1995; Fenton & Pfleeger, 1996) have included measurement associated with internal software quality and specifically the derivation and validation (or lack of validation) of complexity metrics. This chapter also addresses measurement associated with external software quality including external quality relating to websites (Kirakowski & Corbett, 1988; Molich & Nielsen, 1990;

Nielsen & Molich, 1990; Nielsen & Landauer, 1993; Rengger *et al.*, 1993; Bevan & Macleod, 1994; Bevan, 1995; Ivory *et al.*, 2001; ISO 9126, 2001; Cutler & Sterne, 2003; Koyani *et al.*, 2003; Bevan, 2005).

The chapter explores how the attributes of software artefacts can be measured at any stage in the software life cycle. They can be measured for predictive, control or assessment purposes relating to complexity, cost, implementation time, quality, maintenance and similar considerations. The chapter explores important milestone publications of software measurement's history. It also discusses models, methods and methodologies that have become part of the measurement engineer's theoretical toolkit for deriving and validating software metrics.

This chapter is concerned with the scientific understanding of software measurement and its aim is to review the history, derivation and validation of software metrics and position website measurement in that domain. In order to identify the key and seminal publications a literature review begins with Halstead's publication of 1972 and uses that to identify measurement publications from the 1960s. The review also relies on acknowledged publications like Brooks (1975) whose Mythical Man-Month is an acknowledged classic publication, Shepperd & Ince (1993) who critique the domain of software metrics, Zuse (1995) who published an extensive online commentary of software measurement and metrics, and Fenton & Pfleeger (1996;p563-622) who identify a comprehensive set of seminal publications and important papers in their annotated bibliography. In addition, the chapter highlights current practice specific to website measurement. In this way the contribution being made by this research is clearly positioned, first, relative to the historical study of internal software measurement and second, relative to current external website quality research and measurement. The current state of that research is also clarified.

Section 6.3 sets out an historical overview of software measurement. Section 6.4 reviews how researchers have developed models, methods and methodologies for deriving and validating software measures. A discussion of methods that are used in the derivation of software metrics is given in Section 6.5. The challenges and approaches to the validation of software metrics are discussed in Section 6.6. Section 6.7 positions website engagibility relative to other website research and measurement. Section 6.8 presents conclusions.

6.3 Software measurement

Evidence of an interest in software measurement during the 1950s is offered by Maurice Halstead who cites Ita Rose's "Programming Productivity" (Halstead, 1975b). Halstead explains that the "*proper reference [to this paper] is lost in antiquity, [but] this information passed from one computer center manager to another during the 1950's.*" In addition, the landmark publication, the Mythical Man-Month (Brooks, 1975), cites researchers from the 1960s like Bardain (1964) who studied programming productivity time, Nanus & Farr (1964) who report cost contributors and Sackman *et al.* (1968) who compare online and offline programming performance.

6.3.1 Mainstream software measurement research

The productivity of software developers was an early interest for researchers (Brooks, 1975;p90-93), who reported studies at IMB and Bell Telephone Laboratories. The productivity measures reported are deliverable instructions and debugged instructions per man-year (IBM), and debugged words per man-year (Bell). Brooks (p93) also relates how studies in the 1960s at MIT reported "*a mean productivity of 1200 lines of debugged PL/1 statements per man year on the MULTICS [time-sharing operating] system*". Brooks emphasises the change from words to lines. Shepperd & Ince (1993;p9) state that 'lines of code' is the simplest software complexity metric, but its value is questioned.

In the early 1970s, Halstead wrote a number of technical reports at the School of Computing, Purdue University, particularly, two relating to metrics (Halstead, 1972, 1975a). In these reports he hypothesised that algorithms, considered as distillations of thought, may possess a general structure which obeys physical laws (Halstead, 1972). In 1975 he published a second technical report showing that the measurement of small algorithms yields data, which are suitable for estimating the time required to program the algorithms (Halstead, 1975a). This work is based on the number of operators and operands in a program. Later in the 1970s further publications relating to metrics appeared. A representative selection of these include publications from Wolverton (1974) whose work was concerned with software cost estimating and forecasting, and McCabe (1976) who researched program complexity and considered it in the context of nodes and arcs (paths or edges) in a directed graph representation of a computer program. Applying these graph concepts to programming McCabe derived a cyclomatic complexity measure. Gilb (1976) used a novel technique which he called bebugging to measure the number of errors in a program. He introduced intentional errors into a program and, based on the percentage of these intentional errors that testers found, he argued for an estimate of how many genuine errors testers would find.

McCall *et al.*, (1977) and Boehm (1976, 1977) introduced a 3-element Factor-Criteria-Metric concept for modelling and measuring software quality.

In 1977 Halstead (1977) published updated work from his earlier seminal papers in book format. These were followed by Yin & Winchester (1978) who devised several metrics which could be used together to identify coding- debugging- integration- and modification-problem sections of a design based on a system design chart (tree). The work of Benyon-Tinker (1979) is similar to that of Yin & Winchester.

Albrecht (1979) proposed Function Point Analysis, a decomposition approach to predicting the size of a system. This prediction system relies on the number of internal logical files, number of external interface files, number of external inputs, number of external outputs and number of external inquiries from which it calculates adjusted function points. These can be used as a predictor of development effort (Albrecht & Gaffney, 1983; Shepperd & Ince, 1993;p24), and to estimate the number of lines of code in a program (Albrecht & Gaffney, 1983; Pressman, 1994;p54). Symons (1988) developed Mark II Function Points which includes weighted counts of logical transactions. Symons explains that Mark II

Function Point method was developed as a result of questions and difficulties (that arose when teaching and applying Albrecht's method) relating to *Information Processing size* and the restriction to 14 of *The Technical Complexity Factor*.

In 1981, Barry Boehm published COCOMO (COnstructive COst MOdel), a model for estimating project cost, effort, and schedule. To reflect advances in modern software development methods and processes COCOMO has been re-designed and expanded as COCOMO II (2) and to reflect this, the original version has been re-designated COCOMO 81. The metrics of COCOMO 81 are styled Person-Months (PM), Time to Develop (TDEV) and Thousands of Delivered Source Instructions (KDSI) (Boehm, 1981; Boehm *et al.*, 1995).

Sallie Henry and Dennis Kafura focused on system design metrics in order to predict maintainability (Henry & Kafura, 1981). Their metric uses information flow (fan-in and fan-out) between program modules as an indicator of program complexity. They also suggest that a module's internal complexity might be based on module size, measured as lines of code (Shepperd & Ince, 1993;p41). Shepperd (1990) conducted an in-depth study of the information flow metric and proposed an improvement to Henry & Kafura's work. Ince & Shepperd (1988) emphasise that metrics that can be extracted from a system's design are most useful, and they lament the fact that system design metrics were being ignored.

Object-Oriented (OO) metrics have been studied by researchers like Chidamber & Kemerer (1991) who proposed a set of six metrics which they argue can be used to measure the complexity of OO programs. Li & Henry (1993), Churcher & Shepperd (1995), Hitz & Montazeri (1996), and Basili, Briand, & Melo, (1996) have all published in the area of Object-Oriented metrics.

At the time that Tom Gilb's book was published software metrics were concerned with the software product and the process by which it was produced with an overall view of increasing software quality, controlling its cost and easing its maintenance (Gilb, 1976; Curtis *et al.*, 1979; Shepperd & Ince, 1993; Fenton &

Pfleeger, 1996). DeMarco (1982;p49) describes this as *"the software system under development and the system for building it (the project)"*. Emphasis was placed on issues such as ease of implementation, the reliability of implementation and the ease of maintenance. The focus of concern for these researchers was the internal quality of the software. Since then advances in the study of the use of software has supported study of measurement relating to external quality too. Instead of focusing on internal quality, this thesis is mainly focused on usage.

6.3.2 Modern software measurement research

Researchers are also interested in how systems are used and this has given rise to the study of usability measurement. Kirakowski & Corbett (1988) researched user satisfaction and are associated with the Software Usability Measurement Inventory (SUMI) user satisfaction questionnaire. Molich & Nielsen (1990; Nielsen & Molich, 1990) concentrated on measuring usability problems in a system's user interface and devised a set of heuristics that can be used for usability measurement and later Nielsen & Landauer (1993) addressed a mathematical model for finding usability problems. Rengger *et al.* (1993) and Bevan & Macleod (1994) addressed usability measures of effectiveness, efficiency and satisfaction through the European MUSiC (Measurement of Usability in Context) project. Bevan introduced the concept of 'quality in use' and explains that quality of use is the objective and that software product quality is the means of achieving it (Bevan, 1995).

Measurement relating to the WWW has also interested researchers. Researchers of Web measurement can be classified into those who are interested in issues relating to the Web as an international network of systems and those researchers interested in the quality of websites – the focus of this thesis.

To illustrate the extent of web metrics a taxonomy devised by Dhyani, *et al.* (2002) is presented in Figure 6.1.

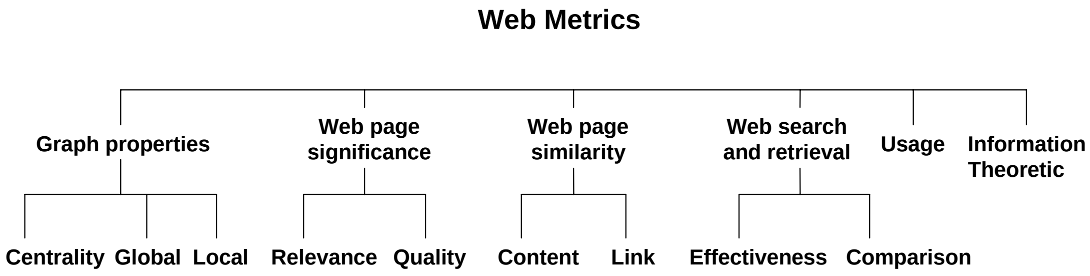


Figure 6.1 – *A taxonomy of web metrics* - Dhyani, *et al.* (2002).

The reader is referred to Dhyani, *et al.* (2002) for a comprehensive review of the taxonomy.

6.3.3 Related website measurement practice

The continued success of eCommerce has triggered a need for website measurement and aspects of measurement relating to conventional information processing systems are now being applied during website quality measurement. For example, for estimating conventional information processing systems, COCOMO (Boehn, 1981) or Function Point Analysis (Albrecht, 1979) are used; and as an evaluation tool, typically SUMI (Kirakowski & Corbett, 1988;1993); or Heuristic evaluation (Nielsen & Molich, 1990) are used. Website measurement is now following a similar estimation and evaluation approach. This study considers these estimation and evaluation functions to be quality-of-product measurement and quality-of-use measurement respectively and they equate to predictive and assessment measurement as explained by Fenton (1994).

In January 2004 the Italian Function Point User Group - Software Metrics Association (GUFPIISMA) Software Measurement Committee (SMC) published a Web Quality Model (WQM), focusing on the non-functional side of web measurement. The outcome from this model is a quality profile, as in ISO/IEC 9126 standard, against 4 characteristics (Information Contents, Usability, Security and Structureness), 18 sub-characteristics and 34 metrics (Buglione *et al.*, 2004). This approach relies on ISO/IEC, IS 9126:1991, and this early version of the standard does not address the five new quality factors for the World Wide Web (Fitzpatrick, 2000). Furthermore, ISO 9126 (2001) explains that good feedback from product use (quality-of-use) will enhance product design and that enhanced product design (quality-of-product) will improve product use. The Italian Function Point User Group - Software Metrics Association's approach makes no mention of this. The approach to measurement in this thesis is different in that it uses website quality as its domain of application. It is centered on one new website quality factor, its 3 characteristics, 8 sub-characteristics (ratios) and 67 identified criteria thereby achieving a finer granularity, all of which builds on published quality factor. The approach is also different in that it is cognoscent of the ISO feedback requirement between product design and product use. This study in this thesis concentrates at the earlier stages of a website's design and focuses on quality-of-product. It is mindful of the requirements of ISO 9126 (2001) and consequently uses existing competitor website design (feedback from product use) to help specify new requirements (enhance product design). The approach is repeatable for all five new website quality factors.

Creating websites that are accessible to disabled visitors is a significant challenge for specifiers and designers of quality websites. There are two popular website accessibility evaluation tools. These are Bobby and LIFT. Watchfire (2006) explain that their Bobby product is a web accessibility testing tool specifically designed to identify barriers to accessibility and support compliance with Section 508 of the US Rehabilitation Act and the World Wide Web Consortium (W3C) Web Content Accessibility Guidelines (WCAG). Bobby also tests for screen reader readability, the provision of text equivalents for all graphic images, animated elements, audio and video. At the current website UsableNET (2006) explain that their LIFT product is an enterprise-wide testing solution that facilitates compliance with the World Wide Web Consortium (W3C) accessibility guidelines. The focus of these two evaluation tools is very much measuring or assessing accessibility compliance.

Other website measurement approaches also exist which are relevant to this study. These include commercial solutions which are very much focused on quality-of-use, that is, they rely heavily on log file analysis and visitor traffic statistics. For example, tools from companies like Target Marketing are typical of this approach. The research involves the continuing study of eMetrics by Cutler & Sterne, (2003) and the E-Metrics summits (E-Metrics 2003; 2004; 2005, 2006) which focus on visitor statistics, and traffic analysis intelligence and mining. Of specific interest is an Online Business Intelligence website scanning software analytic tool from Maxamine Inc. which also addresses these issues but offers no separate measurement to distinguish quality-of-product from quality-of-use (Maxamine, 2004). Here again, their main focus is quality-of-use. So, all of these are focused mainly on use which comes later in the life cycle. For an extensive set of hyperlinks to web analytics tools providers, readers should visit http://www.emetrics.org/summit604/proceedings.html

Ivory *et al.*, (2001) have investigated the usability of information-centric websites with a concentration on word count, body text percentage and emphases, text positioning, link count, page size, graphics counts, colour counts and font counts. They have developed the WebTango tool which automates information-centric web site evaluation.

Web design and usability guidelines have been published by the U.S. Department of Health and Human Services Koyani *et al.*, (2003) and by the International Organisation for Standardisation’s standard ISO/DIS 9241-151 (Bevan, 2005). These guidelines provide good practice advice for developers of quality websites.

The six website measurement approaches addressed in this sub-section will be revisited in Section 6.7 in order to relate them to the website engagibility measurement focus of this thesis.

6.4 Deriving and validating software metrics - models, methods and methodology

As software measurement matured, researchers proposed models, methods and methodologies for deriving and validating software metrics and for implementing an organisational metrics programme. It also became apparent to researchers that there was a need for a scientific approach which consolidated best research practice and the application of mathematical rigor (Kitchenham *et. al.*, 1995). These are considered in this section.

Some measurement researchers acknowledge the intuitiveness of the thinking that underpins their initial work (McCabe, 1976; Nielsen & Molich, 1990; Botafogo, Rivlin & Shneiderman, 1992; Chidamber & Kemerer, 1994; Recker & Pitkow, 1996; Brewington & Cybenko, 2000). When deriving their model-based metrics methodology, Shepperd & Ince (1993;p78) state the need to rely on intuition and existing software engineering knowledge. However, intuition is not sufficient for the science of measurement and Shepperd & Ince (1993) emphasise that this has been a significant failure in software measurement. They emphasise the need to transform this informal approach to a more formal one. Although, many of the classic software measures were derived in the 1970s it was not until the late 1970s and the 1980s that models and methods appropriate to the derivation of software measures were proposed by researchers.

In their evaluation of software measurement methods, Roche, Jackson & Shepperd, (1994) present a review of models and methods that can be used when deriving software measures. Methodologies for the derivation and validation of software metrics did not appear until the 1990s (Schneidewind, 1992; Shepperd & Ince, 1993). These are now considered in more detail. Section 6.4.1 considers models and methods and Section 6.4.2 considers methodology.

6.4.1 Models and methods

The Factor-Criteria-Metric model (McCall *et al.*, 1977; Boehm, 1978) models a 3-element decomposition of software quality by defining it in terms of quality factors which are subdivided into criteria for which metrics can be derived.

The Goal/Question/Metric paradigm (G/Q/M) proposed by Basili & Rombach (1987; 1988) which is a mechanism for defining and evaluating a set of operational goals, using measurement, and in a systems context for defining and interpreting software measurement (Basili, 1992). Basili explains that the paradigm is driven by a need to know:

1. The organisational need (goal) of the measurement;
2. The purpose of the measurement, traceable to a set of questions that identify that data;
3. What data to collect, why it should be collected and how it should be interpreted.

G/Q/M represents this as a top-down approach and was devised in the context of an organisation's software measurement programme. In this context it can be used by an organisation to determine measurements that are specifically driven by the organisation's need or goal. Shepperd & Ince (1993) describe it as part of a methodology. Roche, Jackson & Shepperd, (1994) comment that the method is analogous to scientific method, i.e., establish a hypothesis, collect data, test the hypothesis and draw conclusions.

Between 1987 and 1992 models for implementing a metrics program in industry were published. These included the 10 step company-wide software metrics programme developed by Grady & Caswell (1987) at Hewlett Packard; the model devised by Pfleeger & McGowan (1990) based on Software metrics in the process maturity framework; and the ESPRIT funded cooperative project styled Application of Measurement in Industry (AMI) (Kuntzmann-Combelles *et al.*, 1992).

These represent important models and methods. There are others and for a full review of these is given by Roche, Jackson & Shepperd (1994).

6.4.2 Methodology

A formal methodology for a software metrics program was proposed by Schneidewind (1992). This methodology focuses on the statistical analysis of data and lists thresholds that should be designated for the purpose of assessing if a metric is valid. Schneidewind's six validity criteria are: association, consistency, discriminative power, tracking, predictability and repeatability. Schneidewind's work is concerned with software quality factors (his example is reliability), and particularly measurement that occurs sufficiently early in the life cycle to support quality assessment, control and prediction. He clearly defines core elements (typical examples are quality factor, quality metric, validation process) and vocabulary, in advance of explaining his six validity criteria. The influence of this work can be seen in the IEEE standard 1061 (1998). While this work is presented as a methodology, it is very focused on the statistical analysis of data during an empirical validation. The methodology is developed from the metric user perspective.

Shepperd & Ince (1993) also addressed methodology and devised an end-to-end model-based methodology for metric derivation, validation, application and evolution (Shepperd & Ince, 1993) - Figure 6.2.

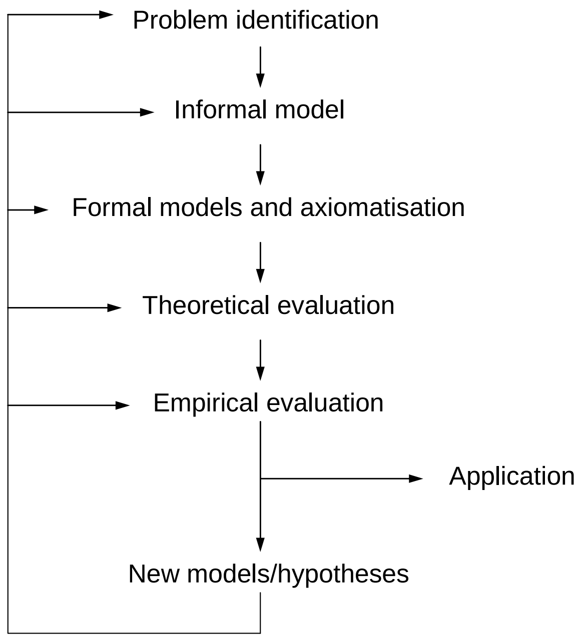


Figure 6.2 – *Stages of the metrics methodology* (Shepperd & Ince, 1993).

The Shepperd & Ince methodology was an important advance. By positioning the many models and methods in a methodology the authors have synthesised the diverse endeavours of researchers. Focusing on theoretical and empirical validation ensures a rigor appropriate to the science. The long term commitment to software metrics derivation and validation, and its iterative nature (as illustrated in the flow lines in Figure 6.2) provides long term confidence to the users of the metric. A useful addition to the illustration of the methodology (Figure 6.2) might be to incorporate a planning, organising, controlling and directing function which clarifies the role of the proposers of a metric (e.g., Boehm's Centre for Software Engineering or IFPUG). This would encourage proposers to take responsibility for managing the long term evolution of their work and demonstrate their commitment to the maturity of software measurement.

In the 1990s Fenton, Pfleeger & Kitchenham explained the need for best measurement practice and a scientific basis for software measurement. In their papers they outlined the elements of measurement and presented a generic structural model for approaching software measurement (Fenton, 1994; Kitchenham *et al*., 1995). Core to their model is the acceptance that measured objects are in the empirical (real) world and measurement is in the Formal (mathematical) world. An *entity* possesses *attributes* for which we can determine *values* (Entity-Attribute-Value). This generic structural model is used in the theory that underpins a new measurement approach proposed in Chapter 7. The authors also explained the importance of units and scale types; values and their permissible properties; the use of a measurement instrument; indirect measures and their properties; compound units (e.g., lines of code per hour, which consists of mixed base units) ; and the implications of measurement validation. These topics are also addressed as part of the new measurement approach proposed in Chapter 7.

6.5 Discussion of models for deriving metrics

A difficulty with these models is that there is no universal set of definitions for the domain of software measurement and consequently each proposer of a model presents it in a way which fits with their own individual understanding. This results in conflicting conceptual diagrams and inconsistent vocabulary. Typical of the difficulty with models like Boehm's Factor-Criteria-Metric model (Boehm, 1978), Kitchenham *et al's* Entity-Attribute-Value model (Kitchenham *et al.*, 1995), and the international standards model (IEEE standard 1061, 1998), is that they do not decompose the measurement process (from quality factor to count) to a level of detail that is appropriate to website measurement. For example, this thesis argues that a website quality factor needs to be expressed as characteristics, which can in turn be represented by a set of subcharacteristics which can then be represented by criteria for which counts can be collected. That is, five levels of decomposition – factor, characteristic, sub-characteristic, criteria and metric. Typically, Boehm's model shows three levels - factor, criteria and metric - while the IEEE standard (1998) also shows three, but different, levels named factor, sub-factor and metric.

The Goal/Question/Metric approach implies three levels also, but in a different paradigm. An organisation using the G/Q/M paradigm in relation to website engagibility might have for its goal to: Analyse a (website's design) for the purpose of (evaluation, prediction and improvement) with respect to (visitor engagibility) from the point of view of the (website owner and designer) in the context of (a set of competitor eCommerce websites).

When considering website engagibility at the question level it might be appropriate to address many questions that span multiple decomposition levels like, what characteristics should be measured? What subcharatcteristics should be measured? What criteria relate to those subcharacteristics and what counts are necessary to quantify those subcharacteristics? Then, at that stage, the subquestion might be, 'What are the appropriate formulae for calculating engagibility ratios?

A five level Goal/Subgoal/Question/Subquestion/Metric approach was proposed by Shepperd (1990). Hetzel (1993) and Bache & Neil (1995) point out that the top-down approach recommended by the Goal/Question/Metric paradigm ignores what it is feasible to measure and they suggest that a bottom-up approach might be more practical.

Models associated with software measurement continue to evolve. Typical of this is how the models in the standards from the International Organisation for Standardisation (ISO/IEC 9126, 1991; ISO/IEC 9126-1, 2001) and the Institute of Electrical and Electronics Engineers (IEEE, std 1061-1992; IEEE, std 1061-1998) have been enhanced with each update of the standard. The G/Q/M paradigm has also continued to evolve over the 12 years mentioned by Basili & Rombach (1987, 1988). This is evident from the publications of Basili & Weiss (1984) and Basili (1985; 1992). Basili & Rombach (1987; 1988) state that "*we do not claim that these templates and guidelines are complete; they will most likely change over time as our experience grows*". In the 1992 publication Basili explains that this continued evolution is part of the future directions envisioned for the paradigm. Boehm's COCOMO 81 model has also been updated to COCOMO II (Boehm, 1995) to reflect advances in the science. Function point measurement also continues to evolve (ISO/IEC 20968, 2002).

6.6 Validating software metrics

Proposers of software metrics need to validate their model and method if the user community are to have confidence in them and adopt them. This section considers the challenge of validation.

6.6.1 The challenge of validation

Commentaries in the research literature emphasise the need for rigorous validation of software metrics (Shepperd & Ince, 1993; Fenton & Pfleeger, 1996; Fenton & Neil, 1999). While the metric's proposer might have completed some validation these researchers point out that all too often when subjected to rigorous formal validation the metrics were found to be wanting, or might not have measured what the proposers originally thought. IEEE std 1061 (1998) also comments along the same lines. Sometimes the proposers eminence or their plausible logical argument was sufficient for the new measure to be accepted within the software engineering community. The 'spark of genius' dimension, which underpinned the metric's theory, seemed to be sufficient to encourage its acceptance.

The software engineering community agree that in order to be considered a mature discipline a more formal approach to metrics validation is required. Also, showing that a predictor metric is formally validated and that it does accurately predict or assess, within defined limits, some critical attribute of interest provides confidence for users of the metric.

6.6.2 Approaches to validation

Several approaches to validating software metrics are reported in the research literature (Kafura & Canning, 1985; Shepperd & Ince, 1993; Schneidewind, 1993; Ejiogu, 1993; Fenton, 1994; Shepperd, 1994; Briand *et al.*, 1995; Kitchenham *et al.*, 1995; IEEE std 1061, 1998). Ejiogu (1993) explains that the purpose of validation involves *technical vindication beyond theoretical cross-checking.*

Fenton & Pfleeger (1996;p107) recommend two aspects to a metric's validation. The first is that the metric might be a measure of some attribute in its own right and second it might be beneficial in a prediction system. Both aspects are separately valuable and both need to be validated. For example, the number of levels in a website hierarchy might be a valid measure of the depth of the website. Alternatively, the number of levels in a website hierarchy might be a valuable input to a website engagibility prediction system.

Researchers consider software metrics validation in two stages - theoretical validation and empirical validation (Shepperd & Ince, 1993; 1996; Briand *et al.*, 1998).

6.6.2.1 Theoretical validation

According to Briand *et al.,* (1998) theoretical validation *"is concerned with demonstrating that a measure is measuring the concept it is purporting to measure"*. To achieve this it is necessary to review any model that underpins the measure and determine if fully captures the decomposition (e.g., Entity-Attribute-

Metric) of what is to be measured. At this time too, vocabulary and definitions need to be confirmed to be in keeping with software engineering researchers' and practitioners' understanding. The aim is to remove any ambiguous use of vocabulary such that it is in keeping with acknowledged custom and practice. Briand *et al.,* (1998) explain that theoretical validation involves modeling intuitive understanding of the attributes we want to measure. This modeling is done in conjunction with measurement theory and will include such issues as defining axioms as formal algebraic expressions, units, scales and avoidance of discontinuities (Fenton, 1994; Kitchenham *et al.*, 1995). International Standard ISO/IEC TR 9126-4 (2004) recommends a set of desirable properties for metrics and it is appropriate during theoretical validation to address these properties to determine the measure's potential to comply with the standard.

6.6.2.2 Empirical validation

Empirical validation seeks to demonstrate that *"the measure is useful in the sense that it is related to other variables in expected ways (as defined in the theories)"* Briand *et al.,* (1998). Empirical validation is a process of comparing a model's performance with known data in a given environment in order to establish the accuracy of the prediction system (Fenton & Pfleeger, 1996:p104). They write, *"validation of prediction systems involves experimentation and hypothesis testing. Rather than being a mathematical proof, validation involves confirming or refuting the hypothesis"*. So, empirical validation involves experimentation and hypothesis testing through data gathering and statistical analysis. Fenton & Pfleeger, (1996:p125) continue that the key steps or phases of formal experimentation are: conception, design, preparation, execution, analysis, and dissemination and decision making. These criteria are important to this thesis and will be considered further in Chapter 9.

IEEE std 1061 (1998) points out that it is important that predictive metrics be validated before use in a software measurement programme. This avoids a measure being used when it has little or no relationship to the characteristic being measured. The standard recommends that six validity criteria need to be addressed using statistical methods when validating software metrics. These validity criteria are: correlation, tracking, consistency, predictability, discriminative power, and reliability. Full details of the use of these six criteria are given in the international standard and by Schneidewind (1993).

The proposer's validation of a new metric is desirable in the first instance and validation results should be available when the metric is first published. The publication of a new metric provides challenges for other researchers to independently investigate them, and the research literature reports these studies such as Kafura and Canning (1985) who combine many metrics and multiple resources and Shepperd (1990) who enhances the fan-in and fan-out work with Henry & Kafura's information flow metric. Proposers, too, need to keep their models and methods up-to-date as is the case with COCOMO II at the Centre from Software Engineering at the University of Southern California. IFPUG also keep function point measurement up-to-date.

6.6.3 Mainstream software metrics validation in practice

It is appropriate to include some examples of how the proposers of metrics have validated their work and how independent researchers have commented on this. In support of the validity of software science, Halstead argued that measurements from small published programs did not disprove his original hypothesis. This stated that "*algorithms, considered as distillations of thought, may possess a general structure which obeys physical laws*" (Halstead, 1972). Later independent studies challenged this and serious problems emerged as evidenced by Shepperd & Ince (1993;p29-36).

McCabe used several FORTRAN programs to illustrate the correlation between intuitive complexity and the graph theoretic complexity (McCabe, 1976).

As explained in Section 6.3.1 Gilb introduced deliberate errors and used the measure of the number of these deliberate errors that were found by testers as a predictor of the number of actual errors that these testers would find (Gilb, 1976).

Yin & Winchester (1978) reported that they validated their system design chart metrics in two project studies and presented correlation/regression analysis charts for both projects. They list seven guidelines for interpreting the results and emphasise the value of their metric in the context that other techniques for improving software quality rarely have quantitative validation data.

Henry & Kafura (1981) claim that their information flow metric was validated in the context of the UNIX operating system. Henry, Kafura & Harris (1981) conducted a relationship study (using the UNIX operating system) where they compared the three complexity metrics (Halstead's effort, McCabe's cyclomatic complexity measure and Henry & Kafura's information flow complexity) and concluded that all three are good indicators of the occurrence of errors; that Halstead's and McCabe's measures have a high degree of relationship; and that the information flow complexity measurement is orthogonal (independent) to the other two. Shepperd and Ince (1993) provide an extensive critique of the Henry & Kafura metric.

Shepperd (1990) comments that when conducting his work on information flow his study was based on 13 versions of the same system and each system was implemented by a team of three or four second-year BSc Computer Science students. He admits that this was unsatisfactory even though the students were working on systems that were larger than typical student-based investigations. However, he states that further empirical work corroborated the findings with the student teams.

COCOMO is based on studies at the Californian automotive and IT company, TRW (Thompson-Ramo-Wooldridge Corporation) which involved programs of 2000 to 100,000 lines of code. Extensive reports of the use of COCOMO are found in the technical literature. Through the Centre for Software Engineering at the University of Southern California COCOMO continues to evolve and its current updated version is COCOMO II.

Albrect's Function Point Analysis was developed in the context of work experience at IBM. It too continues to evolve and even though it is an acknowledged international standard (ISO 20968, 2002), there is still a disclaimer on the Netherlands Software Metrics Users Association (NESMA) website, which reads:

> *"The method has been tried in practice. However, NESMA does not claim that the method in its current form has been validated scientifically. Additional research and practical use is necessary to demonstrate the validity of the method".*
>
> (www.nesma.nl)

Function Point Analysis continues to evolve through the work of the International Function Point Users Group (IFPUG).

Both COCOMO and Function Points need to be calibrated. That is, the variables in the formulae and the subjective interpretation of the software product drivers need to be tailored to reflect user organisations' competence and expertise.

Fenton & Pfleeger (1996;p107/109) advise on how not to validate and caution about the dangers of validating by showing the new measures correlate with well know existing measures.

6.7 Relating engagibility measurement to website measurement approaches

For comparison purposes it is appropriate to compare the focus of the research presented in this thesis with the six measurement approaches that have been reviewed in Section 6.3.3. Such a comparison clarifies the different focus of research and measurement addressed by each approach. By presenting this comparison, the gaps that exist in these approaches are highlighted. Furthermore, the contribution being made by this thesis is also highlighted.

6.7.1 Review of measurement approaches

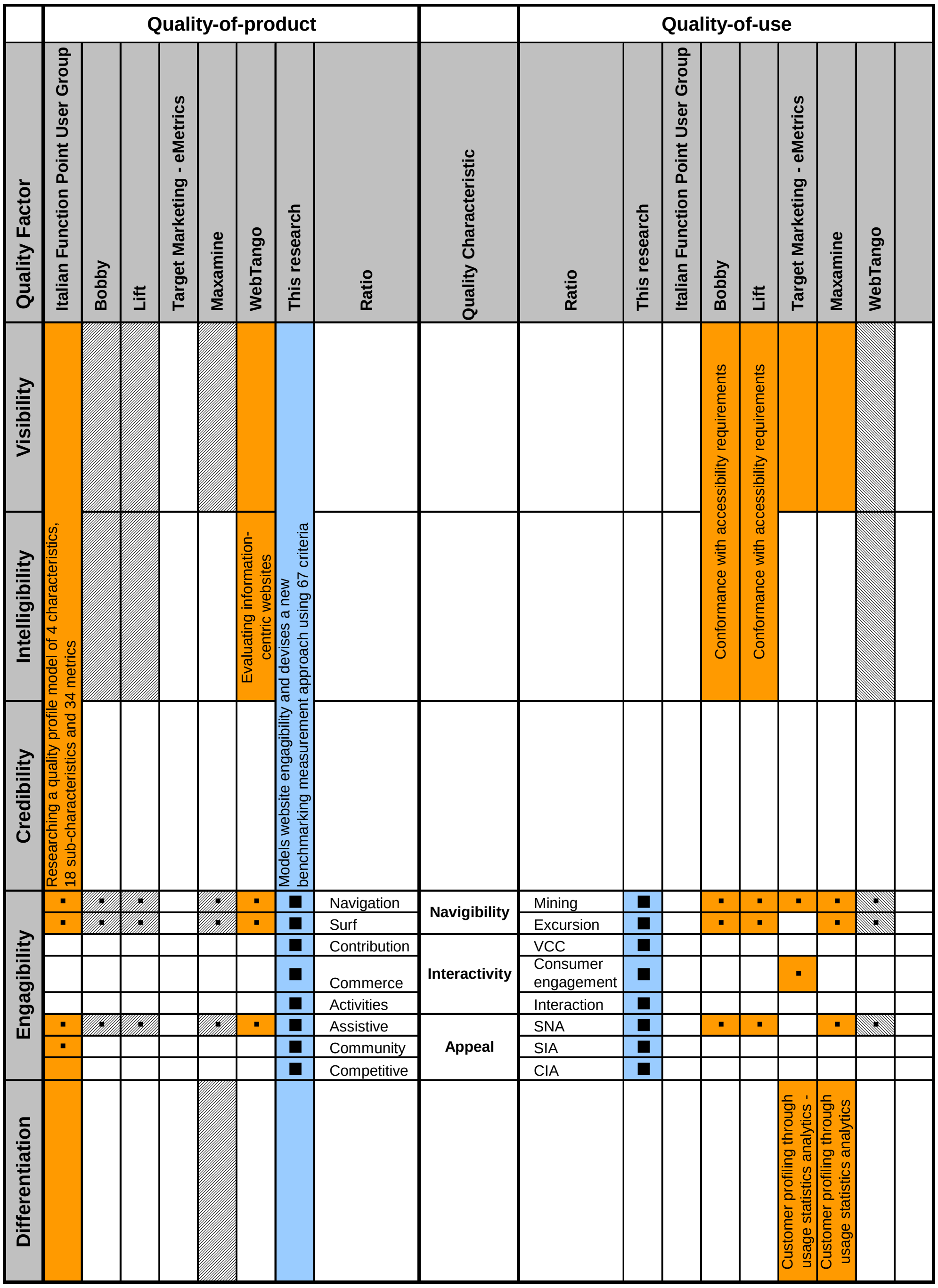
The approaches that are reviewed and compared are:

- The Italian Function Point User Group approach
- The Bobby approach
- The Lift approach
- The Target Marketing – eMetrics – approach
- The Maxamine approach
- The WebTango approach
- This research

These approaches are tabulated at the head of Figure 6.3 and for comparison, each approach is included twice – the first for quality-of-product comparison and the second for quality-of-use comparison. This research, its quality characteristics and ratios are tabulated at the centre of the figure.

The approaches are compared in the context of the five new quality factors for the World Wide Web introduced by this research in Chaper 4, Section 4.7. These are tabulated to the left of the figure forming five comparison rows headed Visibility, Intelligibility, Credibility, Engagibility and Differentiation. The engagibility ratios identified by this research in Chapter 5, Section 5.4 are tabulated in the engagibility row and named in the central columns. That is, Navigation, Surf, Contribution, Commerce, Activities, Assistive, Community and Competitive for the quality-of-product ratios and Mining, Excursion, VCC (Visitor Contributed Content), Consumer Engagement, Interaction, SNA (Special Needs Appeal), SIA (Special Interest Appeal) and CIA (Competitive and Innovative Appeal) for the quality-of-use ratios.

The figure illustrates the quality-of-product or quality-of-use preference of each approach and emphasises the significant engagibility contribution of this research.



	Quality-of-product									Quality-of-use								
Quality Factor	**Italian Function Point User Group**	**Bobby**	**Lift**	**Target Marketing - eMetrics**	**Maxamine**	**WebTango**	**This research**	**Ratio**	**Quality Characteristic**	**Ratio**	**This research**	**Italian Function Point User Group**	**Bobby**	**Lift**	**Target Marketing - eMetrics**	**Maxamine**	**WebTango**	
Visibility	🟧 Researching a quality profile model of 4 characteristics, 18 sub-characteristics and 34 metrics	▨	▨		▨	🟧 Evaluating information-centric websites	🟦 Models website engagibility and devises a new benchmarking measurement approach using 67 criteria						🟧 Conformance with accessibility requirements	🟧 Conformance with accessibility requirements	🟧	🟧	▨	
Intelligibility	🟧	▨	▨			🟧	🟦						🟧	🟧			▨	
Credibility	🟧						🟦											
Engagibility	🟧▪	▨▪	▨▪		▨▪	🟧▪	🟦■	Navigation	**Navigability**	Mining	🟦■		🟧▪	🟧▪	🟧▪	🟧▪	▨▪	
	🟧▪	▨▪	▨▪		▨▪	🟧▪	🟦■	Surf		Excursion	🟦■		🟧▪	🟧▪		🟧▪	▨▪	
							🟦■	Contribution	**Interactivity**	VCC	🟦■							
							🟦■	Commerce		Consumer engagement	🟦■				🟧▪			
							🟦■	Activities		Interaction	🟦■							
	🟧▪	▨▪	▨▪		▨▪	🟧▪	🟦■	Assistive	**Appeal**	SNA	🟦■		🟧▪	🟧▪		🟧▪	▨▪	
	🟧▪						🟦■	Community		SIA	🟦■							
	🟧						🟦■	Competitive		CIA	🟦■							
Differentiation	🟧				▨		🟦								🟧 Customer profiling through usage statistics analytics -	🟧 Customer profiling through usage statistics analytics		

🟧 = *General emphases of research interest*

🟧▪ = *Engagibility emphases of research interest*

▨ = *Corresponding Quality-of-product research interest*

▨ = *Corresponding Quality-of-use research interest*

▨▪ = *Minor Quality-of-product engagibility emphases*

🟦 = *Research domain indentified by this research*

🟦■ = *Engagibility emphases of this research*

▨▪ = *Minor Quality-of-use engagibility emphases*

Key to the focus of research of each measurement approach

Figure 6.3 – *Website measurement approaches compared.*

The figure shows that the Italian Function Point User Group’s broad approach addresses topics in all of the five quality factor comparison rows (orange shading). It has little emphasis in the engagibility row. It does not knowingly address engagibility but an analysis of its research suggests a minor interest in some of the ratios. This is indicated by the four small squares (▪) in the Italian Function Point User Group column. This approach concentrates on quality-of-product or the design stage of the website.

The Bobby approach is concerned with compliance with accessibility regulation. This is represented in Figure 6.3 in the Visibility and Intelligibility rows (orange shading). Because it is a tool for evaluating an existing website it is represented to the right of the figure in quality-of-use. Corresponding quality-of-product research interest is illustrated to the left of the figure by the uncoloured cross-hatched shading in the Bobby column. It, too, has interest in engagibility topics as is indicated by the small squares (▪) in the Bobby columns.

The Lift approach is also concerned with insuring compliance with accessibility regulation and is illustrated with the same quality-of-product and quality-of-use application and research interest.

The eMetrics approach by Target Marketing is very much concerned with gaining competitive advantage through customer profiling based on statistical analysis of site usage. It is therefore shown in the Visibility and Differentiation rows and because of its reliance on usage its research interest is shown to the right of the figure in the quality-of-use column (orange shading). Where engagibility topics are addressed by the approach, it is indicated by the squares (▪) in the Target Marketing - eMetrics column. This approach concentrates on quality-of-use of the website.

The Maxamine tool is also concerned with gaining competitive advantage through customer profiling based on statistical analysis of site usage and is shown in the Visibility and Differentiation rows. Because of its reliance on usage its research interest is shown to the right of the figure in the quality-of-use column (orange shading). Corresponding quality-of-product research interest is illustrated to the left of the figure by the uncoloured cross-hatched shading in the Visibility and Differentiation rows. Where engagibility topics are addressed by the approach, it is indicated by the squares (▪) in the Maxamine columns.

The WebTango approach is concerned with evaluating information-centric websites and its main research interest is in Intelligibility. It research also impacts Visibility and its research in engagibility is indicated by the squares (▪) in the WebTango columns. WebTango's research area of interest is shown to the left of the figure in quality-of-product and is indicated by the orange shading. Corresponding quality-of-use research is illustrated to the right of the figure by the uncoloured cross-hatched shading in the Visibility and Intelligibility rows.

6.7.2 Contribution made by this research

The research in this thesis is illustrated in the five central columns (blue shading) of Figure 6.3. It is illustrated as being aware of the issues at each comparison row in the quality-of-product column but concentrates in depth on topics in the engagibility row. The contribution is different in that:

- It concentrates on website engagibility and explains in detail eight sets of the quality-of-product engagibility ratios together with corresponding quality-of-use ratios as indicated by the blue shading. Three of these quality-of-product sets (Contribution and Activities) are specific to this research. Three others (Commerce, Community and Competitive) are addressed at a deeper level than any other measurement approach.

- It concentrates on counting website design elements with a view to addressing website measurement challenges in order to derive quality-of-use engagibility measurement formulae.
- It is underpinned by international standards and best practice.

The different approaches explained in this section measure different things in different ways. So, the comparison highlights the different areas of interest being addressed by the researchers or proposers of an approach. It specifically highlights the gaps that exist between approaches and that this approach is the only approach that concentrates on engagibility. Figure 6.3 should not be interpreted as indicating the suitability or sufficiency of any method in its area of specialism.

6.8 Conclusion

This chapter has presented an overview of the history of software measurement from the seminal publications of the early days of mainstream software measurement through object-oriented measurement to modern measurement associated with the internet and webpage development. It has discussed models, methods and methodologies that are essential to the science of software measurement and outlines how researchers have validated software metrics. The chapter also positions engagibility measurement in this domain and relates it to other website research and measurement.

The chapter shows how researchers have advocated scientific methods as being essential to the derivation and validation of software metrics. Their concerns and endeavours have been rewarded by the publication of measurement standards from the International Organisation for standardisation (ISO) and the Institute of Electrical and Electronics Engineers (IEEE)

The following chapters concentrate on an approach to measuring website engagibility and a procedure for validating that approach based on scientific method and on international standards.

Chapter 7

Metric Ratio Analysis: An approach to measuring website quality

The aim of the chapter is to devise a new approach for measuring and numerically quantifying website quality which makes use of the criteria and counts from the eCommerce website study.

7.1 Background

The need for website usability metrics and methods for measuring them was raised in *Quality Challenges in E-Commerce Web sites*, a workshop paper for Exploring the Total Customer Experience: Usability Evaluations of (B2C) E-Commerce Environments at INTERACT 2003: Ninth IFIP TC 13 International Conference on Human-Computer Interaction, September 2003, Zurich, Switzerland, (Fitzpatrick 2003a). The five website quality factors identified by this research are new so a new approach to measuring them is needed. The theory underlying the new approach proposed in this chapter recognises that some quality factor criteria will enhance the quality factor while others will hinder it. For example, the higher the number of pages that support a site search engine, the easier it is for a visitor to locate an object in the site and consequently the richer the visitor's engagement will be. Similarly, the higher the number of depths of level in the website the longer it will take a visitor to locate an object and consequently the poorer the engagement will be. Using this logic this chapter presents a new approach to measuring website quality.

7.2 Introduction

The aim of this chapter is to propose a new measurement approach which is suitable for comparing website quality factors for eCommerce websites. The approach is defined by reference to prescribed measurement theory as described in Kitchenham *et al*. (1995) and then uses concepts based on Financial Ratio

Analysis (Lev & Sunder, 1979; Salmi, & Martikainen, 1994), and similarity graph theory (Johnsonbaugh, 2004a). Kitchenham *et al*. (1995) define measurement in the real world to apply to entities and their attributes. Financial Ratio Analysis uses ratios, and similarity graph theory uses an extendable formula which relies on simple subtraction of attribute values and simple addition of the results. The approach presented in this chapter uses aspects of all three and names the new approach Metric Ratio Analysis (MRA).

The chapter defines Metric Ratio Analysis which relies on a formula that uses values derived from counts. This formula can be extended to accommodate the number of values being included. Once defined, the formula can be used to compare any set of values. The chapter delivers a step by step approach. Section 7.3 reviews the elements of measurement and Section 7.4 explains Financial Ratio Analysis. Section 7.5 explains how similarity graph theory can be used as an alternative solution. Section 7.6 considers new measurement challenges and Section 7.7 describes the new measurement approach and names it Metric Ratio Analysis (MRA). The steps followed during Metric Ratio Analysis are fully explained. Having explained MRA, Section 7.8 considers MRA as a composite metric and discusses its strengths and weaknesses, and advantages and disadvantages. Section 7.9 addresses some practical considerations. Section 7.10 draws conclusions.

7.3 The elements of Measurement

In the 1990s Fenton, Pfleeger and Kitchenham published a series of journal papers explaining the need for a scientific basis for software measurement. In these papers they outlined the elements of measurement and presented a generic structural model for approaching software measurement (Fenton, 1994; Kitchenham *et al*., 1995). This work is similar to Zuse (1993; 2004). Core to such models is the acceptance that measured objects are in the empirical (real) world and measurement is in the mathematical (formal) world. An entity possesses attributes and we might want to measure some attributes of the entity. For example, we might want to make some measurements relating to coins. These measurements might be the weight of a coin or the diameter of a coin. Or, it might be necessary to count the coins. Sometimes a measurement instrument is used for this measurement, but not always. That might be a weighing scale, a caliper, a counting machine, or they might be counted directly. The result of measurement is values which can be numerical. But 'categories' are also values for example, 'copper coin' or 'silver coin'. Numerical values can be expressed in units. The weighing scale might indicate a unit such as grams or ounces and the caliper might indicate a different unit such as centimeters or inches. Kitchenham *et al.* (1995) model this in their structural model of measurement which they illustrated in the form of an entity relationship diagram as shown in Figure 7.1 - *A structural model of measurement.*

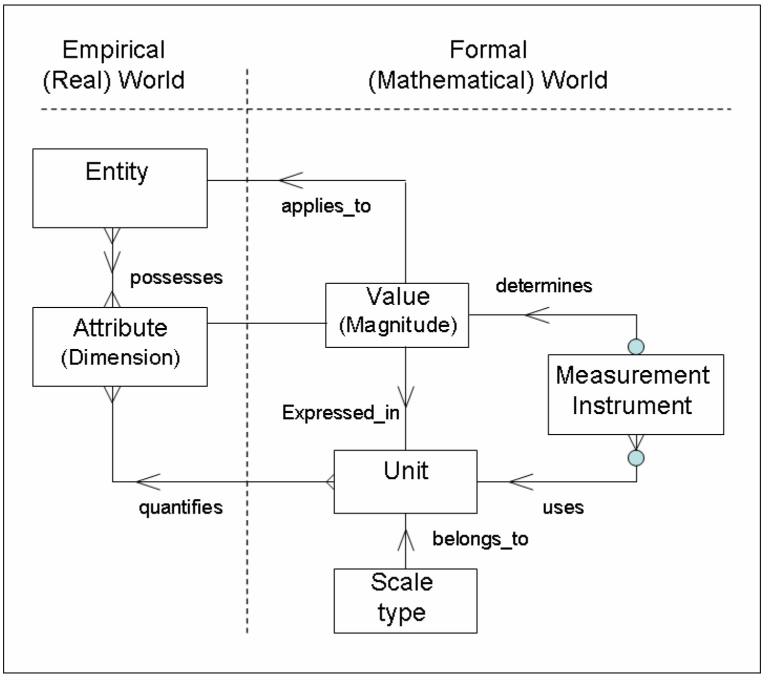


Figure 7.1 - *A structural model of measurement.*
Kitchenham, Pfleeger & Fenton (1995)

In their paper Kitchenham *et al*. expand on this model to incorporate equations, compound units and what they term 'attribute associations'.

In the example explained by Kitchenham *et al.* they show the Measurement Instrument (a thermometer) in the Formal (Mathematical) World. This seems unusual as a thermometer would be part of the real world.

Kitchenham's model is appropriate to the domain of software and is the foundation of the Elements of website quality as illustrated in Chapter 5, Figure 5.3. The vocabulary used in Kitchenham's model and the model itself will be expanded later in this chapter to illustrate the new Metric Ratio Analysis approach. The value of a benchmarking target for comparison purposes will also be introduced.

7.4 Financial Ratio Analysis

The approach used in this chapter is influenced by Financial Ratio Analysis (FRA) which is a well established practice among the banking community for measuring the financial health of a business. The ratios are simple mathematical comparisons of two or more entries from a company's financial statements. Companies return 'pieces of information' about the business performance in their annual Company Statements and by combining these 'pieces of information' in ratio format the ratio provides added value. These can be used by investors and lenders in advance of setting up a company for the purpose of determining the potential company success (Roberts, 1979; Lev & Sunder, 1979). Or, they can be used by company owners and managers to rate its performance against its competitors, in order to uncover trends and potential problem areas thereby providing pointers towards future success. In a systems context these types of measurement are termed predictive measurement, and assessment measurement (Fenton, 1994). The ratios are grouped into categories. While there are many different ratios in these categories two typical examples are Gross Profit Margin which analyses return on sales and capital employed and Current ratio, which outlines a company's short term solvency. These are represented as:

1. Gross Profit Margin = $\frac{(Gross\_profit)}{(Total\_sales)}$

2. Current ratio = $\frac{(Current\_assets)}{(Current\_liabilities)}$

As detached pieces of information these are of no great value. However, when interpreted in comparison with competitor’s ratios they can provide a picture of a company’s financial health.

For a critical review of the theoretical and empirical basis of four central areas of financial ratio analysis the reader is referred to Roberts (1979) and Lev & Sunder (1979). The approach to website measurement presented in this chapter adopts the term ‘Ratio Analysis’ and borrows from the concept of FRA.

7.5 Similarity graphs

Similarity graphs provide a solution for determining how similar two objects might be by examining ‘like’ properties. In correspondence with the author, Professor Richard Johnsonbaugh (2004b) explains that:

> *“this is a [loose] modification of Kruskal's algorithm and more generally, this technique belongs to "clustering" as used in pattern recognition and statistics. There, it's also known as the "single-linkage algorithm," "minimum method," and "nearest neighbor method.”*

The concept of nearest neighbour is very similar to the motivating philosophy of website comparison and the concept of clustering can be visioned in the grouping of similar websites to reflect business sectors. For example, healthcare websites or news station websites might reasonably be clustered as information dispensing sites. Or, all retail websites might reasonably be clustered as eCommerce sites. For these reasons it is appropriate to include graph theory in the study of website comparison alongside Metric Ratio Analysis.

Using computer programs as an example of the object, and program lines, return statements and function calls as properties, Professor Johnsonbaugh explains the construction of a similarity graph *S* as follows:

The vertices correspond to the programs. A vertex is denoted by (p_1, p_2, p_3) where p_i is the value of property i. A dissimilarity function *s* is defined as follows. For each pair of vertices [*v* and *w*] $v = (p_1, p_2, p_3)$ and $w = (q_1, q_2, p_3)$ we set

$$s(v, w) = |p_1-q_1| + |p_2-q_2| + |p_3-q_3|$$

It is appropriate at this point to emphasise that this formula is extended depending on the number of properties that are being considered, i.e., for each pair of vertices [*v* and *w*], *p* and *q* can be extended to p_n and q_n such that, $v = (p_1, p_2, p_3 \dots p_n)$ and $w = (q_1, q_2, q_3 \dots q_n)$

Table 7.1 shows Johnsonbaugh's set of values for five computer programs and Table 7.2 sets out a worked example by Johnsonbaugh.

Table 7.1 – *Program Values*

	Program Values				
	Program 1.	Program 2.	Program 3.	Program 4.	Program 5.
	v_1	v_2	v_3	v_4	v_5
Program Lines (PL)	66	41	68	90	75
Return Statements (RS)	20	10	5	34	12
Function Calls (FC)	1	2	8	5	14

Table 7.2 - *Program similarity (s)*

$s(v, w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3|$

$s(v_1, v_2)$ 36			
$s(v_1, v_3)$ 24	$s(v_2, v_3)$ 38		
$s(v_1, v_4)$ 42	$s(v_2, v_4)$ 76	$s(v_3, v_4)$ 54	
$s(v_1, v_5)$ 30	$s(v_2, v_5)$ 48	$s(v_{3,} v_5)$ 20	$s(v_4, v_5)$ 46

A low value indicates similarity.

In Johnsonbaugh's example the programs are labelled **program 1** through **program 5** as shown in Table 7.1. Also in Table 7.1 they are represented by v_1 through v_5 in order to easily reference them in Table 7.2.

If v and w are vertices corresponding to two programs, $s(v, w)$ is a measure of how dissimilar the programs are. A large value of $s(v, w)$ indicates dissimilarity and a small value indicates similarity. In this study similarity is the preferred expression.

Graph theory represents these similarity values as a graph. Johnsonbaugh explains that:

> *"For a fixed number S, we insert an edge between vertices v and w if s(v, w) < S. In gerneral there will be different similarity graphs for different values of S.*
>
> *If v = w or there is a path from v to w they are described as being in the same class. Johnsonbaugh chooses a value of S = 25 and Figure 7.2 shows a graph corresponding to the programs in Table 7.1 with S = 25."*

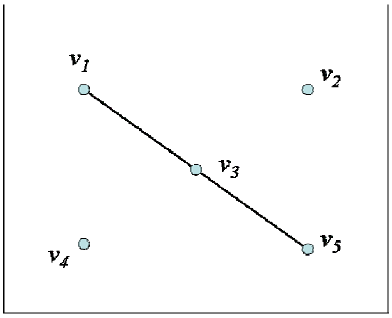


Figure 7.2 – *Similarity graph for programs in Table 7.1 with S = 25*

Johnsonbaugh continues that:

> *"in this graph the programs are grouped into three classes: {v_1, v_3, v_5}, {v_2} and {v_4}. In a real problem, an appropriate value for S might be selected by trial and error or the value of S might be selected automatically according to some predetermined criteria".*

7.6 New challenges

There are three challenges precipitated by these approaches to measurement. These are:

1. The challenge of clearly stating the aspect of the entity that a value relates to.

2. The challenge of establishing an individual measure for each entity.

   In order to perform benchmark comparisons, an individual measure for each entity is necessary.

3. The challenge of indicating if the individual measure is 'good' or 'bad' (rich or poor).

In order to overcome these challenges this chapter proposes a new measurement approach. In the first instance, the approach is motivated by Kitchenham *et al's* measurement theory and model. Kitchenham's model only identifies three considerations (entity, attribute and value). In order to support the granularity of the elements of website quality as explained in Section 5.3.3, MRA needs to address seven considerations (entity, feature, factor, characteristic, ratio, criteria and count). So, Kitchenham's model needs to be enhanced accordingly, and Metric Ratio Analysis addresses this.

The approach also uses the concepts of Financial Ratios where two criteria, combined in a formula as a numerator and denominator, are used to calculate an individual value for that ratio. In order to support website measurement multiple criteria are arranged as numerators and denominators in a single formula in order to calculate individual ratios. Websites present a second consideration in that a mechanism is needed which allows the different criteria to be easily identified as numerators or as denominators. So, the two-criteria formula needs to be enhanced accordingly, and Metric Ratio Analysis addresses this too.

Finally, the approach uses concepts of graph theory where similarity and clustering are used for benchmark comparison. Graph theory is an holistic, pairwise approach. It uses a formula that can be extended to take into account the number of pairs of values that are being considered and through a summation of differences, graph theory represents a smoothing of disparities between the values of the website. In order to support website benchmark comparison a sharper, individual measure is needed, and Metric Ratio Analysis also addresses this.

7.7 Metric Ratio Analysis

Metric Ratio Analysis is an approach to numerically quantifying website quality. This approach combines aspects of the three devices explained in Sections 7.3, 7.4 and 7.5. First, it employs the conceptual measurement model of Kitchenham *et al*., (1995) and extends it in order to apply it to website measurement. Second, it employs the Financial Ratio Analysis approach by combining measurable website values as numerators and denominators in a formula. And, third, it employs the graph theory for comparison purposes. MRA complies with the measurement framework which had to be developed by this research in order to overcome the limitations of current website measurement practice.

Metric Ratio Analysis is built on the concept that selected numerical values (criteria counts or indirect values) of an entity's attributes can be combined in a formula for the purpose of obtaining a calculated individual ratio. It embraces the logical arguments that:

- Some values are 'rich' and are positive for the website's quality and are therefore arranged as numerators in a formula so that as they increase they increase the calculated individual ratio.

- Some values are ‘poor’ and negative for the website’s quality and are therefore arranged as denominators in a formula so that as they increase they decrease the calculated individual ratio.

In this research the ‘rich’ and ‘poor’ considerations reflect intuitive understanding of how the criteria impact upon the calculated individual ratio. For example, consider that website navigation (Section 5.4.1) is being measured and the Number of pages supporting site search engine is a criteria. As the number of pages containing the site search engine increases, the easier it is for a visitor to locate an object in the site and consequently the site visitor’s navigation experience will increase and so too will the measure of navigation increase – a rich experience for the visitor and a positive increase in the calculated ratio. Another criteria might be Number of levels below Home page. In this case, as the number of levels increases, visitors will take longer to locate an object in the site and consequently their navigation experience will decrease and so too will the measure of navigation decrease – a poor experience for the visitor and a decrease in the calculated ratio.

The ‘rich’ and ‘poor’ considerations are then arranged to calculate an individual ratio.

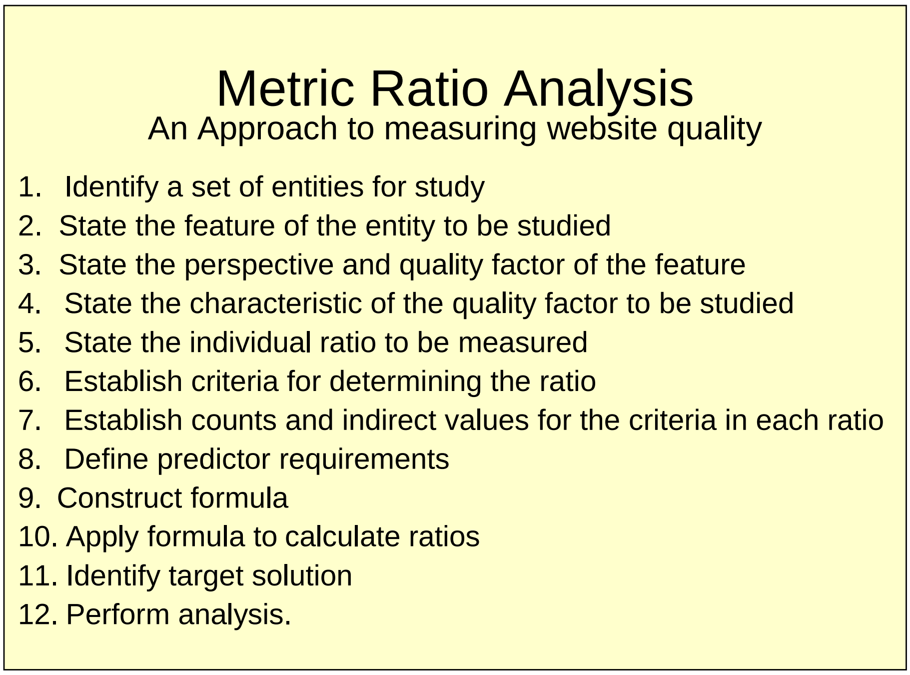
Applying this argument, Metric Ratio Analysis calculates an individual ratio by reference to whether a value (criteria count or indirect value) causes that ratio to increase or decrease. It does this by constructing a formula and setting as its enumerators those values which, when they *increase*, cause the calculated ratio to increase (A, B). Likewise it sets as denominators those values which, when they *increase*, cause the calculated ratio to decrease (C, D, E). In the formula all numerators are multiplied and their product is divided by the product of all denominators. This is the MRA formula and is simply expressed as:

$$\frac{A \times B}{C \times D \times E}$$

Where *A* and *B* are the values that cause the calculated ratio to increase as they increase and *C, D* and *E* are the values that cause the calculated ratio to decrease as they increase.

MRA has been specifically devised as an approach for measuring and comparing the quality factors of websites. Typically, MRA can be used by website owners in order to compare their website against their competitors' offering. It has uses either as a predictive measurement tool or as an assessment measurement tool.

Metric Ratio Analysis follows a set of twelve steps. These steps are essential to MRA and they are used again in Chapter 9 for validation. The steps are stated in Figure 7.3 and each is explained further.



Metric Ratio Analysis

An Approach to measuring website quality

1. Identify a set of entities for study
2. State the feature of the entity to be studied
3. State the perspective and quality factor of the feature
4. State the characteristic of the quality factor to be studied
5. State the individual ratio to be measured
6. Establish criteria for determining the ratio
7. Establish counts and indirect values for the criteria in each ratio
8. Define predictor requirements
9. Construct formula
10. Apply formula to calculate ratios
11. Identify target solution
12. Perform analysis.

Figure 7.3 – *The steps of Metric Ratio Analysis.*

7.7.1 Identify a set of entities for study

To comply with the model of measurement proposed by Kitchenham *et al*., (1995) the first step is to identify the entity that will be measured. An entity is any real world object and in this study the entities to be compared are eCommerce websites. These websites are live and are available to members of the public through the Internet. Their owners are actively engaged in using these sites to sell their products.

7.7.2 State the feature of the entity to be studied

Readers will recall from Chapter 5, Section 5.3.3.1 that,

> *An entity like a website has many features. Typically these might, be its classification; its strategic significance; its quality; its compliance with statutory requirements, and the one of interest in this study is quality.*

For this study, quality is the feature of the websites that will be studied.

7.7.3 State the perspective and quality factor of the feature to be studied

As explained by Fitzpatrick, Smith & O'Shea (2004a) there are many perspectives of quality and for this study the perspective is concerned with quality-of-product. That is, it is concerned with design considerations only.

Software product quality has been well researched and there is a scholarly body of knowledge published by researchers like McCall *et al* (1977), Boëhm (1978), ISO 9126-1 (2001) and Fitzpatrick (2000). For this study the quality factor is engagibility.

7.7.4 State the characteristic of the quality factor to be studied

Website engagibility has the characteristics of Navigability, Interactivity and Appeal. One of these would need to be selected and for this study, Navigability is considered in full in Chapter 8.

7.7.5 State the individual ratio to be measured

There are eight sub-characteristics associated with the previous step. One of these now needs to be considered. For example, Navigability consists of the navigation ratio and the surf ratio. Chapter 8 considers the navigation ratio in full.

At this point is it now very clear what aspect of the website the measurement relates to. MRA has imposed a granularity rigor that identifies a specific sub-characteristic. This resolves challenge 1 in Section 7.6.

7.7.6 Establish criteria for determining the ratio

A full set of criteria has been established in Chapter 5 and an appropriate sub-set of these is selected for the ratio being studied. For this study the navigation ratio criteria are used in Chapter 8.

Before advancing, it is valuable to state the difference between Kitchenham's model and the MRA approach. The Kitchenham *et al*., model is based on an entity and its attributes. When these attributes are measured the results or magnitude are named values. The MRA approach is based on an entity, a feature of that entity, a factor of that feature, a characteristic of that factor, a ratio or sub-characteristic and criteria. Because Metric Ratio Analysis is specifically developed for measuring website quality, MRA is consequently based on a website, its quality, its quality factors, characteristics of those quality factors, sub-characteristics which MRA calls ratios, and criteria which can be measured. Finally, when the criteria are measured the results are named counts. That is, where Kitchenham *et al*. identify three considerations (entity, attribute and value), MRA identifies seven considerations (entity, feature, factor, characteristic, ratio, criteria and count).

7.7.7 Establish counts and indirect values for the criteria in each ratio

Kitchenham *et al*., explain that an appropriate measurement instrument should be employed for measurement. MRA counts have been partially established using a computer-based tool and have been partially counted manually – see Chapter 5.

7.7.8 Define predictor requirements

Metric Ratio Analysis examines each website value and indirect value and predicts how a change in each of these will impact the calculated ratio. In the MRA approach, this prediction is a formula requirement such that 'rich' criteria, are set as multiplication (X) operators, i.e., numerators, and 'poor' criteria, are set as division (÷) operators, i.e., denominators.

7.7.9 Construct formula

To construct Ratio Formula, the values and indirect values are arranged as numerators or denominators as explained in Section 7.7.8 and to conform with the simple formula

$$\frac{A \times B}{C \times D \times E}$$

Difficulties arise with this formula if any of the values or indirect values is 0 (zero). Such a situation will calculate a zero result or division by zero. This would not be a true reflection of reality. For example, just because there might be zero Number of pages supporting site search engine it doesn't mean that the website cannot be navigated. MRA takes the view that if any of the values is zero, it means that it is not a contributor to the website richness and therefore should not be considered in the calculation. That is, its effect should be nullified or neutralised so that the other values can still be used in the calculation of the ratio and therefore reflect reality. Its effect can be nullified by adding 1 to it. So, where a value is 0 it has 1 added, so that it becomes 1. With a value of 1 it has no effect as a multiplier or as a divisor on the calculated ratio - its effect is nullified or neutralised in the formula. That is:

```
if   $value = 0$
     $value = value + 1$
else
     $value = value + 0$
endif
```

Nullifying a value of 0 and using the other values in their original state preserves a purity of calculation in the calculated ratio.

To further avoid any confusion and to clarify that 1 is not included in any MRA tables of values, MRA uses the expression "*The 1 is in the formula*" and the 1 is only added during the calculation of the ratio.

Difficulty also arises in that all website do not consist of equal numbers of pages. Consequently, the counts and indirect values used by MRA need to be normalised before they can be used. Also, values used in the formula are not necessarily of equal significance, so, it might be appropriate to introduce a weighting for each value. And, different ranges of websites might require different exponents to be applied in the formula.

All of these considerations are addressed further in Chapter 8.

Meanwhile, applying these considerations to the simple Metric Ratio Analysis formula from Section 7.7, the universal MRA formula can be expressed as:

$$\frac{\{(e_1 + x)\times ew_1\}^{p_1} \times\{(e_2 + x)\times ew_2)\}^{p_2} \times\{(e_3 + x)\times ew_3\}^{p_3} ....\times\{(e_n + x)\times ew_n)\}^{p_n}}{\{(i_1 + x)\times iw_1)\}^{r_1} \times\{(i_2 + x)\times iw_2)\}^{r_2} ....\times\{(i_n + x)\times iw_n)\}^{r_n}} \times constant$$

where $e_1 \dots e_n$ and $i_1 \dots i_n$ are MRA values or indirect values

x is a discontinuities variable and has a value of 1 or 0 depending on the MRA values or indirect values

$ew_1 \dots ew_n$ and $iw_1 \dots iw_n$ are value or indirect value weighting coefficients

$p_1 \dots p_n$ and $r_1 \dots r_n$ are website range exponents

and *constant* is a smoothing constant specific to the individual ratio.

At this phase of MRA development

x = 1 or 0;

$ew_1 \dots ew_n$ = 1

$iw_1 \dots iw_n$ = 1

$p_1 \dots p_n$ = 1

$r_1 \dots r_n$ = 1.

7.7.10 Apply formula to calculate ratios

Having derived a particular Ratio Formula, it is populated with values for the websites in the study in order to calculate ***individual ratios*** for each website. So, using MRA all of these websites now have an individual measure thereby addressing challenge 2.

7.7.11 Identify target solution

Challenge 3 is concerned that there is no indication whether the similarity between the websites is rich or poor. Specifying a target solution for an engagibility rich website addresses this.

Metric Ratio Analysis uses a target solution as the basis of benchmark comparison. The target represents an ideal but achievable website (engagibility ‘rich’ or ‘good’ website) and a full set of counts and values for this target is included in Appendix B.

7.7.12 Perform analysis

The final step of MRA is to analyse a combination of similarity results, tables of values and indirect values, and calculate individual ratios in order to complete a target-based website benchmark comparison.

As explained in Section 7.6.5, navigation is one of two concerns of Navigability. The other is support for surfing and both are illustrated in Figure 7.4.

In this section the 12 steps of MRA have been explained. These steps have to be repeated for all eight engagibility ratios. For Navigability, a navigation ratio and a surf ratio need to be calculated. These two ratios can then be combined to give a value for Navigability and MRA names this the Navigability Quotient (Figure 7.4). Figure 7.4 also illustrates the other characteristics of Engagibility. As explained in Chapter 5, Navigability is just one characteristic – Interactivity and Appeal being the others.

So, using the same MRA approach it is possible to calculate an Interactivity Quotient and an Appeal Quotient. Then, by combining the Navigability Quotient, the Interactivity Quotient and the Appeal Quotient a single Engagibility value can be calculated. Metric Ratio Analysis names this the Engagibility Index.

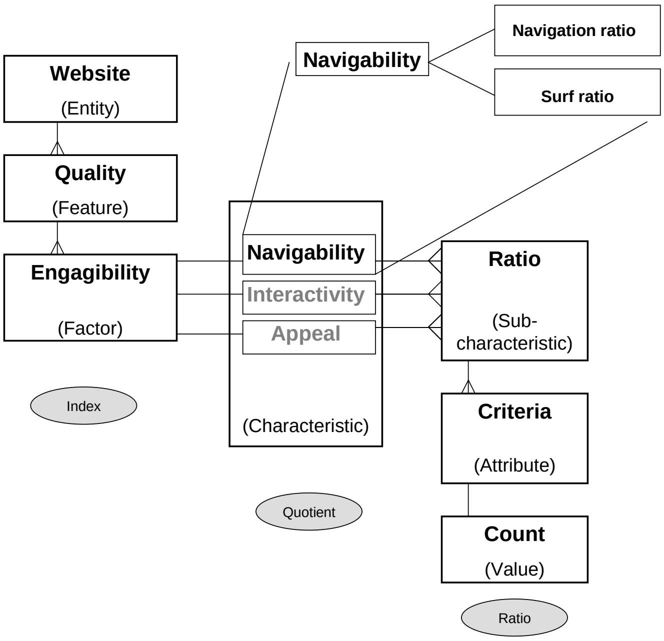


Figure 7.4 – *Elements of website Navigability.*

By using the terms Ratio, Quotient and Index, MRA continues the policy of only using the expression 'metric' as a higher level term thereby avoiding ambiguity.

Appendix D includes a worked example of a website Engagibility Index.

The steps set out in Figure 7.3 clearly model the order for completing a Metric Ratio Analysis study. Throughout Section 7.6 each step has been explained and illustrated in the context of website navigation.

For completeness, an MRA Entity Relationship Diagram after Kitchenham *et al's* structural model for measuring multi-dimensional attributes is illustrated in Figure 7.5. In this figure the Empirical World is fully expanded to show the many levels of granularity that are applied in Metric Ratio Analysis. Entities that have no incoming arrow are considered to be 'given'. For example, the measurement instrument is 'given'. It is not required that a measurement instrument must be devised for the study. Other entities which are considered ‘given’ are the entity being studied, any equation used and any predictors.

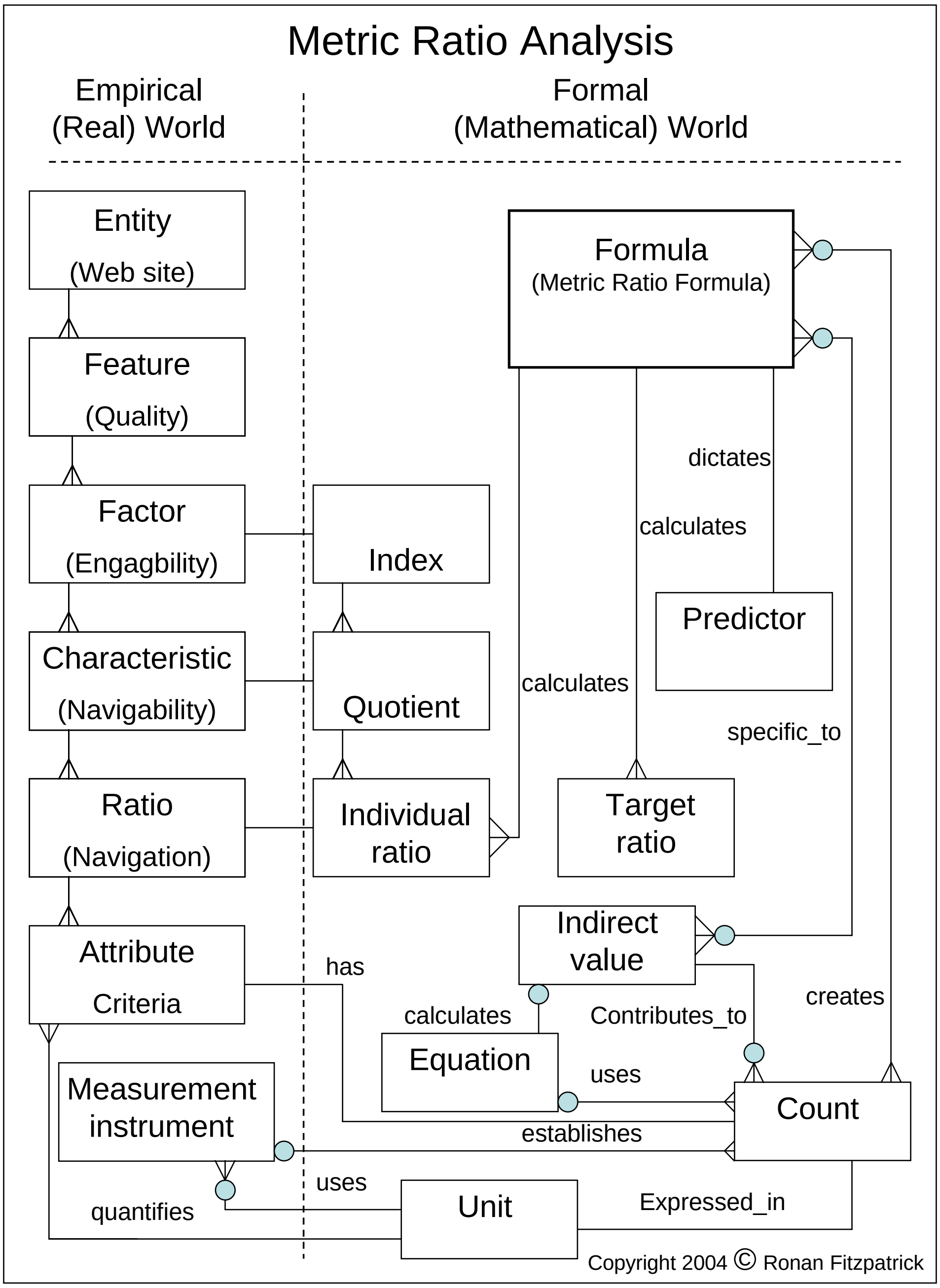


Figure 7.5 – *Entity relationships in Metric Ratio Analysis.*

This section has introduced the formal 12 step MRA approach. There are important matters that need more detailed explanation and clarification. These are addressed in Chapter 8.

7.8 Metric Ratio Analysis as a composite metric

This section discusses issues relating to composite metrics. It clarifies how some authors use different expressions to describe a composite measure (Duncan, 1988; Ince, 1989; Shepperd & Ince, 1993; Ejiogu, 1993; Kitchenham *et al.*, 1995; Fenton & Pfleeger, 1996; ISO/IEC 15939, 2002; Eiffel, 2006). It then considers the value of using a composite metric together with concerns that are addressed by those who research and use them. The section also discusses the strengths and weaknesses of the general MRA formula and discusses the advantages and disadvantages of the proposed composite ratio.

7.8.1 Composite metrics - vocabulary

Authors use different terms to describe a composite metric. Duncan (1988), Ince (1989;p43), Ejiogu (1993), and Eiffel (2006) are indicative of authors who prefer the term composite metric. Kitchenham *et al.* (1995) use the term indirect measure, Fenton & Pfleeger (1996;p81) use the term composite measure, and ISO/IEC 15939 (2002) uses the term derived measure. Ejiogu (1993) also uses the term derived. Ince (1989) describes a composite metric in the context of the multi-dimensional aspect of a measure and cites the work of Hansen (1978) and Oviedo (1980) where Hansen seeks to combine cyclomatic complexity with one of Halstead's metrics, and Oviedo seeks to combine the number of edges in a graph of a program with variable occurrences. Shepperd & Ince (1993;p12) restyle this combining of two independent metrics as a hybrid metric. A valuable practitioner perspective of a composite metrics is given by the Eiffel software organisation (Eiffel, 2006) who describe a composite metric as one whose values are defined by a mathematical formula involving other metrics (elementary or previously defined composite metrics). It explains that composite metrics are calculated by manipulating primitive metrics. The ISO/IEC 15939 standard defines a derived measure as a function of two or more values of base measures. So, a composite metric is not a direct measure or count but it is the result of calculation. These terms and sources are summarised in Figure 7.6.

Term	**Author**
Composite metric	Duncan (1988)
Composite metric	Ince (1989;p43)
Hybrid metric (in the context of two independent sponsor's metrics)	Shepperd & Ince (1993p;p12)
Composite or derived	Ejiogu (1993)
Indirect measure	Kitchenham *et al.,* (1995)
Composite measure	Fenton & Pfleeger (1996;p81)
Derived measure	ISO/IEC 15939 (2002)
Composite metric	Eiffel (2006)

Figure 7.6 – *The vocabulary of composite metrics.*

Metric Ratio Analysis derives composite metrics by its ratio calculation process.

7.8.2 Composite metrics – The promises and the concerns

The value of the multi-dimensional aspect of a composite metric is addressed by Shepperd & Ince (1993;p13;116;135) who state that:

- useful models will normally incorporate more than one dimension
- a multi-dimensional model is more effective at identifying problems (problem modules in their example).

A composite metric models multiple components and multiple parameters, and the interplay between them. The authors explain that some sponsors of metrics abrogate responsibility for integrating metrics into a composite model. In the case of engagibility measurement the measure identifies the over concentration, absence or partial absence of significant parameters (outliers) such that a measurement specialist can use informed knowledge to make decisions about website design enhancement. These parameters might be constructively 'engineered' into the website early in its life cycle in the best interest of website quality (Zage & Zage, 1993). This is particularly useful in the quality-of-product/quality-of-use feedback cycle where it supports decision making regarding the continuing competitive advantage of the website's design.

Shepperd & Ince, 1993 explain that:

- A model that deals with the product of dimensions overcomes problems of units.
- In the event that two hybrid metrics are being combined, there is a need to be concerned about dimensional consistency and how independent researchers can show these might be flawed.

A flawed component will result in a flawed composite metric. Fenton & Pfleeger (1996:p81/2) advise that:

- The component attributes might not be a complete and accurate description of the [overall] one.
- It is importance to understand if weighting is appropriate.

That is, all of the components in a composite metric might not be a full set and might not all be of equal significance. Some might be more important than others and this difference needs to be accounted for by weighting the individual components.

Eiffel (2006) explain that composite metrics can cause confusion due to their lack of universal consistency. Ince (1989;p44) comments that Oviedo's metric is complicated, as is the work reported by Kafura & Canning (1985), so, this research adds:

- Because composite metrics are often complicated, rules or guidelines for their universal use need to be defined (e.g., Function Point Analysis or COCOMO).
- Software measurement needs to comply with agreed international standards and practice.

Kitchenham *et al.,* (1995) state that an indirect measure is invalid if any of the conditions in Figure 7.7 hold:

1. There is no underlying model to justify its construction;
2. There is an underlying model but the measure can be shown to be invalid in the circumstances when it is being applied;
3. The measurement fails a dimensional analysis (e.g., it measures effort when it is supposed to measure size);
4. The measure is discontinuous within its defined numerical bounds;
5. The measure uses scale types incorrectly (e.g., it adds nominal scale attributes);
6. The measure uses units inconsistently (e.g., it mixes effort in hours with effort in days.

Figure 7.7 – *Properties that invalidate indirect measures* - Kitchenham *et al.* (1995).

Metric Ratio Analysis engagibility measurement has a policy of ensuring that its measures are not invalidated through breach of measurement properties as expressed by Kitchenham *et al.* It has a comprehensive underlying model, and theoretical and empirical validation will establish that it is a valid measure and that it is a measure of engagibility. The formula is specifically constructed to avoid multiplication and division by zero, so it does not breach the discontinuities property. The formula only uses counts (number or occurrence). It has no component of length (lines of code); it has no component of time (hour, day or month); and it has no component of size (Byte or Kbyte). So, it does not mix units. It calculates a clearly named measure and uses a 100 point scale.

Metric Ratio Analysis conforms to the software measurement considerations addressed in this section. How this is achieved is highlighted in the following figures of strengths and weaknesses, and advantages and disadvantages.

7.8.3 Strengths and weaknesses of the MRA universal formula

MRA has been based on a continuing strategy of conforming to current academic thinking and best business practice. It is goal driven and employs a top-down decomposition approach. It conforms to software measurement theory and with the properties of composite measures. However, some weaknesses still need to be addressed. In the first instance there are some ‘intuitive and plausibility’ issues that need to be considered. There are also some issues that relate to measurement theory. All of these issues would be substantially resolved by theoretical and empirical validation as proposed in Chapter 9. Figure 7.8 sets out the strengths and weakness of MRA.

Software measurement strengths and weaknesses of the Universal MRA formula	
Strengths	**Weaknesses** (Challenges to be resolved as the MRA approach matures)
1. The formula is underpinned by a top-down model of decomposition which is fully defined using a clear vocabulary to six levels of granularity.	1. The formula relies on intuitive and plausible understanding of the criteria that constitute engagibility.
2. The formula has a consistent format for all comparisons.	2. The formula relies on intuitive and plausible understanding of predictor influence.
3. The formula is strongly influenced by software measurement modeling theory.	3. Axioms that the formula must satisfy need to be identified and expressed algebraically.
4. The formula is constructed to avoid discontinuities (multiplication and division by zero).	4. The formula does not reflect a 'saturation' point beyond which it is suspected that engagibility is not improved and might in fact be a cause of visitor confusion.
5. The formula relies on counts alone and does not mix them with measures of length, time or size.	5. All values in the formula are considered to be of equal weighting. The formula will benefit from weighting coefficients.
6. The formula calculates a clearly named measure (e.g., navigation ratio, surf ratio) on a 100 point scale.	6. Further research is required to theoretically and empirically validate it.
7. All inputs to the formula are measured – there are no subjective inputs.	7. Further research is required to determine how the formula scales to very large websites.
8. The formula is modeled to reflect a 'rich' and 'poor' arrangement of values which correspond with classical mathematical theory.	8. Further research is required to clarify the formula's use with different ranges of websites.
9. The formula is flexible, so, as understanding of engagibility matures, it can be extended to include additional values as part of a benchmark comparison study.	
10. The formula supports target-based comparisons.	

Figure 7.8 – *Software measurement strengths and weaknesses of the general MRA formula.*

7.8.4 Advantages and disadvantages of the MRA composite ratio

There are also a number of advantages associated with the MRA approach to measurement which help to differentiate it. These are classified as software measurement advantages and strategic advantages. The first of the software measurement advantages is that MRA is focused on the early stages of the life cycle. Consequently, it will identify design problems and highlight engagibility issues mainly through missing or partially missing parameters. The second advantage is that the ratios calculated by MRA do not rely on any other sponsor's work. Consequently any new thinking that might contribute to the evolution and maturing of MRA is not hindered by association with other metrics. Furthermore, by not relying on outside metrics, MRA is not devalued by any controversy that might surround other sponsors' work. The third advantageous feature of MRA is its corresponding quality-of-product and quality-of-use perspectives which are used in the context of website design and corresponding website visitor engagement. The only significant disadvantage at this time is that it is not yet validated. These advantages and disadvantages are shown in Figure 7.9.

Software measurement advantages and disadvantages of the MRA composite ratio	
Advantages	**disadvantages** (Challenges to be addressed as the approach matures)
1. The composite ratio is a design-focused, multi-dimensional prediction measure which can be used early in the website life cycle to identify design problems and highlight engagibility issues.	1. Not yet validated. A procedure is proposed in this thesis for theoretically and empirically validating the approach.
2. The composite components of the ratio are autonomous and independent of any other 'external' sponsor's measure.	
3. The composite ratio is underpinned by corresponding perspectives which support analysis in the quality-of-product/quality-of-use feedback cycle.	

Figure 7.9 – *Software measurement advantages and disadvantages of the MRA composite ratio.*

Metric Ratio Analysis also offers strategic advantages to organisations planning to implement a website engagibility measurement programme. These are influenced by the relevant strategic drivers identified in Chapter 3. There are also some disadvantages that will be resolved or minimised through validation, maturity and application in a commercial measurement programme. The strategic advantages and current disadvantages are set out in Figure 7.10.

Strategic advantages and disadvantages of the MRA composite ratio	
Strategic advantages	**Strategic disadvantages** (Challenges to be addressed as the approach matures)
1. The measure can be used as an indicator of competitive advantage through benchmark comparison with competitor websites.	1. Application. At this early stage of development there is no supporting evidence of the merit of the measure. Implementation as part of a commercial measurement programme will address this.
2. The underpinning comprehensive model and method provide confidence for the user organisation.	2. Cost. Initial cost will be associated with validation and dissemination, and continuing cost will be associated with its support as the approach evolves and matures.
3. In the context of financial investment in a strategic eCommerce website, MRA is a cost effective measure which supports informed corporate investment.	3. Detail. The approach is detailed and will benefit from universally accepted rules and guidelines.
4. The measure is strongly influenced by international standards (feedback from use to enhance design to enhance use; and to be validated per ISO standard guidelines).	4. Acceptance. There may be Initial reluctance to accept the novelty of the predictor arrangement of the approach.
5. Can be used as a predictor of website visitor engagibility	

Figure 7.10 – *Strategic advantages and disadvantages of the MRA composite ratio.*

7.9 Metric Ratio Analysis in use – considerations

The chapter has explained the process of Metric Ratio Analysis and in this a number of practical considerations arise. These include:

- Users of Metric Ratio Analysis need to satisfy themselves of the suitability and sufficiency of the criteria that they use in their target-based comparisons and their relevance to the ratio being calculated.
- Defining the formula predictor requirements should be intuitive and indicated by Real World observation. Or, it might be the case that the increase/decrease prediction needs special study in order that they can be corroborated empirically.
- A Metric Ratio Formula will be extended to accommodate the number of counts or indirect values that are required to calculate the ratio, i.e., extend formula to *n* where *n* is the number of formula elements required in order to include all of the counts and indirect values that are used for the calculation.

- Depending on the magnitude of the values, individual ratios might be calculated to two places of decimals where the ratios are low. Or, it might be appropriate to introduce scaling constants (e.g., X *by* 0.001) for clarity.

- Target values might be specified based on historical evidence or they might be derived as a mean or desirable requirement based on the measured counts of the study. For example, having determined a set of values if might be desirable that the highest value for a given criteria is the target to be achieved.

7.10 Conclusion

This chapter proposes a new approach to measuring website quality. The chapter has demonstrated how a measurement model proposed by Kitchenham, Pfleeger & Fenton, Financial Ratio Analysis and similarity graph theory can underpin a new measurement approach called Metric Ratio Analysis (MRA). The chapter explains a 12 step model of the MRA measurement.

Metric Ratio Analysis (MRA) combines an intuitive predictive understanding of website criteria behaviour with a mathematical basis in order to calculate a website's individual ratio for target-based website quality comparisons.

The calculated individual ratio uses a number of specific, individual values. These values are established by measuring criteria relating to a website design and can be determined directly from an online published website. A set of calculated ratios can be used by website owners, specifiers and designers to rate a website's performance against competitor websites in the set in order to identify trends, deficiencies and pointers to future improved quality.

Definitions of the term 'composite metric' are discussed and considered. Strengths and weaknesses of the general MRA formula are set out. Advantages and disadvantages from a software measurement perspective and from a strategic management perspective are also considered. The strengths and weaknesses and the advantages and disadvantages, set out in the chapter reflect the current iteration of MRA’s development.

In Appendix D the steps of Metric Ratio Analysis are followed in order to establish individual ratios for all of the Engagibility ratios that were identified in Chapter 5, and Fitzpatrick *et al.,* (2005) for all five websites in the eCommerce study.

In Chapter 8 Metric Ratio Analysis will be applied in detail to one engagibility ratio. Matters such as criteria selection, justification, numerator and denominator requirements, normalisation, weighting, target values, and ranges are also addressed.

Chapter 8

Applying Metric Ratio Analysis to the navigation ratio

> *The aim of this chapter is to apply Metric Ratio Analysis in detail to one ratio. The navigation ratio is used for this purpose.*

8.1 Background

Following the general formulation of the MRA approach there is a need to apply the approach in detail. This chapter does so, for the navigation ratio and also addresses matters such as criteria selection, justification, numerator and denominator requirements, normalisation, weighting, target values, and ranges.

8.2 Introduction

Chapter 7 proposed a new approach to measuring website quality. The aim of this chapter is to apply the MRA approach in detail to one ratio – the navigation ratio. In addition to following the 12 MRA steps the chapter will also address criteria selection and justification, numerator and denominator arrangement, normalisation, weighting, target values, and ranges. Sections 8.3 to 8.7 apply MRA steps 1 to 5 and confirm the feature, perspective and quality factor, characteristic, and individual ratio for the five websites being studied. Section 8.8 clarifies how the criteria used for the navigation ratio were identified and selected, and provides supporting justification for their inclusion. Section 8.9 explains in detail how these criteria become the values for calculating the navigation ratio. It gives a description of each value, the counts used in it, and justifies its inclusion. This section also clarifies the use of numerators and denominators. Illustration charts indicating how the navigation ratio is impacted by each value used in its formula are also included. The section explains how the values could be normalised in the Navigation Ratio Formula and discusses the relative importance of each value and how it might be weighted. Section 8.10 defines predictor requirements and Section 8.11 constructs the Navigation Ratio Formula. Section 8.12 calculates the navigation ratio, Section 8.13 identifies a target website, and Section 8.14 performs analysis. Section 8.15 adds comments on the target website and Section 8.16 draws conclusions.

8.3 Identify a set of entities for study

The entities that will be studied are the online websites of:

- BMIbaby
- CityJet
- Eircom
- Royal Tara
- Sheila's Flowers.

8.4 State the feature of the entity to be studied

The feature of these websites that the study is concerned with is website quality.

8.5 State the perspective and quality factor of the feature

The study is concerned with the quality-of-use perspective of website engagibility of these websites.

8.6 State the characteristic of the quality factor to be studied

For this study Navigability will be studied.

8.7 State the individual ratio to be measured

The study focuses on the navigation ratio.

8.8 Establish criteria for determining the ratio

This section explains how the definition of the navigation ratio is used as the basis of identifying and selecting the navigation criteria.

8.8.1 Identifying the navigation criteria

In Chapter 5 the navigation ratio is defined as:

> The degree of a website’s support for sitebound hyperlinking.

The four constructs in this definition (degree, support, sitebound, and hyperlinking) are used to identify the navigation criteria and are explained as follows:

1. The **degree** is a calculated value which quantifies the navigation ratio, and is calculated by using the formula.

2. A website’s **support** for sitebound hyperlinking is the manner in which the design elements (criteria) of the site’s design enable or inhibit visitor navigation with the website. In order to calculate the **support**, MRA arranges values based on the criteria such that enabling values are numerators and inhibiting values are denominators in the formula derived by MRA. The values used for these enablers or inhibiters are either direct counts of a website’s criteria or are indirect values based on the counts. Where an indirect value is used in the calculation of the navigation ratio, that indirect value is constructed to ensure that the calculation of the navigation ratio properly reflects the predictable result. The indirect values ***SBpages*** and ***Menus*** are typical of the challenge presented by this requirement and their solutions are explained in detail in subsections 8.9.3 and 8.9.4 later in this chapter.

3. MRA considers that there are two forms of hyperlinks. Those that link to other destinations within the site are styled **sitebound**, while those which enable visitors to leave a site and link to another external site are styled outbound hyperlinks. Only **sitebound** hyperlinks to destinations within the site are used for calculating the navigation ratio.

4. **Hyperlinking** is the use of hypertext links for linking to other destinations within and outside the website. Hyperlinks can take the form of text or graphics.

MRA derives a formula for calculating the degree of the site's support for sitebound hyperlinking.

8.8.2 Selecting the navigation criteria

To comply with the two definition constructs sitebound and hyperlinking, it is a core requirement that all navigation criteria must be concerned with sitebound hyperlinking. A need for a set of measurable elements which is considered by this research to be common to all quality websites (irrespective of website's domain of application or business sector) is a driver for selecting these criteria. In order to identify the criteria it is necessary to take account of the occurrences of sitebound hyperlinks, their distribution throughout the website and the proximity of a destination to the visitor. So, criteria were devised to reflect these three topics (occurrences, distribution and proximity). It was also necessary to take account of backward sitebound linking, so, MRA also includes generic hyperlinking opportunities to Home and Top of page which support visitor backward navigation. The selected set of criteria (as already identified in the dataform in Chapter 5) and the intuitiveness of their selection is illustrated here with the aid of a simple grid.

	Navigation criteria	Occurrence	Distribution	Proximity
SBlinks	Total occurrences of sitebound links in the website.	✓	✓	✓
SBHome	Number of sitebound links from Home page.	✓		✓
SBpages	Number of active HTML pages in the site.	✓	✓	✓
	Number of pages containing sitebound links.	✓	✓	✓
Menus	Total occurrences of horizontal menus in site.	✓	✓	✓
	Total occurrences of vertical menus in site.	✓	✓	✓
	Number of different horizontal menus in site.	✓	✓	✓
	Number of different vertical menus in site.	✓	✓	✓
Levels	Number of levels below Home page.		✓	✓
Home_ Top	Total occurrences of links to Home.	✓		✓
	Total occurrences of links to Top.	✓		✓
Search	Number of pages supporting site search engine.	✓		✓

Figure 8.1 – *Navigation criteria.*

The first criteria included is the occurrences of sitebound links in the website. MRA considers that the occurrence of a criteria is dependent on the number of pages and the number of menus in the site. So, criteria were written to emphasise page counts together with counts of the number of links from those pages. Counts for the number of different horizontal and vertical menus, and occurrences for links to/from Home, top of page and site search are also written for the occurrence.

Distribution is considered in terms of the number of pages that contain hyperlinks, so, criteria are written to emphasis page counts for active HTML pages. By only counting active HTML pages the calculated ratio cannot be distorted by the inclusion of discarded or redundant pages. Distribution of the links is also considered in terms of the number of menus in the site. So, some criteria already written for occurrences are again included for distribution (e.g., the number of different horizontal and vertical menus and their occurrences). The number of levels in a website also influences the extent of the distribution. MRA considers that during navigation the proximity of a destination is also influenced by the presence (occurrence) of sitebound hyperlinks.

MRA considers that the proximity of a visitor’s destination is influenced by the number of pages, menus and levels in the website, and therefore, criteria relating to pages, menus and levels in a website are included to support it. Support for reaching a visitor’s destination from the Home Page by way of sitebound hyperlink counts from the Home Page is also included in the criteria.

Generic hyperlinks that are included are links to the Home Page and links to the Top of Page. A count of site search opportunities is included as a special generic feature for supporting visitor navigation through the site. These criteria support the visitor’s proximity to website content.

The column at the left of Figure 8.1 illustrates how the navigation criteria are used in the Navigation Ratio Formula. Some of the criteria are combined to form indirect values. This column ‘variable’ names for easy use in the Navigation Ratio Formula. These ‘variable’ names are explained in detail in Section 8.9.

At this stage of MRA development the criteria are intuitive and plausible and need to be theoretically and empirically validated.

8.8.3 Justification of the navigation criteria

The selection of the criteria represents new theory, influenced by occurrences, distribution and proximity, and which have been selected independently of other approaches to navigation measurement. Their selection is not driven by a need to synthesise the work or findings of other researchers, nor are they selected to enhance any other navigation measure. However, support for their selection can be found in good practice guidelines such as the U.S. Department of Health and

Human Services (HHS) Research-Based Web Design and Usability Guidelines (Koyani *et al*., 2003); the ISO Draft International Standard on software ergonomics for World Wide Web user interfaces (ISO DIS 9241-151, 2005); and the UK's Joint Information Systems Committee for higher education (JISC) guidelines for academic websites (Bevan & Kincla, 2003). There are also similarities to the elements of software science (Halstead, 1972; 1977) in that Halstead also measured counts (or numbers) and occurrences (typically, number of different operators occurring in an algorithm; number of different operands; and total occurrences of operators and operands). Proximity is used by the Maxamine website analytical tool as part of its measurement strategy. Typical examples of how the guidelines and the standard's considerations might be mapped to the MRA list of criteria are set out in Figure 8.2.

MRA criteria	Supporting source
• Total occurrences of sitebound links in the website.	**HHS Guideline 10.9:** Link to related content (4 – 2). **HHS Guideline 7.3:** Do not create pages with no navigational options (4 – 2). **ISO/DIS 9241-151:** C. Providing crosslinking to potentially relevant content D. Identification of links D. Distinguishing navigation links from transactions.
• Number of sitebound links from Home page	**HHS Guideline 5.3:** Present all major options on the homepage (5 – 2). **ISO/DIS 9241-151:** C. Directly accessing relevant information from home page.
• Number of active HTML pages in the site.	**HHS Guideline 6.1:** Use appropriate page lengths (4 – 3). **HHS Guideline 7.9:** Keep navigation-only pages short (2 – 4). **HHS Guideline 8.3:** Use paging rather than scrolling (2 – 4). **ISO/DIS 9241-151:** D1. Quantity of text per information unit/page C. Subdividing long pages
• Number of pages containing sitebound links.	**HHS Guideline 7.3:** Do not create pages with no navigational options (4 – 2).
• Total occurrences of horizontal menus in site. • Total occurrences of vertical menus in site. • Number of different horizontal menus in site. • Number of different vertical menus in site.	**HHS Guideline 7.8:** Use appropriate menu types (3 – 4). **ISO/DIS 9241-151:** C. Supporting the user's navigation strategy C. Organising the navigation in a meaningful manner C. Minimising navigation effort C. Choosing suitable navigation structures.
• Number of levels below Home page.	**HHS Guideline 16.1:** Organize information at each level of the website so that it shows a clear and logical structure to typical users (5 - 4). **HHS Guideline 16.2:** Put critical information high in the hierarchy of a website (5 – 3). **ISO/DIS 9241-151:** C. Making several levels visible C. Going back to higher levels C. Minimise the number of navigation steps needed to reach a certain piece of content.
• Total occurrences of links to Home. • Total occurrences of links to Top.	**HHS Guideline 5.4:** Enable users to access the homepage from any other page on the website (4 – 3). **ISO/DIS 9241-151:** C. Linking back to the home page C. Going back to higher levels C. Providing a 'step back' function.
• Number of pages supporting site search engine.	**HHS Guideline 17.1:** Provide a search option on each page of a content-rich website (5 – 2). **ISO/DIS 9241-151:** C. Availability of search. **JISC Guideline:** Provide for repeat searches at top and bottom of page.

Figure 8.2 – *Typical examples of mapping between MRA criteria and industry guidelines.*

The guidelines and considerations included in this list are a selected set and have been chosen from the extensive list of items included in the guidelines and standard because they include terms and vocabulary which is similar to that used by MRA. There are many other supporting items in the guidelines and standard that also apply but are not cited in this set of examples.

The HHS guidelines include simple scores for relative importance and strength of evidence. This is typically shown in Figure 8.2 for the first item, Guideline 10.9, as (4 – 2), where the relative importance score is 4 and the strength of evidence is 2. The importance score could be used to devise a weighting factor for each of the values in the Navigation Ratio Formula. Unfortunately, ISO/DIS 9241-151 (2005) does not include a corresponding set of scores. The HHS guidelines also include detailed lists of authoritive source citations for each guideline and readers are referred to those detailed lists for the sources and to Bevan (2005) for a detailed analysis of these guidelines. The vocabulary used in these guidelines and considerations also supports the numerator/denominator arrangement in the Navigation Ratio Formula. For example, expression like present all major options on the Home page and provide a search option on each page imply that complying with this guideline is good and, consequently, is an enabler of navigation. In this case it is supportive of MRA's use of the Number of sitebound links on Home page (***SBHome***) and the Number of pages supporting site search engine (***Search***) as numerators when calculating the navigation ratio. Similarly, recommending that important information should be positioned high in the hierarchy of the website implies that the number of levels should be kept low. Consequently increasing the number of levels inhibits navigation and in this case it is correct to use Number of levels below Home page ***Levels*** as a denominator.

Fully justifying the inclusion of each of the criteria is a validation issue and it is proposed in Chapter 9 that the completeness and sufficiency of the full set of MRA criteria must be considered as part of the theoretical validation of MRA.

8.9 Establish counts and indirect values for the criteria in each ratio

This section explains how these criteria become the values that are used in the Navigation Ratio Formula. This section gives a description of each value, how it is counted, why it is included, and justification for its inclusion. The use of each value as a numerator or denominator is also clarified. This section also includes an illustration chart for each value showing how the MRA product navigation ratio compares with the suggested use navigation ratio. The section includes a table of the counts and indirect values that for the websites in the study.

Counts of the navigation criteria identified in Chapter 5 are used alone or in combination as seven values (direct or indirect respectively) in the Navigation Ratio Formula in order to calculate a navigation ratio. Their descriptions and MRA formula predictor requirements are set out in Figure 8.3.

Navigation ratio values The degree of a website's support for sitebound hyperlinking			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
SBlinks	Total occurrences of sitebound links in the website.	Increase	Numerator (**X**)
SBHome	Number of sitebound links from Home page.	Increase	Numerator (**X**)
SBpages	Number of active HTML pages in the site ÷ Number of pages containing sitebound links.	Decrease	Denominator (÷)
Menus	Total occurrences of all menus in site ÷ sum of different horizontal and vertical menus in site.	Increase	Numerator (**X**)
Levels	Number of levels below Home page.	Decrease	Denominator (÷)
Home_Top	Sum of Total occurrences of links to Home and Total occurrences of links to Top.	Increase	Numerator (**X**)
Search	Number of pages supporting site search engine.	Increase	Numerator (**X**)

Figure 8.3 – *Criteria and predictor requirements for the Navigation Ratio Formula.*

The seven values are ***SBlinks, SBHome, SBpages, Menus, Levels, Home_Top, and Search***. Three of these - ***SBpages, Menus, and Home_Top*** - are indirect values and their individual explanation will show that the arrangement of the criteria used in them is correct and logical. Each is explained in this section.

8.9.1 *SBlinks* - Total occurrences of sitebound links in the website

Figure 8.4 illustrates the arrangement of sitebound hyperlinks through the various levels in a typical website in the MRA eCommerce study. It illustrates a single Home page (level 0) and three pages at level 1 each accessed from a sitebound link from level 0 – illustrated by the arrow lines. Each of the pages at level 1 has sitebound links to level 2. The linking continues to the lowest level in the tree structure as illustrated by level 3 and level 4. It is also design practice for sitebound links to link pages back to higher levels in the tree as typically illustrated by the arrows from page 2.2 to 1.1 and from pages 3.3 and 3.4 to 2.4.

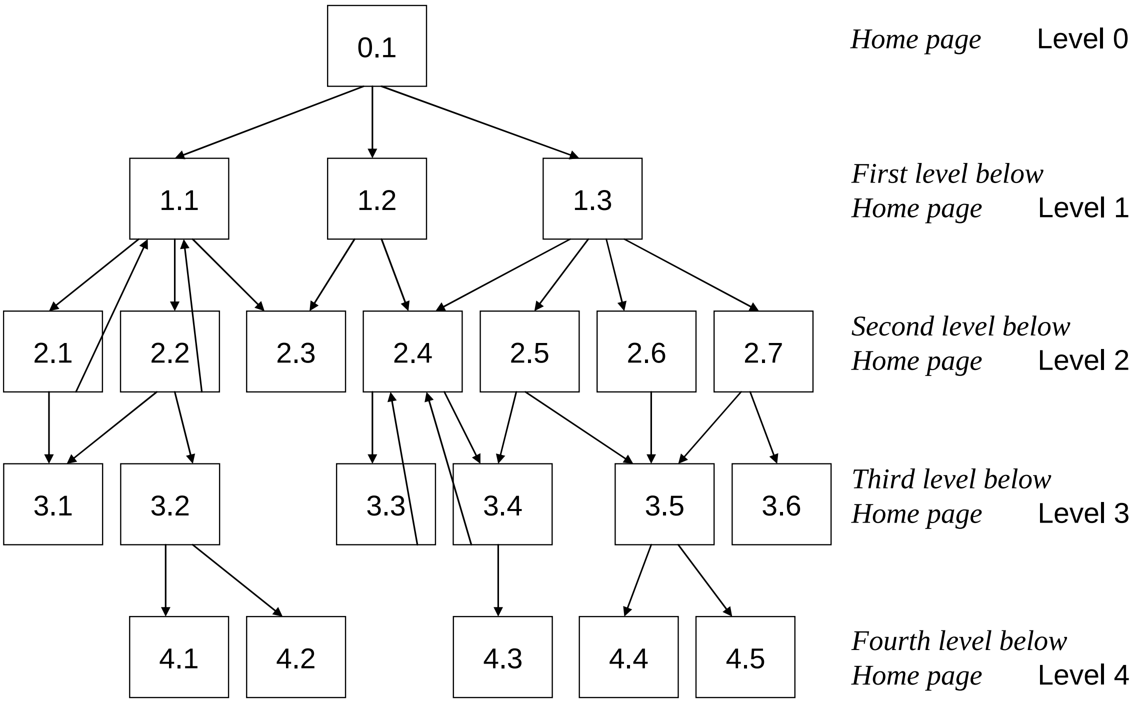


Figure 8.4 – *Sitebound hyperlinks and site levels.*

Naming the Home page level 0 supports the cognitive mapping of 'level below Home page' with 'level number'. That is, the first level below Home page is level 1, the third level below the Home page is level 3, or the ***x***th level below the Home page is level ***x***.

The MRA total for these sitebound links is the simple count of all outgoing links from all pages to other pages within the site. The links that are counted include those in paragraphs of text, graphics, those in lists of hyperlinks and those arranged as menus. In this way, a count of all sitebound hyperlinks on all pages, includes all forward or backward links, and is a total of all occurrences of sitebound hyperlinks in the website. MRA only counts the link where it originates. It does not count it a second time at the destination page.

It would be desirable that each page would have links back to the Home page. However, these links are not included in the ***SBlinks*** count because they are counted separately for another value in the Navigation Ratio Formula (See ***Home_Top*** later in this section).

In the MRA approach, as the Total occurrences of sitebound links in the website increases, visitors are better able to navigate the site, so, the website's support for sitebound hyperlinking will increase. That is, the calculated navigation ratio will increase. Accordingly, to comply with MRA operation this value is used as a multiplication (**X**) operator, i.e., a numerator in the Navigation Ratio Formula.

Guidelines from the U.S. Department of Health and Human Services, and the ISO Draft International Standard considerations, which would support the inclusion of ***SBlinks*** are:

1. **HHS Guideline 10.9:** Link to related content (4 – 2).
2. **HHS Guideline 7.3:** Do not create pages with no navigational options (4 – 2).
3. **ISO/DIS 9241-151:** C. Providing crosslinking to potentially relevant content
    - D. Identification of links
    - D. Distinguishing navigation links from transactions.

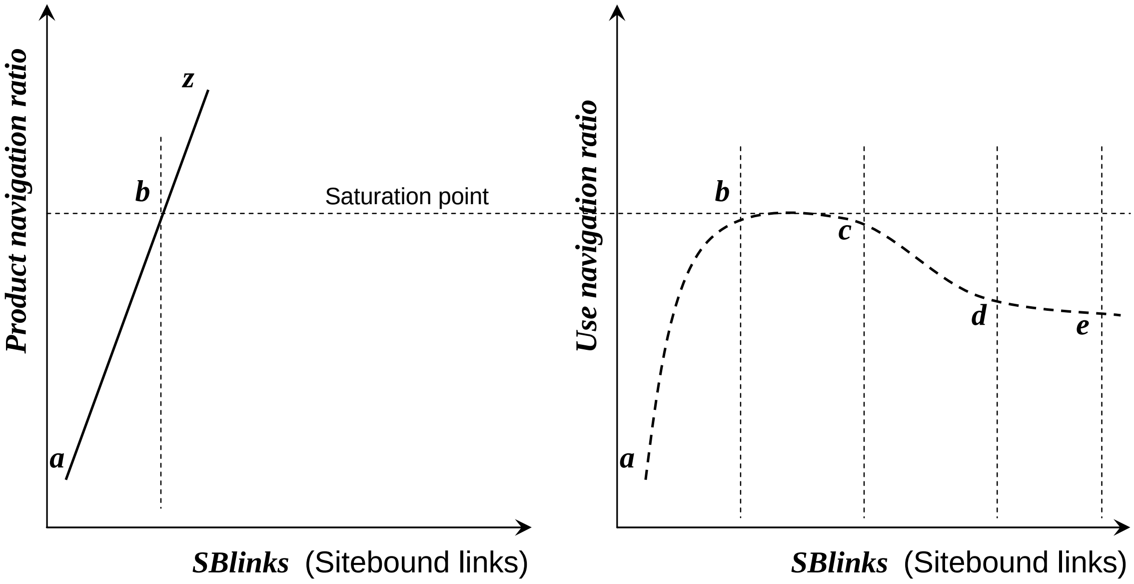


Figure 8.5 – *Navigation ratio and **SBlinks** chart.*

Figure 8.5 uses two graphs to illustrate how ***SBlinks*** impacts the navigation ratio. The product navigation ratio graph on the left illustrates how the Navigation Ratio Formula calculates that impact. As the count of ***SBlinks*** increases so too will the navigation ratio increase. This is illustrated by the line ***a-b-z*** in the figure. However, it is suggested that during visitor engagement continued increase in the count of ***SBlinks*** will not follow a straight line. Continued addition of sitebound links may not enhance the engagement experience and, as more links are added the navigation experience may remain generally constant as illustrated by line ***b-c*** in the use navigation graph on the right of the figure. From point ***c***, it is suggested that adding ***SBlinks*** might cause confusion for visitors and as a consequence the engagement experience will decrease (line ***c-d***) and that after a point ***d*** adding addition links will have no effect. It is suggested that ***b-c*** relates to an optimum value for ***SBlinks***. The target value is on line ***a-z*** and as it is based on the custom and practice in a given website study it could easily be on line section ***b-z*** assuming a straight line graph. That is, website owners might be over designing such that they are including a redundancy of sitebound hyperlinks and this is being reflected in the calculation of the calculated target values. So, further discussion relating to the target value (as introduced in Chapter 7) is given later in this chapter.

8.9.2 *SBHome* - Number of sitebound links from Home page

This is a count of the number of sitebound hyperlinks from the Home page to other pages in the website. The count includes each sitebound link that is arranged or grouped in a set or list of links (see ***Menus***). It also includes those that are presented in the body of the Home page text. The count includes text and graphics links. As this is the Home page, links to itself are not counted.

MRA considers that as the Number of sitebound links from Home page increases the website is easier to navigate, so, the website's support for sitebound hyperlinking will increase. In this case, the navigation ratio increases. So, to comply with MRA operation this value will be used as a multiplication (**X**) operator, i.e., a numerator. This value's abbreviated referenced is ***SBHome.***

Guidelines from the U.S. Department of Health and Human Services, and the ISO Draft International Standard considerations, which would support the inclusion of ***SBHome*** are:

1. **HHS Guideline 5.3:** Present all major options on the homepage (5 – 2).
2. **ISO/DIS 9241-151:** C. Directly accessing relevant information from home page.

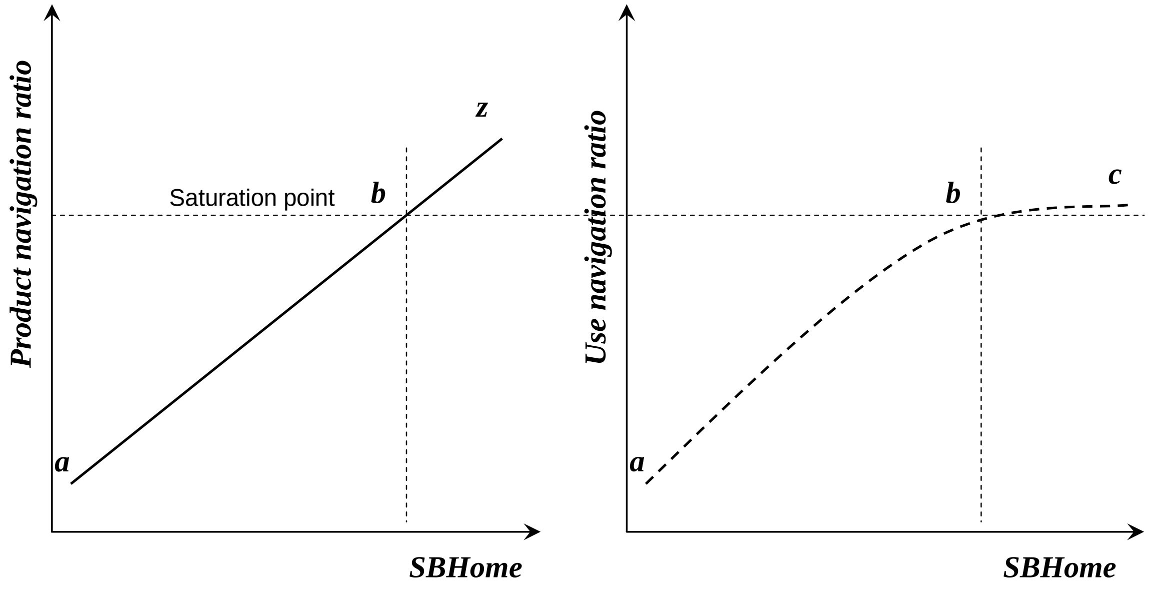


Figure 8.6 - *Navigation ratio and* ***SBHome*** *chart.*

The graph to the left of Figure 8.6 illustrates how the Navigation Ratio Formula is impacted by the Number of sitebound links from Home page. A straight line graph (***a-b-z***) shows that as the count of the links on the Home page increases so too does the calculated navigation ratio. However, if the count of the links becomes excessive it is suggested that the additional effort required by a visitor to scan and locate a desired link will slow that visitor's access to that desired link as illustrated in the use navigation graph on the right of the figure. In this case the impact of ***SBHome*** during visitor use of the website will follow line ***b-c*** as illustrated.

8.9.3 *SBpages* - Number of active HTML pages in the site ÷ Number of pages containing sitebound links

MRA considers that as the number of pages in a website increases, the longer it will take for a visitor to navigate to a destination. That is, increasing numbers of pages in a website inhibit visitor engagement. Consequently, the navigation of the website takes longer or becomes more difficult, so, the website's support for sitebound hyperlinking will decrease. That is, as the number of pages increases, the poorer the engagement and consequently the lower the calculated ratio should be. MRA also considers that the extent of this inhibition is reduced by the number of pages that contain sitebound links. So, to reflect this, MRA uses an indirect value for ***SBpages*** which is a quotient of HTML pages in the site and pages containing sitebound links. It is expressed as:

$$\frac{\textit{Number of active HTML pages in the site}}{\textit{Number of pages containing sitebound links}}$$

The ***SBpages*** value relies on two direct counts. The number of HTML pages is a count of static HTML pages that must be crafted to meet the design requirements. This count includes only those pages that are active and previous or redundant versions of a page are not counted. The count of pages containing sitebound links includes pages containing text links and graphics links. Pages which only contain a link to home are not included in this count (links to Home are counted in the ***Home_Top*** value – see later). The manner in which a website is structured impacts the calculated value of ***SBpages*** and this impact would need to be reflected in the weighting process. Because ***SBpages*** is an inhibitor, the overall effect of ***SBpages*** is to decrease the calculated navigation ratio, and so, to comply with MRA operation this value will be used as a division (÷) operator, i.e., a denominator.

In order to confirm that the ***SBpages*** quotient is a valid arrangement of the two counts, and that it will properly reflect the expected navigation ratio, MRA tested nine alternative arrangements of them as listed in Figure 8.7.

Alternative arrangement	Site A Pages = 100 Pages with sitebound links = 80		Site B Pages = 100 Pages with sitebound links = 60	
1. Addition		180		160
2. Subtraction		20		40
3. Division *i*	100/80	1.25	100/60	1.66
4. Division *ii*	80/100	0.8	60/100	0.6
5. Multiplication		8000		6000
6. Average		90		80
7. Percent		80		60
8. Square Root		of 80 = 8.94		of 60 = 7.75
9. Square		6400		3600

Figure 8.7 – *Possible **SBpages** values for example websites* A *and* B.

The test considers two versions of the same website (Site A and Site B) where both are identical except for the Number of pages containing sitebound links. Both have 100 pages but Site A has 80 pages containing sitebound links while Site B has only 60 pages. So, the counts used for calculating ***SBpages*** are 100/80 for Site A and 100/60 for Site B. In this example, Site A is the richer site because its 80 pages provide more opportunity for visitor navigation. Because Site A is the richer site, its calculated navigation ratio should be higher than that of Site B (all other values being equal). To achieve this higher calculated navigation ratio, and knowing that ***SBpages*** will be uses as a denominator, ***SBpages*** for Site A must have a lower value than ***SBpages*** for Site B. Using the 100/80 and 100/60 counts, calculated indirect values for ***SBpages*** for each of the nine alternative arrangements are shown in Figure 8.7. From this figure it can be seen that the calculations per alternatives 2 and 3 are the only arrangements where ***SBpages*** for Site A is lower than ***SBpages*** for Site B. Of these, alternative 3 (Division *i*) is considered a closer representation of the 80 and 60 pages in the two websites in the example. Consequently, the MRA arrangement of the counts for ***SBpages*** is a quotient as represented by alternative 3. In order to avoid discontinuity 1 is added if the denominator is zero.

Guidelines from the U.S. Department of Health and Human Services, and the ISO Draft International Standard considerations, which would support the inclusion of ***SBpages*** are:

1. **HHS Guideline 6.1:** Use appropriate page lengths (4 – 3).
2. **HHS Guideline 7.9:** Keep navigation-only pages short (2 – 4).
3. **HHS Guideline 8.3:** Use paging rather than scrolling (2 – 4).
4. **HHS Guideline 7.3:** Do not create pages with no navigational options (4 – 2).
5. **ISO/DIS 9241-151:** D1. Quantity of text per information unit/page
   C. Subdividing long pages.

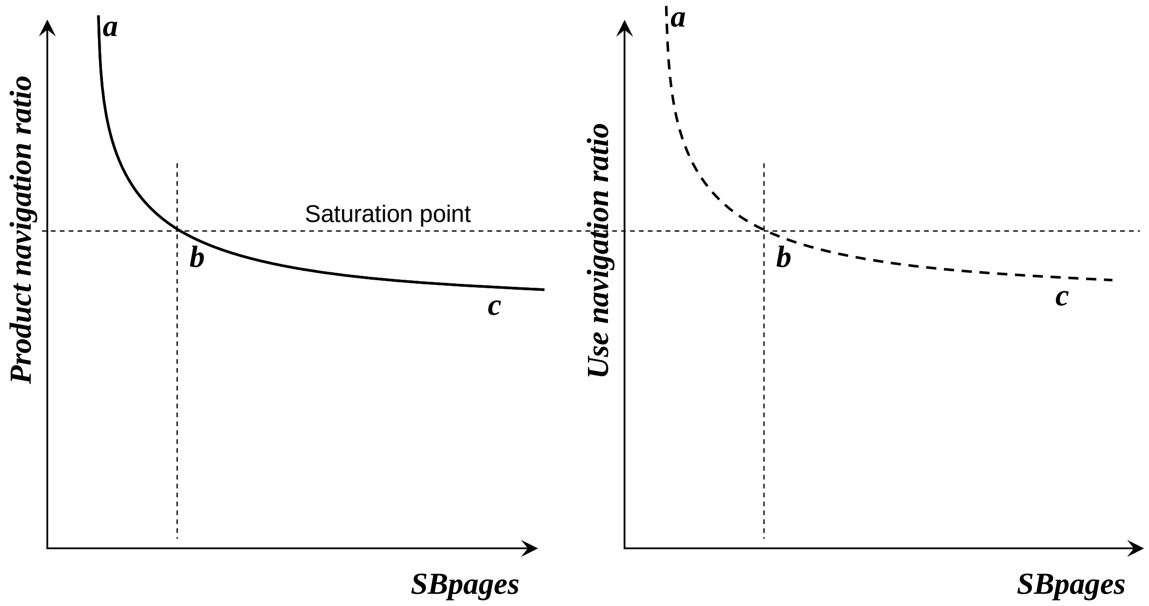


Figure 8.8 - *Navigation ratio and* ***SBpages*** *chart.*

The impact of ***SBpages*** on the calculated navigation ratio is illustrated by line ***a-b-c*** in the product navigation ratio graph to the left of Figure 8.8. This shows that as ***SBpages*** increases, the calculated navigation ratio value will decrease representing the fact that ***SBpages*** is an inhibitor of the navigation ratio. The construction of the MRA formula ensures that the calculated navigation ratio will never be zero and so the graph follows the line ***b-c*** as illustrated. It is suggested that continued research will show that the impact of ***SBpages*** during website usage will correspond with this calculated value as illustrated in the use navigation ratio graph on the right of Figure 8.8.

8.9.4 *Menus* - Total occurrences of all menus in site ÷ sum of different horizontal and vertical menus in site

MRA considers a grouped set of hyperlinks to be a menu. The utility of such a grouping is that it can be repeatedly and consistently displayed in order to support visitor interaction with the website. The links can be sitebound or they can be to other websites. A menu displays the set of hyperlinks in the same screen position, containing the same set of hyperlinks, and in the same order. A menu may be horizontal (header or footer) or vertical (list). Occasionally, a menu might be presented to achieve visual effect but MRA will classify it as a header, footer or list. The links in a menu can be text or graphics.

The navigation ratio ***Menus*** value is an indirect value comprised of the total occurrences of all menus in site and the sum of different horizontal and vertical menus in site. There are four counts in this indirect value. These are:

- Total occurrences of horizontal menus in site.
- Total occurrences of vertical menus in site.

which are added to give the total occurrences of all menus in site and

- Number of different horizontal menus in site.
- Number of different vertical menus in site.

which are added to give the sum of different horizontal and vertical menus in site.

MRA considers that as the occurrence of menus in a website increases the website is easier to navigate, so, the website's support for navigation will increase. In this case the navigation ratio will increase. However, it is possible to randomly generate menus such that a visitor could be presented with a different menu on each page. MRA considers that this approach would confuse visitors and consequently inhibit navigation and to comply with MRA operation the number of different menus in a site is used to reduce the calculated value of the navigation ratio. To reflect the combined effect of these criteria MRA constructs the indirect value ***Menus*** as a quotient as is expressed in the formula:

$$\frac{\textit{Total occurrences of all menus in site}}{\textit{Sum of different horizontal and vertical menus in site}}$$

The overall impact of ***Menus*** is to support visitor navigation, so, this indirect value is used as a multiplication (**X**) operator, i.e., a numerator in the Navigation Ratio Formula.

In order to confirm that the ***Menus*** quotient is a valid arrangement of these counts, and that it will properly reflect the expected navigation ratio, MRA tested nine alternative arrangements as listed in Figure 8.9.

Alternative arrangement	Site A Occurrences of all menus = 300 Sum of different horizontal and vertical menus = 3	Site B Occurrences of all menus = 300 Sum of different horizontal and vertical menus = 10
1. Addition	303	310
2. Subtraction	297	290
3. Division ***i***	300/3 100	300/10 30
4. Division ***ii***	3/300 0.01	10/300 0.03
5. Multiplication	900	3000
6. Average	151.50	155.00
7. Percent	1	3.33
8. Square Root	of 3 = 1.732	of 10 = 3.162
9. Square	9	100

Figure 8.9 – *Possible* ***Menus*** *values for example websites* **A** *and* **B**.

The figure considers two versions of the same website (Site A and Site B) where both are identical except for the sum of different horizontal and vertical menus in site. Both have 300 occurrences of menus (100 pages with 3 menus on each) but Site A has 3 different menus while Site B, which generates random menus, has 10 different menus. So, the counts used for calculating ***Menus*** are 300/3 for Site A and 300/10 for Site B. In this example, Site A is the richer site because it is less confusing and therefore better supports visitor navigation. Because Site A is the richer site, its calculate navigation ratio should be higher than that of Site B (all other values being equal). To achieve this result, and knowing that ***Menus*** will be uses as a numerator, ***Menus*** for Site A must have a higher value than ***Menus*** for Site B. Using the 300/3 and 300/10 counts, calculated indirect values for ***Menus*** for each of the nine alternative arrangements are shown in Figure 8.9. From this figure it can be seen that alternatives 2 and 3 are the only arrangements where ***Menus*** for Site A is higher than ***Menus*** for Site B. Of these, alternative 3 (Division *i*) is considered a closer representation of the 3 and 10 menus in the two websites in the example. Consequently, the MRA arrangement of the counts for ***Menus*** is a quotient as represented by alternative 3. In order to avoid discontinuity 1 is added if the denominator is zero.

Guidelines from the U.S. Department of Health and Human Services, and the ISO Draft International Standard considerations, which would support the inclusion of ***Menus*** are:

1. **HHS Guideline 7.8:** Use appropriate menu types (3 – 4).
2. **ISO/DIS 9241-151:** C. Supporting the user's navigation strategy
   C. Organising the navigation in a meaningful manner
   C. Minimising navigation effort
   C. Choosing suitable navigation structures.

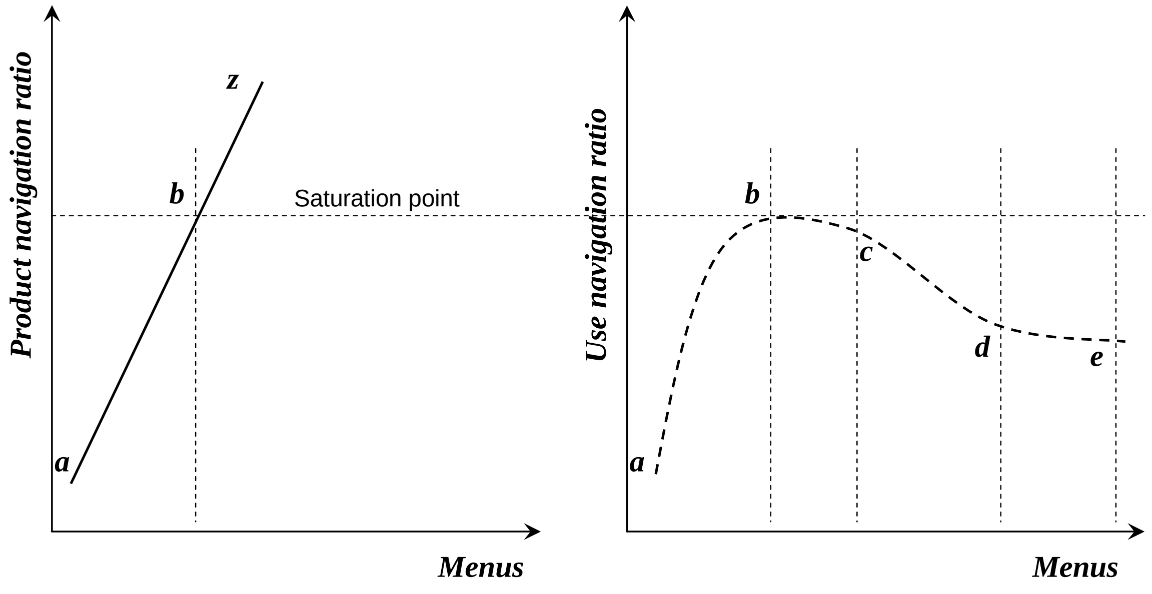


Figure 8.10 - *Navigation ratio and **Menus** chart.*

The impact of ***Menus*** on the calculated navigation ratio is illustrated by line ***a-b-z*** in the product navigation ratio graph to the left of Figure 8.10. This shows that as the value of ***Menus*** increases so too will the calculated navigation ratio increase.

In this way ***Menus*** supports engagibility as visitor access to consistent menus increases. However, it is suspected that as more menus are included they will make no significant difference to the visitor's engagibility experience. This is illustrated by the curve in the graph at ***b-c*** in the chart at the right of the figure. At this point it is suggested that as more menus are added the visitor's engagibility experience will become confusing and the engagibility ratio will decrease as illustrated by line ***c-d*** and that after a point ***d*** adding additional menus makes no difference to the visitor's engagement.

8.9.5 *Levels* - Number of levels below Home page

The MRA ***Levels*** value is a count of the number of hierarchical levels in the website's tree structure. The Home page is counted as level 0 and lower levels are indicated by the number of links in the path by which they are reached when forward linking – Figure 8.4. So, for example, the path to reach page 3.5 has 3 forward links (0.1 to 1.3; 1.3 to 2.5 (or 2.6, 2.7); 2.5 to 3.5) indicating level 3. The first level below the home page is accessed by 1 forward link from the Home page and is therefore level 1. The second level is accessed by 1 additional forward link from level 1 indicating 2 links in the path by which it is reached from the Home page, i.e., level 2. If this is the depth of the tree then the count for ***Levels*** is 2. Similarly for level 3 and level 4.

MRA considers that as the number of levels in a website increases the visitor takes longer to navigate to a destination. So, the website's support for sitebound hyperlinking will decrease. In this case the navigation ratio will decrease and to comply with MRA operation this value will be used as a division (**÷**) operator, i.e., a denominator.

Guidelines from the U.S. Department of Health and Human Services, and the ISO Draft International Standard considerations, which would support the inclusion of ***Levels*** are:

1. **HHS Guideline 16.1:** Organize information at each level of the website so that it shows a clear and logical structure to typical users (5 - 4).
2. **HHS Guideline 16.2:** Put critical information high in the hierarchy of a website (5 – 3).
3. **ISO/DIS 9241-151:** C. Making several levels visible
   C. Going back to higher levels
   C. Minimise the number of navigation steps needed to reach a certain piece of content.

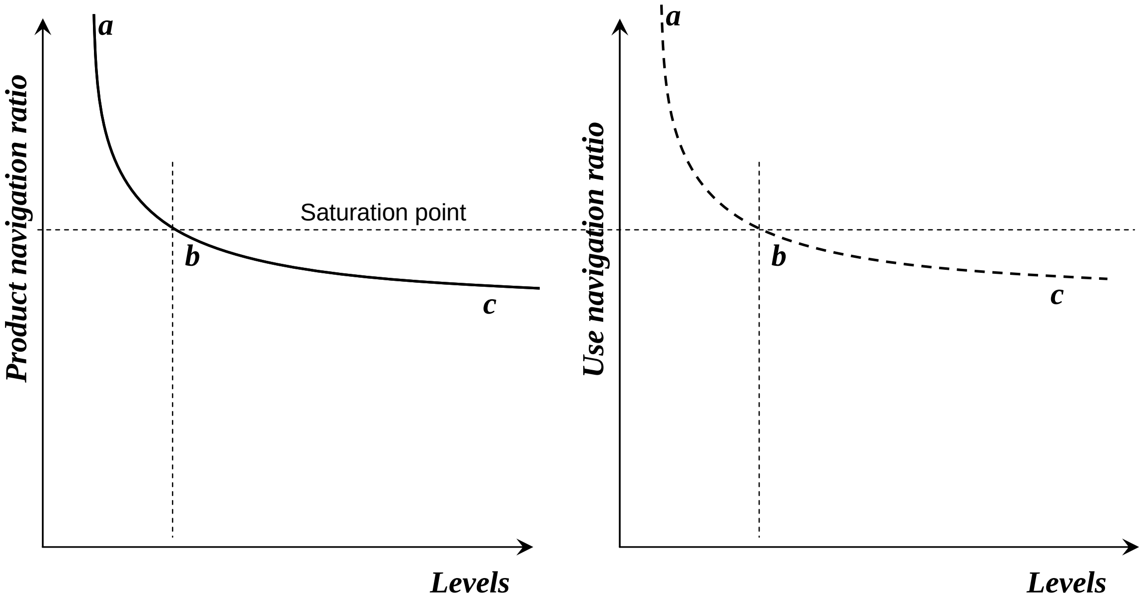


Figure 8.11 – *Navigation ratio and **Levels** chart.*

The ***Levels*** value is included to reflect the fact that the further down the website tree structure a page is located then the longer it will take a visitor to access that page. The visitor's engagement with that page is poorer because of its low position in the tree. So, as the number of levels increases the MRA calculated navigation ratio decreases as illustrated in the graph on the left of Figure 8.11. The construction of the MRA formula ensures that the calculated navigation ratio will never be zero and so the graph follows the line ***b-c*** as illustrated. It is suggested that continued research will show that visitor engagement with a website will correspond to this calculated value as illustrated in the Use navigation graph on the right of Figure 8.11.

8.9.6 *Home_Top* - Sum of Total occurrences of links to Home and Total occurrences of links to Top

MRA includes a backward linking value for returning to the Home page and for retracing within a site. This ***Home_Top*** value is the sum of two counts – Total occurrences of links to Home and the Total occurrences of links to Top. These are simple counts of all links (text and graphic) to the Home page and links from points within a page back to the top of the page. MRA considers that links to Home and links to the top of the page support visitor navigation, so, the website's support for sitebound hyperlinking will increase. In this case the navigation ratio increases. So, to comply with MRA operation this value will be used as a multiplication (**X**) operator, i.e., a numerator.

Home_Top is the third indirect value. However, it is a simple sum of two criteria, both of which support navigation and consequently there are no issues surrounding either of them being used as a denominator.

Guidelines from the U.S. Department of Health and Human Services, and the ISO Draft International Standard considerations, which would support the inclusion of ***Home_Top*** are:

1. **HHS Guideline 5.4:** Enable users to access the homepage from any other page on the website (4 – 3).
2. **ISO/DIS 9241-151:** C. Linking back to the home page
   C. Going back to higher levels
   C. Providing a 'step back' function.

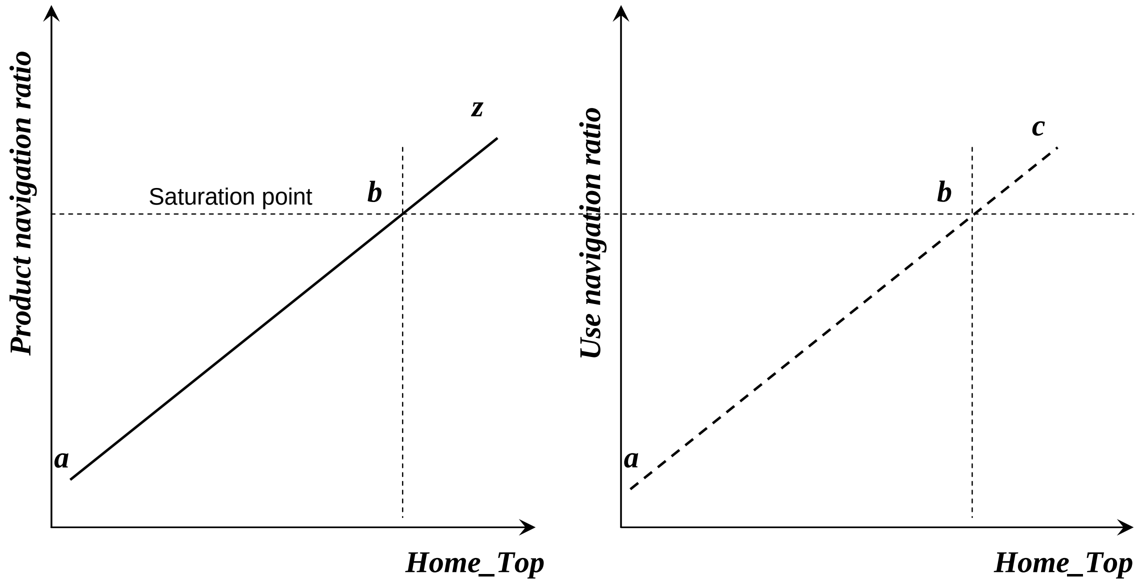


Figure 8.12 - *Navigation ratio and* ***Home_Top*** *chart.*

The graph on the left of Figure 8.12 illustrates how the calculated navigation ratio is impacted by ***Home_Top***. It is a straight line (***a-b-z***) indicating that as the total of links to Home and to Top of page increases so too does the calculated navigation ratio increase.

Generic links to Home and links to top of page are always well understood links to the same destination. There is nothing about the use of these links to cause visitor confusion nor are there any issues about them which diminish visitor ease of navigation. Consequently, it is anticipated that the impact of ***Home_Top*** on the calculated use navigation ratio will be a straight line as illustrated to the right of Figure 8.12.

8.9.7 *Search* - Number of pages supporting site search engine

The final value used for constructing the Navigation Ratio Formula is the Number of pages supporting site search engine. This value's abbreviated reference is ***Search*** and it is a count of the number of active HTML pages that support a site search engine. Its use within the Navigation Ratio Formula is such that as the number of pages supporting a site search engine increases the site is easier to navigate and, so, the website's support for sitebound hyperlinking will increase. In this case the navigation ratio increases. So, to comply with MRA operation this value will be used as a multiplication (**x**) operator, i.e., a numerator.

Guidelines from the U.S. Department of Health and Human Services, the ISO Draft International Standard considerations, and the Joint Information Systems Committee for higher education (JISC) guidelines, which would support the inclusion of ***Search*** are:

1.	**HHS Guideline 17.1:**	Provide a search option on each page of a content-rich website (5 – 2).
2.	**ISO/DIS 9241-151:**	C. Availability of search
3.	**JISC Guideline:**	Provide for repeat searches at top and bottom of page.

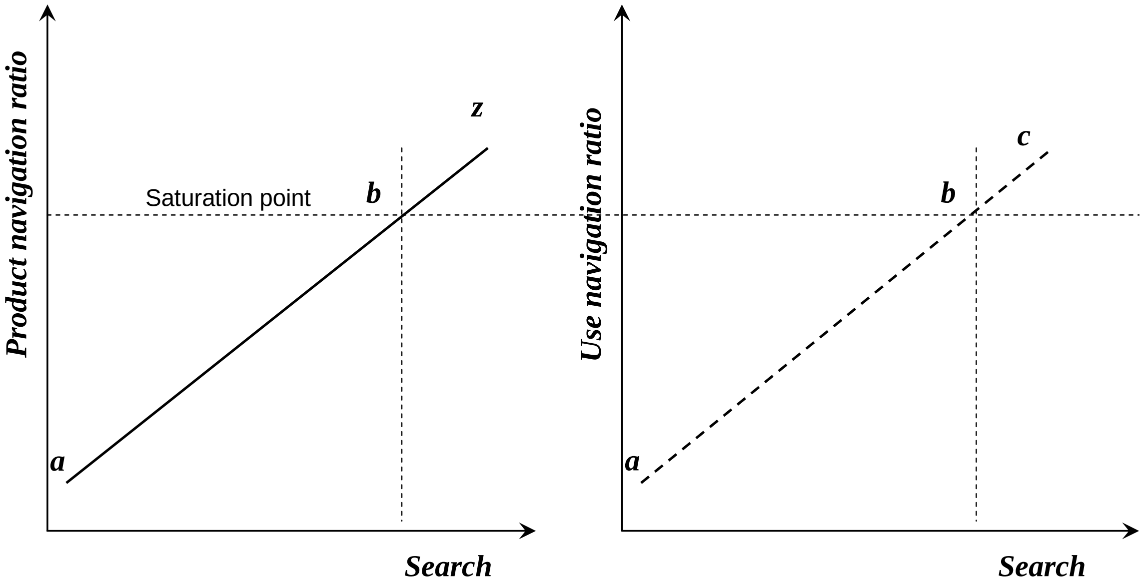


Figure 8.13 - *Navigation ratio and* ***Search*** *chart.*

The ***Search*** value graph illustrated on the left of Figure 8.13 is a straight line representing the increase in navigation ratio as the number of pages supporting a site search option increases. MRA recommends one search field on each page (based on the websites in the eCommerce study) but the Joint Information Systems Committee for higher education (JISC) guidelines recommend two for academic websites. Confusion is not considered to be an issue because of the generic nature of ***Search*** and so the same straight line graph is illustrated in the use navigation ratio chart on the right of the figure.

8.9.8 Normalising navigation values for website comparison

Where MRA is used for comparing a set of websites, the website values used in the MRA formula need to be normalised to take account of the fact that each site consists of different numbers of pages. The page counts for the websites in the eCommerce study in this research are 118, 96, 104, 89 and 130. To take account of these differences it is appropriate to normalise all values relative to some common count and the 100 pages in the target website is chosen as that common value. There are seven values used by the MRA Navigation Ratio Formula and five of these seven (***SBlinks, SBpages, Menus, Home_Top, and Search***) rely directly on HTML page counts. The two remaining values (***SBHome and Levels***) are less influenced by page counts during the website’s design. The normalisation calculation in this situation could take the form of first calculating each site’s navigation ratio and then multiplying each calculation by a conversion factor of ***100/p***, where ***p*** is the number of HTML pages in the website. An alternative form of normalisation would be to normalise each value and indirect value in advance of calculating the navigation ratio. This calculation would also use the conversion factor ***100/p***. However, in this second alternative a decision can be made as to the correctness of applying the conversion factor to the two values that do not rely directly on page counts.

During tests, the research shows that using the second alternative MRA calculated the same normalised ratio for all sites irrespective of whether ***SBHome and Levels*** are normalised or not.

The calculation of the navigation ratio as explained in Section 8.9 later in this chapter is based on normalized values and because of the consistency demonstrated by the tests, ***SBHome and Levels*** are left unnormalised.

8.9.9 Weighting

At this stage of MRA development all values have been considered to be of equal importance. It is unlikely to be true that all values will be of equal relative importance, so, MRA values may need to be weighted. This weighting will be influenced by such issues as the objective of the website or the domain where it will be used. For example, the weighting process might need to consider if a site search option better supports navigation than the number of links in a site. Another example might be the critical importance of having a ‘contact us’ option compared with having a product configurator as part of the website’s interactivity. In both examples it would be appropriate to consider what is more critical for visitor engagement. It might be mandatory to have a product configurator in some websites while it might be discretionary for others. In addition, weighting used in one study might be different to that weighting needed for a different study, for example, retail compared with banking. This section discusses matters relating to relative importance and how values might be weighted in the MRA formulae. The discussion is mainly in the context of navigibility.

8.9.9.1 Weighting the values in the navigation ratio

As shown in Figure 8.2 the U.S. Department of Health and Human Services (HHS) Research-Based Web Design and Usability Guidelines (Koyani *et al*., 2003) include simple scores for relative importance and strength of evidence. These scores use a scale of 1 to 5 where 5 is high. These scores confirm that some of the values in the Navigation Ratio Formula have a higher significance than others. This higher significance is correctly represented in the ratio formula by weighting each of the formula’s values. Based on these relative importance scores a simple weighted list of the navigation ratio values might be:

SBlinks	4
SBHome	5
SBpages	Varies from 4 to 2
Menus	3
Levels	5
Home_Top	4
Search	5

Note that the guideline values are generally in the top half of the 1 to 5 scale thereby indicating the importance of the criteria used by MRA. The guidelines also include an overall relative score which is the product of relative importance and strength of evidence. Using the overall relative score might be an alternative approach to weighting the formula values.

However, it is necessary to fully understand how these relative importance scores relate to an eCommerce study. For example, the HHS guideline 17.1 advises that using a ***Search*** option would relate to content-rich (text, graphics and pictures per HSS Glossary p199) websites but that searches do not add value on other types of websites. So the weighting of ***Search*** for an eCommerce website might be different to its weighting for a content-rich website.

Another consideration that might be investigated is the significance, if any, of occurrences, distribution and proximity as introduced in Section 8.8.2. In this investigation it will be realised that all three considerations are not impacted by all criteria and, therefore, might suggest different relative importance of the criteria.

8.9.9.2 Weighting the navigation ratio in the navigability quotient

In order to calculate the navigability quotient, the navigation ratio and the surf ratio are combined in a single formula. It may be necessary to weight these two ratios depending on the purpose of the website being studied. For example, there is an obvious and easily understood difference between the weighting of navigation and surfing if the website is a portal. In this case the website is intended to redirect visitors to appropriate external sites of interest. That is, it supports surfing. Using Pareto’s principle, the 80/20 rule (Pareto, 1896), it would be reasonable to estimate or expect that the surf ratio would represent approximately 80% of navigability and that the navigation ratio within the portal site might represent 20%. And it would be reasonable to estimate or expect that these percentages would be reversed for an eCommerce website seeking to retain visitors and convert them to purchasers. So, validation of MRA weighting would establish accurate values to replace the 80/20 divide. Similar considerations might be examined in the context of different business sectors such as manufacturing, retail, education and training, professional services, agriculture, hospitality and tourism, government and administration, healthcare, insurance and finance, and military. These issues would be considered during empirical validation.

A driver for deciding the extent of external surfing from a website might be the need to prevent loss of hard won customers to competitor websites. Another driver might be the need to ensure the bone fide nature of external links. In this regard, site URLs that are linked to can cease to be maintained by the original owner and may be acquired by others offering an offensive product, service or message or may be otherwise inappropriate to the eCommerce site in the study. Keeping external links to a minimum can address this situation.

The assistive ratio raises the issue of compliance. Legislation is now in place that website owners and designers must comply with, so, the assistive ratio's inclusion in a formula needs weighting accordingly.

8.9.9.3 Weighting quotients in the engagibility index

The engagibility index consists of three quotients, i.e., navigability quotient, interactivity quotient and the appeal quotient. In the eCommerce study, support for interacting with a product configurator might be critical to the engagibility of the site while support for navigation might be of less importance. So, weighting of the interactivity quotient might be higher.

This section has discussed example issues associated with weighting. A full investigation of all weighting issues needs to address the relative importance of all of the 67 MRA criteria and values, all eight MRA calculated ratios and all three engagibility quotients. Weighting the values, calculated ratios and quotients is a validation issue and it is proposed in Chapter 9 that such weighting needs to be addressed in detail as part of continuing research. Meanwhile, the approach to weighting in this chapter continues to regard the navigation ratio values to be of equal relative importance and that each value is weighted at 1.

8.9.10 Tabulating the counts and indirect values

The counts and indirect values associated with navigation are tabulated in Table 8.1. Two points must be noted:

- **Normalised values** - The values and indirect values are normalized in advance of calculating the navigation ratio. Because of the consistency demonstrated during preliminary research tests (explained in Section 8.9.8) ***SBHome*** and ***Levels*** are left unnormalised.

- **Zero adjusted formula** - the formula used to calculate the ratio will 'add 1 only when a value is zero'.

Table 8.1 – *Navigation ratio values*

		eCommerce website study					
		Websites					
		BMIbaby	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		118	96	104	89	130	*1*
		Navigation ratio values					
		Un-normalised					
SBlinks	x	4023	2979	967	1082	2447	*0*
SBHome	x	31	33	24	15	29	*0*
SBpages	÷	1.00	1.23	1.16	1.02	1.00	1.00
Menus	x	118	92	64	61	12	1.00
Levels	÷	5	2	4	2	3	*0*
Home_Top	x	346	270	131	349	268	*0*
Search	x	0	0	0	87	126	*0*
		Navigation ratio values					
		(Normalised to 100 pages)					
SBlinks	x	3409.32	3103.13	929.81	1215.73	1882.31	*0*
SBHome	x	31.00	33.00	24.00	15.00	29.00	*0*
SBpages	÷	0.85	1.28	1.11	1.15	0.77	1.00
Menus	x	100.00	95.83	61.54	68.16	9.30	1.00
Levels	÷	5.00	2.00	4.00	2.00	3.00	*0*
Home_Top	x	293.22	281.25	125.96	392.13	206.15	*0*
Search	x	*0.00*	*0.00*	*0.00*	97.75	96.92	*0*

The websites are represented by v_1, v_2, v_3, v_4 and v_5. The first panel of values shows the page count for each of the websites. The centre panel tabulates the seven values and indirect values which are derived in accordance with the explanations in Sections 8.9.1 to 8.9.7. These are unnormalised values. The bottom panel shows those values that are mainly influenced by the page count, normalized on the basis of 100 pages in each website, i.e., ***SBHome*** and ***Levels*** are left unnormalised. The 100 page has been selected to conform to a 100 page target website. In this format, the values further support item 1 of the challenges in Section 7.6 in that they are navigation specific. However, in this summary form these values provide no meaningful insight into the websites' navigation or into any other aspect of the quality of the websites. So, the first step towards interpreting them is to evaluate them using a similarity graph formula (Johnsonbaugh, 2004) as shown in Table 8.2.

Table 8.2 - *Website navigation similarity (ns)*

$$ns(v, w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4| + |p_5 - q_5| + |p_6 - q_6| + |p_7 - q_7|$$

$ns(v_1, v_2)$ 328			
$ns(v_1, v_3)$ 2693	$ns(v_2, v_3)$ 2374		
$ns(v_1, v_4)$ 2441	$ns(v_2, v_4)$ 2142	$ns(v_3, v_4)$ 668	
$ns(v_1, v_5)$ 1806	$ns(v_2, v_5)$ 1485	$ns(v_{3,} v_5)$ 1188	$ns(v_4, v_5)$ 928

A low value indicates website navigation similarity.

Using Johnsonbaugh's formula - $ns(v, w) = |p_1\text{-}q_1| + |p_2\text{-}q_2| + |p_3\text{-}q_3| + |p_4\text{-}q_4| + |p_5\text{-}q_5| + |p_6\text{-}q_6| + |p_7\text{-}q_7|$- navigation similarity is calculated for all of the websites in the study. The calculation uses the normalized set of values. These calculations show that websites $\boldsymbol{v_1}$ and $\boldsymbol{v_2}$ are the most similar. These similarity calculations do not indicate whether this similarity is rich or poor (i.e., if the sites' navigation structures support engagibility), nor do they suggest a target value for comparison purposes. The reader will realise that the *ns(v, w)* values returned by the formula are for pairs of websites. An individual value for each website is missing. However, the similarity calculations support a nearest neighbour concept and they also support clustering as explained in Section 7.5. Consequently, similarity is included in this benchmark comparison study. Metric Ratio Analysis addresses website benchmark comparison by constructing a Navigation Ratio Formula and using the values already derived and set out in Table 8.1 to calculate an individual ratio for each website.

8.10 Define predictor requirements

The predictor requirements are as clarified in Section 8.9 of this chapter. For convenience these are:

SBlinks	Numerator (**X**)
SBHome	Numerator (**X**)
SBpages	Denominator (**÷**)
Menus	Numerator (**X**)
Levels	Denominator (**÷**)
Home_Top	Numerator (**X**)
Search	Numerator (**X**)

8.11 Construct formula

To construct the Navigation Ratio Formula (NRF), values and indirect values are arranged as numerators or denominators. This arrangement is influenced by the predictor requirements of the ratio, that is, where a predictor indicates that a value will increase richness, then, the value is used as a numerator (the operator is a multiplier, **X**) and where a predictor indicates that a value will decrease richness, then, the value is used as a denominator (the operator is a devisor, **÷**). The formula specifically addresses matters of discontinuity. The constructed formula is shown in Figure 8.14.

Navigation Ratio Formula

The Navigation Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Navigation Ratio Formula

$$\frac{\{(SBlinks+x)\times 1\}^{1}\times\{(SBHome+x)\times 1\}^{1}\times\{(Menus+x)\times 1\}^{1}\times\{(Home\_Top+x)\times 1\}^{1}\times\{(Search+x)\times 1\}^{1}}{\{(SBpages+1)\times 1\}^{1}\times\{(Levels+1)\times 1\}^{1}\times C}$$

Where

$SBlinks$ = Total occurrences of sitebound links in the website.

$SBHome$ = Number of sitebound links from Home page.

$SBpages$ = Number of active HTML pages in the site ÷ Number of pages containing sitebound links.

$Menus$ = Total occurrences of all menus in site ÷ sum of different horizontal and vertical menus in site.

$Levels$ = Number of levels below Home page.

$Home\_Top$ = Sum of Total occurrences of links to Home and Total occurrences of links to Top.

$Search$ = Number of pages supporting site search engine.

x = 1 or 0

C = 1000000 = A navigation ratio constant arrived at when applying the formula.

Figure 8.14 – *Navigation Ratio Formula.*

In this example, the seven values are used with one scaling constant. The scaling constant for the navigation ratio in this study is 1000000 and it is introduced in order to reduce the magnitude of results being calculated by the formula. It is decided on by reference to the first calculated results and applying the constant value in order to simplify the calculated ratios. When calculating other ratios a different number of values and a different constant might be necessary.

8.12 Apply formula to calculate ratio

Having derived a Navigation Ratio Formula, it is populated with values for the five websites in the eCommerce study in order to calculate individual navigation ratios for each website. The set of ***individual ratios*** as calculated using the Navigation Ratio Formula is illustrated in Table 8.3. In these calculations the values are normalized (excluding ***SBHome*** and ***Levels***) and the formula adds 1 to ***Search*** for websites v_1, v_2 and v_3.

Table 8.3 - *Table of calculated individual navigation ratios*

eCommerce website study

Websites

		BMIbaby	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**
		v_1	v_2	v_3	v_4	v_5
p(age) count		118	96	104	89	130
		Navigation ratio values (Normalised to 100 pages)				
SBlinks	x	3409.32	3103.13	929.81	1215.73	1882.31
SBHome	x	31.00	33.00	24.00	15.00	29.00
SBpages	÷	0.85	1.28	1.11	1.15	0.77
Menus	x	100.00	95.83	61.54	68.16	9.30
Levels	÷	5.00	2.00	4.00	2.00	3.00
Home_Top	x	293.22	281.25	125.96	392.13	206.15
Search	x	*0.00*	*0.00*	*0.00*	97.75	96.92
Individual ratio		731.37	1076.43	38.92	20727.29	4394.43

For each of the websites the individual navigation ratios are **731.37**, **1076.43**, **38.92**, **20727.29** and **4394.43**. So, using Metric Ratio Analysis all of these websites now have an individual measure (for the navigation ratio) thus addressing challenge number 2.

Challenge 3 is concerned that there is no indication whether the similarity between the websites is rich or poor. Specifying a target solution for a navigation rich website addresses this.

8.13 Identify target solution

In order to address challenge 3 (Section 7.5.1, i.e., if the individual measure is good or bad), Metric Ratio Analysis uses benchmark comparison. To support this comparison, MRA sets a target website as the benchmark and all websites in the eCommerce study are compared to this target. The target uses the same set of 67 criteria as each website in the study and a full set of counts and values is defined for the target. The counts and values for the target criteria are derived to suit the specific circumstances of the comparison being made and by considering average, maximum and calculated values, which represent the best achievements of the five sites in the website study.

Based on the profile of the five websites in the eCommerce study the average number of pages in the websites was 103. In this study it is considered that a 100-page website is a suitable compromise for the size of the target website. This is a universally acknowledged and understood figure and is appropriate considering the size of the sites being studied. The target navigation ratio values for such a site are illustrated at the left of Table 8.4 in the **Target (v_o)** column. MRA considers that there would be two (2) horizontal menus and one (1) vertical menu on each page. A total of seven sitebound links is considered appropriate for the two horizontal menus with five links from the vertical menu. Two additional sitebound links from the body of each page are also included. This means that there is a total of 14 sitebound links on each page giving a value of 1400 for ***SBlinks***. The 14 sitebound links on each page includes the Home page, so, in this case, ***SBHome***, the count of sitebound links on the Home page is 14. It is desirable that all pages in the website will have sitebound links, so, the calculated value for ***SBpages*** is 1, that is, 100 active HTML pages ÷ 100 pages containing sitebound links. The target ***Menus*** value is 100, that is, 100 active HTML pages in the website each with three menus giving a total of 300 occurrences of all menus in the site. This is divided by 3, it being the sum of the different horizontal (2) and vertical (1) menus in the site. In the target website, ***Levels*** would be 3, it being a simple rounded average of the five values in the study. MRA considers two links to Home and two links to Top of page are appropriate on each HTML page in the site giving a value for ***Home_Top*** at 400. Finally, a target site would include a site search option on each page, so, ***Search*** would be 100. Being based on a 100 page website the target values are considered to be normalized for this study and using the same Navigation Ratio Formula a positive figure at ***26133.33*** is calculated for this target website as illustrated in Table 8.4. The target represents an achievable website (engagibility rich) and a set of target counts and values is included in Appendix B.

Table 8.4 – *Website values and individual ratios - Target added*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Navigation ratio values					
			(Normalised to 100 pages)					
SBlinks	x	1400.00	3409.32	3103.13	929.81	1215.73	1882.31	*0*
SBHome	x	14.00	31.00	33.00	24.00	15.00	29.00	*0*
SBpages	÷	1.00	0.85	1.28	1.11	1.15	0.77	1.00
Menus	x	100.00	100.00	95.83	61.54	68.16	9.30	1.00
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	*0*
Home_Top	x	400.00	293.22	281.25	125.96	392.13	206.15	*0*
Search	x	100.00	*0.00*	*0.00*	*0.00*	97.75	96.92	*0*
Individual ratio		26133.33	731.37	1076.43	38.92	20727.29	4394.43	0.00

The Navigation Ratio Formula is validated at a lower limit. The lower limit is a 1-page website which is considered as a minimum or worst case example. In this case there is no need for sitebound links so, ***SBlinks*** = 0 and ***SBHome*** = 0, there are no levels below the Home page and there is no need for menus. Links to Top of page could be provided but in a worst case situation they are deemed not to be. A site search component is not considered to be necessary. The indirect values ***SBpages*** and ***Menus*** are both 1 as a result of adding 1 to their numerator and denominator when calculating their indirect value. All other target values that have a value of zero have 1 added by the Navigation Ratio Formula when calculating the navigation ratio. The Navigation Ratio Formula calculates a figure at ***0*** for this lower limit website. The values for this example are illustrated at the right of Table 8.4 in the **1-page website** column.

The full set of target values used in the website study is set out in Appendix B. In order to complete further comparison evaluations an evaluator might build on this set of target values. Alternatively, the evaluator might devise a new set which is considered more appropriate to a new study or use an internationally agreed set of values for an optimum website.

8.14 Perform analysis

To analyse the success of using Metric Ratio Analysis in this instance, similarity is revisited. Individual ratios are next converted to a scale of 1 - 100 so that they can be better represented graphically (to mirror the similarity graph approach). Finally, the results are interpreted and reviewed as implied by Metric Ratio Analysis. From the values in Table 8.4, similarity results using the target solution can be derived as shown in Table 8.5 for the dissimilarity functions $s(v_o, v_1)$ to $s(v_o, v_5)$.

Table 8.5 – *Website navigation similarity (ns) - Target added*

$$ns(v, w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4| + |p_5 - q_5| + |p_6 - q_6| + |p_7 - q_7|$$

$ns(v_1, v_2)$ 328			
$ns(v_1, v_3)$ 2693	$ns(v_2, v_3)$ 2374		
$ns(v_1, v_4)$ 2441	$ns(v_2, v_4)$ 2142	$ns(v_3, v_4)$ 668	
$ns(v_1, v_5)$ 1806	$ns(v_2, v_5)$ 1485	$ns(v_{3,}\ v_5)$ 1188	$ns(v_4, v_5)$ 928

$ns(v_o, v_1)$	2235
$ns(v_o, v_2)$	1946
$ns(v_o, v_3)$	894
$ns(v_o, v_4)$	228
$ns(v_o, v_5)$	785

A low value indicates website navigation similarity.

Table 8.6 – *Calculated navigation ratios – Scaled measures added*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Navigation ratio values					
			(Normalised to 100 pages)					
SBlinks	x	1400.00	3409.32	3103.13	929.81	1215.73	1882.31	*0*
SBHome	x	14.00	31.00	33.00	24.00	15.00	29.00	*0*
SBpages	÷	1.00	0.85	1.28	1.11	1.15	0.77	1.00
Menus	x	100.00	100.00	95.83	61.54	68.16	9.30	1.00
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	*0*
Home_Top	x	400.00	293.22	281.25	125.96	392.13	206.15	*0*
Search	x	100.00	*0.00*	*0.00*	*0.00*	97.75	96.92	*0*
Individual ratio		26133.33	731.37	1076.43	38.92	20727.29	4394.43	0.00
Scale 1-100		*100*	*2.80*	*4.12*	*0.15*	*79.31*	*16.82*	*0.00*

Table 8.6 includes a conversion of the individual ratios to a scale of 1-100 and the results are styled scaled ratios. This scale sets the target calculated ratio to 100, and calculates a scaled measure for each individual ratio using the formula:

$$\text{Scaled ratio} = \frac{Individual\_ratio \times 100}{Target\_Individual\_ratio}$$

Or,

$$\text{Scaled ratio} = Individual\_ratio \times k \quad where\ k = \frac{100}{Individual\_target\_ratio}$$

If as a result of excessively including some of the parameters (exceeding a target value) in Table 8.6, a calculated scaled ratio exceeds the 100 target then for such websites it might be appropriate to cap that scaled ratio such that:

```
if      $scaled\ ratio > 100$
        $scaled\ ratio = 100$
endif
```

Future research would be necessary to fully understand how this scaling should be weighted to reflect this excessive inclusion of parameters.

Now, returning to the three challenges in Section 7.6 all three have been addressed by Metric Ratio Analysis. viz.

1. It is clear what the calculated ratio relates to - website navigation ratio.
2. Each website now has its own individual value - calculated individual ratio.
3. It is possible to compare each website's ratio with a target solution.

8.14.1.1 Illustration

Returning to Table 8.5 to consider the similarity graph approach and using the requirement that, $ns = 1000$ the websites can now be grouped in two classes:
$\{v_o, v_3, v_4, v_5\}$, $\{v_1, v_2\}$ as illustrated in Figure 8.15.

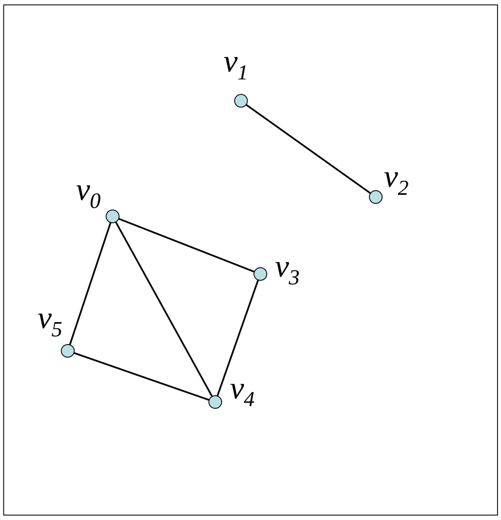
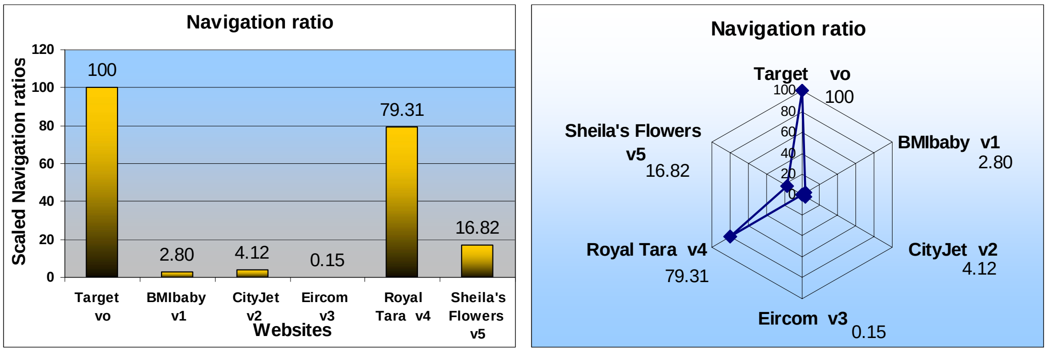


Figure 8.15 – *Similarity graph for websites in Table 8.5 with ns = 1000*

The value *ns = 1000* in this example is an arbitrary selection, chosen in the absence of any empirical alternative. This type of numerical classification of websites is an uncharted domain of study with significant future challenges. These challenges might address the fact that websites can be clustered to reflect business sectors (sites offering full eCommerce might cluster differently to information dispensing websites) for which empirical values to replace *ns = 1000* can be established by future research. This in turn will support evaluators to know that their website designs comply with acknowledged *ns* values for their chosen business sector. For this reason graph theory comparison is retained in this study and a set of similarity calculations is always presented with each ratio.

To support analysis of the individual ratios, two charts are illustrated in Figure 8.16. Both use the same data, so, they illustrate the same results in formats that support different reading. Charts ***a*** presents the results relative to the horizontal axis. The target solution is illustrated by the column on the left. The same data are presented as a Kiviat diagram in the chart ***b***. In each case the proximity of **website 4** to the target clearly contrasts with how far removed the other websites are.



***a** – Column diagram* ***b** – Kiviat diagram*

Figure 8.16 – *Charting the navigation ratio.*

8.14.1.2 Interpretation and review

From Figure 8.15, for *ns = 1000*, graph theory confirms that websites v_o, v_3 v_4 and v_5 are in the same class, that is, they are similar to each other and dissimilar to v_1 and v_2.

As shown in Table 8.5, the lowest value returned by the similarity formula for website similarity is $ns(v_o\ v_4) = 228$ for website v_4. Because v_o. is the target solution and because of the similarity with this solution it implies that website v_4 is the closest to supporting website navigation. But it does not indicate how far from the target the individual website is nor does it help to determine how much adjustment or improvement is necessary in order to achieve the target.

The similarity formula returns a value of *2235* for $ns(v_o\ v_1)$. Because of this dissimilarity it might be reasonably to conclude that website v_1 is the least supporting of website navigation. However, Metric Ratio Analysis would suggest differently and that website v_3 is furthest from the target requirements. So, while similarity graph theory provides a foundation for identifying similarity and clustering between the websites it does not support a complete understanding. A more meaningful comparison with a sharper focus is provided by MRA.

Using Metric Ratio Analysis it is possible to calculate individual navigation ratios in order to compare the degree that the five websites in the study support sitebound hyperlinking. The calculated individual ratios are ***731.37, 1076.43, 38.92, 20727.29*** and ***4394.43***. The study shows that an overall individual ratio of ***26133.33*** is a target value for the website owners to seek to achieve. From this, the study shows that **website v_4** is the closest in this set to the target site. While its individual ratio does not achieve the target, other website owners might want to equal this achievement and add additional (or adjusted) navigation in order to achieve ***20727.29***. Achieving this will provide their visitors with a similarly rich navigation experience. Adding additional or adjusting navigation can be done by reference to the website's profile values shown in Table 8.6. For example, **website v_1** has significantly exceeded ***SBlinks*** and may be causing a confused visitor experience. The same website has a ***Search*** value of 0, indicating that the site has significantly under achieved in the provision of a site search option. Setting ***Levels*** to 5 seems excessive in the context of the five websites in the eCommerce study. So, by reference to each website's profile, design improvements can be identified resulting in an improved navigation ratio.

Another outlier-type value is ***Menus*** in **website v_5**. Its value 9.30 in Table 8.6 results from randomly generating menus and is creating an inconsistency that breaches the rules for consistency in quality user interface design as advocated by researchers like Shneiderman (1987) and Nielsen (1993). MRA considers that adding menus to a website will support navigation, so, an increase in ***Menus*** should predictably result in a ratio increase. However, if this increase is achieved through using different menus this will cause the ratio to decrease thereby indicating visitor confusion and predictably cause the visitor experience to decrease. In this situation ***Menus*** lies along the line ***c-d-e*** in Figure 8.10. So, by reference to the profile of the website design improvements can be identified resulting in an improved navigation ratio. So, an added advantage of Metric Ratio Analysis is that when used in conjunction with the website's profile the evaluator gets an indication of how much adjustment or improvement is necessary.

MRA considers that websites in the study that return values below the target, while fully navigable by visitors to the website, are not achieving their full engagibility potential and would gain from further design review. Websites with a figure above the target have over subscribed to navigation and have probably over invested. However, this needs to be considered in conjunction with the maximum and minimum range (see section 8.9) wherein calculated website navigation ratios would be valid.

As illustrated in Table 8.6, further design work could be done on **websites** v_1, v_2 and v_3 in order to improve their support for sitebound hyperlinking. By reference to the ***Search*** values for these websites (0) it is clear that if more search functionality is added their individual ratios will increase towards the target value. Also, ***SBlinks*** for v_5 is higher than the target, so, it is appropriate to investigate if ***SBlinks*** for v_5 is and over investment. When applying this style of analysis the absence or over provision of a parameter can be seen to be significant. This type of analysis is not convenient using graph theory.

For completeness, Table 8.7 presents similarity values for the target solution and the individual ratios of the five websites.

Table 8.7 – *Navigation ratio similarity (nrs)*

$$nrs(v,w) = |p_1 - q_1|$$

$nrs(v_o, v_1)$	25402
$nrs(v_o, v_2)$	25057
$nrs(v_o, v_3)$	26094
$nrs(v_o, v_4)$	5406
$nrs(v_o, v_5)$	21840

In the single pairwise calculation the ratio similarity is manifest, i.e., **website** v_4 is closest to the target solution and **website** v_3 is furthest removed. The reader will realize that in order to establish how much adjustment or improvement is needed (as per challenge 2) individual ratios as calculated by Metric Ratio Analysis are a necessary requirement, hence the value of the MRA approach.

8.15 Comments on the target website

This section addresses matters relating to the target website validity and explains how maximum and minimum range values might be applied.

8.15.1 Matters relating to the target website validity

For benchmark comparison, MRA uses a target website which is deemed to be an achievable website design and would be indicative of a rich engagibility experience. This target website suggests desirable counts for the various criteria – for not dissimilar research, Schneidewind (1994), uses the term critical values. For example, what is a desirable number of menus that a website should use? Should it be three different menus or would ten different be acceptable? And then, how many links should be included in each menu? Another consideration is how many levels are appropriate to visitor engagement? Would three be sufficient and would twenty be excessive? Another issue is how many sitebound links should be included on the Home page? As the number increases does the website tend towards a portal? The number of pages in the website would also be a consideration. So, it is necessary for website designers and developers to understand how best to specify a target website in a specific domain or business sector. To assist them it is necessary to know the range within which each value in the ratio formula might be bounded. Knowing which business sector applies it will also be necessary to consider the goals of the website and typical website goals that are mentioned in the HHS guidelines include educate, inform, entertain and sell. Having studied a selection of websites, the MRA approach was able to limit its study to a set of retail sites whose goal was to sell products. Based on the custom and practice in these websites it was possible to identify values for a target website. For example, early indications would suggest that three menus is custom and practice for the selected websites and that such menus contain approximately seven hyperlinks each. The study also shows that approximately 100 active HTML pages are used to develop these sites. Using this research it is possible to get an indication of how maximum and minimum range values appropriate to a study can be identified.

8.15.2 Maximum and minimum range values

It would be inappropriate to use statistical methods which rely on only 5 retail websites from an eCommerce website site study to derive a range wherein all calculated website navigation ratios would be valid. So, at this stage in MRA development it is more appropriate to define sets of maximum and minimum navigation ratio values appropriate to the 5 retail websites in the study. Proposed sets of such values appropriate to this eCommerce study are set out in Figure 8.17.

		Navigation ratio range		
		Minimum 90 pages	**Target 100 pages**	**Maximum 110 pages**
SBlinks	**x**	1080	1400	1650
SBHome	**x**	12	14	15
SBpages	÷	1	1	1
Menus	**x**	90	100	110
Levels	÷	3	3	3
Home_Top	**x**	360	400	440
Search	**x**	90	100	110
Individual ratio		12597	26133	43923
Scale 1-100		*48.20*	*100.00*	*168.07*

Figure 8.17 – *Proposed sets of maximum and minimum target range values.*

The target website has a page count of 100 pages and MRA would consider that a range from 90 to 110 pages would be a valid range for page counts.

Using the same approach that was used to derive the set of target values, MRA considers that for the minimum website in the range there would be one (1) horizontal menu and one (1) vertical menu on each page. Six sitebound links would be minimum for the two horizontal menus with five links from the vertical menu. One additional sitebound link from the body of each page would also be minimum. This means that there is a total of 12 sitebound links on each page giving a value of 1080 for ***SBlinks***. This 12 sitebound links on each page includes the Home page, so, in this case, ***SBHome***, the count of sitebound links on the Home page is 12. MRA requires that all pages in the website will have sitebound links, so, the calculated value for ***SBpages*** is 1, that is, 90 active HTML pages ÷ 90 pages containing sitebound links. The target ***Menus*** value is 90, that is, 90 active HTML pages in the website each with two menus giving a total of 180 occurrences of all menus in the site. This is divided by 2, it being the sum of the different horizontal (1) and vertical (1) menus in the site. In the minimum website, ***Levels*** would be 3, it being a simple rounded average of the five values in the study and being consistent with the 90/100/110 website page size. MRA considers that two links to Home and two links to Top of page are appropriate on each HTML page in the site giving a value for ***Home_Top*** for the minimum in the range at 360 {(90 x 2) + (90 x 2)}. Finally, a minimum site would include a Site Search option on each page, so, ***Search*** would be 90. Using the same Navigation Ratio Formula a positive figure at ***12597*** is calculated for this minimum website.

MRA considers that for the maximum website in the range there would be two (2) horizontal menus and one (1) vertical menu on each page. Seven sitebound links would be the total for the two horizontal menus with five links from the vertical menu. Three additional sitebound links from the body of each page would be maximum. This means that there is a total of 15 sitebound links on each page giving a value of 1650 for ***SBlinks***. This 15 sitebound links on each page includes the Home page, so, in this case, ***SBHome***, the count of sitebound links on the Home page is 15. MRA requires that all pages in the website will have sitebound links, so, the calculated value for ***SBpages*** is 1, that is, 110 active HTML pages ÷ 110 pages containing sitebound links. The target ***Menus*** value is 110, that is, 110 active HTML pages in the website each with three menus giving a total of 3300 occurrences of all menus in the site. This is divided by 3, it being the sum of the different horizontal (2) and vertical (1) menus in the site. In the minimum website, ***Levels*** would be 3, it being a simple rounded average of the five values in the study and being consistent with the 90/100/110 website page size. MRA considers two links to Home and two links to Top of page are appropriate on each HTML page in the site giving a value for ***Home_Top*** for the maximum in the range at 440 {110 x 2) + (110 x 2)}. Finally, a minimum site would include a Site

Search option on each page, so, ***Search*** would be 110. Using the same Navigation Ratio Formula a positive figure at ***43923*** is calculated for this maximum website.

These calculated minimum and maximum ratios scale to 53.56 and 168.07. So, it would be appropriate to define the calculated navigation ratio range for which the target is valid at 50 to 170 for websites in the range of 90 to 110 HTML pages. The consequences for websites outside the 90 to 110 HTML page range is not considered further at this stage.

Four of the five websites in this study are outside the target range of values. In each case, reference to the site's profile indicates the absence or over inclusion of parameters.

8.16 Conclusion

This chapter has applied the MRA approach derived in Chapter 7 in the context of the navigation ratio and in doing so has clarify issues relating to its application. The chapter is structured around the 12 steps set out in Chapter 7 and re-stated the feature, perspective and quality factor, characteristic and individual ratio of the websites being studied. The chapter then explains how the navigation criteria were identified and selected, and provides supporting justification for their inclusion. Each of these criteria is then explained in detail so that it is clear how counts associated with it are measured and how each count is used as a numerator or denominator in the Navigation Ratio Formula.

The chapter contributes a discussion on matters surrounding normalisation of values for website site comparison and matters relating to weighting the values in the MRA formulae. The chapter also discusses matters relating to the target website together with a range of websites for which the target value would be valid.

The chapter clearly shows that by using the MRA approach an engagibility sub-characteristic can be quantified by calculation and that its calculated value can be used in a website comparison study. By reference to each study website's profile it is possible to identify how a website design can be enhanced for improved engagibility.

Similar considerations to those explained in this chapter relating to the navigation ratio, also apply to the other seven engagibility ratios and a worked example of all eight ratios is included in Appendix D.

As explained in Chapter 6, this approach to website measurement needs to be validated so that it can be used with confidence. Validation is the subject of Chapter 9.

Chapter 9

Validation

> *The aim of this chapter is to propose a procedure for the theoretical and empirical validation of Metric Ratio Analysis as a reliable predictor of website visitor engagement.*

9.1 Background

A principal deliverable of this research is an approach that quantifies website engagibility. This approach is named Metric Ratio Analysis (MRA) and it includes the derivation of formulae for quantifying different sub-characteristics of engagibility. Each formula calculates a composite measure for each ratio and MRA asserts that these composite measures are predictors of website visitor engagement. However, the formulae that are derived rely on intuitive and plausible parameters and predictions of how these parameters should be arranged in the formulae. It is not unreasonable to use intuitive parameters and predictions (McCabe, 1976; Nielsen & Molich, 1990; Botafogo, Rivlin & Shneiderman, 1992; Chidamber & Kemerer, 1994; Recker & Pitkow, 1996; Brewington & Cybenko, 2000). Shepperd & Ince (1993;p78) state that intuition and existing software engineering knowledge is often brought to bear upon a problem. However, in order to substantiate the Metric Ratio Analysis approach formal validation is necessary. The general validation hypothesis that will be addressed in this chapter is that:

> *For corresponding sets of quality-of-product and quality-of-use formulae, criteria, and counts, the Metric Ratio Analysis formulae will calculate sets of quality-of-product and quality-of-use ratios which demonstrate a statistical correlation with each other.*

Undertaking a full theoretical and empirical study to validate this hypothesis is beyond the scope of this research. However, this chapter proposes a validation procedure.

9.2 Introduction

In order to use the predictor measure of website engagibility, it is essential that the MRA approach should be validated so that website specifiers and designers are assured that the measure is a valid predictor. So, the aim of this chapter is to propose a procedure for validating MRA. The chapter builds on the discussions of metrics validation from Chapter 6; addresses what needs to be included in the validation; and how during further research this validation can be completed. The chapter does not attempt to perform the validation as it is not a short term undertaking. The chapter explains that a significant number of websites must be included and significant numbers of website visitors need to be engaged in the validation study.

The validation procedure corresponds to the relevant two stages in the *Stages of the metrics methodology* proposed by Shepperd & Ince (1993) – Figure 6.2 - and the phases for conducting formal experiments recommended by Fenton & Pfleeger (1996). One stage of the methodology addresses theoretical validation and the other stage addresses empirical validation. The theoretical validation addresses the MRA model and method and the empirical validation proposes two parallel studies of data collection and hypothesis testing. These are a website design study and a corresponding website usage study. The procedure also proposes two supporting evaluations – a heuristic evaluation and a visitor questionnaire. Statistical methods are identified for determining how the MRA measurements are supported by metrics validity criteria. The proposed procedure is based on published work and international standards.

Section 9.3 clarifies the need for MRA validation. Section 9.4 addresses theoretical validation and Section 9.5 addresses empirical validation. Section 9.6 draws conclusions.

9.3 The need to validate Metric Ratio Analysis

The need to validate software measures and the models and methods that form part of a metrics validation toolkit have been explained in Chapter 6. MRA has its own underpinning model with clearly explained methods for calculating engagibility measures and has been carefully developed in keeping with the stages of a metrics methodology.

According to Barbara Kitchenhan there are three assumptions on which predictor metrics are based. These are:

> 1. *We can accurately measure some property of the software*
> 2. *A relationship exists between what we can measure and what we would like to know about the product's behavioural attributes*
> 3. *This relationship is understood, has been validated and can be expressed in terms of a formula or model.*
>
> (Kitchenham, 1990).

Clearly, as per item 1, MRA can accurately measure counts for a significant set of criteria relating to website engagibility. MRA proposes a model that clarifies the relationship between the counts and website engagibility and includes formulae for converting the counts into a measure of website engagibility. However, the relationship that exists between what can be measured and engagibility relies on intuition and plausibility. How this measure can be expressed as a relationship with visitor engagement (items 2 and 3) is the challenge of this validation. So, the MRA model and formulae now need rigorous validation as explained by Kitchenham (1990) and Shepperd & Ince (1993) so that MRA measures can be used with confidence by website acquirers, specifiers, designers and developers to predict website engagibility. This chapter proposes a procedure for validating MRA.

9.3.1 Desirable properties of MRA

ISO/IEC TR 9126-4 (2004) provides guidance on metrics validation and recommends seven desirable properties for software metrics. Metrics should be reliable, repeatable, reproducible, available, indicative of improvement, correct, and meaningful. Theoretical validation will need to confirm that MRA is compliant with these desirable properties. The ISO/IEC TR 9126-4 (2004) text is shown in Figure 9.1.

> a) ***Reliability (of metric)****:* Reliability is associated with random error. A metric is free of random error if random variations do not affect the results of the metric.
>
> b) ***Repeatability (of metric*****)**: repeated use of the metric for the same product using the same evaluation specification (including the same environment), type of users, and environment by the same evaluators, should produce the same results within appropriate tolerances. The appropriate tolerances should include such things as fatigue, and learning effect.
>
> c) ***Reproducibility (of metric)****:* use of the metric for the same product using the same evaluation specification (including the same environment), type of users, and environment by different evaluators, should produce the same results within appropriate tolerances.
>
> NOTE It is recommended to use statistical analysis to measure the variability of the results.
>
> d) ***Availability (of metric*****):** The metric should clearly indicate the conditions (e.g. presence of specific attributes) which constrain its usage.
>
> e) ***Indicativeness (of metric*****):** Capability of the metric to identify parts or items of the software which should be improved, given the measured results compared to the expected ones.
>
> NOTE The selected or proposed metric should provide documented evidence of the availability of the metric for use, unlike those requiring project inspection only.
>
> f) ***Correctness (of measure)*****:** The metric should have the following properties:
>
> ***Objectivity (of measure)***: the metric results and its data input should be factual: i.e., not influenced by the feelings or the opinions of the evaluator, test users, etc. (except for satisfaction or attractiveness metrics where user feelings and opinions are being measured).
>
> ***Impartiality (of measure)***: the measurement should not be biased towards any particular result**.**
>
> ***Sufficient precision (of measure)***: Precision is determined by the design of the metric, and particularly by the choice of the material definition used as the basis for the metric. The metric user will describe the precision and the sensitivity of the metric.
>
> g) ***Meaningfulness (of measure)*****:** the measurement should produce meaningful results about the software behaviour or quality characteristics. The metric should also be cost effective: that is, more costly metrics should provide higher value results.

Figure 9.1 - *Desirable properties for metrics* - ISO/IEC 9126-4 (2004).

9.3.2 Methods for Demonstrating the Validity of MRA

IEEE std 1061 (1998;p11-12) and ISO/IEC TR 9126-4 (2004;p14-15) recommend a number of methods for demonstrating the validity of metrics. The full text from the IEEE std 1061 standard is shown in Figure 9.2.

Where

V = square of the linear correlation coefficient

B = rank correlation coefficient

A = prediction error

α = confidence level

P = success rate

a) ***Correlation***. The variation in the quality factor values explained by the variation in the metric values, which is given by the square of the linear correlation coefficient (R^2) between the metric and the corresponding quality factor shall exceed V. This criterion assesses whether there is a sufficiently strong linear association between a quality factor and a metric to warrant using the metric as a substitute for the quality factor, when it is infeasible to use the latter.

b) ***Tracking***. If a metric M is directly related to a quality factor F, for a given product or process, then a change in a quality factor value from F_{T1} to F_{T2}, at times T1 and T2, shall be accompanied by a change in metric value from M_{T1} to M_{T2}. This change shall be in the same direction (e.g., if F increases, M increases). If M is inversely related to F, then a change in F shall be accompanied by a change in M in the opposite direction (e.g., if F increases, M decreases). To perform this test, compute the coefficient of rank correlation (r) from n paired values of the quality factor and the metric. Each of the quality factor/metric pairs shall be measured at the same point in time, and the n pairs of values are measured at n points in time. The absolute value of r shall exceed B. This criterion assesses whether a metric is capable of tracking changes in product or process quality over the life cycle.

c) ***Consistency***. If quality factor values F_1, F_2, F_n, corresponding to products or processes 1, 2, n, have the relationship $F_1 > F_2 > F_n$, then the corresponding metric values shall have the relationship $M_1 > M_2 > M_n$. To perform this test, compute the coefficient of rank correlation (r) between paired values (from the same software components) of the quality factor and the metric. The absolute value of r shall exceed B. This criterion assesses whether there is consistency between the ranks of the quality factor values of a set of software components and the ranks of the metric values for the same set of software components. This criterion shall be used to determine whether a metric can accurately rank, by quality, a set of products or processes.

d) ***Predictability***. If a metric is used at time T1 to predict a quality factor for a given product or process, it shall predict a related quality factor Fp_{T2} with an accuracy of $|(Fa_{T2} – Fp_{T2})/Fa_{T2}| < A$ where Fa_{T2} is the actual value of F at time T2. This criterion assesses whether a metric is capable of predicting a quality factor value with the required accuracy.

e) ***Discriminative power***. A metric shall be able to discriminate between high-quality software components (e.g., high MTTF) and low-quality software components (e.g., low MTTF). The set of metric values associated with the former should be significantly higher (or lower) than those associated with the latter. This criterion assesses whether a metric is capable of separating a set of high-quality software components from a set of low-quality components. This capability identifies critical values for metrics that shall be used to identify software components that have unacceptable quality. To perform this test, put the quality factor and metric data in the form of a contingency table and compute the chi-square statistic. This value shall exceed the chi-square statistic corresponding to α.

f) ***Reliability***. A metric shall demonstrate the correlation, tracking, consistency, predictability, and discriminative power properties for at least P% of the applications of the metric. This criterion is used to ensure that a metric has passed a validity test over a sufficient number or percentage of applications so that there shall be confidence that the metric can perform its intended function consistently.

Figure 9.2 – *Methods for demonstrating metrics validity* (IEEE std 1061, 1998;p11-12).

These are considered later in the chapter.

There are two stages to the validation of MRA which correspond with two of the stages in the Shepperd & Ince (1993) metrics methodology. First the theory has to be validated in order to ensure that the intuitiveness and plausibility issues are resolved. The second stage presents a procedure for empirically validating MRA. Both of these stages – theoretical validation and empirical validation are considered in the following sections.

9.4 Theoretical validation of Metric Ratio Analysis

The first stage of the validation is theoretical validation as per Shepperd & Ince's (1993) *Stages of the metrics methodology.* However, before commencing theoretical validation it is appropriate to address three issues:

1. For universal acceptance, validating the MRA approach might involve the efforts of internationally acknowledged experts from academia and industry to contribute towards an agreed standardisation of the topics. Specific expertise might be contributed by software quality and measurement professionals, and website design engineers.
2. Opportunities for undertaking cooperation by these experts are presented by conference workshops for collaborating like-minded researchers. Another model of cooperation is that used by industry when it prepares and releases 'white paper' publications. The overall aim is to secure domain expert affirmation and universal endorsement of the theory of website engagibility.
3. The outcome of the deliberations of the validating team will need to be documented and disseminated.

9.4.1 Theoretical validation considerations

Using the Shepperd & Ince (1993;p65) suggested approach to theoretical model validation, four characteristics of MRA need to be considered. These are:

1. The model must conform to widely accepted theories of software development and cognitive science.
2. The model must be as formal as possible (i.e., the relationship between the input measurements and the output predictions must be precise in all situations)
3. The model must use measurable inputs rather than estimates or subjective judgements
4. The ordering of model evaluations is intentional (meaningful empirical work is of questionable significance when based upon meaningless models of software).

To comply with characteristic 1, this theoretical validation will seek to show that:

- Modeling MRA as a 5-element top-down decomposition of engagibility is correct
- The MRA vocabulary and definitions are in keeping with software engineering practice, common usage, and custom and practice
- Corresponding quality-of-product and quality-of-use ratios are valid
- Intuitive and plausible understanding relating to engagibility criteria are correct.

To comply with characteristic 2 this theoretical validation will seek to show that:

- The MRA general formula is mathematically valid in relation to predictor usage and complies with measurement theory relating to axioms, weightings, units, scales and avoidance of discontinuities
- MRA is capable of properly addressing the desirable properties (reliability, repeatability, reproducibility, availability, indicativeness, correctness and meaningfulness) for metrics as outlined by Shepperd & Ince (1993), Fenton & Pfleeger (1996) and ISO/IEC TR 9126-4 (2004).

To comply with characteristic 3 this theoretical validation will show that:

- All input values and indirect values used in the model are based on measurable counts.

To comply with characteristic 4

- This theoretical validation will be completed in advance of a significant empirical study.

Compliance with characteristic 3 is self evident from the practice of MRA outlined in Chapters 7, 8 and Appendix D. Compliance with characteristic 4 is also self evident from the structure of this proposed validation procedure.

For the purpose of addressing the six considerations outlined in characteristics 1 and 2, they are given summarised heading as follows:

1. The elements of the MRA website quality model
2. The MRA vocabulary and definitions of website engagibility

3. Corresponding MRA quality-of-product and quality-of-use ratios
4. Engagibility criteria completeness and sufficiency
5. Mathematical and measurement theory compliant
6. The desirable properties of software metrics.

The following sections clarify what needs to be addressed by each of these six considerations.

9.4.1.1 The elements of the MRA website quality model

The theory to be validated is the decomposition of the entity (website) to its lowest level of decomposition as illustrated in Figure 9.3.

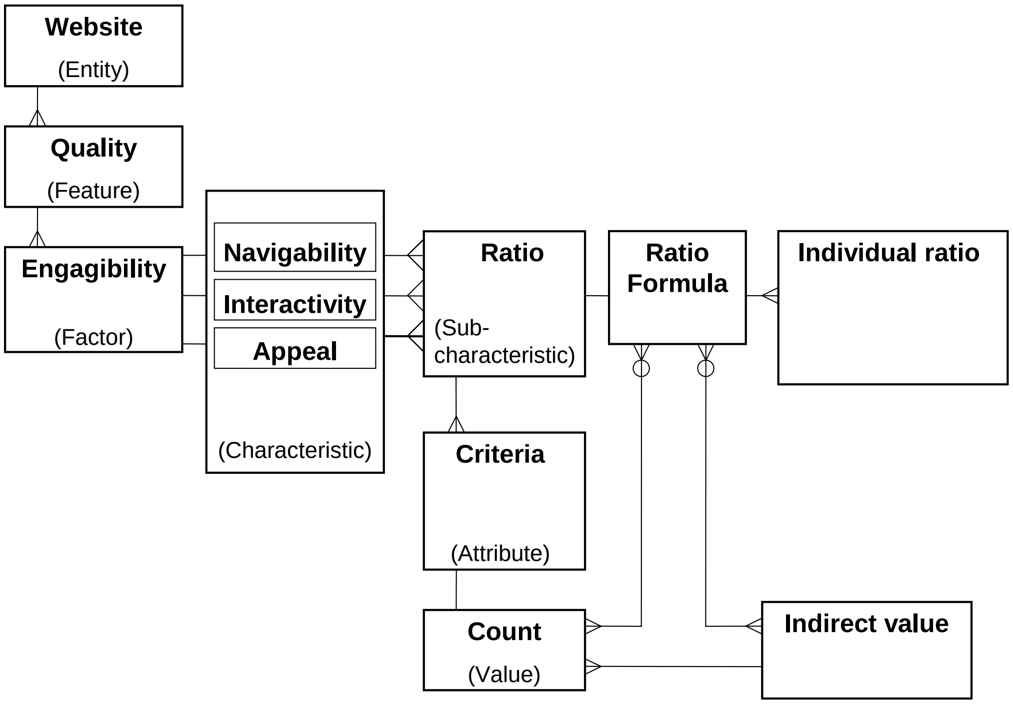


Figure 9.3 – *Elements of website quality.*

Validating the model is concerned with confirming that engagibility is fully and correctly decomposed to the level of a calculated individual ratio. This is necessary because engagibility is a new quality factor (Fitzpatrick, 2000) and needs to be conceptually modelled for universal acceptance. It is clear from the research so far that modelling website engagibility is different to the 3-element conceptual models presented by Basili & Romback, (1987; 1988) in the

Goal/Question/Metric paradigm, and in international standards like ISO/IEC 15939 (2002) and IEEE Std 1061 (1998). It requires a greater level of decomposition.

It is also appropriate to validate that the characteristics of engagibility, i.e., Navigability, Interactivity and Appeal are a complete set and that the quality-of-product and quality-of-use sets of sub-characteristics are also complete sets.

9.4.1.2 The MRA vocabulary and definitions of website engagibility

Measurement researchers, international standards experts and editors, and text book authors in the domain of software measurement all have their own favourite vocabulary which can cause confusion to those who read their work. Care has been taken during the development of MRA to ensure that all of the elements of website quality are properly defined and that MRA consistently uses a vocabulary that reflects common usage and naturally understood English (Section 5.3.3). The vocabulary also reflects custom and practice in the domains of software quality, measurement, and website engineering (Chapter 4; Chapter 6; Chapter 7). Theoretical validation would encourage domain expert affirmation and universal endorsement of these definitions and the vocabulary of engagibility.

9.4.1.3 Corresponding MRA quality-of-product and quality-of-use ratios

The research has developed a corresponding set of eight quality-of-product ratios and eight quality-of-use ratios (Section 5.4). Confirmation and acceptance of these sets of ratios by cooperating experts and collaborating researchers would be encouraged at this time.

9.4.1.4 Engagibility criteria completeness and sufficiency

As part of this consideration it will be valuable to have the cooperating experts and collaborating researchers validate the completeness of the set of 67 quality-of-product criteria (Section 5.5) and their sufficiency for each individual ratio.

A tightly coupled corresponding quality-of-use set of criteria also needs to be identified. To ensure integrity, this corresponding set needs to be identified independently of the visitor statistics that web analytics tools are capable of identifying. That is, the identification process will use a top-down approach which identifies what must be measured rather than a bottom up approach of relying on what is available. In the first instance they might be identified as being intuitive and plausible and then confirmed through expert endorsement in readiness for empirical validation at the next stage.

It is expected that like other approaches such as COCOMO II and Function Point Analysis, Metric Ratio Analysis will continue to evolve. The number of engagibility criteria and their sufficiency for each ratio will change, particularly as technology develops and new competitive advantage strategies for website use are exploited. However, for this validation study it is essential that stable (fixed) sets of criteria are used.

9.4.1.5 Mathematical and measurement theory compliant

In Chapter 7 the strengths and weaknesses of the proposed universal formula are set out. This provides pointers to their mathematical validation. Typically, these strengths relate to the avoidance of discontinuities and clearly named measures (e.g., navigation ratio, surf ratio) on a 100 point scale. Another strength is that the formula relies only on counts and does not mix them with measures of length, time or size.

At this time there are some weaknesses that need to be addressed. The formula arranges values as numerators or denominators based on intuitive predictions of how these values will impact on a calculated measure of visitor engagement at a website. The validity of these predictors would be confirmed by empirical validation as in Section 9.5.

There is also a need for a set of axioms related to the general formula (Prather, 1984; Weyuker, 1986). Two typical examples might be:

- There exist websites that have equal calculated ratios but have different values associated with them (after Weyuker/Shepperd &Ince).

- MRA must not assign a calculated ratio of zero in the absence of a value.

Such a set of axioms needs to be formally expressed. Meanwhile, a set of axioms that that MRA complies with is included in Appendix F.

It is suggested that the count of some criteria will reach a saturation point beyond which engagibility is not improved and might in fact be a cause of visitor confusion. Dynamically creating a different set of links in a menu of items for sale is typical of this difficulty. An approach like this would breach best practice regarding interface consistency (Nielsen & Molich, 1990; Shneiderman, 1992). This is addressed in Chapters 7 and 8 and validation could consider it further in anticipation of outlier difficulties.

While the research currently considers that all formulae values are of equal importance it is aware that some need to be weighted in order to reflect a greater important. Also at this time the research is aware of the magnitude of some of the calculations. There are also validation issues surrounding the interpretation of MRA results relative to a range of websites. The reader is referred to Sections 7.8.3 and 7.8.4 for a full listing of strengths and weaknesses, and advantages and disadvantages that need to be addressed as part of the theoretical validation.

9.4.1.6 The desirable properties of software metrics

As explained in Section 9.3.1 a software measure should exhibit desirable properties, viz., reliable (e.g., free from random error), repeatable (e.g., same website, same environment, same visitors and same evaluator), reproducible (e.g., same website, same environment, same visitors but different evaluator), available (e.g., constraint conditions), indicative of improvement (e.g., of the website design for improved engagibility), correct (e.g., objective, impartial and precise) and meaningful (e.g., about the website's behaviour or quality characteristics). Theoretical validation would review the MRA approach to ensure that these desirable properties can be satisfied.

That completes the review of considerations that must be addressed during the theoretical validation of MRA. As explained by Shepperd & Ince (Section 9.4.1) the theoretical validation outlined in this section must be completed before the empirical stage can commence.

9.5 Empirical validation of Metric Ratio Analysis

Having completed a theoretical validation the next stage is empirical validation. The purpose of this validation is to demonstrate that *"the measure is useful in the sense that it is related to other variables in expected ways (as defined in the theories)"* Briand *et al.,* (1998). Schneidewind (1992) explains that metrics should be validated to determine whether they measure what they purport to measure prior to using them. This section proposes a procedure for empirically validating that the MRA quality-of-product measures are accurate predictors of a visitor's engagement at a website.

There is no definitive model for an engagibility metric empirical validation, so, the challenge is to propose a procedure which incorporates best practice from mainstream metrics validation with best practice from system usage evaluation.

The proposed procedure is underpinned by scientific method techniques (Gauch, 2003) for hypothesis testing using formal experiments for data gathering and statistical analysis (Kafura & Canning, 1985; Shepperd & Ince, 1993; Ejiogu, 1993; Shepperd, 1994; Schneidewind, 1994; Fenton & Pfleeger, 1996; IEEE std 1061, 1998; ISO/IEC TR 9126, 2004). From these it draws validation methodology, a validation model, and non-parametric statistical methods.

Shepperd & Ince (1993;p66) state that for empirical validations to be meaningful they must:

- be large-scale in a variety of different environments, particularly industrial
- have adequate controls so that it is possible for the null hypothesis to stand
- involve different teams of workers for statistical variability.

To these, this research adds, specifically for the MRA approach:

- have supporting validation. That is, empirical validation of the measure should be supported by heuristic expert evaluation and a subjective user questionnaire.

The procedure proposed for the empirical validation of Metric Ratio Analysis addresses these challenges. Also, to comply with the IEEE std 1061 (1998) and ISO/IEC TR 9126-4 (2004) guidance relating to desirable properties for software measures the empirical validation study will use:

- An hypothesis to be tested
- A set of stabilised (fixed) commercial online eCommerce websites
- Websites of similar page size that target similar visitors
- Teams of website visitors of the same profile from the same user community
- Visitors with similar web usage skills
- Similar laboratories
- The same connection specification for accessing the internet
- Consistent pairs of commercial automatic measurement tools
- Measured counts as data – no subjective inputs
- Impartiality in the predictor arrangements
- Precise and consistent definitions

To complete this stage, two corresponding studies of a stabilised set of websites would be completed. One is a website design study which will collect quality-of-product counts from the published online websites and use the MRA quality-of-product formulae to calculate values for quality-of-product ratios. The other is a website usage study which will monitor visitor usage of the same websites and collect quality-of-use counts, and then using corresponding quality-of-use formulae, will calculate corresponding values for quality-of-use ratios.

These proposed corresponding studies involve formal experiments which are core to the validation. They are supported by an expert heuristic evaluation which provides support for the website design study - similar to that explained by Nielsen & Molich (1990) and Nielsen (1998c) - and a user questionnaire which provides support for the website usage study - similar to that explained by Kirakowski & Corbett (1988) and Kirakowski & Corbett (1993). Instantiations of the same set of study websites would be used for all studies. Statistical methods would be used to validate the study results. Using two studies means that a ‘double-blind’ approach (Fenton & Pfleeger, 1996;p124) can be used such that the participants in one study are unaware of the outcome of the other study and cannot influence them.

Fenton & Pfleeger (1996;p125) suggest a six phase model for completing this type of study. The phases are:

- Conception
- Design
- Preparation
- Execution
- Analysis
- Documentation and decision making

These phases are now followed.

9.5.1 Conception

Metric Ratio Analysis is an approach to measuring website engagibility and derives formulae for predicting how a proposed website design will support website visitor engagement. It asserts that these formulae calculate quality-of-product ratios that predict engagibility. This study seeks to show that the MRA measure of a website’s design is a valid predictor of a visitor’s engagement experience when visiting the website.

9.5.2 Design

To show that a website’s design can be used to predict visitor engagibility, the study would rely on the corresponding sets of quality-of-product and quality-of-use ratios. It would postulate that if the formulae calculate valid results then a corresponding assessment of visitor engagement at an instantiation of the website will return results that demonstrate statistical correlation to predicted calculations. Expressed as an hypothesis this is:

> *For corresponding sets of quality-of-product and quality-of-use formulae, criteria, and counts, the Metric Ratio Analysis formulae will calculate sets of quality-of-product and quality-of-use ratios which demonstrate a statistical correlation with each other.*

This is illustrated in Figure 9.4 which shows that a calculated quality-of-use ratio is a function of a calculated quality-of-product ratio.

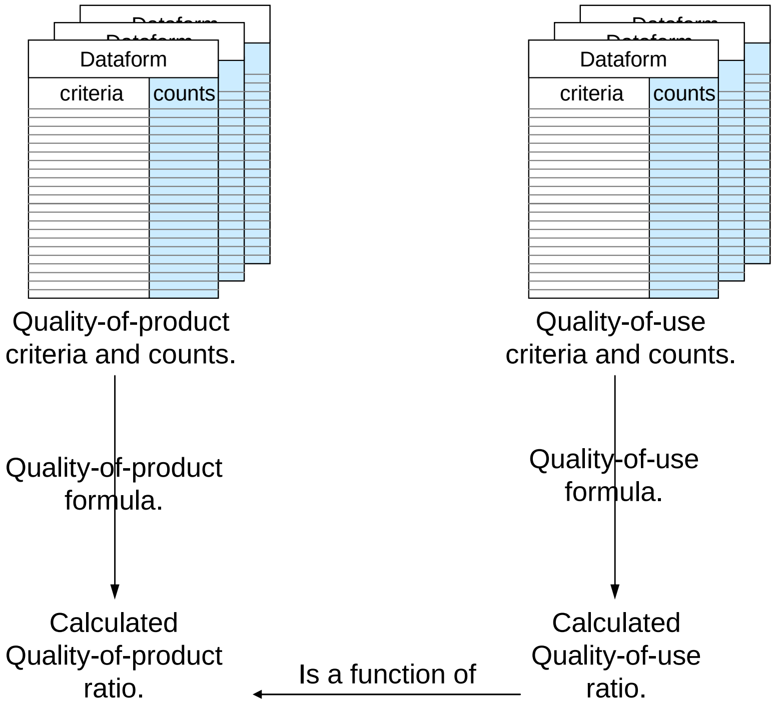


Figure 9.4 – *Corresponding calculations.*

The rationale for this hypothesis is that if a website incorporates well-defined structural components in its design it will provide a visitor with a rich engagibility experience. Empirically measuring that visitor's engagement at a website will return a measure of quality-of-use richness. Knowing how the structural components have engaged visitors during a visit to a website allows for mapping to how the structural components have been designed into the website. This should return corresponding quality-of-product and quality-of-use measures which demonstrate statistical correlation. The validation experiment may provide data which will lead to subsequent improvement of the formulae. The procedure for testing the hypothesis is illustrated in Figure 9.5.

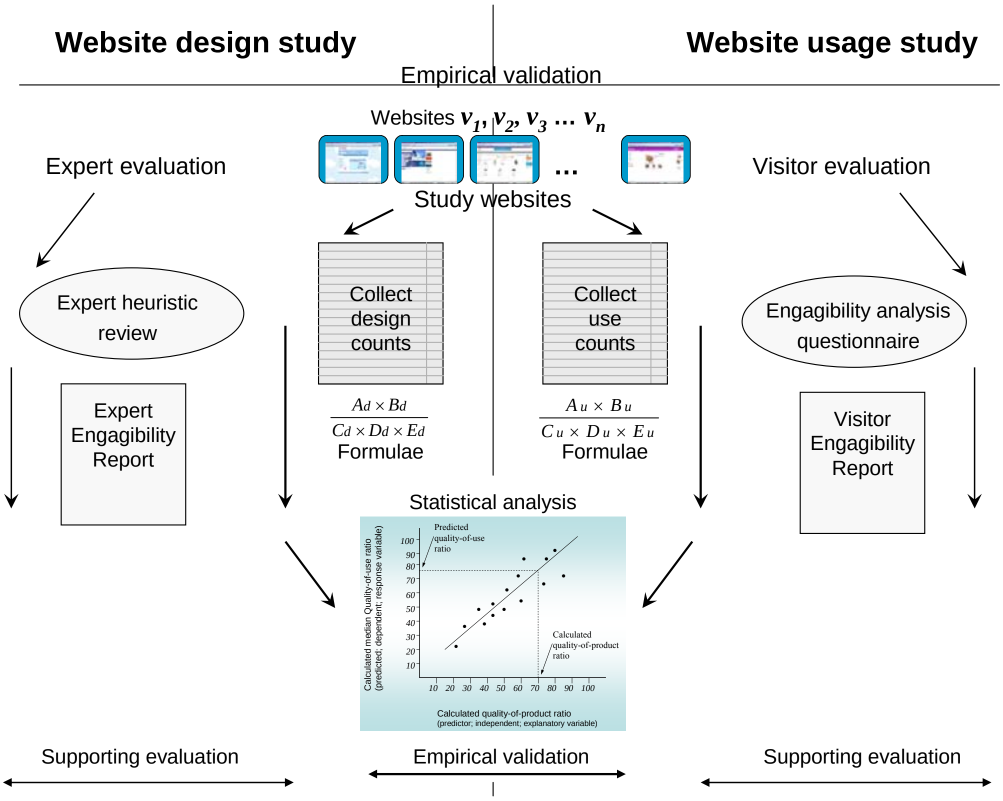


Figure 9.5 – *Empirical validation of Metric Ratio Analysis.*

Figure 9.5 is divided into two to illustrate the website design study and the website usage study. Both studies use the same set of v_n websites. These would be websites which are already published, online and freely accessible on the World Wide Web. During the website design study counts for the quality-of-product criteria are collected (automatically and manually) for each website. These counts are then used in the appropriate quality-of-product formulae in order to calculate individual ratios. At the same time a website usage study is completed. This study involves teams of website visitors engaging with the websites. During this engagement counts for the quality-of-use criteria are collected (automatically or manually) for each visitor at each website. These counts are used in the appropriate corresponding quality-of-use formulae in order to calculate corresponding quality-of-use individual ratios. The calculations from each study are charted, compared and analysed, using statistical techniques, in order to determine their correlation and to confirm the hypothesis.

In both of these studies, validation involves data gathering and hypothesis testing. In addition, the MRA procedure would support the validation through further evaluation. In the website design study this support would be through an expert heuristic review and in the case of the website usage study the support would be through a visitor engagibility analysis questionnaire as in Figure 9.5. The findings of these evaluations would be presented in report format. These are optional and recommended especially in the case of the visitor questionnaire as it avails of an excellent opportunity to capture a visitor's experience immediately following a visit to the website. Both the website design study and the website usage study are explained in detail as part of the execution phase later in this section.

Schneidewind (1994) explains that when validating software quality metrics:

> *We perform validation of the relationship between quality factors and metrics on a set of modules called the* ***validation set*** *and then apply them to a second set of modules - the* ***application set*** *from the same or a similar project.*

The focus of this validation is on a set of websites (v_n) which are a validation set.

9.5.3 Preparation for empirical validation

In order to have confidence in the results of the validation procedure a number of considerations must be addressed. These would be part of planning and organising for the empirical validation and are:

- The size of the study – websites and visitors
- The study environment
- The empirical validation team
- The study timescale

Each is now considered in detail.

9.5.3.1 The size of the study – websites and visitors

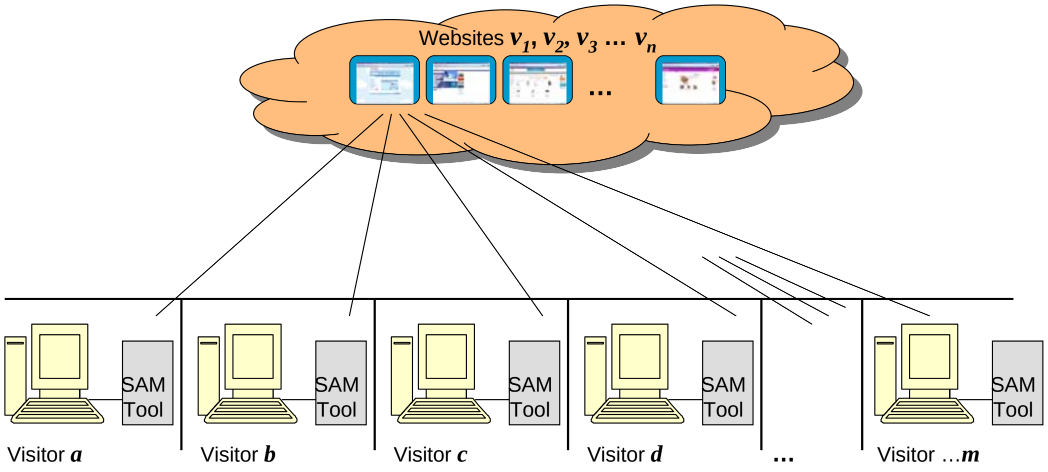
The websites and the visitors that are used in the validation study are specified as follows:

9.5.3.1.1 The study websites (the validation set)

The study websites will be chosen from the same sector (e.g., retail, manufacturing, finance, education) which will be seeking to attract visitors with the same or similar profiles. For example, if commercial websites are being studied then the sites might be selected from the retail sector seeking to attract eCommerce shoppers. Or, the sites might be selected from the manufacturing sector seeking to attract professional buyers. The evaluator should also select websites that have a similar number of pages. As part of preparation for the validation procedure the study websites will need to be captured so that a fixed and consistent version of each site is always available. Once the study websites have been decided they are accessed using a scanning tool or manually, and counts are recorded on the dataform.

Ince & Shepperd (1988) explain that many empirical validations rely on too little data. They report one satisfactory study that relied on 73 designs being assessed. So, a similar number of website designs might be assessed to validate MRA. Such an undertaking is not a trivial study and would involve a lengthy elapsed timeframe. On-going proposer support for MRA will continue to extend the number of websites in the study, thereby establishing confidence in the measure.

A strategy to overcome this might be to appoint multiple (two or three) centres to act as validation laboratories. Each laboratory would be responsible for assessing the study websites and completing a website design study and a website usage study. The laboratory function is to provide access to each of the eCommerce websites for a selected number of visitors (in this instance ***m,*** and as explained further in the next section) and to use a statistical analysis monitoring (SAM) software tool to record each visitor's usage of the sites functionality and features. The laboratory function is illustrated in Figure 9.6.



SAM = Statistical Analysis Monitoring tool

Figure 9.6 – *Illustrated laboratory function.*

The figure illustrates all ***m*** visitors accessing one website and being monitored by the SAM tool. The procedure is repeated for all v_n sites in the study. The analysis of these visitors' engagement at the sites is considered later in this chapter.

Once initial results are available for the v_n study websites and lessons learned have been implemented it would be appropriate to broaden the study to a significant number of website designs as advised by Ince & Shepperd (1998). This broadened study might allow for refining the formulae to reflect any lessons learned. This broader study might be confined to using the same laboratory or could be expanded to include additional collaborating laboratories as appropriate.

9.5.3.1.2 The study subjects – the website visitors

Sufficient visitors need to be selected so that the empirical validation will have sufficient data. In the context of web testing (in this case completing a supporting questionnaire study) the "Magic Number of 5" was argued for at a CHI 2003 Panel discussion. The panellists were Carol Barnum, Nigel Bevan, Gilbert Cockton, Jakob Nielsen, Jared Spool and Dennis Wixon (Barnum, 2003). ISO/IEC TR 9126-4 (2004) suggests that eight users are sufficient for a quality in use evaluation. So, for the visitor questionnaire evaluation eight visitors are recommended which in turn means that a minimum of eight visitors participate in the formal validation study. This needs to be balanced against the Nielsen &

Landauer (1993) estimate that for small projects 7 test users are required and very large project require 20 test users. Kirakowski *et al.*, (1998) also recommend the higher number of testers. In their paper they explain that their research had data from 25 sites and approximately 1500 user responses.

The multiple laboratory strategy means that at least eight visitors are easily assessed. So, each laboratory would have five visitors engaging with five websites. These minimum numbers can be increased as appropriate to suit the resources available at the time of validation. However, eight visitors is a low set of study subjects. Continuing research would seek to expand this.

The visitors should be from the intended community. Care must be taken to ensure that the visitors used in the process are representative of the visitors that the site intends to engage. Recruiting the visitors should address visitor knowledge, experience, website usage skills, ability, motor and sensory capabilities and similar considerations that are addressed by international standards and best practice (ISO 9241-11, 1998). Ince & Shepperd (1988) warn against using atypical subjects. They point out that all too often students taking computing courses are used. This can be a convenient and cost effective approach but the students might not be representative of the intended subjects. However, if the websites being studied are educational sites that are seeking to engage students then students are typical subjects. Equally, if students or faculty staff members are typical of the visitor community that the eCommerce websites are trying to attract then students and faculty staff are typical subjects.

9.5.3.2 The study environment

To ensure consistent experiment conditions the technology required for the validation must be the same for all visitors. So, the websites are accessed through the same connection to the internet from similar computers. Consistent corresponding pairs of automatic measurement tools for collecting the quality-of-product and quality-of-use counts must be used.

All validation laboratories should replicate the same environment especially for the expert heuristic review and for completing the visitor engagibility questionnaire.

Ideally, visitor engagement goals are not set and visitors are allowed freeform engagement with the site to suit their needs. The automatic measuring tool would collect quality-of-use counts relating to this engagement. However, in keeping with the study timing considerations and the concept of engagibility (Section 9.5.3.4) there would be ample opportunity to include a pre-defined set of goals that a visitor might be required to successfully achieve.

9.5.3.3 The empirical validation team

The empirical validation team will need to include expertise and skills relating to heuristic evaluation, user-centred measurement, user-centred questionnaire analysts, and statistical analysis.

9.5.3.4 The study timescale

When validating MRA the elapsed time of the validation study needs to be considered. (This should not be confused with the period of engagement of a visitor at a website which might be a quality-of-use criteria for possible use in a formula). Evaluators are alert to the fact that published websites change and updated versions are regularly published. For the validation to be meaningful it is, therefore, essential to ‘freeze’ each website so that the same version of each website is available to both the design study and the usage study, and that all visitors in the study access these ‘frozen’ versions.

Websites can be accessed by multiple visitors at the same time, so, it is possible for the design study counts and the visitor use counts for a study website to be collected at the same time. That is, in the case of website v_1, the design automatic counting tool and m visitors could all simultaneously access the website. This procedure would be repeated for each website in the study. However, collecting the design study counts is not a lengthy activity and need not be delayed to synchronise with the elapsed time of the website usage study.

Understanding how the time period or time limit that should be allocated to a visitor will be influenced by the quality-of-use criteria that are used for the Website usage study. As these have not yet been identified it is not possible at this time to state a time period. However, the emphasis of this study is engagibility, so, it seems more appropriate to allow visitors to engage with the website rather than limit their engagement. In this case a morning or afternoon session with perhaps a three hour overall limit might be appropriate. An alternative argument is that website visitors want to access the site's functionality, engage in their eCommerce activity and leave. At the same time Website owners want visitors to engage in as much eCommerce activity as possible. So, understanding the Website's aims and target visitor needs are important to stating a study time period. Visitor effectiveness, efficiency and safety considerations should be drivers of the study timescale (ISO 9241-11, 1998).

The time of day when visitors are assessed might also a consideration. Websites that seek to attract visitors who normally engage with the site in the evening might be best assessed in the evening. Or, websites that seek to attract gaming visitors who play at the weekend might be assessed at the weekend. Commercial sites might need to have their visitors assessed during normal working hours.

9.5.4 Execution – performing the empirical study

To commence the validation it is necessary to state the feature of the entity to be studied (quality) and state the perspectives (quality-of-product and quality-of-use) and quality factor (engagibility) of the feature. The three characteristics of the quality factor (navigability, interactivity and appeal) are to be studied and all eight individual ratios to be measured and validated. These considerations are grouped at the start of the validation procedure and are illustrated as steps 1 to 5 in the panel headed Defining the website engagibility study in Figure 9.7.

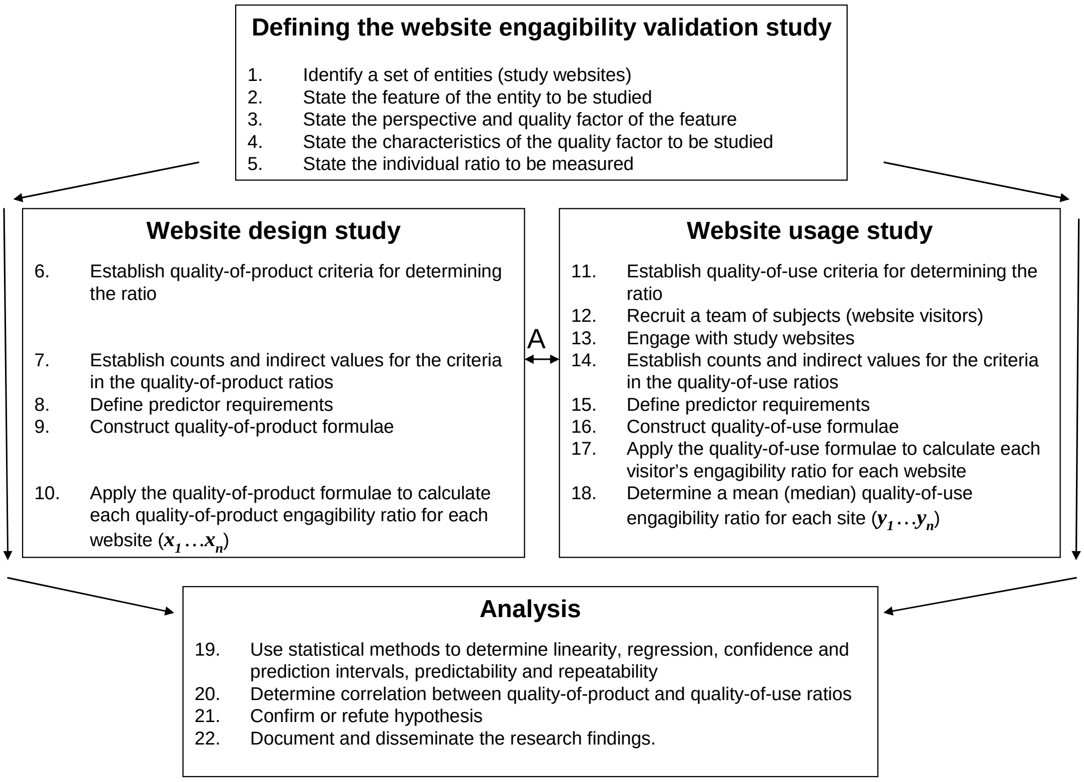


Figure 9.7 – *Metric Ratio Analysis empirical validation model.*

The validation procedure now involves the two corresponding studies of the set of websites. While there are eight corresponding sets of ratios, the validation procedure is written for any one ratio.

9.5.4.1 The website design study

At this point the validation procedure separately addresses quality-of-product measurement (website design study) and quality-of-use measurement (website usage study) in parallel as illustrated in Figure 9.7. The two panels in the figure are arranged to show corresponding steps. The quality-of-product measurement follows the steps of Metric Ratio Analysis as explained in Chapter 7. It uses the criteria identified in Chapter 5 and uses both automatic and manual counting to collect the counts. This is the data gathering point in the websites design study. It then follows the steps explained in Chapter 7 to define numerator and denominator predictors, construct formulae and calculate engagibility ratios. This study is managed by an engagibility evaluator.

If a supporting engagibility-expert heuristic review is planned then it is advisable to complete it at the same time as step 7 to insure that the websites that are measured are the same websites that are reviewed. At step 10 each quality-of-product engagibility ratio is calculated for each website to return values $x_1 \ldots x_n$.

9.5.4.2 The website usage study

The quality-of-use measurement commences with step 11. This step uses the corresponding tightly coupled set of quality-of-use criteria identified in the theoretical validation stage of this study.

The next step is to recruit a team of individuals who will act as visitors to the study websites.

At step 13 the visitors engage with the website, attracted by the appealing aspects of the website and engaging in navigation, surfing, eCommerce and other interactivity as offered by the website. This engagement is measured using an automatic tool (of the type that records site visitor statistics), and manual methods if necessary, in order to collect the counts for the quality-of-use criteria. This is that data gathering point in the website usage study. It involves collecting counts for each visitor for each website – if the team of visitors consists of 8 persons and the study involves n websites then 8 x n sets of counts will be collected. This is step 14 of the validation procedure and from the collected counts it will be possible to determine any indirect values that will be needed in the quality-of-use formulae. For a meaningful validation quality-of-product counts and quality-of-use counts must be collected for the same instantiations of the study websites. So, at steps 7 and 14 counts must be collected concurrently as highlighted at A in Figure 9.7. Step 14 is completed simultaneously with step 13.

Immediately following step 14 it would be appropriate for the evaluator to have each visitor complete the supporting engagibility analysis questionnaire. This instrument would subjectively report their engagement experience.

Steps 15 and 16 correspond with steps 8 and 9. They use the same approach to defining predictor requirements and to the construction of the quality-of-use formulae. At step 17 the collected counts and any indirect values are used to calculate individual ratios for each visitor at each website.

Using each visitor's calculated quality-of-use ratio for a chosen website from step 17, a mean (median) quality-of use ratio is determined for that website at step 18. This will be used later in the analysis. Meanwhile, an observation that can be made at this time is that the distribution (upper and lower quartiles) of the visitor values gives an early indication of consistency of engagement at this website. In addition, if the mean (median) is of close similar value to the quality-of-product ratio then there is reason to be confident that the quality-of-product ratio will be shown later, using statistical methods, to be a good predictor of quality-of-use.

This process of calculating mean (median) quality-of-use ratios is repeated v_n times for all the websites in the validation study to return values $y_1 \ldots y_n$.

Before addressing the analysis steps, it is appropriate to consider the supporting evaluations.

9.5.4.3 Supporting website engagibility heuristics study

The aim of a heuristics study would be to determine expert evaluation of the website's potential to engage visitors. At the time of collecting the quality-of-product counts a team of engagibility specialists would review the same instantiations of the study websites to assess their engagibility potential. Their aim would be to identify engagibility design strengths and weaknesses which would provide further understanding of potential visitor engagement. They would rely on heuristics which reflect good practice and acknowledged guidelines, and the deliverable from this study would be an Expert Engagibility Report as illustrated in Figure 9.5.

Heuristics for website engagibility have yet to be identified, so, further comment on this supporting evaluation is not progressed in this proposed validation procedure.

9.5.4.4 Subjective website engagibility questionnaire

The aim of this study would be to determine typical website visitors' subjective assessment of the site's engagibility. Having assembled a team of visitors who act as subjects in the usage study, the evaluator is presented with an ideal opportunity to accomplish a subjective evaluation of each visitor's engagibility experience.

This questionnaire study would be laboratory based and would involve the same set of visitors completing a psychometric evaluation questionnaire (Kirakowski & Corbett, 1993) in order to assess their subjective engagibility experiences with the websites. The study would use a consistent questionnaire for all visitors. These questionnaires would be completed immediately following the usage study while the visitors' experiences are still fresh. This subjective evaluation would be managed by the engagibility evaluator and the deliverable from this study would be a Visitor Engagibility Report as illustrated in Figure 9.5. Performing such an evaluation would provide supporting quality-of-use measures and additional insight into each visitor's engagement.

Engagibility evaluation questions need to be written for such a questionnaire and these questions should be focused on the eight quality-of-use engagibility ratios. Further comment on this supporting evaluation is not progressed further in this proposed validation procedure.

Common industry report format styles for this type of report are included in ISO/IEC TR 9126-4 (2004) and ISO/IEC 25026 (2006).

9.5.5 Analysis

The next part of the validation procedure is to show that a quality-of-product ratio calculated during a website design study is a reliable predictor of a quality-of-use ratio, and that it can be used with confidence to predict website engagibility. That is that it is being validated in the 'broad sense' to show that it is part of a prediction system. To validate that the quality-of-product measure is a reliable predictor it will be necessary to use statistical methods (Kafura & Canning, 1985; Shepperd & Ince, 1993; Ejiogu, 1993; Shepperd, 1994; Schneidewind, 1994; Fenton & Pfleeger, 1996; IEEE std 1061, 1998; ISO/IEC TR 9126, 2004). Using these statistical methods the challenge is to show that the predictor measure complies with validity criteria which demonstrate: association, tracking changes capability, consistency, predictability, discriminative power and reliability (IEEE 1061, 1998). Schneidewind (1992, 1994) discusses these validity criteria and explains that the quality function being supported (quality assessment, quality control, quality prediction) will influence the particular criteria that are tested. Schneidewind (1992) lists statistical methods that are appropriate to quality prediction of the validity criteria as per Table 9.1.

Table 9.1 – *Statistical methods for validating quality measures* – Schneidewind (1992).

Quality Function	**Validity Criterion**	**Purpose of Valid Metric**	**Statistical Method**
Quality Assessment	Correlation (Association)	Assess differences in quality	1. Coefficient of Determination $R_2 > \beta a$. 2. H0: Population Correlation Coefficient = 0. 3. H0: Population Correlation Coefficient > $\sqrt{\beta a}$. 4. Linear Partial Correlation Coefficient (Metric Normalisation. Accounting for Size). 5. Population Correlation Coefficient Confidence Interval. 6. Factor Analysis (Tests of Independence).
Quality Control	Tracking	Control quality (track changes)	1. Binary Sequences Test and Wald-Wolfowitz Runs Test.
Quality Assessment	Consistency	Assess relative quality	1. Rank Correlation Coefficient $r > \beta c$.
Quality Prediction	Predictability	Predict quality	1. Scatter Plot to Investigate Linearity. 2. Linear Regression • Test Assumptions • Examine Residuals. 3. Find Confidence and Prediction Intervals. 4. Test for Predictability < Threshold (βp) and Repeatability > Threshold (β*is*). 5. Non-linear Regression. 6. Multiple Linear Regression • Test Assumptions • Examine Residuals • Test for Predictability < Threshold (βp) and Repeatability > Threshold (β*is*).
Quality Control	Discriminative power	Control Quality (discriminate between high and low)	1. Mann-Whitney Comparison of Average Ranks of two groups of components. 2. Chi-square Contingency Table for Finding Critical Value of Metric. 3. Short-Cut Technique for Finding Critical value o Metric: Maximise $O_{11}O_{22}$. 4. Sensitivity Analysis of Critical Value of Metric. 5. Krusal-Wallis Test of Average Metric Rank per Given Value of Quality Factor. 6. Discriminant Analysis (Use of a Single Metric's Mean as Discriminator).
All Quality Functions	Repeatability	Ensure metric validated with specified success rate	1. Ratio of Validations to Total Trials > Threshold (β*is*).

MRA is principally a predictor metric and consequently this proposal for its validation is confined to statistical methods appropriate to predictability and repeatability as shown in Table 9.1. Fenton & Pfleeger (1996) caution about selecting methods until something is known about the data especially techniques for assessing distribution.

Where a strategy of using multiple laboratories might be used for a longitudinal study it would be desirable that all analysis should be completed at one headquarters.

At step 19 (Figure 9.7) the quality-of-product ratios from steps 10 are tabulated alongside the set of quality-of-use ratios, from step 18, as shown in Figure 9.8.

Website	Quality-of-product ratio	Mean (Median) Quality-of-use ratio
v_1	x_1	y_1
v_2	x_2	y_2
v_3	x_3	y_3
v_4	x_4	y_4
v_5	x_5	y_5
v_6	x_6	y_6
.	.	.
.	.	.
.	.	.
.	.	.
v_n	x_n	y_n

Figure 9.8 – *Website quality-of-product and corresponding quality-of-use ratios.*

Using these data the quality prediction methods from Table 9.1 are now considered in the context of determining MRA validity.

Using the ***x*** and ***y*** data from Figure 9.8 each website's quality-of-product and quality-of-use ratios are plotted as illustrated in Figure 9.9.

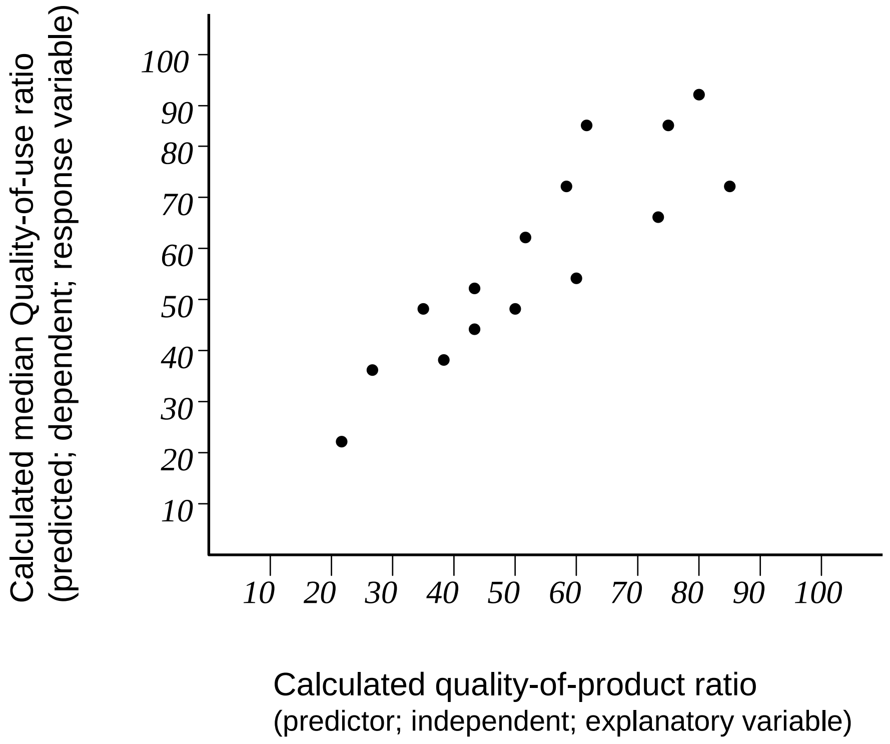


Figure 9.9 – *Scatter plot for* $\boldsymbol{v_n}$ *websites.*

In the absence of data it is impossible to correctly represent the direction and strength of the plot in Figure 9.9. However, it would be anticipated that it would approximate towards a positive relationship. That is, a low quality-of-product ratio will be a predictor of a low quality-of-use ratio, and, when a quality-of-product predictor is high, then the corresponding quality-of-use ratio will also be high. While this illustration would suggest a general trend it does not include any outliers which can be expected to appear in study data.

In order to measure the association (direction and strength) between the quality-of-product and quality-of-use ratios correlation coefficients can be calculated. To determine the correlation coefficient (***r***) three alternatives that might be used are:

- Pearson's correlation coefficient

- Spearman's rank correlation coefficient
- Kendall's robust correlation coefficient.

Typically, Pearson's correlation coefficient is calculated using a well understood formula which will produce a result that varies from -1 to +1 where 1 indicates a perfect positive linear relationship such that as the quality-of-product ratio increases the corresponding quality-of-use ratio will also increase in equal linear steps. When the calculation is -1 it indicates a perfect negative linear relationship. That is, as one variable increases the other variable decreases linearly. And, when the calculation is 0 no relationship exists between the variables. So, as one variable increases the other might increase or decrease (Fenton & Pfleeger 1996;p209). The authors explain that use of Pearson's correlation coefficient is appropriate for normally distributed values. Spearman's rank correlation coefficient returns a measures of association for non-normal data and Kendall's robust correlation coefficient is an alternative to Spearman's coefficient that can identify partial correlations (Fenton & Pfleeger 1996;p200). So, which measure to use will depend on the form of the data returned by the study.

A linear regression technique (e.g., least squares regression) is used to identify the line of best fit among the data points. The goal is to express the quality-of-use ratio (***y***) in terms of the quality-of-product ratio (***x***) in an equation of the form:

$$y = a + bx$$

This line is illustrated in Figure 9.10 and is the basis of using a quality-of-product ratio to predict a quality-of-use ratio.

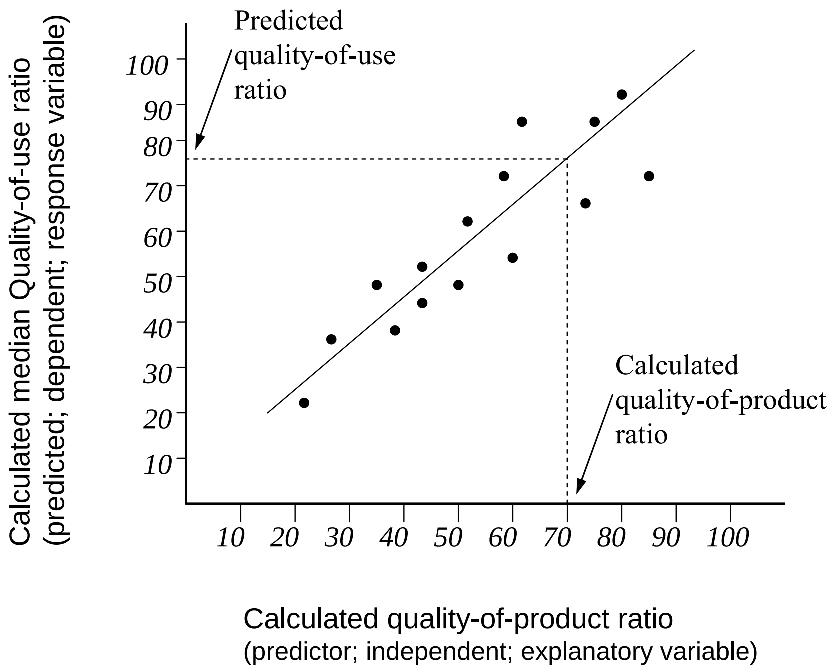


Figure 9.10 – *A regression line fitted to a quality-of-product ratio to predict a website's quality-of-use.*

Montgomery & Peck (1982); Neter, *et al.* (1996) and Weisberg (2005) all provide comprehensive details concerning statistical analysis relating to residual plots, outliers and other influential observations in order to better understand the correlation.

So, using the data from the validation studies and using statistical methods the analysis step seeks to show that there is a clear relationship between the quality-of-product and quality-of-use ratios. It also seeks to establish the level of confidence that website specifiers and designers can have when predicting website engagibility in a broader population of websites. This is represented by step 20 in Figure 9.7.

The eventual aim would be that the completed validation study would be in a position to compare the engagibility of one website with another where a number of engagibility criteria, up to a maximum of 67, would be considered. To Validate MRA as a predictor of engagibility quality it would be necessary to apply it to a number of websites in keeping with Schneidewind (1994). The chi-square goodness-of-fit technique would be an appropriate method.

9.5.5.1 Hypothesis confirmation.

Step 21 revisits the hypothesis. Once all of the statistical analysis has been completed it will be possible to decide if the hypothesis (null hypothesis) can be rejected. That is, the validation procedure indicates if the Metric Ratio Analysis approach is a reliable predictor of website engagibility.

9.5.6 Documentation and decision making

This is the last of the phases in Fenton & Pfleeger (1996) six phase model and is step 22 in the empirical validation model. A secretariat function will now take responsibility for all data and the analysis results. This involves taking responsibility for documenting: the aim and any objectives, the hypothesis, study website details and website visitor details, the environments, the collected counts, the calculated ratios, the statistical tests and all results. Details of the design of the experiments, software tools should be documented. According to Fenton & Pfleeger (1996) there are three motivations for completing this phase:

1. To provide evidence for users of the MRA approach of the strengths and weaknesses, advantages and disadvantages of MRA
2. To document for future independent researchers how the results are arrived at so that they can replicate the experiments
3. To perform similar experiments with variations of websites and visitors.

Dissemination of the research and its results among the research community would be part of this phase.

9.6 Conclusion

This chapter has proposed a procedure for the theoretical and empirical validation of Metric Ratio Analysis. The proposed procedure draws on acknowledged academic knowledge and commercial expertise which are combined with guidance and good practice recommendations from international standards bodies.

The study is structured to conform to two relevant stages of the metrics methodology of Shepperd & Ince (1993) and with the Fenton & Pfleeger (1996) phases for carrying out a formal experiment. The theoretical validation stage addressed the validation of the model and method that underpin MRA. The empirical validation stage proposes parallel studies for data collection and hypothesis testing. These are a website design study and a website usage study. The websites proposed for the study are commercially developed online eCommerce websites. It is recommended that the visitors whose engagibility is measured should be typical of the intended user community.

The proposed procedure involves data gathering using state of the art data collection techniques and hypothesis testing as recommended by best academic thinking and international practice. Statistical analysis techniques are recommended for determining conformance with measurement validation criteria.

The study also proposes two supporting evaluations. The first is a heuristic evaluation of the website's design and the other is a website visitor engagement questionnaire. Ejiogu (1993) points out that many reports of model validation are actually correlation analysis studies of independent metrics and that there is a significant difference between model validation and correlation analysis. He explains that for a correlation analysis two or more different models are under experimental study; but for a model validation one model is subjected to a hypothesis to the complete exclusion of any other model. So, in this proposed procedure MRA is subjected to an hypothesis and the expert heuristic review and the engagibility analysis questionnaire are both supporting studies intended to add additional understanding of the working of the MRA approach. They are not part of the formal validation to show that website design is a predictor of website engagibility.

At this time the formulae, criteria, and measurement tool that would be used to complete the website usage study have not be defined. This would happen as part of continuing research. Heuristics that are appropriate to website engagibility also need to be determined as part of future research. And, questions for a website engagibility questionnaire also need to be written as part of continuing research.

The chapter explains how this validation needs a longitudinal study that embraces a large number of websites and a large number of website visitors. Such a study is not trivial. For practical, management and analysis purposes it might be appropriate to use multiple laboratories which would perform the experiments with smaller groups of visitors, but all using the same instantiations of the same study websites.

Website engagibiliy measurement is new and an open minded philosophy is probably the wisest approach. It is most likely that ongoing validation will be addressed independently by researchers and practitioners seeking to create designs that they can confidently predict will engage visitors to their websites. This style of independent calibration and validation is encouraged.

Chapter 10

Conclusion

This chapter concludes the thesis by presenting a summary and review of the achievements, benefits and conclusions of the research. It also revisits the thesis hypothesis, presents a comparison summary of the various approaches to website measurement and considers future challenges that might be addressed in order to advance the research.

10.1 Introduction

The intellectual challenge addressed in this scholarly undertaking was to create new knowledge relating to software quality through original research and to apply that new knowledge and understanding to the specific context of quality websites. Through a methodical review and analysis of seminal and authoritative publications and through an eCommerce website study the undertaking has mastered the challenge and has specifically addressed website engagibility. The undertaking has made significant contributions to the body of knowledge and has disseminated this knowledge through international peer review publications and through this thesis on the theory and practice of website engagibility.

Engagibility is a new website quality factor so the work in this thesis is original. The theory presented is the first endeavour to define and model it. Other researchers might use alternative or additional theory and that will be valuable to the understanding of visitor engagement at quality websites.

This chapter presents a conclusion of the thesis. Section 10.2 reviews the principal contributions of the research and sets out a detailed summary of the achievements chapter by chapter. Section 10.3 revisits the research hypothesis. Section 10.4 sets out the benefits of the research and Section 10.5 compares Metric Ratio Analysis and other measurement approaches. Section 10.6 presents a concluding discussion, Section 10.7 considers future challenges and Section 10.8 is a closing statement.

10.2 Review and thesis summary

This thesis makes six significant contributions to the advancement of theory and practice in the domain of software quality and specifically website engagibility.

- It synthesises a comprehensive and methodical review and analysis of the domain of software quality.
- It creates a number of new conceptual models for researchers and students of software quality.
- It clarifies the broader perspectives of software quality in new and evolving domains.
- It presents a foundation theory for assessing website quality.
- It describes an extensive set of quantitative measures for assessing website quality-of-product engagibility.
- It demonstrates a 12 step practice for website quality measurement.
- It defines a detailed process for validating the measurement approach.

Findings and theory presented in this thesis have been published by the author as set out in the following chapter reviews.

Chapter 1 - Introduction

The first chapter in the thesis introduces the research domain and explains the intellectual challenge involved, research methodology, scope limitations, contributions to knowledge and strategy for disseminating the research findings.

Chapter 2 - Total Software Quality and the Software Quality Star

This chapter synthesises seven different perspectives of software quality and for each perspective, quality, as a measure of excellence, is considered. The synthesis focuses on the supplier (producer) and the acquirer (procurer), as identified in ISO/IEC 12207, as stakeholders in the software life cycle process. The main deliverable of this chapter is the Software Quality Star, which was first published as the core of a second model in *Strategic Drivers of Software Quality: Beyond external and internal software quality,* (Fitzpatrick, 2001). More recently the

Software Quality Star was published in *The Software Quality Star: A conceptual model for the software quality curriculum*, (Fitzpatrick, 2003b). Content from this chapter was also published in *Software Quality Challenges*, (Fitzpatrick, Smith & O'Shea, 2004b).

Chapter 3 - The Strategic Drivers of Software Quality

This chapter explains the different issues that impact the strategic acquisition of software products. These issues are explained in the context of the supplier and acquirer and the chapter addresses eleven issues, which it calls strategic drivers. The principal deliverable of this chapter is a the Software Quality – Strategic Driver Model (*SQ – SDM*) and content from the chapter was published in *Strategic Drivers of Software Quality: Beyond external and internal software quality*, (Fitzpatrick, 2001). Content from this chapter was also published in *Software Quality Challenges*, (Fitzpatrick, Smith & O'Shea, 2004b).

Chapter 4 - Additional quality factors for the World Wide Web

The chapter proves the need to interpret our understanding of established quality factors relevant to evolving domains and where appropriate new domain-specific quality factors are identified. The deliverable of this chapter is a set of five new quality factors and their characteristics which are appropriate to the World Wide Web. These were published as *Additional Quality Factors for the World Wide Web*, (Fitzpatrick, 2000b). Content from the chapter was also published in *Interpreting quality factors for the World Wide Web,* (Fitzpatrick, 2000a) and in *Software Quality Challenges*, (Fitzpatrick, Smith & O'Shea, 2004b)

Chapter 5 - Website engagibility ratios, criteria and counts: Theory and practice

Chapter 5 takes a step towards numerically quantifying website engagibility. The chapter presents an end-to-end solution which clearly and unambiguously clarifies and illustrates how data for a website measurement evaluation study should be collected.

The outputs of this chapter are:

- The taxonomy of quality-of-product and quality-of-use engagibility ratios.
- The criteria for measuring website quality-of-product engagibility (presented in a standard dataform suitable for documenting criteria counts).
- Five complete sets of counts for the sites in an eCommerce website study.

Content from this chapter has been published in *Software Quality Revisited*, (Fitzpatrick, Smith & O'Shea, 2004a) and in *Web site engagibility: A step beyond usability,* (Fitzpatrick, Smith & O'Shea, 2005).

Chapter 6 – Perspectives of software measurement

This chapter presents a review of software measurement and especially the historical evolution of the derivation and validation of software metrics. It considers internal and external software metrics and provides a foundation and context for the theory and practice of Metric Ratio Analysis. In particular the chapter identifies the Shepperd & Ince (1993) stages of a metrics methodology. The two appropriate validation stages from this methodology – theoretical validation and empirical validation – are used as the basis of the proposed validation procedure outlined in Chapter 9. The chapter positions the website measurement of this thesis in the domain of software measurement.

Chapter 7 - Metric Ratio Analysis: An approach to measuring website quality

The chapter delivers a new fully explained 12-step approach to quantifying website quality. Relying on acknowledged measurement theory, Financial Ratio Analysis and graph theory, the approach is fully explained and is complete with an underpinning mathematical argument. The approach is especially suited to establishing metrics for benchmark comparison measurement. The output from this chapter is Metric Ratio Analysis: An approach to measuring website quality. Content from this chapter has been published in *Quality Challenges in E-Commerce Web sites,* (Fitzpatrick 2003a).

Chapter 8 - Applying Metric Ratio Analysis to the navigation ratio

Chapter 8 builds on the content of Chapter 7 and demonstrates MRA in the context of the navigation ratio. This includes detailed clarification of issues relating to criteria selection, justification, numerator and denominator requirements, normalisation, weighting, target values, and ranges. The chapter explains matters of MRA practice, particularly in relation to making accurate counts, numerator and denominator practice, and formula structure. It illustrates MRA using normalized values.

Chapter 9 – Validation

This chapter proposes a procedure for validating the Metric Ratio Analysis approach. The proposed procedure is based on the relevant two stages in the *Stages of the metrics methodology* proposed by Shepperd & Ince (1993). The chapter also relies on authoritive research publications and international standards. The chapter explains that the validation process is a lengthy undertaking and that performing the validation is beyond the scope of this thesis.

Chapter 10 - Conclusion

The Conclusion chapter presents a summary review and critique, research benefits, details of future challenges and a concluding statement.

The thesis has not addressed quality-of-use ratios so the theory and practice presented by this thesis needs to be further enhanced as a result of a comprehensive study similar to the quality-of-product study presented here.

The thesis has not been able to avail of industry acknowledged quality websites during the eCommerce website study so the practice of benchmark comparison might be refined by comparing an alternative set of websites.

The eCommerce website study could not quantify some of the engagibility ratios because the website owners did not have a strategy for including those ratios.

10.3 Research Hypothesis revisited

The first hypothesis addressed in this thesis is:

Website engagibility is an important quality factor to be considered when designing a website and it is possible to derive formulae which use measures of website design elements to calculate metrics that are predictors of visitor engagibility.

The second hypothesis is:

A target-based website engagibility comparison can be developed, which sets a particular website within the context of marketplace custom and practice.

The thesis proves both hypotheses. In the first instance the thesis clearly identifies a theory and practice of website engagibility. It identifies a significant set of website design elements and uses these to derive engagibility measurement formulae. These formula are derived in detail for website navigation.

The thesis shows that two parallel studies - a website design study and a website usage study - are necessary in order to validate the formula. The thesis has shown that the first of these studies can be completed. However, extensive future research must be completed in order to complete the website usage study. Due to the magnitude of these studies (excessive cost and timescale involved) full theoretical and empirical validation has to be left for future research.

A target-based website engagibility comparison study has shown that reference to marketplace custom and practice is a valuable approach to analysing website engagibility. By reference to the calculated website engagibility ratio and the presence or absence of design parameters, website owners, specifiers and designers can make engagibility design changes early in the website development process.

10.4 Benefits of the research contributions

The principal beneficiaries of this thesis and research project are:

- Software quality researchers seeking to expand knowledge and understanding of the domain.
- Website owners seeking to gain competitive advantage from their Internet presence.
- Website specifiers and designers (students and professionals) seeking to create high quality engagable websites.

Aspects of the research have been embraced by undergraduate students and three students at the School of Computing at DIT have completed undergraduate final year projects directly related to the research. One postgraduate student has focused on website differentiation and completed her MSc dissertation with distinction, in collaboration with Staffordshire University. Other MSc students at other Institutes have relied on the theory and thinking in the research publications.

Opportunities exist for lecturers and instructors to adopt the Software Quality Star as a conceptual end-to-end model of the software product life cycle. It’s sister conceptual Strategic Drivers model can also be used as a teaching tool. At least two third-level lecturers – one in Dublin and one in Finland – include the Software Quality Star and the Additional WWW quality factors in their lectures.

The Software Quality Star was the underlying reason for an invited paper at HCI International 2005.

As part of the DIT Computer Science Degree which is franchised in China to the Harbin Institute of Technology (HIT), website engagibility has been combined with server side scripting as two important topic of the Web Development module. During summer 2006 students at HIT were successfully introduced through a studio classroom model to website engagibility. Valuable feedback has been written for conference publication.

10.5 Concluding discussion

The practice for mathematically quantifying a website quality factor as demonstrated by Metric Ratio Analysis might be criticised as being too complex and hence difficult to use. While the 'whole' methodology is sophisticated and appears to be complex, in practice, this is not the case. Because the theory is sound, users of the approach need not concern themselves with that theory and need only concern themselves with the practice. The simplicity of applying the underpinning approach is demonstrated in Appendix D. To successfully use MRA, an evaluator simply selects a set of competitor websites**,** and knowing counts from design plans for a proposed website, the evaluator compares the design counts with counts from the competitor sites. A target can be set based on values derived as part of this study or alternative desirable target counts and values might be used, or internationally agreed target counts and values might be available in the future. This gives a comparison indication of the engagibility of the proposed website in advance of implementing the design. Users of MRA might tailor the criteria in order to measure their own ratio needs and the approach supports that.

The reader will realise that the target website as explained in Chapter 7 is not the definitive solution. Neither do the counts used in the target define an internationally acknowledged set of counts. This is an initial first approach. Individual evaluators might approach it differently, tailoring the criteria, counts and values that they use in their formulae.

10.6 Future challenges

This thesis provides a sound foundation for significant future research opportunities where the theory and practice in the domain of website quality can be extended and broadened as follows:

- Completing the validation of Metric Ratio Analysis is a significant future challenge and would be the first priority of continuing research.
- The Metric Ratio Analysis universal formula is:

$$\frac{\{(e_1+x)\times ew_1\}^{p_1}\times\{(e_2+x)\times ew_2)\}^{p_2}\times\{(e_3+x)\times ew_3\}^{p_3}.......\times\{(e_n+x)\times ew_n)\}^{p_n}}{\{(i_1+x)\times iw_1)\}^{r_1}\times\{(i_2+x)\times iw_2)\}^{r_2}.......\times\{(i_n+x)\times iw_n)\}^{r_n}}\times constant$$

where $e_1 \dots e_n$ and $i_1 \dots i_n$ are MRA values or indirect values

x is a discontinuities variable and has a value of 1 or 0 depending on the MRA values or indirect values

$ew_1 \dots ew_n$ and $iw_1 \dots iw_n$ are value or indirect value weighting coefficients

$p_1 \dots p_n$ and $r_1 \dots r_n$ are website range exponents

and *constant* is a smoothing constant specific to the individual ratio.

Future research will establish valid values for these variables.

- The research has addressed quality factor criteria for measuring website engagibility from a quality-of-product perspective. There are four other website quality factors that can be researched. There are also other perspectives like quality-of-use that need to be researched in order to enhance understanding of the broader quality for the WWW domain.
- An on-going comprehensive website engagibility study which would gather counts from participating website owners could be initiated. This would support statistical analysis of current website quality-of-product design practice with a view to establishing business sector norms or ranges, and best practice design standards.
- The successful use of MRA depends on easy and accurate counting of criteria, so, a Metric Ratio Analysis software tool which can automatically collect the criteria counts and automatically perform the required calculations is a significant future challenge.

10.7 Closing statements

The novelty of the theory and practice addressed by this thesis presented intellectual challenges whereby existing work could be built upon. In particular, the novelty presented difficulties relating to the validation procedure. Much of the research relating to metrics validation is focused on software complexity, i.e., internal software quality, and is very suited to the quantitative nature of the science of measurement. This research, on the other hand, is concerned with external software quality, which is more suited to subjective qualitative measurement.

The research has challenged conventional thinking and practice in the discipline of software quality and has highlighted shortcomings, identified new challenges and proposed solutions. Revisiting the opening sentence in Chapter 1 and using the vocabulary of website engagibility as precipitated by this undertaking it is appropriate to write:

> *"For website engagibility measurement to be considered a mature engineering discipline there is a need to understand how website quality can be measured and a need for tools and formula for use in that measurement."*

Having devised a theory and practice of website engagibility measurement, it is reasonable to conclude that this thesis is one step towards a mature engineering discipline.

References

2WCSQ (2000) *Proceeding of the Second World Congress for Software Quality*, Union of Japanese Scientists and Engineers, Tokyo, Japan

Albrecht, A.J. (1979) *Measuring Application Development Productivity*, Proceedings IBM Application Development Symposium. Monterey, CA, Oct. 1979, pp 83-92

Albrecht, A.J. and Gaffney, J.E. (1983) *Software Function, Source Lines of Code, and Development Effort Prediction: A Software Science Validation*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol. SE-9, p639-648

America, P., Rommes, E. and Obbink, H. (2004) *Multi-view variation modeling for scenario analysis*, in Software Product-Family Engineering, Springer, Berlin/Heidelberg, Germany

ANSI/ASQC A3 (1978) *Quality Management and Quality Assurance - Vocabulary*-ISO 8402:1994; (ASQ A8402-1994 is a Revision and Redesignation of ASQ A3-1987

B.S. 4478 (1987) British Standard, *Quality Vocabulary: Part 1, International Terms*, British Standards Institute, London, UK

Bache, R. and Neil, M. (1995). *Introducing metrics into industry: a perspective on GQM*. In Fenton, E., Whitty, R and Iizuka, Y. (eds.), Software quality assurance and measurement: a world-wide perspective, International Thomson Computer Press, London

Barnum, Carol (2003) *The Magic Number 5: Is it enough for web testing*, Panel discussion, CHI 2003, Ft. Lauderdale, Florida, USA, ACM, USA

Basili, V.R. (2006) email communication with the author

Basili, V.R. and Romback, H.D. (1988) *The TAME Project: Towards improvement-oriented software environments*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA Vol 14(6) p758-773

Basili, V.R. and Weiss, D.M. (1984) *A Methodology for Collecting Valid Software Engineering Data*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol. SE-10, No 6, p728-738

Basili, V.R. (1985) *Quantitative Evaluation of Software Methodology, Technical Report TR-1519, Department of Computer Science*, University of Maryland, at Clooege Park, California, USA

Basili, V.R. (1992) *Software Modeling and Measurement: The Goal Question Metric Paradigm*, Computer Science Technical Report Series, CS-TR-2956 (UMIACS-TR-92-96), University of Maryland, College Park, MD, USA

Basili, V.R., Briand, L.C. and Melo, L.W. (1996) *A validation of object-oriented design metrics as quality indicators*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol 22(10), p751–761

Bennett, P. (1998) The evaluation and management of Information Technology investments, MSc dissertation, School of Computing, Staffordshire University, UK

Benyon-Tinker, G. (1979) *Complexity models in an evolving large system*, Proceedings of ACM Workshop on Quantitative Models, Complexity and Cost, New York, NY, USA, p117-127

Bevan, N. (1995) *Measuring usability as quality of use*, Software Quality Journal, Springer, Netherlands, Vol 4, p115-150

Bevan, N. (1998) *Usability issues in Web site design*, Proceedings of UPA'98, Washington DC, 22-26 June 1998

Bevan, N. (1999) *Quality in Use: Meeting User Needs for Quality*, Journal of System and Software, http://www.dc.ufscar.br/~junia/qualiusabi.pdf accessed 8 July 2005

Bevan, N. (2005) *Guidelines and standards for Web usability*, proceedings of HCI International 2005, Las Vegas, Lawrence Erlbaum Associates, New Jersey, USA

Bevan, N. and Kincla, S. (2003) *Usability guidelines for academic websites*, accessed 1 July 2006, http://www.usabilitynet.org/guidelines/

Bevan, N. and Macleod, M. (1994) "*Usability measurement in context*", Behaviour and Information Technology, Taylor & Francis Ltd, Basingstoke, UK, Vol(1 & 2), p132-145

Bickerton, P., Bickerton, M. and Pardesi, U. (1996) *Cybermarketing*, Butterworth Heinemann, Oxford, UK

Bobby Online (2005) Web accessibility software tool, http://bobby.watchfire.com/bobby/html/en/about.jsp accessed 12 January 2005

Boëhm B. (1978) *Characteristics of software quality*, Vol 1 of TRW series on software technology, North-Holland, Amsterdam, Netherlands

Boëhm, B. (1981) *Software Engineering Economics*, Prentice-Hall

Boehm, B., Clark, B., Horowitz, E., Westland, C., Madachy, R. and Selby, R. (1995) *The COCOMO 2.0 Software Cost Estimation Model*, International Society of Parametric Analysts, On-line resource at the University of Southern California, http://sunset.usc.edu/research/COCOMOII/Docs/ispa95.pdf accessed 22 April, 2006

Boehm, B.W., Brown, J.R. and Mipow, M. (1976) *Quantitative Evaluation of Software Quality*, Proceedings Second International Conference of Software Engineering, IEEE Computer Society Press, Los Alamitos, CA pp. 592-605.

Briand, L., Emam, K.E. and Morasca, S. (1998) *Theoretical and Empirical Validation of Software Product Measures*, International Software Engineering Research Network, technical report No ISERN-95-03, online publication at http://www2.umassd.edu/SWPI/ISERN/isern-95-03.pdf

Brooks, F.P. (1975) *The mythical man-month: Essays on software engineering*, Addison-Wesley Publishing Company, Reading, Massachusetts, USA

Buglione, L., Gasparro, F., Giacobbe, E., Grande, C., Iovieno, S., Lelli, M., Scarcia, A. and Sedehi, H. (2004) *A Quality Model for Web-based*

Environments: First Results, Proceedings of the Software Measurement European Forum (SMEF 2004, Rome), Istituto di Ricerca Internazionale S.r.l., Milan, Italy, ISBN 88-86674-33-3, p160-168

Chidamber, S.R. and Kemerer, C.F. (1991) *Towards a Metrics Suite for Object Oriented Design*, OOPSLA '91, ACM Press New York, NY, USA, p197-211

Churcher, N.I. and Shepperd, M.J. (1995) *Comments on "A Metrics Suite for Object Oriented Design"*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol 21(3), p263-265

Council Directive (90/270/EEC) (1990) *Minimum safety and health requirements for work with display screen equipment*, Official journal of the European Communities, pp. L 156/14-18

Crosby, P.B. (1984) *Quality without tears*, McGraw-Hill books, New York, USA, p60

CUPRIMDSO i.e., capability [functionality], usability, performance, reliability, instalability, maintainability, documentation/information, service, and overall satisfaction in *Software Metrics: Establishing A Company Wide Program*, Grady, R.B. and Casewell, D.L. Hewlett-Packard (1987) Prentice-Hall, Inc., NJ, USA

Curtis, B., Hefley, W.E. and Miller, Sally (1995) *People Capability Maturity Model (P-CMM)*, Software Engineering Institute, Carnegie Mellon University, Pennsylvania, USA http://www.sei.cmu.edu/cmm-p/#TOP accessed 25 October, 2000

Curtis, B., Sheppard, S.B., Milliman, P., Borst, M.A., and Love, T. (1979) *Measuring the psychological complexity of software maintenance tasks with Halstead and McCabe metrics*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, SE-5 (2), p96-104

Cutler, M. and Sterne, J., (2003) *E-Metrics – Business metrics for the new economy*, NetGenesis Corp., Cambridge, MA, USA,

Daily, K. (1992) *Quality management for software*, NCC Blackwell Ltd., Oxford, UK

De Troyer, O. (1999) *Designing well structured websites: lessons to be learned from database schema methodology*, Conceptual modelling – ER'98. 17th International Conference on Conceptual Modeling, Proceedings, Springer-Verlag, Berlin, Germany, p51-64

De Villiers, R. (1999), http://robbie.com/rdv/bi.html, accessed 29 June 1999

DeMarco, T. (1982) *Controlling Software Projects: Management, Measurement & Estimation*, Yourdon Press, New York, USA

DeMarco, T. (2006) email communication with the author

Deming, W.E. (2000) *Out of the crises*, MIT Press, Cambridge, Mass., USA, p168-169

Diaz, M. and Sligo, J. (1997) How software process improvement helped Motorola, IEEE Software, IEEE Computer Society, Los Alamitos, CA, USA, Vol 14(5), p75-81

DIN 55350 Part 11 (1995) *Concepts on quality and statistics - Part 11: Concepts of the quality management,* Deutsches Institut Fur Normung E.V., Germany.

Dix, A., Finlay, J., Abowd, G. and Beale, R. (1993) *Human-computer interaction*, Prentice Hall, Hemel Hempstead, UK

Dreyfus, P. (1998) *Usability and the Future of the Web*, Devedge View Source Magazine, Netscape, http://developer.netscape.com/news/viewsource/archive/editor98_1_20.htm accessed 16 June 1999

Duncan, Anne Smith, (1988) *Software development productivity tools and metrics*, Proceedings of the 10th international conference on Software engineering, Singapore, IEEE Computer Society, Los Alamitos, CA, USA, p41-48

Eardley, W.A. (2000) *SLIM/SLIP: a Proposed Method for Linking a Business Strategy to Strategic IS/IT Applications*. PhD Thesis, University of Southampton, UK

Eiffel (2006) *Elementary and composite metrics – Definitions* http://docs.eiffel.com/eiffelstudio/docs_no_content.html accessed 17 April 2006

Ejiogu, L.O. (1993) *Five Principles for the Formal Validation of Models of Software Metrics*, ACM SIGPLAN Notices, Vol 28(8), p67-76

E-Metrics (2003, 2004, 2005, 2006) Web Analytics Conference, London & Santa Barbara, Proceedings of E-Metrics Summits 2003 to 2006, http://www.emetrics.org/previous_emetrics_summits.php

Euro Review (1994) *Euro review on research in health and safety at work*, European Foundation for the improvement of living and working conditions, Shankill, Co. Dublin, Ireland

Feigenbaum, A.V. (1961) *Total Quality Control: Engineering and Management*, McGraw-Hill, New York, p13

Fenton, N. (1994) *Software Measurement: A Necessary Scientific Basis*, *IEEE Transactions on Software Engineering*, 20 (3), p199-206

Fenton, N. (2006) email communication with the author

Fenton, N.E. and Pfleeger, S.L. (1996) *Software Metrics: A Rigorous and Practical Approach*, International Thomson Computer Press, London, UK

Fenton, N.E. and Neil, M. (1999) *A critique of software defect prediction models*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol 25(5) p675-689

Fitzpatrick, R. (1997) *An investigation and analysis of current methods for measuring software usability*, MSc dissertation, School of Computing, Staffordshire University, UK

Fitzpatrick, R. (2000) *Additional Quality Factors for the World Wide Web*, Proceedings of the Second World Congress for Software Quality, Yokohama, Japan, Union of Japanese Scientists and Engineers (JUSE), Tokyo, Japan, p115-120

Fitzpatrick, R. (2001) *Strategic Drivers of Software Quality: Beyond external and internal software quality*, Second Asia-Pacific Conference on Quality

Software, Proceedings of APAQS 2001, Hong Kong; IEEE Computer Society Press, California, USA, p65-72

Fitzpatrick, R. (2003a) *Quality Challenges in E-Commerce Web sites*, Workshop paper for Exploring the Total Customer Experience: Usability Evaluations of (B2C) E-Commerce Environments at INTERACT 2003: Ninth IFIP TC 13 International Conference on Human-Computer Interaction, September 2003, Zurich, Switzerland, p11-12

Fitzpatrick, R. (2003b) *The Software Quality Star: A conceptual model for the software quality curriculum*, Workshop paper, Proceedings of Closing the Gaps: Software Engineering and Human-Computer Interaction, INTERACT 2003: Ninth IFIP TC 13 International Conference on Human-Computer Interaction, September 2003, Zurich, Switzerland, p9-13

Fitzpatrick, R. and Higgins, C. (1998). *Usable software and its attributes: A synthesis of software quality, European Community law and human-computer interaction,* In: People and Computers XIII. Proceedings of HCI’98 Conference, Springer, London, UK, p3-21

Fitzpatrick, R., Smith, P. and O'Shea, B. (2004a) *Software Quality Revisited*, Proceedings of the Software Measurement European Forum (SMEF 2004, Rome), Istituto di Ricerca Internazionale S.r.l., Milan, Italy, ISBN 88-86674-33-3, p307/315

Fitzpatrick, R., Smith, P. and O'Shea, B. (2004b), *Software Quality Challenges*, Proceedings of the Second Workshop on Software Quality at the 26th International Conference on Software Engineering (ICSE 2004), Edinburgh, Scotland, IEE, Stevenage, Herts, UK, p6-11

Fitzpatrick, R., Smith, P. and O'Shea, B., 2005 *Web site engagibility: A step beyond usability*, invited paper Proceeding of HCI International 2005, Universal Access in Human-Computer Interaction, Las Vegas, USA, Lawrence Erlbaum Associates, Inc (LEA), CD publication

FURPS i.e., Functionality, Usability, Reliability, Performance and Support Ability in *Software Metrics: Establishing A Company Wide Program*, Grady, R.B. and Casewell, Hewlett-Packard (1987) Prentice-Hall, Inc., NJ, USA

Gauch, H.G. (2003) Scientific method in practice, Cambridge University Press, Cambridge, UK

Gehrke, D and Turban, E. (1999) *Determinants of successful Website design: relative importance and recommendations for effectiveness*, Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences, IEEE, Los Alamitos, CA, USA

Ghezzi, C., Jazayeri, M. and Mandrioli, D. (1991) *Fundamentals of software engineering,* Prentice-Hall, New Jersey, USA

Gilb, T. (1976) *Software Metrics*, Studentlitteratur AB, Lund, Sweden

Gilb, T. (2006) email communication with the author

Ginsburg, M. and Kambil, A. (1999) *Annotate: a Web-based knowledge management support system for document collection*, Proceedings of the 32nd

Annual Hawaii International Conference on Systems Sciences, IEEE, Los Alamitos, CA, USA

Halstead, M.H., (1972) *Natural Laws Controlling Algorithm Structure?* Department of Computer Science Technical Report No 66, Purdue University, West Lafayette, Indiana, USA

Halstead, M.H., (1977) *Elements of Software Science*, Elsevier North-Holland, New York, USA

Halstead, M.H., (1975a) *Toward a Theoretical Basis for Estimating Programming Efforts*, Department of Computer Science Technical Report No 143, Purdue University, West Lafayette, Indiana, USA. See also Halstead, M.H., (1975b)

Halstead, M.H., (1975b) *Toward a Theoretical Basis for Estimating Programming Efforts,* Proceedings of the 1975 ACM Annual Conference, ACM/CSC-ER, ACM Press New York, NY, USA, p222-224

Hansen, W. (1978) *Measurement of program complexity by the pair: (Cyclomatic Number, Operator Count),* ACM SIGPLAN Notices, ACM Press New York, NY, USA, Vol 13(3), p29-33

Harley, S., Gluck, S., Kantor. M. and Berkovich, H. (2000) *Starting from CMM level 1 and heading towards CMM Level 4 – A Practical Experience*, Proceedings of the Second World Congress for Software Quality, Union of Japanese Scientists and Engineers, Tokyo, Japan, p583-588

Hauser, J. and Clausing, D. (1988), *The House of Quality*, Harvard Business Review, May-June

Henderson, J. and Venkatraman, H. (1989) *Strategic Alignment: A model for organizational transformation via Information technology*, Working Paper 3223-90, Sloan Management Review

Henry, S.M. and Kafura, D. (1981) *Software structure metrics based on information flow*, IEEE Transactions on Software Engineering, Vol 7(5), p510-518

Herbsleb, J., Zubrow, D., Goldenson, D., Hayes, W. and Paulk, M. (1997) Software quality and the Capability Maturity Model, Communications of the ACM, ACM Press, New York, NY, USA, Vol 40(6), p30-40

Hetzel, B. (1993) *Making Software Measurement Work: Building an Effective Measurement Program*, John Wiley & Sons, Inc. New York, NY, USA

Hitz, M. and Montazeri, B. (1996) *Chidamber and Kemerer's Metrics Suite: A Measurement Theory Perspective*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol 22(4), p267-271

Holcomb, R. and A Tharp (1991) *Users, a software usability model and product evaluation*, Interacting with Computers, Butterworth-Heinemann, Oxford, UK, Vol 3(2) p155-166

Humphrey, W.S., Snyder, T.R. and Willis, R.R. (1991) Software Process Improvement at Hughes Aircraft, IEEE Software, IEEE Computer Society, Los Alamitos, CA, USA, Vol 8 (4), p11-23

IBM (1999) *The World Wide Web,* http://www.ibm.com/ibm/easy/design/lower/f060100.html accessed 18 June 1999

IEEE (1983) *IEEE Standard glossary of software engineering terminology*, Institute of Electrical and Electronics Engineers, IEEE Std 729-1983

IEEE (1989) *IEEE Standard for software quality assurance plans*, Institute of Electrical and Electronics Engineers, IEEE Std 730-1989

IEEE Std 1061 (1992) *IEEE Standard for a Software Quality Metrics Methodology*, IEEE Computer Society, Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 1W1Z USA

IEEE Std 1061 (1998) *IEEE Standard for a Software Quality Metrics Methodology*, IEEE Computer Society, Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 1W1Z USA

Ince, D. (1989) *Software Metrics.* In Measurements for Software Control and Assurance, (Eds. Kitchenham, B.A. and Littlewood, B.) Elsevier Science Publications, Essex, England, UK, p27-62

Ince, D. (1994) *ISO 9001 and software quality assurance*, McGraw-Hill, UK

Ince, D.C. and Shepperd, M.J. (1988) *System Design Metrics: A review and Perspective*, Software Engineering 88., Second IEE/BCS Conference, Liverpool, UK, p23-27

Instone, K. (1999) *15 sub-topics or general issues that impact Web usability*, Usable Web, http://usableweb.com/items/issues.html accessed 16 June 1998

INUSE Project (1998) *Quality of Use Maturity Scale*, HFRG, University College Cork, Ireland http://www.ucc.ie/hfrg/projects/inuse/quality/index.html 29 Sept. 1998

ISBSG, (2004), International Software Benchmarking Standards Group, http://www.isbsg.org/ accessed 18 December, 2004

Ishikawa, Kaoru (1985) *What is Total Quality Control? : The Japanese way*, Prentice Hall, Englewood Cliffs, London, UK, p44/5

ISO 13407:1999 *Human-centred design processes for interactive systems*, International Organisation for Standardisation, Genève, Switzerland

ISO 8402 (1994) *Quality management and quality assurance – Vocabulary*, International Organisation for Standardisation, Genève, Switzerland, (Withdrawn and replaced by ISO 9000:2000)

ISO 9000 (1987) *International Standard. Quality management and quality assurance standards*, International Organisation for Standardisation, Genève, Switzerland

ISO 9000-3 (1991) *International Standard. Quality management and quality assurance standards - Part 3:Guidelines for the application of ISO 9001 to the development, supply and maintenance of software*, International Organisation for Standardisation, Genève, Switzerland

ISO 9000-3 (1997) *International Standard. Quality management and quality assurance standards - part 3:Guidelines for the application of ISO 9001:1994 to the development, supply, installation and maintenance of computer software*, International Organisation for Standardisation, Genève, Switzerland

ISO 9241-11 (1998) *International Standard. Ergonomic requirements for office work with visual display terminals (VDTs). Part 11:Guidance on usability,* International Organisation for standardisation, Genève, Switzerland

ISO DIS 9241-151 (2005) *Ergonomics of human-system interaction -- Part 151: Guidance on World Wide Web user interfaces,* International Organisation for Standardisation, Genève, Switzerland

ISO Standard 9001 (1994) *Quality Systems – Model for quality assurance in design, development, production, installation and servicing,* International Organisation for Standardisation, Genève, Switzerland

ISO/CD 23973 (2004) *Software ergonomics for World Wide Web user interfaces,* International Organisation for Standardisation, Genève, Switzerland

ISO/DIS 9000-3 (1996) *Committee Draft International Standard. Quality management and quality assurance standards - part 3:Guidelines for the application of ISO 9001 to the design, development, supply, installation and maintenance of computer software,* International Organisation for Standardisation, Genève, Switzerland

ISO/FDIS 9000-3 (1997) *Final Draft International Standard. Quality management and quality assurance standards - part 3: Guidelines for the application of ISO 9001:1994 to the development, supply, installation and maintenance of computer software,* International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 12207 (1995) International Standard*. Information technology - Software life cycle processes*, International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 12207 (1995) International Standard*. Information technology - Software life cycle processes*, International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 14598-1 (1999) International Standard. *Information technology - Software product evaluation - Part 1: General Overview,* International Organisation for Standardisation, Genève, Switzerland.

ISO/IEC 15504 (2003/2004) International Standard. *Information technology - Software process assessment – (Parts 1–4),* International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 15939 (2002) International Standard. *Software engineering - Software measurement process*, International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 20968, (2002) International Standard. *Software engineering — Mk II Function Point Analysis — Counting Practices Manual,* International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 25026, (2006) International Standard. *Software engineering - Software product quality requirements and evaluation (SQuaRE) - Common Industry Format (CIF) for usability test reports,* International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 9126 (1991) International Standard. *Information technology - Software product evaluation - quality characteristics and guidelines for their use,* International Organisation for Standardisation, Genève, Switzerland

ISO/IEC 9126-1:2001 International Standard. *Software engineering - Product quality - Part 1: Quality model,* International Organisation for Standardisation, Genève, Switzerland.

ISO/IEC TR 15504-9:1998 Technical Report. *Information technology - Software process assessment – (Parts 1–9),* International Organisation for Standardisation, Genève, Switzerland

ISO/IEC TR 9126-4 (2004) International Standard. *Software engineering – Product quality, Part 4: Quality in use metrics*, British Standards Institution, 389 Chiswick High Road, London, UK

ISO/TR 16982:2000 Technical Report. *Ergonomics of human-system interaction – Usability methods supporting human centered design,* International Organisation for Standardisation, Genève, Switzerland

Ivory, Melody (2005) email communication with the author

Ivory, Melody (2001) *An Empirical Foundation for Automated Web Interface Evaluation*, PhD Thesis, University of California at Berkeley, California, USA, http://www.ischool.washington.edu/myivory/publish/index.html accessed 12 January 2005

Ivory, M.Y., Sinha, R.R. and Hearst, M. (2001) *Empirically Validated Web Page Design Metrics,* in Proceedings of the Conference on Human Factors in Computing Systems, CHI Letters 3(1), p53-60

Johnsonbaugh, R. (2004a) *Discrete Mathematics*, Prentice-Hall, Upper Saddle River, New Jersey 07458, USA.

Johnsonbaugh, R. (2004b) Email dated 1 November 2004 to Ronan Fitzpatrick

Johnsonbaugh, R. (2005a) Email dated 16 March 2005 to Ronan Fitzpatrick

Juran, J.M. (1988) *Juran on Planning for Quality*, Free Press, New York, U.S.A, p11

Kafura, D. and Canning, J. (1985) *A validation of software metrics using many metrics and two resources*, Proceedings of the 8th international conference on Software Engineering, IEEE Computer Society Press, IEEE Computer Society, Los Alamitos, CA, USA, p378-385

Kan, S. (1995) *Metrics and models in software quality engineering*, Addison-Wesley, USA

Kasse, T. and McQuaid, P. (2000) *Choosing a process Improvement Strategy*, Proceedings of the Second World Congress for Software Quality, Union of Japanese Scientists and Engineers, Tokyo, Japan, p249-255

Keeker, K. (1997) *Improving Web Site Usability and Appeal: Guidelines* compiled by MSN Usability Research, 22 September 1998, http://msdn.microsoft.com/workshop/management/planning/improvingsiteusa.asp accessed 17 June 1999

Keevil, B. (1999) *Measuring the usability index of your Web site*, Sixteenth Annual International Conference of Computer Documentation. Conference Proceedings. Scaling the Heights: Future of Information Technology, ACM, NY, USA, p271-277

Kelvin, Lord (Thomson, William) (1883) *Electrical Units of Measurement in Popular Lectures and Addresses* (1891-1894, 3 volumes), vol. 1. cited from http://zapatopi.net/kelvin/quotes/ accessed 20 April, 2006

Kim, H. and Nam, J. (2000) *A case study of Product Quality Improvement program in a Systems Integration Company certified with ISO 9000 standard*, Proceedings of the Second World Congress for Software Quality, Union of Japanese Scientists and Engineers, Tokyo, Japan, p511-516

Kirakowski, J., Claridge, N. and Whitehand, R. (1998) *Human centered measures of success in web site design*, in Proceedings of the Fourth Conference on Human Factors & the Web (Basking Ridge, NJ, June). Online resource available at http://research.microsoft.com/users/marycz/hfweb98/kirakowski/index.htm

Kirakowski, J. and Corbett, M. (1988) *Measuring user satisfaction*: In People and computers IV, Eds. Jones, D. M., & Winder, R., Proceedings of HCI 88**,** Cambridge, UK, Cambridge University Press, p329-338

Kirakowski, J. and Corbett, M. (1993) *SUMI: the software usability measurement inventory*, British Journal of Educational Technology, Vol 24(3), p210-212

Kitchenham, B., Pfleeger, S. L., & Fenton, N. (1995) *Towards a Framework for Software Measurement Validation*, IEEE Transactions on Software Engineering, 21(12), p929-944

Kitchenhan, B. (1990) *Software metrics*. In Software Reliability Handbook (Ed. Rook, P.) Elsevier, London, UK

Koyani, S.J., Bailey, R.W. and Nall, J.R. (2003) *Research-Based Web Design & Usability Guidelines,* U.S. Department of Health and Human Services, accessed 30 June 2006, http://www.usability.gov/pdfs/guidelines.html

Lavine, R. (1995) *Guide to Web style*, Sun Microsystems, http://www.sun.com/styleguide/ accessed 17 June 1999

Lawlink, (1999) *Guidelines for Web Accessibility*, New South Wales Attorney General's Department Web Accessibility Guidelines, http://www.lawlink.nsw.gov.au/lawlink.nsf/pages/access_guidelines accessed 17 June 1999

Lev, B., and Sunder, S. (1979), *Methodological issues in the use of financial ratios*, Journal of Accounting and Economics 1/3, 187-210

Li, Wei and Henry, Sallie (1993) *Object-Oriented Metrics that Predict Maintainability*, Journal of Systems and Software, Elsevier, Amsterdam, The Netherlands, 23, p111-122

Lift (2004) Accessibility & usability testing tool, http://www.usablenet.com/ accessed 12 January 2005

Lynch, P. and Horton, S., (1999) *Web Style Guide: Basic Design Principles for Creating Web Sites*, Yale University Press, USA

Maxamine (2004) Online Business Intelligence website scanning software, Maxamine, San Ramon, California, USA http://www.maxamine.com/

McCabe, T.J., (1976) *A Complexity Measure*, IEEE Transacions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol 2(4), p308-320

McCall, J., Richards, P. and Walters, G (1977) *Factors in software quality*, Vols I-III, Rome Aid Defence Centre, Italy

Molich, R. and Nielsen, J. (1990) *Improving a human computer dialogue*, Communications of the ACM, ACM Press, New York, NY, USA, Vol 33(3), p338-348

Montgomery, D.C. and Peck, E.A. (1982) *Introduction to Linear Regression Analysis*, John Wiley, New York, USA

Neter, J. Wasserman, W. and Kutner, M.H. (1996) *Applied linear regression models*, Irwin, London, UK

Network Solutions, (1999), *12 Tips for a Better Web Site*, http://www.networksolutions.com//dotcomseries/iii_1.html accessed 17 June 1999

Nielsen, J and Landauer, T.K. (1993) *A Mathematical Model of the Finding of Usability Problems*, Proceedings of the INTERCHI '93, Conference on Human Factors in Computing Systems, ACM Press, New York, NY, USA, p206-213

Nielsen, J. and Molich, R. (1990) *Heuristic evaluation of user interfaces, Proceedings of the SIGCHI conference on Human factors in Computing Systems*: Empowering people, ACM Press, New York, NY, USA, p249-256

Nielsen, J. (1993) *Usability engineering*, Academic Press Limited, London, UK

Nielsen, J. (1996) *Top ten mistakes in Web design*, Sun Microsystems, http://www.sun.com/960416/columns/alertbox/index.html accessed 17 June 1999

Nielsen, J. (1998a) *Content usability*, NPL:Usability Forum - Making Webs Work, Tutorial, NPL, Middlesex, UK

Nielsen, J. (1998b) *Sun's new Web design*, http://www.sun.com/980113/sunonnet/index.html accessed 17 June 1999

Nielsen, J. (1998c) *Usability Heuristics for the Web*, http://webreview.com/wr/pub/97/10/10/usability/sidebar.html accessed 17 June 1999

Nielsen, J. (1999) *User interface directions for the Web*, Communications of the ACM, Vol 42(1), p65-72

Nolan, R. (1979) *Managing the crisis in data processing*, Harvard Business Review, March/April p115-126

Oakland, J.S. (1993) *Total Quality Management*, Butterworth-Heinemann, p4

Oviedo, E.I. (1980) *Control Flow, Data Flow and Program Complexity*, Proceedings of the Fourth International Computer Software and Applications Conference, (COMPSAC '80), p146-152

Pareto, V. (1896) *Cours d'Economie Politique*, Droz, Geneva, Switzerland

Paulk, M.C., Curtis, B., Chrissis, Mary Beth and Weber, C.V. (1993a) *Key practices of the Capability Maturity Model, Version 1.1*, Software Engineering Institute, Carnegie Mellon University, Pennsylvania, USA

Paulk, Mark C., Curtis, Bill, Chrissis, Mary Beth and Weber, Charles V. (1993b) "*Capability Maturity Model, Version 1.1*," IEEE Software, Vol. 10, No. 4, July 1993, pp. 18-27. (http://www.sei.cmu.edu/activities/cmm/cmm.articles.html)

Porteous, M., Kirakowski, J. and Corbett, M. (1993) *SUMI users handbook*, Human Factors Research Group, University College, Cork, Ireland

Porter, M.E. (1980) *Competitive Strategy: Techniques for analyzing industries and competitors*, Free Press, New York, USA

Porter, M.E. (1985) *Competitive Advantage*, Free Press, New York, USA

Prather, R.E. (1984) *An Axiomatic Theory of Software Complexity Metrics*, The Computer Journal, Vol 27, p42-45

Preece, J., Rogers, Y., Sharpe, H., Benyon, D., Holland, S. and Carey, T. (1994) *Human-computer interaction*, Addison-Wesley, Wokingham, UK

Pressman, R. (1994) Adapted by Darrel Ince, *Software Engineering: A Practitioner's Approach*, (European edition), McGraw-Hill International, Berkshire, UK

Ravden, S. and Johnson, G. (1989) *Evaluating usability of human computer interfaces:a practical method*, Ellis Horwood Ltd., Chichester, UK

Recker, Margaret M. and Pitkow, James E. (1996) *Predicting Document Access in Large Multimedia Repositories*, ACM Transactions on Computer-Human Interaction, ACM Press, New York, NY, USA, Vol 3(4), p352–375

Reiterer, H. and Oppermann, R. (1993) "*Evaluation of user interfaces: EVADIS II - a comprehensive evaluation approach*", Behaviour and information technology, Taylor and Francis, Basingstoke, UK, Vol 12(3), pp. 137-148

Rengger, R., Macleod, M., Bowden, R., Drynan, A. and Blaney, M. (1993) *MUSiC Performance Measurement Handbook*. National Physical Laboratory, DITC, Teddington, UK

Roberts, F.S. (1979) *Measurement theory with applications to decision making, utility, and the social sciences*, Addison-Wesley, London, UK

Robson, W. (1994) *Strategic management and information systems: An integrated approac*h, Pitman Publishing, London, UK

Roche, J., Jackson, M. and Shepperd, M. (1994) *Software Measurement Methods: An Evaluation and Perspective*, Proceedings of the Third Symposium on Assessment of Quality Software Development Tools, Washington, DC, USA, IEEE Computer Society, Los Alamitos, CA, USA,, p50-69

Salmi, T. and Martikainen, T. (1994) *A Review of the Theoretical and Empirical Basis of Financial Ratio Analysis*, The Finnish Journal of Business Economics, Runeberginkatu 14-16 FIN-00100 Helsinki Finland, 4(94) p426-448

Schneidewind, N.F. (1992) *Methodology for validating software metrics*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol 18(2) p410-422

Schneidewind, N. F. (1994) Validating Metrics for Ensuring Space Shuttle Flight Software Quality, Computer, IEEE Computer Society, Los Alamitos, CA, USA, Vol 27(8) p50-57

Serco (1999) *E-commerce Guidelines: Shopping*, http://www.usability.serco.com/netscape/index.html accessed 18 June 1999

Shepperd, M. (1990) *Design Metrics: an empirical analysis*, Software Engineering Journal, IEEE Electronic resource available at http://ieeexplore.ieee.org/iel1/2225/1643/00042969.pdf?isnumber=&arnumber=42969, accessed 8 March 2006, p3-10

Shepperd, M. [editor] (1994) *Software Engineering Metrics: Measures and Validations*, Mcgraw-Hill International, Dallas, TX, USA

Shepperd, M.J. and Ince, D. (1993) *Derivation and validation of Software Metrics*, Clarendon Press, Oxford, UK

Shingo, S(higeo) (1986) *Zero Quality Control: Source inspection and the poka-yoka stytem*, productivity press, Cambridge, Mass, USA, page vi

Shneiderman B. (1992) *Designing the user interface: strategies for effective human-computer interaction*, Addison-Wesley, USA

Sterne, J. (1995), *World Wide Web marketing*, Wiley, Chichester, New York

Symons, C. (1988) *Function Point Analysis: Difficulties and Improvements*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol 14(1), p2–11

Taguchi, G., Elsayed, E.A. and Hsiang, T. (1989) *Quality engineering in productions systems*, McGraw-Hill, new York, USA, p2-3

Thomson, William (1883) see Kelvin, Lord

Tillman, Hope N. (1997) *Evaluating quality on the Net* (An updated version of a presentation delivered at the John F. Kennedy School of Government, Harvard University, Cambridge, Massachusetts Sept 6 1995), http://www.tiac.net/users/hope/findqual.html#my accessed 18 June 1999

Trower, T. (1999) *The Human Factor: Guidelines for Designing Interactive HTML Documents*, http://www.microsoft.com/devnews/SepOct96/HumanFactor5_5.htm accessed 18 June 1999

UsableNET (2006) *LIFT Machine*, accessed 21 June 2006, http://www.usablenet.com/products_services/lift_machine/lift_machine.html

W3C (1999) *Unified Web Site Accessibility Guidelines*, http://trace.wisc.edu/docs/html_guidelines/htmlgide.htm accessed 17 June 1999

Wallmüller, E. (1994) *Software quality assurance: A quality approach*, Prentice-Hall International, Hertfordshire, UK

Watchfire (2006) *Accessibility testing*, accessed 21 June 2006, http://www.watchfire.com/products/webxm/bobby.aspx

Webventures, (1999) Get Results with Good Quality Web Pages, http://www.webventures.com.au/web/WV_bad.htm, accessed 18 June 1999

Weill, P. and Olson, M.H. (1989) *Managing investments in Information Technology, mini case examples and implications*, MIS Quarterly, 13(1), p3-18

Weisberg, S. (2005) *Applied Linear Regression*, John Wiley

Weyuker, E.J. (1986) *Axiomatizing software test data adequacy*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol. SE-12, p1128-1138

Wilson, R. (1996) *Web interactivity and customer focus*, Web Marketing Today, Wilson Internet Services, Vol 20, http://www.wilsonweb.com/articles/interactive.htm accessed 16 June 1999

Wolverton, R.W. (1974) *The cost of developing large-scale software*, IEEE Transactions on Computers, IEEE Computer Society, Los Alamitos, CA, USA, Vol 23(6), p 615-636

Yin, B.H. and Winchester, J.W. (1978) *The establishment and use of measures to evaluate the quality of software designs*, Proceedings of the software quality assurance workshop on Functional and performance issues, ACM, ACM Press, New York, NY, USA, p45-52

Zage, W.M., and Zage, D.M. (1993) *Evaluating design metrics on large-scale software*, IEEE Software, IEEE Computer Society, Los Alamitos, CA, USA, Vol 10(4), p75-81

Zuse, H. (1995) *History of software measurement*, Electronic resource at http://irb.cs.tu-berlin.de/~zuse/metrics/3-hist.html, accessed 12 March 2006

Zuse, H. (2004) WWW site http://irb.cs.tu-berlin.de/~zuse/index.html accessed November 2004

Bibliography

Bailey, J. and Burd, E. (2005) *Tree-Map Visualisation for Web Accessibility*, Proceedings of the 29th Annual International Computer Software and Applications Conference (COMPSAC'05), IEEE Computer Society, Los Alamitos, CA, USA

Bardain, E.F. Unpublished study quoted by Mayer, D.B. and Stalnaker A.W. (1968) *Selection and evaluation of computer personnel*, Proceedings of the 23rd ACM conference, p661

Basili, V.R. and Rombach, H.D. (1988) *Tailoring the software process to project goals and environments*, Proceedings, 9th International Conference on Software Engineering, Monterey CA, USA, p 345-357, ACM, USA

Basili, V.R. Caldiera, G. and Romback, H.D., (undated) *The Goal Question Metric Approach*, Online tutorial, http://www.cs.umd.edu/~mvz/handouts/gqm.pdf, accessed 8 March 2006

Birk, A., van Solingen, R. and Jarvinen, J. (1998) *Business impact, benefit, and cost of applying GQM in industry: an in-depth, long-term investigation at Schlumberger RPS*, Proceedings of the Fifth International Software Metrics Symposium, IEEE Computer Society, Los Alamitos, CA, USA

Botafogo, R., Rivlin, E. and Shneiderman, B. (1992) *Structural analysis of hypertexts: identifying hierarchies and useful metrics*, ACM Transactions on Information Systems, ACM Press New York, NY, USA, p142-180

Brewington, B. and Cybenko, G. (2000) *How dynamic is the Web?* Proceedings of the Ninth International World Wide Web Conference (WWW9), 2000, Amsterdam,NL, Computer Networks, Vol(33), June 2000, P257-276

Broder, A.Z., Glassman, S.C., Manasse, M.S. and Zweig, G. (1997) *Syntactic clustering of the Web***,** Computer Networks and ISDN Systems, Vol 29(8-13), p1157-1166

Chapin, N. (1979) *A measure of software complexity*, Proceedings of NCC 79, p995-1002

Chi, E.H., Pirolli, P. and Pitkow, J. (2000) *The scent of a site: a system for analyzing and predicting information scent, usage, and usability of a Web site*, Proceedings of the SIGCHI conference on Human factors in computing systems, ACM Press New York, NY, USA, p161-168 and plates 581-582

Chidamber, S.R. and Kemerer, C.F. (1994) *A Metrics Suite for Object Oriented Design*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol. 20(6), p476-493

Clark, B., Devnani-Chulani, S. and Boehm, B. (1998) *Calibrating the COCOMO II Post-Architecture Model*, Proceedings of the 1998 (20th) International Conference on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, p477-480

CSE, (2002) *COCOMO*, Centre for Software Engineering, USC, http://sunset.usc.edu/research/COCOMOII/index.html accessed 22 April, 2006

Dhyani, D., Week, Ng and Bhowmick, S.S. (2002) *A Survey of Web Metrics*, ACM Computing Surveys (CSUR), ACM Press New York, NY, USA, Vol 34 (4), p469-503

Grady, R.B. and Caswell, D.L. (1987), *Software Metrics: Establishing A Company Wide Program*, Prentice-Hall, Inc., NJ, USA

Hafner, Ms Kammi Kai, (1995) *An experience-based optimization of the Goal/Question/Metric paradigm*, in proceedings of the California Software Symposium, University of California, Irvine, p79-89

Hawking, D., Craswell, N., Thistlewaite, P., Harman, D. (1999) *Results and Challenges in Web Search Evaluation*, Proceedings of the eight WWW Conference, Toronto '99, Elsevier Science, p243-252, available on-line at http://www8.org/w8-papers/2c-search-discover/results/results.html

Henry, S.M., Kafura, D., and Harris, K., (1981) *On the relationships among three software metrics*, Proceedings of ACM SIGMETRICS, pp. 81-89

Holdsworth, J. (1992) *The AMI project: Validating quantitative approaches to software management*. In: Proc. Eurometrics '92 European Conf. on Quantitative Evaluaion of Sofrware and Systems: Practical and Theoretical Issues, Brussels, Belgium, 13-15 April p125-134

Ince, D.C., (1990) *Software metrics - an introduction*, IEE Colloquium on Software Metrics, London, accessed online at http://0-ieeexplore.ieee.org.ditlib.dit.ie/iel3/1930/4878/00190902.pdf?tp=&arnumber=190902&isnumber=4878, accessed 5 March 2005

Ince, D., (1990) *Software metrics: Introduction*, Information and Software Technology, Vol 32 (4), p297-303 May 1990

ISO/IEC TR 9126-2 (2003) *Software engineering – Product quality*, Part 2: External metrics, British Standards Institution, 389 Chiswick High Road, London, UK

Kirakowski, J. (2006) *Background to SUMI*, Electronic resource, http://www.improveqs.nl/pdf/SUMIbackground.pdf, accessed 12 April, 2006

Kitchenham, B.A. (1987) *Towards a constructive quality model Part I : Software quality modelling, measurement and prediction*, Software Engineering Journal, Michael Faraday House, Herts, UK, Vol 2(4), p105-113

Kogure, M. and Akao, Y. (1993) *Quality Function Deployment and CWQC in Japan*, Quality Progress, (October), pp25-29

Kuntzmann-Combelles, A., Comer, P., Holdsworth, J. and Shirlaw, S., ed. (1992) *Handbook of the Application of metrics in Industry: A quantitative approach to software management*, AMI ESPRIT project

Larson, R.R. (1996) *Bibliometrics of the World-Wide Web: An exploratory analysis of the intellectual structure of cyberspace*, Proceedings of the Annual Meeting of the American Society for Information Science, Baltimore, Maryland, October 1996

Lee, D. Chuange, H. and Seamons, K. (1997) *Document Ranking and the Vector-Space Model*, IEEE Software, IEEE Computer Society, Los Alamitos, CA, USA, Vol 14(2), p67-75

Macleod, M., Bowden, Rosemary and Bevan, N. (1998) *The MUSiC Performance Measurement Method*, National Physical Laboratory, Middlesex, UK

Malacinski, Scott and Hatrick, (2001) *Measuring Web Traffic, Part 1*, accessed 1 July 2006 www-106.ibm.com/developerworks/web/library/wa-mwt1/

Marciniak, John J., ed. (1994) *Encyclopedia of Software Engineering*, John Wiley & Sons, New York, NY, USA, p131-165

Mayer, D.B. and Stalnaker A.W. (1968) *Selection and evaluation of computer personnel*, Proceedings of the 1968 23rd ACM National Conference, ACM Press New York, NY, USA, p657-660

McCall, J.A., (1980) *An assessment of current software metric research*, EASCON '80, Electronics and Aerospace Systems Conference, Arlington, VA; USA, p323-333

Nanus, B. and Farr, L. (1964) *Some cost contributors to large-scale programs*, AFIPS Proceedings SJCC, 25 Spring 1964, p 239-248

NASA, (2006) *Cost Estimating Web Site*, http://www1.jsc.nasa.gov/bu2/COCOMO.html accessed 22 April, 2006

Nielsen, Jakob (2001) *Usability metrics*, at Jakob Nielsen's Alertbox http://www.useit.com/alertbox/20010121.html, accessed 12 March 2006

NPL (1995) *MUSiC Performance Measurement Handbook (Version 3)*, National Physical Laboratory, Middlesex, UK

Perkowitz, M. and Etzioni, O. (2000) *Towards adaptive web sites: Conceptual framework and case study*, Artificial Intelligence, Elsevier, Vol 118, p245–275

Petersen, P.G., Andersen, O., Heilesen, J.H., Klim, S. and Schmidt, J. (1989) *Software quality drivers and indicators*, Proceeding of the Twenty-Second Annual Hawaii International Conference on System Sciences, 1989. Vol. II: Software Track, IEEE Electronic resource accessed 11 July 2006 available at http://ieeexplore.ieee.org/iel2/233/1806/00047994.pdf?isnumber=&arnumber=47994, p210-218

Pfleeger, S.L. and McGowan, C. (1990) *Software metrics in the process maturity framework*, Journal of Systems and Software, Elsevier Science Inc., New York, NY, USA, 12(3), p255-261

Pirolli, P., Schank, P., Hearst, M. and Diehl, C. (1996) *Scatter/gather browsing communicates the topic structure of a very large text collection*, Proceedings of the SIGCHI conference on Human factors in computing systems, ACM Press, New York, NY, USA, p213-220

Pitkow, J. and Pirolli, P. (1997) *Life, Death and lawlessness on the electronic frontier*, Proceedings of CHI '97, Atlanta, GA, USA, ACM Press, New York, NY, USA, p383-390

Shelley, C. (2002) *Beyond numbers*, 14th Annual UK Software Metrics Association Conference, University of Wolverhampton, England, UKSMA, 204 Woodbridge Road, Ipswich, Britain, IP4 2BF

Sackman, H., Erikson, W.J. and Grant, E.E. (1968) *Exploratory experimentation studies comparing online and offline programming performance*, Communications of the ACM, ACM Press, New York, NY, USA, Vol 11(1), p3-11

Shepperd, M. and Ince, D. (1990) *Multi-Dimensional Modelling and Measurement of Software Designs*, Proceedings of the 1990 ACM annual conference on Cooperation, Washington, D.C., USA, ACM Press, New York, NY, USA, p76-81

Shepperd, M. (1988) *A critique of cyclomatic complexity as a software metric*, Software Engineering Journal, March 1988, IEEE Electronic resource available at http://ieeexplore.ieee.org/iel5/2225/361/00006887.pdf?arnumber=6887, accessed 8 March 2006, p30-36

Sterne, J. (2002) *Web Metrics: Proven Methods for Measuring Web Site Success*, John Wiley & Sons Inc. NY, USA

Symons, C.R., (1991) *Software sizing and estimating: Mk II FPA (Function Point Analysis)*, John Wiley & Sons, Inc., New York, NY, USA

Troy, D.A., and Zweben, S.H. (1981) *Measuring the quality of structured designs*, Journal of Systems and Software, Vol 2, p113-120

Weyuker, Elaine (1988) *Evaluating software complexity measures*, IEEE Transactions on Software Engineering, IEEE Computer Society, Los Alamitos, CA, USA, Vol. 14, p1357-1365

Wikipedia (2005) *The free encyclopedia*, http://en.wikipedia.org/wiki/Software_metric, accessed 5 March 2005

Yuwono, B, and Lee, D. (1996) *Search and ranking algorithms for locating resources on the World Wide Web*, Proceedings of the 12th international conference on data engineering, New Orleans, IEEE Computer Society, IEEE Computer Society, Los Alamitos, CA, USA, p164-171

A theory and practice of website engagibility

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Volume 2 of 2

Contents

A theory and practice of website engagibility

Ronan Fitzpatrick MSc CEng MBCS CITP

PhD Appendix A
The Attributes of a usable software product

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Appendix A

The attributes of a usable software product

The aim of the appendix is to explain the product perspective in the producer/procurer/product triad in order to clarify the external quality attributes of a software product.

A.1 Background

Chapter 3 identified the strategic drivers of software quality from the perspectives of the producer and procurer. This appendix continues the study of the triad in the Software Quality Star by addressing software product quality. In doing so, the appendix recognises that there are both the internal and external quality factors (Ghezzi *et al.*, 1991) but because of the specific focus of the thesis it emphasises the external factors, that is, the usability factors.

The appendix is included for completeness so that the reader can better understand the focus of later chapters in the thesis. The content builds on my previous MSc work *An investigation and analysis of current methods for measuring software usability*, MSc dissertation, School of Computing, Staffordshire University, UK (Fitzpatrick, 1997), much of which was published in the joint publication *Usable software and its attributes: A synthesis of software quality, European Community law and human-computer interaction* (Fitzpatrick & Higgins, 1998). The work presented here is the original motivation for this PhD thesis and it was specifically chosen as the continuation point from my MSc.

However, there are two additions which are new to this thesis. These are:

- A new definition of usability
- Quality in the domain of the World Wide Web is introduced.

A.2 Introduction

Software usability is described in terms of attributes of a software product, the methods that should be used to measure those attributes, and metrics (numbers) which are the results of measurement (Holcomb & Tharp, 1991; Preece *et al.*, 1994; ISO/IEC 9126, 1991; ISO/DIS 9241-11, 1995). So, in order to measure usability it is necessary to know what attributes must be measured, the type of methods that must be considered and what metrics to expect. The aim of this appendix is to identify the attributes which should be measured. Chapters in the thesis consider measurement in the context of quality websites.

Strategic managers and IS professionals who are responsible for specifying, supplying and acquiring quality software products have to deal with a continuing flow of new international standards, legislation and user requirements which arise as a result of evolving technology. So, in order to clarify the current situation for everybody concerned with software quality, and especially those interested in usability, there is a need for a new review and evaluation of the various strands that contribute to software quality. By way of review, this appendix recalls the original software quality factors which were defined almost thirty years ago by McCall *et al.*, (1977) and presents a methodical analysis and synthesis of three modern strands (software quality, statutory obligations and human-computer interaction) which influence these factors.

The appendix begins with a review of formal definitions associated with software usability (McCall *et al.*, 1977; Ravden & Johnson, 1989; ISO/DIS 9241-11, 1995). The reason for this review is to show how computer scientists' view of usability has changed over the past thirty years and to show that there are new and evolving challenges associated with these definitions. The appendix continues with an examination of three strands which identify the set of attributes which are used to measure software usability. The three strands relate to software quality, statutory obligations and human-computer interaction. All three strands rely on well respected sources which include the European Council Directive on minimum safety and health requirements for work with display screen equipment, ISO/DIS 9241-10 (1993) and ISO/FDIS 9000-3 (1997). This synthesis proposes a new set of quality factors, and the appendix provides a new perspective of software usability by showing that the external quality factors in this new set are the usability attributes of a software product. New attributes like suitability, adaptability, functionality, installability and safety are identified and other attributes like usability and integrity are clarified within the three strands. Section A.3 introduces some facets of software usability and explains the motivation for the three strand approach. Section A.4 reviews definitions and models of usability and explains problems associated with them. Section A.5 examines the three strands in detail and in addition to identifying a comprehensive list of software quality factors (external and internal) it also identifies the usability attributes of a software product as a new deliverable from this appendix. Section A.6 clarifies how the quality attributes of a usable software product can be used and Section A.7 introduces the need for external quality factors to be examined in the context of the World Wide Web.

A.3 Facets of software usability

Usability is a key component in the overall quality of a software product (Porteous *et al.*, 1993) which is concerned with making the product easy to learn and [easy to] operate (McCall *et al.*, 1977). Usability also has a legal dimension. There are legal obligations for employers to protect the health of employees who use software interfaces (Council Directive 90/270/EEC, 1990). Usability is also a key concept of human-computer interaction (HCI), where, in addition to being concerned with making systems easy to learn and easy to use (Preece *et al.*, 1994), it is also concerned with supporting users during their interactions with computers (Shneiderman, 1987). So, usability is a desirable feature that threads its way into different facets (quality, legal and HCI) of computer software. Collectively, these three facets are of interest to quality assurance managers, system designers, system developers, end-users and to those with organisational responsibility for selecting and acquiring usable systems (Reiterer & Oppermann, 1993; Robson, 1994). In its simplest form, usability can be described as the extent to which a computer system's interface supports end-users. Because there are many facets to usability and in order to fully understand what usability is (so that it can be specified and measured), it is necessary to first establish a comprehensive set of attributes that make up usability. In this appendix, usability is considered to be an all embracing description of software. So, the attributes that make up usability can also be termed as the attributes of a usable software product.

There are many different definitions and models which clarify the meaning of software usability (McCall *et al.*, 1977; Ravden & Johnson, 1989; ISO/IEC 9126, 1991; ISO/DIS 9241-11, 1995; Nielsen, 1993; Bevan & Macleod, 1994). Some of these, e.g. (ISO/IEC 9126, 1991; Nielsen, 1993) concentrate on the attributes that constitute usability while other definitions concentrate on how usability should be measured, e.g. (ISO/DIS 9241-11, 1995; Bevan & Macleod, 1994). However, while these definitions support our understanding of software usability, there are problems associated with them. For example, the definitions that focus on attributes are weak in their support for measures and visa versa.

There is a natural relationship between usability and a quality software interface and it follows that an interface that has a high level of quality will have a high level of usability (Ince, 1994). Consequently, the attributes that influence usability can be viewed as being quality factors. This appendix establishes the quality factors that influence usability by reviewing three strands, each of which contributes different quality factors. These strands are reviewed using a quality-focused philosophy and are called the software quality strand (Section A.5.1), the statutory obligations strand (Section A.5.2) and the human-computer interaction strand (Section A.5.3).

The software quality strand reviews quality models (McCall *et al.*, 1977; Boëhm, 1978) and international standards (ISO 9000-3, 1991; ISO/DIS 9000-3, 1996; (ISO/IEC 9126, 1991; IEEE, 1989) which relate to software quality. The statutory obligations strand addresses the legislation enacted throughout the European Community (Council Directive 90/270/EEC, 1990) which requires that software should be easy to use and easy to adapt. This legislation also sets minimum requirements for the equipment that should be available to users and for the environment in which the users must work. The human-computer interaction strand examines current principles and practice in order to establish the usability requirements of end-users (Shneiderman, 1992).

The motivation for this three strand approach is the growing strategic need within business organisations for quality interfaces, which comply with current legislation and which support end-users (Reiterer & Oppermann, 1993; Robson, 1994). Only by combining the three strands is it possible to identify a comprehensive set of quality-focused attributes that influence usability. The presence or absence of these attributes is what is measured during usability measurement (Reiterer & Oppermann, 1993).

Before reviewing the three strands, it is first necessary to examine definitions and models of usability that are used in the software industry and in academia.

A.4 Definitions and models of software usability

In this section, four definitions of usability are reviewed to show how computer scientists' views of usability have changed with advances in technology. Academic and commercial models are reviewed, and problems associated with these definitions and models are examined.

A.4.1 Definitions of usability

Usability as a software quality factor was defined by McCall *et al.*, (1977, p. 3-5) as *"the effort required to learn, operate, prepare input and interpret output of a program."*

To gain a proper understanding of McCall's perspective of usability in 1977, it is appropriate to recall the taxonomy of computers in those days. The environment consisted of mainframe and mini computers running major data processing applications. Staff were simply required to learn how to operate the system, input data, receive output and keep the system running. Software was developed for low specification monitors that used simple combinations of green and black text. Usability was perceived to be confined to operators and their learning process in this environment. The era of end-user computing was only beginning. More recently, Ravden & Johnson (1989, p. 9) defined usability as *"the extent to which an end-user is able to carry out required tasks successfully, and without difficulty, using the computer application system."*

From this definition comes some idea of the complexity of usability, especially considering that there are many different:

- profiles of end-users
- skills among end-users
- attitudes among end-users
- complexities of tasks
- measures for success
- interpretations of difficulty.

To these can be added the different equipment that users need and the different environments in which users can work (Council Directive 90/270/EEC, 1990). An important advance in Ravden & Johnson's (1989) definition is that they introduced an element of measure by using the expression "the extent" in their definition. This thesis argues that using the expression “the extent” it follows that metrics can be applied to usability.

The International Organisation for Standardisation (ISO) also define usability. In their standard (ISO/IEC 9126, 1991), usability is defined as *"a set of attributes of software which bears on the effort needed for use on an individual assessment of such use by a stated or implied set of users"*. This has been updated in ISO/IEC 9126-1, 2001 to *“the capability of the software product to be understood, learned, used and attractive to the user when used under specified conditions”*.

This definition adds to our understanding of usability by considering a set of attributes of software. The standard names three attributes (which it calls sub-characteristics). These are learnability, understandability and operability.

The element of measure is also contained in a new International Standard (ISO/DIS 9241, 1995), which is currently under development. The standard is named "Ergonomic requirements for office work with visual display terminals (VDTs)" and consists of 17 parts. Part 11 (eleven) is specifically concerned with usability and defines it as "*the extent to* *which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*".

A summary table of definitions of usability is presented in Figure A.1.

Source	Definition
McCall *et al.* (1977)	The effort required to learn, operate, prepare input and interpret output of a program.
Ravden & Johnson (1989)	The extent to which an end-user is able to carry out required tasks successfully, and without difficulty using the computer application system.
ISO/IEC 9126: 1991	A set of attributes of software which bear on the effort needed for use and on the individual assessment of such use by a stated or implied set of users.
ISO/IEC 9126-1: 2001	The capability of the software product to be understood, learned, used and attractive to the user when used under specified conditions
ISO/DIS 9241-11: 1995	The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

Figure A.1 - *Definitions of usability.*

A.4.2 Usability models

Nielsen (1993) explains usability as part of the wider aspect of system acceptability and suggests that usability is part of a much broader scene - see Figure A.2.

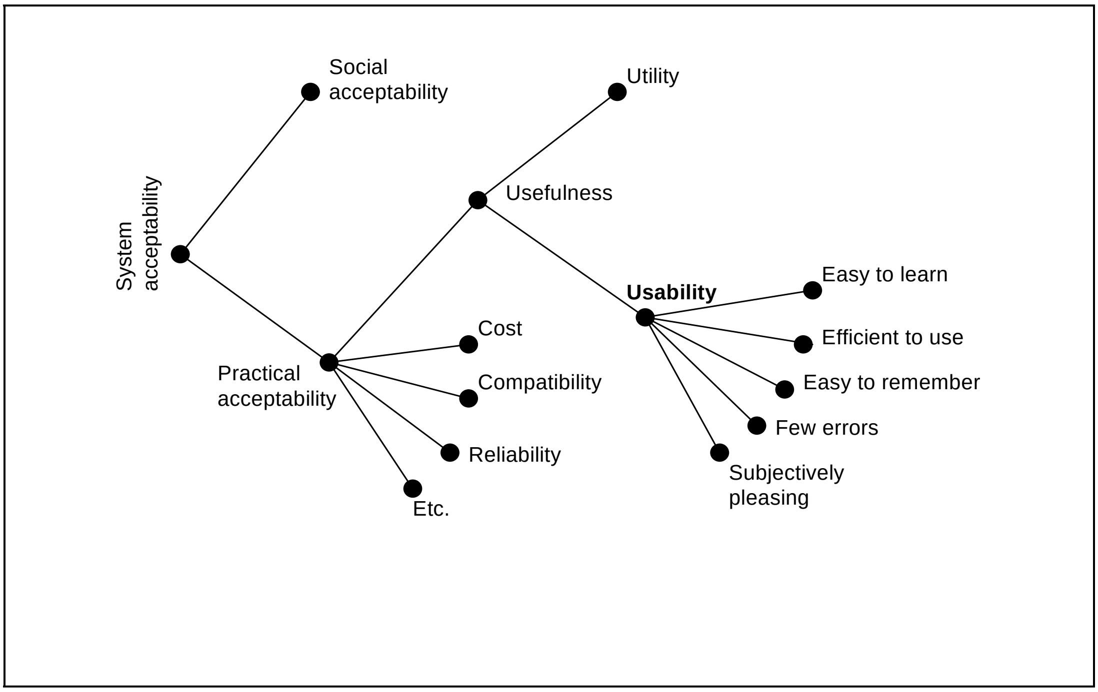

Figure A.2 - *Nielsen's model of system acceptability.*

Nielsen's approach focuses on social acceptability and practical acceptability. In his text, the concept of social acceptability is not developed to any great extent other than in the context of an example of a possible undesirable system. Systems with cultural influences or subliminal practices would be appropriate for consideration under social acceptability.

The sub-characteristics of practical acceptability of Nielsen's model are not unlike the technical or internal quality characteristics of a software product (Ghezzi *et al.,* 1991; Ince, 1994; ISO/DIS 9000-3, 1996). For example, compatibility is the same as interoperability. Perhaps, to correspond with the Etc. in the model, the author intended that practical acceptability should refer to factors like efficiency, portability, testability, maintainability and reusability as these are the factors that are not mentioned elsewhere in the model. Nielsen’s model (1993, p. 25) sub-divides usefulness into utility and usability which are described respectively as: "*the question of whether the functionality of the system in principle can do what is needed [and] the question of how well users can use that functionality*". The usability dimension of the model incorporates "easy to learn", "efficient to use", "easy to remember", "fewer errors" and "subjectively pleasing". All of these are familiar expressions easily associated with the definitions of usability in Section A.4.1. They are also similar to the external quality characteristics of a software product (Ghezzi *et al.,* 1991; Ince, 1994; ISO/DIS 9000-3, 1996). Consequently there are close connections between usability and software quality. "Subjectively pleasing", however, is new and introduces a new view of usability where end-users' subjective evaluations of a system come into play. This approach is also considered by Kirakowski & Corbett (1993) and by Bevan & Macleod (1994).

Kirakowski of the Human Factors Research Group at University College Cork has conducted extensive research in this area (Kirakowski & Corbett, 1993). His work is based on subjective user evaluations and he has developed a method for measuring software usability. This method - Software Usability Measurement Inventory (SUMI) -

measures five sub-scales, i.e. efficiency, affect, helpfulness, control and learnability (Porteous *et al.*, 1993). The method is an attitude-measuring questionnaire that is completed by end-users.

More recently, Bevan & Macleod (1994, p. 136) have suggested that usability has to be viewed in different ways for different purposes, focusing on one or more of the following complementary views.

> "***a. the product-centred view of usability****: that the usability of a product is the attributes of the product which contribute towards the quality-of-use.*
> ***b. the context-of-use view of usability****: that usability depends on the nature of the user, product, task and environment.*
> ***c. the quality-of-use view of usability****: that usability is the outcome of interaction and can be measured by the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments*".

Another approach to understanding software usability is to consider actual practice as conducted by industrial leaders like IBM, Apple, Hewlett Packard and Microsoft. Kan (1995) reports that

> *"IBM monitors the CUPRIMDSO satisfaction levels of its software products (capability [functionality], usability, performance, reliability, installability, maintainability, documentation, service and overall). Hewlett-Packard focuses on FURPS (functionality, usability, reliability, performance and serviceability)".*

A.4.3 Problems with usability definitions and models

There are three problems associated with the above definitions of software usability. The first problem is that there is no consistent set of attributes of software. While ISO/IEC 9126 (1991) and Nielsen (1993) focus on the attributes of software, their listings of the attributes are different. They are also inconsistent with commercial practice. For example, ISO/IEC 9126 (1991) mentions usability and suggests that its sub-characteristics are learnability, understandability and operability while Nielsen (1993) considers the broader concepts of social acceptability and practical acceptability and lists, easy to learn, efficient to use, easy to remember, few errors and subjectively pleasing. Commercial organisations like IBM and Hewlett-Packard use similar listings (Kan, 1995), but, there is no consistent set. Furthermore, is it not possible to know if a composite list of these four would represent all of the attributes of a usable software product.

The second problem with usability definitions is that, while recent definitions and models concentrate on the need to measure usability and even state what the measures should be, the definitions do not support a universal set of measures. ISO/DIS 9241-11 (1995) and Bevan & Macleod (1994) favour effectiveness, efficiency and satisfaction (updated to effectiveness, productivity, safety and satisfaction in ISO/IEC FDIS 9126-2, 2000) as usability measures while IBM measure satisfaction only (Kan, 1995). Kirakowski's SUMI product measures efficiency, affect, helpfulness, control and learnability.

The third problem is that it is not clear whether each measure should be applied to all attributes or whether some measures only apply to a selected set.

Therefore, strategic managers who have responsibility for software products are not supported by all this confusion. What end-users want to use, and what strategic managers want to acquire are usable software products which comply with the latest legislation. Therefore, what is now required is a clear listing of the attributes of a usable software product together with the measures that should be applied to these attributes. Then, by applying the measures to the attributes it should be possible to establish a "usability quotient" for any software product. The remainder of this appendix focuses on the first of these requirements and identifies these attributes using a three strand approach.

A.5 Three strands that influence usability

To identify the attributes of a usable software product, three specific strands are examined. The first strand is the software quality strand, which in turn identifies the statutory obligations strand, which in turn identifies the human-computer interaction strand. From these strands, software quality factors are identified and a specific set of these factors (those that directly impact on the end-user) are shown to be usability attributes of a software product.

A.5.1 Software quality strand

The first strand to be examined is concerned with software quality. Studies in this domain began in the 1970s when desirable features for inclusion in software products were quantified by authors like McCall *et al.,* (1977) and Boëhm (1978) who both produced quality models. Later, the world-wide success of quality standards like ISO 9000 (1987), resulted in international standards for software quality (ISO 9000-3, 1991; IEEE, 1989).

A.5.1.1 Quality models and quality factors

Software quality is defined by the Institute of Electrical and Electronics Engineers (IEEE, 1983) as

> *"the degree to which software possesses a desired combination of attributes".*

These attributes are typically referred to as quality factors or quality characteristics and models for these were suggested in the late '70s by McCall *et al.,* (1977) and Boëhm (1978). Such quality factors include software correctness, reliability, efficiency, integrity, usability, maintainability, testability, flexibility, portability, reusability and interoperability (or interface facility). For a full explanation and recent review of each of McCall's quality factors, the reader is referred to Wallmüller (1994) and Fitzpatrick (1997). These factors can be conveniently categorised as external quality factors (mainly relating to HCI issues) and internal quality factors (which relate to the technical excellence of the product).

Ghezzi *et al.,* (1991, p. 18) support this view by stating that

> "*In general, users of the software only care about the external qualities*".

Because external factors affect users, this thesis refers to these as usability factors. So, McCall's quality factors can be sub-divided into external and internal factors. A sub-division of these factors (based on Wallmüller) is set out in Figure A.3.

Quality Factor	Category
• Integrity • Reliability • Usability • Correctness • Efficiency • Interoperability	External quality factors (i.e. Usability factors)
• Maintainability • Testability • Flexibility • Reusability • Portability	Internal quality factors

Figure A.3 - *Categorised quality factors.*

The reader's attention is drawn to the quality factor called "usability". McCall's definition of this factor is shown in Figure A.1. The focus of this appendix is that the term usability is better used to describe the entire software product and that repeating the term to describe a quality factor is inappropriate. Accordingly, this quality factor will be renamed as learnability (a term that has gained popularity among researchers) and ease-of-use to better reflect the topics addressed by McCall *et al.*, and thereby avoiding further confusion. Ghezzi *et al.*, (1991) and Daily (1992) suggest that it is important to prioritise these factors. These authors argue that if a software product cannot be installed, then it cannot be launched and therefore cannot be used. As a result, the other quality factors cannot be considered. Daily (1992, p. 19) also addresses this issue and suggests that "*once the software is usable, correct and reliable then efficiency, compatibility [interoperability] and integrity can be considered in more detail*".

In the intervening years since 1977/78 (when quality models were first published), there has been enormous technological advances and it is necessary to rethink and revise this area accordingly. Reference to Wallmüller (1994) shows that during this time some of the quality factors have become outdated. The remainder of this appendix shows that some quality factors need to be renamed to reflect modern vocabulary and understanding. It also shows that new factors need to be added to McCall's list.

A.5.1.2 International quality standards

The systems professional who has the responsibility for selecting and acquiring quality software might, with good reason, look to the international standard relating to quality as a starting point to provide guidance on the best approach to adopt. In 1991, the International Organisation for Standardisation published “Guidelines for the application of ISO 9001 to the development, supply and maintenance of software (ISO 9000-3, 1991). It is reasonable to expect that this international standard would address quality factors using the same vocabulary and meaning as used by McCall *et al.*, (1977) and by Boëhm (1978). Unfortunately, this was not the case and consequently a new Draft International Standard ISO/DIS 9000-3, 1996 was introduced and approved in June 1996. This became a Final Draft International Standard in 1997. This Final Draft ISO/FDIS 9000-3, 1997 goes a long way towards resolving the deficiencies of its predecessor. In the first instance its title is

Quality management and quality assurance standards - part 3: Guidelines for the application of ISO 9001 to the design, development, supply, installation and maintenance of computer software. This title mentions installability and the concept of installability is new. It is favoured by IBM (Kan, 1995) and supported by Ghezzi *et al.*, (1991) and Daily (1992). So, installability is the first new quality factor which must be added to McCall's original list. The second instance where this new standard is helpful is in Section A.4.4 (p. 11) which uses language in keeping with established quality models. It reads

> *"The requirements may include, but not be limited to the following characteristics: functionality, reliability, usability, efficiency, maintainability and portability (see ISO/IEC 9126). Sub-characteristic may be specified, for example security. Safety considerations and statutory obligations may also be specified.*
>
> *If the software product needs to interface with other software or hardware products, the interfaces between the software product to be developed and other software or hardware products should be specified".*

So, using familiar terminology, the proposed standard is now recognising six quality factors by name. A seventh factor, interface facility (interfaces between software products) is covered by the second paragraph. Elsewhere in the document (clause 4.10) testability is mentioned. Functionality is a new quality factor, so, it is the second addition to McCall's list. The inclusion of security, safety and statutory obligations are welcome additions to the draft.

Security in the draft standard appears to relate to integrity as stated by McCall *et al.*, (1977) and as stated by Boëhm (1978). McCall *et al.*, describe it as being concerned with putting into place controls which guard against programs and data being incorrectly altered either by accident or by design. As an external quality factor, it supports user confidence in the software. To comply with the quality focus of this appendix the term security (as opposed to integrity) will be used.

There are two aspects to safety. First there is the issue of operator safety which is covered by law and will be addressed in Section A.5.2.1 under the statutory obligations strand. The second aspect of safety is the safety of the general public. This is a special application of software for which designers and specifiers of safety-critical systems need to specify.

To reflect McCall's vocabulary, the interface facility as mentioned in the second paragraph of Section A.4.4 (of the standard) can be renamed interoperability (Ince, 1994).

However, the most significant aspect of clause 4.4.4 of the draft international standard is the inclusion of the expression "statutory obligations". This immediately brings into play all statutory regulations relating to health and safety issues including those relating to the minimum safety and health requirements for work with display screen equipment (Council Directive, 1990). This is the justification for the second strand in this three strand approach. This Council Directive is described in Section A.5.2.

So, from this review of the software quality strand, installability, functionality and safety are new factors to be added to McCall's list. McCall's integrity needs to be renamed as security and interface facility (in the standard) needs to be renamed interoperability.

That concludes the review of the software quality strand - the first of the three strands being considered in this appendix. The second strand - statutory obligations - is examined in detail in the next section to identify additional factors that influence usability.

A.5.2 Statutory obligations strand

The second strand that impacts on usability is legislation and in keeping with clause 4.4.4 of ISO/DIS 9000-3 (1996), this strand is addressed as statutory obligations.

Statutory obligations are concerned with regulations which relate to health and safety issues but particularly those relating to the minimum safety and health requirements for work with display screen equipment. These obligations are outlined in a European Directive (Council Directive, 1990). National Governments also legislate for the safety and health of workers in their own countries. Both the Directive and general regulations relating to end-users health and safety are now explained.

A.5.2.1 European display screen directive

On the 29th May 1990, the Council for the European Communities published a directive relating to minimum safety and health requirements for those working with display screens (Council Directive, 1990). This directive became fully effective from 31 December 1996. The directive sets out the employer's obligations and the employee's entitlements in relation to matters like:

- Analysis of workstations to ensure compliance with the directive.
- Training of employees.
- Employees daily work routine.
- The need for employee consultation and participation.
- Procedures for the protection of worker's eyes and eyesight.

The workstation definition (per the directive) clearly includes software, so employers, as part of their analysis, training and consultation procedures must take cognisance of current best practice in human-computer interaction. This is also stated in the annex of the directive which states the minimum requirements under the heading Operator/ Computer Interface. The five principles set out in Part 3 of the directive are relevant to usability and external software quality, and are set out in Figure A.4.

3. OPERATOR/COMPUTER INTERFACE

In designing, selecting, commissioning and modifying software, and in designing tasks using display screen equipment, the employer shall take into account the following principles:

software must be suitable for the task;
software must be easy to use and, where appropriate, adaptable to the operator's level of knowledge or experience; no quantitative or qualitative checking facility may be used without the knowledge of the workers;
systems must provide feedback to workers on their performance;
systems must display information in a format and at a pace which are adapted to operators;

the principles of software ergonomics must be applied, in particular to human data processing.

Figure A.4 - *European Council Directive 90/270/EEC 1990 Summary of minimum safety and health requirements*.

Closer examination reveals that they are quality factors. "Suitable for the task" is easily expressed as suitability; "easy to use" could be usability (but to avoid adding further confusion it will be referred to here as ease-of-use). And the third principle, "adaptable to the operator's level of knowledge" is adaptability. Feedback, format & pace and software ergonomics all correspond to the golden rules for dialogue design (Shneiderman, 1987). These rules are an essential component of human-computer interaction and are the justification for the third strand as explained in Section A.5.3.

So, from this strand three more quality factors can be added to those identified in the earlier strands. These new factors are suitability, ease-of-use and adaptability and have been derived from European Council Directive (1990). The full list of new software quality factors that have been identified, so far, are installability, functionality, safety, suitability, ease-of-use and adaptability. Later, these will be combined with McCall's list to create an updated set of quality factors. At that stage, two factors (integrity and interface facility) will be renamed as security and interoperability respectively.

That concludes the examination of the second strand and in the next section the human-computer interaction strand will be examined for further quality factors.

A.5.3 Human-Computer Interaction strand

Human-computer interaction (HCI) is described as "*the study of people, computer technology and the way these influence each other*" (Dix *et al.*, 1993). It is the third strand to be examined in this appendix. Authors in this domain (Shneiderman, 1987; Dix *et al.*, 1993; Preece *et al.*, 1994) address these topics in three categories. These categories are human issues, technology issues and interaction issues and they are described in the following sub-sections under the headings Human dimensions in HCI, The computer's capabilities in HCI and Users interacting with systems.

A.5.3.1 Human dimensions in HCI

Issues that contribute to effective human usage of computers are well defined as part of the science of human psychology. The issues involved are human behaviour, human memory, ability to learn, human knowledge acquisition, cognitive issues, human perception of the working of the system and how these workings are best conceptualised (Shneiderman, 1987). Other issues that must be considered relate to the profile of the user and include the user's physical abilities and motor skills, previous knowledge or expertise in the domain, general education and training and the overall attitude of the user towards technology (see ISO/DIS 9241-11, 1995, for a full listing of user considerations). Through study and understanding of these issues, HCI professionals can specify and design interfaces that support these human factors. A useful way of illustrating these issues is to review some examples of their practical implementation. For example, the Internet might support users wishing to search for books in a second-hand bookshop. Typical users will want to browse many different departments searching for items that appeal to them. The interface style (metaphor) selected to present such an application on screen might include a series of floor plans with departments like local history, early printed and antiquarian books, maps, historical documents, prints, military, nautical history and similar divisions. Simple pointing and clicking accesses the preferred department for browsing, so there is no relearning expected of the user. All of the departments use names familiar to the user. Furthermore, the software applications developed to support these users are popularly referred to as browsers. So it is easy for the non-technical user to have the impression of browsing through the familiar departments of a bookshop. The system has become transparent to the user. This is illustrative of a new definition of usability that is proposed in Section A.5.4. Another example of a practical implementation of a software interface assisting human factors might be where interface designers support coherence by grouping similar tasks together. Similar design strategies can be used to best match other human factors with modes of interaction and other computer capabilities.

A.5.3.2 The computer's capabilities in HCI

The main technological focus of HCI is concerned with devices for human interaction with computers. Generally the devices used reflect the preferred dialogue style. A dialogue style is one of a number of methods by which users interact with the system (Shneiderman, 1987). These methods have evolved from command line solutions in the early days of computing to the hands-free, voice recognition systems (and particularly voice-enabled Web systems) which are becoming available. The most common dialogue styles are, command line interaction, batch programs, form filling, menu selection, query language, voice recognition WIMPS (Wigits, Icons, Menus and Pointers) and hyperlinks. Another term that can be used is WIRPS (Wireless, Intelligent, Remote, Probes and Sensors), which is appropriate for describing the dialogue style of hostile environments. The evolution of these styles has been driven by a desire to improve the overall usability of the interface. For example, command line interfaces normally use keyboards as the input device while voice communication requires microphones. An excellent review of input and output devices is given by Preece *et al.,* (1994).

Achieving the objectives of HCI is enhanced by the proper alignment of the input/output devices, both with the tasks to be completed and with the skills of the users. For example, secretaries with keyboarding skills are obviously more effective using a keyboard for word processing tasks while supermarket checkout operators are obviously more effective using a barcode scanner as their input device. Voice recognition and gesture recognition also enable easier interaction by users with differing skills. Different types of devices are needed for different environments. Office, home and educational environments are generally regarded as safe environments. Workshop floor and engineering plants are described as harsh environments while underwater and radioactive environments are hazardous environments. All three environments have very different device requirements.

A.5.3.3 Users interacting with systems

There are two distinct topics of interest in this area which affect end-users and which will be used to identify further characteristics that impact on usability. These are the established good principles and guidelines for dialogue design and the equipment and environment available to the user.

A.5.3.3.1 Principles and guidelines for dialogue design

Principles and guidelines for dialogue design have been suggested for interface evaluation (Shneiderman, 1987; Ravden & Johnson, 1989). Naturally these same principles and guidelines can also be used for specifying the requirements for interface design. Typically, these principles address:

- Consistency of screen presentation
- Visual clarity on screen
- Informative feedback to users
- Compatibility with user conventions and expectations
- Error prevention and correction
- Appropriate functionality
- User control, confidence and satisfaction
- General user support

Dialogue principles are currently being addressed by the proposed international standard for ergonomic requirements for office work with visual display terminals (ISO/DIS 9241-10, 1993). The proposed standard addresses some of the issues covered by the above list together with some familiar quality factors which were identified in earlier strands. The seven dialogue principles in the standard and how they might be expressed as quality factors are:

• Suitability for task	Suitability
• Self descriptiveness	Usability (Ease-of-use)
• Controllability	Usability (Ease-of-use)
• Conformity with user expectations	Usability (Ease-of-use)/Learnability
• Error tolerance	Security
• Suitability for individualisation	Adaptability
• Suitability for learning	Learnability

Self descriptiveness is the standard's terminology for informative user feedback, controllability relates to user control/user pacing of the use of the product and conformity with user expectation addresses compatibility with user conventions. User feedback, user control/pacing and compatibility with user conventions are all part of Shneiderman's golden rules which were the issues in Section A.5.2.1. that justified the human-computer interaction strand.

A.5.3.3.2 Equipment and environment

User productivity, confidence and satisfaction are all supported by the proper equipment to perform the tasks and by a proper environment in which to work (Preece, 1994). So, HCI specialists are particularly interested in ensuring that these two issues are also addressed. The Council Directive (1990) has focused on this aspect and has set out a full schedule of minimum requirements. See Figure A.4.

Associated with the equipment and the environment is the health and safety of users. The research literature in the field of ergonomics shows considerable concern for a vast array of human disorders and explains how to design interaction in order to best prevent them. These include musculoskeletal disorders like Repetitive Strain Injury (RSI), Work Related Upper Limb Disorders (WRULDs), radiation emissions and facial rash (Euro Review, 1994; DST, 1997).

Combining all of the above topics, it is easy to see how human-computer interaction is concerned with the broad range of issues which contribute to the development of usable systems interfaces. The proper combination of all the topics, (i.e. human issues, technology issues and interaction issues), make the computer operator's role easier to perform, less prone to error, less anxious, builds confidence and many other psychological considerations that impact on computer users (Shneiderman, 1987; Reiterer & Oppermann, 1993).

Central to these topics have been the disciplines of psychology and ergonomics, both of which have contributed to defining best practice to support those who interact with computers. The overall aim of HCI should be to devise usable interfaces that employ the most suitable metaphor and then layout the screen so that human memory, coherence, cognition, perception, learning and previous knowledge are all supported to maximum effect. Interfaces should be designed to be as adaptable as possible in order to better support all end-user skills. Finally, the environment should be made as safe and comfortable as possible using selected devices which best suit the tasks to be performed. The ultimate objective is to create interfaces that are totally transparent to the users.

Like the Software quality strand and the statutory obligations strand, the human-computer interaction strand also identifies quality factors. These factors include suitability, usability (ease-of-use), security, adaptability and learnability (see - Principles and guidelines for dialogue design in the previous sub-section). Learnability is a new factor and must be added to McCall's list. This strand also identifies the needs of different users, particularly their needs in different environments using equipment appropriate to that environment. This in turn has given rise to the study of the context of use. Furthermore, the human-computer interaction strand provides a series of checklists and guidelines which combine current best practice for interface development.

A.5.4 A composite table of software quality factors

This concludes the review of the three strands that identify quality factors. Currently, as three separate strands, their scope is very broad with considerable duplication. For the benefit of systems professionals, one composite table that combines the different strands is needed. Such a table should reflect the original and changing significance of the quality factors suggested by McCall *et al.,* the guidelines offered by ISO/DIS 9000-3 (1996), the statutory obligations strand resulting from Council Directive (1990) and the

Human-Computer Interaction strand (ISO/DIS 9241-10, 1993). Such a table is shown in Figure A.5. All of the identified factors are listed, categorized as external or internal together with their origin as either an original (or renamed) McCall *et al.*, quality factor or one identified from one of the three strands.

Quality Factor	Category	Origin
Suitability	External quality factors (i.e. Usability factors)	Statutory obligations strand
Installability		Software quality Strand
Functionality		Software quality Strand
Adaptability		Statutory obligations strand
Ease-of-use		Original McCall *et al*. quality factor - renamed
Learnability		Human-Computer Interaction strand
Interoperability		Original McCall *et al*. quality factor
Reliability		Original McCall *et al*. quality factor
Safety		Software quality Strand
Security		Original McCall *et al*. quality factor - renamed
Correctness		Original McCall *et al*. quality factor
Efficiency		Original McCall *et al*. quality factor
Maintainability	Internal quality factors	All original quality factors as proposed by McCall *et al*.
Testability		
Flexibility		
Reusability		
Portability		

Figure A.5 - *Software quality factors table.*

To prepare this table, McCall's model is used as a foundation and it is sub-divided to show external and internal quality factors. Simple priority is also incorporated in the external factors. From Figure A.3, reliability, correctness and efficiency are all included together with the internal quality factors. Note that usability is not included at this stage and is replaced by ease-of-use. From the software quality strand, installability, functionality and safety are included. Integrity is renamed as security in order to better reflect the wording of ISO/DIS 9000-3 (1996) and interface facility (in ISO/DIS 9000-3, 1996) is renamed as interoperability to reflect McCall's vocabulary.

To fulfill the ISO requirement that statutory obligations must be complied with, the items set out in sub-division Operator/Computer Interface of the Council Directive (1990) are also included in the table. These items are suitability, ease-of-use and adaptability. From the human-computer interaction strand, learnability is added.

It is now necessary to return to McCall's original definition of usability, i.e. easy to learn and operate. Both of these issues are now catered for as quality factors in their own right, i.e. learnability and ease-of-use, and, as both are included in the new list, usability from McCall's original list is obsolete and is omitted.

No further research is presented on these quality factors in this thesis. Readers are referred to ISO 9126-1 (2001) for latest software quality thinking and particularly the standards quality model for external and internal quality.

A.5.5 The Usability attributes of a software product

In Section A.3, usability is described as being "concerned with supporting users during their interactions with computers" and in Section A.2 it is explained that it is preferable to describe external quality factors as usability factors. To confirm that this preference is valid, it is only necessary to apply the following simple query to each quality factor. Does the individual quality factor support the user? If it does, then it is a usability attribute. Applying this technique, the software quality factors in Figure A.5 can be transposed to a list of usability attributes as set out in Figure A.6 and called the usability attributes of a software product (or the attributes of a usable software product).

Attribute	McCall *et al.*	Comments/Source
Suitability		• **To comply with EU law - Council Directive (1990)**
Installability		• **To reflect commercial practice** • **To comply with ISO/FDIS 9000-3 (1997)**
Functionality		• **To comply with ISO/FDIS 9000-3 (1997)**
Adaptability		• **To comply with EU law - Council Directive (1990)**
Ease-of-use	**Usability**	• **To comply with EU law - Council Directive (1990)**
Learnability		• **To comply with ISO/DIS 9241-10 (1993)**
Interoperability	**Interoperability**	• **Original quality factor**
Reliability	**Reliability**	• **Original quality factor**
Safety		• **To comply with ISO/FDIS 9000-3 (1997)**
Security	**Integrity**	• **To reflect the wording of ISO/FDIS 9000-3 (1997)**
Correctness	**Correctness**	**Original quality factor**
Efficiency	**Efficiency**	**Original quality factor**

Figure A.6 - *Usability attributes of a software product.*

The attributes set out in Figure A.6 are those that impact the end-user. They are external quality factors and include attributes which must be considered during software usability measurement and evaluation in order to comply with current ISO standards and European Community law.

This thesis supports the concept that it is most important not to hinder users while using software products. So, having reviewed software usability and cogniscant of the transparency issues raised in Section A.5.3.1 the thesis now proposes a new definition of usability as

A measure of transparency at the user interface.

A.6 Using the attributes of a usable software product

The attributes of a usable software product can be used by producer and procurer organisations and by their consultants, IS professionals and users in the specification, design, development and evaluation processes of quality software products.

A.7 Software quality and the World Wide Web

The development of the Internet has supported an organisational move to the use of eCommerce as a strategic approach to conducting business. This business is been done through eCommerce websites and as organisations invest more in this approach their need for quality solutions becomes more focused. Consequently, it is appropriate to consider each of these quality factors in the context of quality websites. For example, interpreting them for evaluating data processing systems is different to interpreting them for evaluating safety critical systems which in turn is different to interpreting them for evaluating educational and information dispensing systems. Each interpretation has its own set of considerations and eCommerce investors have a different perspective of what a quality website might be and a different expectation of how these factors should be interpreted.

A detailed investigation and interpretation of these perspectives and expectations is beyond the scope of this thesis and is not pursued further. A different question is addressed, that is, whether the established set of quality factors is a complete set for the different domain that is the World Wide Web.

Much of the research relating to website external quality is centered on good practice recommendations and guidelines (Lavine, 1999; Nielsen, 1996: Nielsen, 1998b; Nielsen, 1998c; Bevan, 1998; Lynch, & Horton, 1999; Instone, 1999; Trower, 1999; IBM, 1999); the research does not address the concept of defining quality factors for the World Wide Web.

Typical of the quality issues that are specific to the World Wide Web that need to be addressed include the ease with which users can locate and access a website, their trust and confidence in the website content (perhaps as a result of trust in the website owner) and the support for visitor engagement that is provided by the website. Websites owners need to focus on the strategic drivers of software quality especially strategies which include appeal, brand promotion, and which encourage visitor loyalty.

So, there is a significant challenge to identify additional quality factors for the World Wide Web. And, it follows that once these factors are identified then a method for measuring them, the criteria that might be measured and the metrics to expect will also need to be researched. These issues are the focus of the remainder of the thesis.

A.8 Conclusion

The quality of user interfaces is a central part of software development, not least because of European Community Law. This appendix explained how the study of software usability has advanced over the past twenty years by reviewing four formal usability definitions. This review showed that some of the definitions focus on software attributes while other definitions focus on usability measures. The appendix showed that in order for management to assess usability there is a need for a consistent set of usability quality attributes.

The approach used to identify this set of attributes involves a methodical analysis of well regarded sources in order to establish academic thinking and commercial practice. The appendix uses a quality-focused self-justifying synthesis of three strands and identifies a new critical set of quality factors. It is then shown that the external quality factors in this set are the "usability attributes of a software product".

Which of the three strands is the most important is an issue that might arise for strategic managers. Both quality and HCI issues are matters of organisational policy, which may be decided by management. But statutory obligations are part of European Community law and must be complied with.

In addition to producing the usability attributes of a software product as a new deliverable from this appendix, the appendix defined usability as a measure of transparency at the user interface. The appendix also argued that metrics can be applied to usability.

Readers are reminded that the appendix is included for completeness so that they can better understand the focus of chapters in the thesis. The content builds on previous MSc work from *An investigation and analysis of current methods for measuring software usability*, MSc dissertation, School of Computing, Staffordshire University, UK (Fitzpatrick, 1997), much of which was published by Fitzpatrick and Higgins (1998) and completes the producer/procurer/product triad introduced in the Software Quality Star. The appendix emphasizes two additions which are new to this thesis. These are:

- A new definition of usability
- Quality in the domain of the World Wide Web is introduced.

Quality factors in this appendix might be considered as being appropriate to “traditional software applications” and that eCommerce investors have a different perspective of what a quality website might be and a different understanding of how these factors should be interpreted. Chapter 4 addresses the challenge of identifying additional quality factors for the World Wide Web.

A theory and practice of website engagibility

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PhD Appendix D

Using Metric Ratio Analysis to measure website engagibility

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Appendix D

Using Metric Ratio Analysis to measure website engagibility

> *The aim of the Appendix is to use Metric Ratio Analysis to quantify and analyse the eight quality-of-product engagibility ratiosof the five websites in an eCommerce website study and to demonstrate how these ratios can be combined to derive an engagibility index for each website.*

D.1 Background

This Appendix applies Metric Ratio Analysis to the eight engagibility quality-of-product ratios which were identified in Chapter 5 with a view to further refining Metric Ratio Analysis; calculating individual ratios for website analysis; and deriving an engagibility index for each site in the eCommerce website study.

Content from this Appendix has been published in a paper titled *Web site engagibility: A step beyond usability*, Proceeding of HCI International 2005, Universal Access in Human-Computer Interaction, Las Vegas, USA, Lawrence Erlbaum Associates, Inc (LEA) (Fitzpatrick, Smith, & O'Shea, 2005).

D.2 Introduction

Previous work has identified eight quality-of-product engagibility ratios (Navigation ratio, Surf ratio, Contribution ratio, Commerce ratio, Activities ratio, Assistive ratio, Community ratio and Competitive ratio) and has determined a set of 67 counts for each of the five eCommerce websites in the study. This equates to the completion of step 7 of the 12 steps of Metric Ratio Analysis as set out in Chapter 7 - Figure 7.3.

The next stage in the research is to use these counts in order to compare the five websites. The process continues with step 8 of Metric Ratio Analysis and advances to devising a formula for each of the quality-of-product ratios. Once the formula has been devised four tables are presented for each ratio. The first table contains counts and indirect values from the website study together with a calculated individual ratio for each website. The second table builds on the first by adding target counts and indirect values. It also presents a target calculated individual ratio. A lower limit is also included in this second table which shows that the formula will always return a positive value. The third table presents the results of applying graph theory similarity calculations to each website in the study. The fourth table presents calculated scaled ratios on a scale of 1 – 100. An analysis of the results is included at this point. This approach is repeated so that all eight engagibility ratios in the study are considered.

The results are of value to website owners and designers who need to know how the structure of their website supports visitor engagibility. From these results they can formulate strategies about further investment in their eCommerce presence.

Section D.3 derives a formula and calculates an individual ratio for each of the eight ratios identified in Chapter 5. It uses the 12 steps of Metric Ratio Analysis to impose a rigor on the process. The section explains how upper and lower limits for the ratios are tested and there is an analysis on each engagibility ratio. Section D.4 uses a column diagram, a Kiviat diagram (sometimes called a radar or spider diagram) and bar diagram to graphically illustrate results. As the Appendix progresses a set of counts for a target website are identified. A full set of these target values are presented in Appendix A as a contribution to website engagibility measurement in the form of two sets of lower and upper target counts for the 67 criteria.

D.3 Engagibility ratios

This section considers each of the eight engagibility ratios in detail by applying steps 8 to 12 of Metric Ratio Analysis to each ratio. These steps are set out again for convenience in Figure D.1

Metric Ratio Analysis

An Approach to measuring website quality

1. Identify a set of entities for study
2. State the feature of the entity to be studied
3. State the perspective and quality factor of the feature
4. State the characteristic of the quality factor to be studied
5. State the individual ratio to be measured
6. Establish criteria for determining the ratio
7. Establish counts and indirect values for the criteria in each ratio
8. Define predictor requirements
9. Construct formula
10. Apply formula to calculate ratios
11. Identify target solution
12. Perform analysis.

Figure D.1 – *The 12 steps of Metric Ratio Analysis.*

D.3.1 Navigation ratio

The Navigation ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree of a website's support for sitebound hyperlinking.

Navigability is one of the three sub-factors of engagibility and embraces the Internet philosophy of linking within a website and linking to other websites. So, in order to measure navigability, hyperlinking within the website is considered separately from hyperlinking to external websites. The sitebound hyperlinking is measured, in this section, as a navigation ratio and the outbound hyperlinking is measured, in the following section, as a surfing ratio. So, the aim of this section is to apply Metric Ratio Analysis in order to derive a Metric Ratio Formula to calculate a figure (individual ratio) which represents the degree of a website's support for sitebound hyperlinking. To achieve this aim a selected group of previously established website counts, which are appropriate to navigation, are combined. These counts reflect a website's design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether a new design will result in a website which supports navigation.

D.3.1.1 Navigation ratio values and predictor requirements

The formula used for calculating the *Navigation ratio* is based on occurrences of sitebound hyperlinks in the entire website and sitebound links from the Home page, hypertext pages, site levels and menus. The formula also includes links to the Home page, links to Top of page and occurrences of the Site search component all of which support site navigation.

The values that are used for deriving the Navigation Ratio Formula are set out in Figure D.2. ***SBpages***, ***Menus*** and ***Home_Top*** are indirect values which rely on counts from the website quality-of-product engagibility study. ***SBlinks, SBHome, Levels*** and ***Search*** are counts from the same study.

Navigation ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
SBlinks	Total occurrences of sitebound links in the website.	Increase	Numerator (**X**)
SBHome	Number of sitebound links from Home page.	Increase	Numerator (**X**)
SBpages	Number of active HTML pages in the site ÷ Number of pages containing sitebound links.	Decrease	Denominator (**÷**)
Menus	Total occurrences of all menus in site ÷ sum of different horizontal and vertical menus in site.	Increase	Numerator (**X**)
Levels	Number of levels below Home page.	Decrease	Denominator (**÷**)
Home_Top	Sum of Total occurrences of links to Home and Total occurrences of links to Top.	Increase	Numerator (**X**)
Search	Number of pages supporting site search engine	Increase	Numerator (**X**)

Figure D.2 - *Values and requirements for the Navigation Ratio Formula.*

Two columns are included to the right of the figure. These clarify formula requirement, indicating a predictable increase or decrease in the ratio as a result of increase in a formula value. Also indicated are the simple corresponding mathematical operators that can be used in the formula.

Indirect values

Three indirect values are included in this set. These are ***SBpages, Menus*** and ***Home_Top***. ***SBpages*** is a quotient of HTML pages in the site and pages containing sitebound links. By including both values, MRA considers ***SBpages*** is a more representative value for page impact in the formula. ***Menus*** is a product of the occurrences of menus in the site and the number of different menus. ***Home_Top*** is a simple sum of the occurrences of ‘Links to Home’ and ‘Links to Top’ in the website.

Based on the MRA model, the constructed Navigation Ratio Formula is set out in Figure D.3.

D.3.1.2 Constructing the Navigation Ratio Formula

Navigation Ratio Formula

The Navigation Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Navigation Ratio Formula

$$\frac{\{(SBlinks+x)\times 1\}^{1}\times\{(SBHome+x)\times 1\}^{1}\times\{(Menus+x)\times 1\}^{1}\times\{(Home\_Top+x)\times 1\}^{1}\times\{(Search+x)\times 1\}^{1}}{\{(SBpages+1)\times 1\}^{1}\times\{(Levels+1)\times 1\}^{1}\times C}$$

Where

$SBlinks$ = Total occurrences of sitebound links in the website.

$SBHome$ = Number of sitebound links from Home page.

$SBpages$ = Number of active HTML pages in the site ÷ Number of pages containing sitebound links.

$Menus$ = Total occurrences of all menus in site ÷ sum of different horizontal and vertical menus in site.

$Levels$ = Number of levels below Home page.

$Home\_Top$ = Sum of Total occurrences of links to Home and Total occurrences of links to Top.

$Search$ = Number of pages supporting site search engine.

x = a discontinuities variable and has a value of 1 or 0.

C = 1000000 = A navigation ratio constant arrived at when applying the formula.

Figure D.3 – *Navigation Ratio Formula.*

D.3.1.3 Applying the Navigation Ratio Formula to five eCommerce websites

Having derived a Navigation Ratio Formula, it is populated with values for the five websites in the eCommerce study in order to calculate individual navigation ratios for each website. The set of ***individual ratios*** as calculated using the Navigation Ratio Formula is illustrated in Table D.1. In these calculations the values are normalized on the basis of 100 page websites (excluding ***SBHome*** and ***Levels***) and the formula adds 1 to ***Search*** for websites v_1, v_2 and v_3.

Table D.1 - *Navigation ratio values and individual ratios*

		eCommerce website study				
		Websites				
		BMIbaby	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**
		v_1	v_2	v_3	v_4	v_5
p(age) count		118	96	104	89	130
		Navigation ratio values				
		(Normalised to 100 pages)				
SBlinks	x	3409.32	3103.13	929.81	1215.73	1882.31
SBHome	x	31.00	33.00	24.00	15.00	29.00
SBpages	÷	0.85	1.28	1.11	1.15	0.77
Menus	x	100.00	95.83	61.54	68.16	9.30
Levels	÷	5.00	2.00	4.00	2.00	3.00
Home_Top	x	293.22	281.25	125.96	392.13	206.15
Search	x	*0.00*	*0.00*	*0.00*	97.75	96.92
Individual ratio		731.37	1076.43	38.92	20727.29	4394.43

For each of the websites the individual navigation ratios are **731.37**, **1076.43**, **38.92**, **20727.29** and **4394.43**.

D.3.1.4 Navigation Ratio – Target solution and validation

Table D.2 has two additional columns of values headed, **Target** (v_o), **and 1-page website** (v_m). These two columns are used for the purpose of testing the Navigation Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.2 - *Table of calculated individual Navigation ratios – Target added*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Navigation ratio values					
			(Normalised to 100 pages)					
SBlinks	x	1400.00	3409.32	3103.13	929.81	1215.73	1882.31	*0*
SBHome	x	14.00	31.00	33.00	24.00	15.00	29.00	*0*
SBpages	÷	1.00	0.85	1.28	1.11	1.15	0.77	1.00
Menus	x	100.00	100.00	95.83	61.54	68.16	9.30	1.00
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	*0*
Home_Top	x	400.00	293.22	281.25	125.96	392.13	206.15	*0*
Search	x	100.00	*0.00*	*0.00*	*0.00*	97.75	96.92	*0*
Individual ratio		26133.33	731.37	1076.43	38.92	20727.29	4394.43	0.00

The Navigation Ratio Formula is tested at a lower limit. The lower limit is a 1-page website which is considered as a minimum or worst case example. In this case there is no need for sitebound links so, ***SBlinks*** = 0 and ***SBHome*** = 0, there are no levels below the Home page and there is no need for menus. Links to Top of page could be provided but in a worst case situation they are deemed not to be. A site search component is not considered to be necessary. The indirect values ***SBpages*** and ***Menus*** are both 1 as a result of adding 1 to their numerator and denominator when calculating their indirect value. All other target values that have a value of zero have 1 added by the Navigation Ratio Formula when calculating the navigation ratio. The Navigation Ratio Formula calculates a figure at 0 for this lower limit website. The values for this example are illustrated at the right of Table D.2 in the **1-page website** column.

Based on the profile of the five websites in the eCommerce study the average number of pages in the websites was 103. In this study it is considered that a 100-page website is a suitable compromise for the size of the target website. This is a universally acknowledged and understood figure and is appropriate considering the size of the sites being studied. The target navigation ratio values for such a site are illustrated at the left of Table D.2 in the **Target (v_o)** column. MRA considers that there would be two (2) horizontal menus and one (1) vertical menu on each page. A total of seven sitebound links is considered appropriate for the two horizontal menus with five links from the vertical menu. Two additional sitebound links from the body of each page are also included. This means that there is a total of 14 sitebound links on each page giving a value of 1400 for ***SBlinks***. The 14 sitebound links on each page includes the Home page, so, in this case, ***SBHome***, the count of sitebound links on the Home page is 14. It is desirable that all pages in the website will have sitebound links, so, the calculated value for ***SBpages*** is 1, that is, 100 active HTML pages ÷ 100 pages containing sitebound links. The target ***Menus*** value is 100, that is, 100 active HTML pages in the website each with three menus giving a total of 300 occurrences of all menus in the site. This is divided by 3, it being the sum of the different horizontal (2) and vertical (1) menus in the site. In the target website, ***Levels*** would be 3, it being a simple rounded average of the five values in the study. MRA considers two links to Home and two links to Top of page are appropriate on each HTML page in the site giving a value for ***Home_Top*** at 400. Finally, a target site would include a Site Search option on each page, so, ***Search*** would be 100. Being based on a 100 page website the target values are considered to be normalized for this study and using the same Navigation Ratio Formula a positive figure at ***26133.33*** is calculated for this target website as illustrated in Table D.2.

In order to reduce the magnitude of the values returned by the Navigation Ratio Formula a constant at 1/1000000 is applied to all five individual ratio calculations.

D.3.1.5 Analysis

An approach to interpreting these figures is to evaluate them using Johnsonbaugh's acknowledged formula for similarity graphs (Johnsonbaugh, 2004) as shown in Table D.3. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios as calculated using Metric Ratio Analysis are shown in Table D.4.

Table D.3 - *Website navigation similarity (ns)*

$$ns(v, w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4| + |p_5 - q_5| + |p_6 - q_6| + |p_7 - q_7|$$

$ns(v_1, v_2)$	328						
$ns(v_1, v_3)$	2693	$ns(v_2, v_3)$	2374				
$ns(v_1, v_4)$	2441	$ns(v_2, v_4)$	2142	$ns(v_3, v_4)$	668		
$ns(v_1, v_5)$	1806	$ns(v_2, v_5)$	1485	$ns(v_{3,} v_5)$	1188	$ns(v_4, v_5)$	928

$ns(v_o, v_1)$	2235
$ns(v_o, v_2)$	1946
$ns(v_o, v_3)$	894
$ns(v_o, v_4)$	228
$ns(v_o, v_5)$	785

A low value indicates website navigation similarity.

Table D.4 - *Table of calculated individual Navigation ratios - Scaled*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Navigation ratio values					
			(Normalised to 100 pages)					
SBlinks	x	1400.00	3409.32	3103.13	929.81	1215.73	1882.31	*0*
SBHome	x	14.00	31.00	33.00	24.00	15.00	29.00	*0*
SBpages	÷	1.00	0.85	1.28	1.11	1.15	0.77	1.00
Menus	x	100.00	100.00	95.83	61.54	68.16	9.30	1.00
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	*0*
Home_Top	x	400.00	293.22	281.25	125.96	392.13	206.15	*0*
Search	x	100.00	*0.00*	*0.00*	*0.00*	97.75	96.92	*0*
Individual ratio		26133.33	731.37	1076.43	38.92	20727.29	4394.43	0.00
Scale 1-100		*100*	*2.80*	*4.12*	*0.15*	*79.31*	*16.82*	*0.00*

Using Johnsonbaugh's formula - $ns(v, w) = |p_1-q_1| + |p_2-q_2| + |p_3-q_3| + |p_4-q_4| + |p_5-q_5| + |p_6-q_6| + |p_7-q_7|$ - in conjunction with the values in Table D.1 website navigation similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.3. From these calculations it can be seen that companies $\boldsymbol{v_1}$ and $\boldsymbol{v_2}$ are the most similar. However, the calculations do not indicate whether this similarity is rich or poor, i.e., whether the sites' navigation structures support engagibility. Furthermore, the similarity values do not suggest a target value that a website owner might seek to achieve in order to insure improved quality-of-product. Such a target is identified as part of Metric Ratio Analysis and is presented in Table D.2. The reader will also realise that the values returned by the similarity formula are for pairs of websites. An individual value for each website is missing. The Navigation Ratio Formula addresses this by retuning an individual ratio for each website per Table D.2. Having identified a set of target values the similarity graph formula is revisited and website navigation similarity is calculated for this target website. The results are presented in the lower panel of Table D.3.

Using Metric Ratio Analysis it is possible to calculate individual navigation ratios in order to compare the degree that the five websites in the study support sitebound hyperlinking. The calculated individual ratios are **731.37**, **1076.43**, **38.92**, **20727.29** and **4394.43**. The study shows that an overall individual ratio of ***26133.33*** is a target value for the website owners to seek to achieve. From this, the study shows that **website** $\boldsymbol{v_4}$ is the closest in this set to the target site. While its individual ratio does not achieve the target, other website owners might want to equal this achievement and add additional (or adjusted) navigation in order to achieve ***20727.29***. Achieving this will provide their visitors with a similarly rich navigation experience. Adding additional or adjusting navigation can be done by reference to the website's profile values as shown in Table D.4. For example, **website** $\boldsymbol{v_1}$ has significantly exceeded ***SBlinks*** and may be causing a confused visitor experience. The same website has a ***Search*** value of 0, indicating that the site has significantly under achieved in the provision of a site search option. Setting ***Levels*** to 5 seems excessive in the context of the five websites in the eCommerce study.

So, by reference to each website's profile, design improvements can be identified resulting in an improved navigation ratio.

MRA considers that websites in the study that return values below the target, while fully navigable by visitors to the website, are not achieving their full engagibility potential and would gain from further design review. Websites with a figure above the target have over subscribed to navigation and have probably over invested. However, this needs to be considered in conjunction with the maximum and minimum range wherein calculated website navigation ratios would be valid.

Four of the five websites are outside the target range of values. In each case, reference to the site's profile indicates the absence or over inclusion of parameters. As illustrated in Table D.4, further design work could be done on the study websites in order to improve their support for sitebound hyperlinking. By reference to the ***Search*** values at 0 for three websites it is clear that if more search functionality is added their individual ratios will increase towards the target value. When applying this style of analysis the absence or over provision of a parameter can be seen to be significant.

The six values used in the Navigation Ratio Formula to calculate a website's Navigation ratio rely on twelve counts from a set of 67 counts, which have previously been established for all five websites in this study.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.3.2 Surf ratio

The Surf ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree of a website's support for outbound hyperlinking.

A dilemma experienced by website designers is to know what level of linking to provide to other websites on the Internet. This dilemma is sometimes driven by significant business issues such as avoiding unwitting links to illegal websites. In other circumstances it is driven by a need to retain hard earned customers. The dilemma is also driven by a decision to implement a portal site or when creating a site which relies on advertisement links for generating income. There is a need to balance the early World Wide Web philosophy of hyperlinking to other websites with a need for legal protection and return on investment. To this end, specifiers and designers need some means of understanding what an appropriate surf level might be. So, the aim of this section is to derive a formula to calculate a figure (individual ratio) which represents the potential for website visitors to exit the site in order to visit other websites. The counts of outbound links that are used are deemed to be to trusted partners only. To achieve this aim the selected group of previously established counts relating to website surf criteria, are combined using Metric Ratio Analysis. These counts reflect a website's design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether a new design will result in a website which supports appropriate Internet surfing.

D.3.2.1 Surf ratio values and predictor requirements

The formula used for calculating the *Surf ratio* uses Metric Ratio Analysis and is based on counts and occurrences of outbound hyperlinks in the entire website and outbound links from the Home page, hypertext pages, site levels and menus.

The values that are used for deriving the Surf Ratio Formula are set out in Figure D.4. ***OBpages*** and ***Menus*** are indirect values which rely on counts from the website quality-of-product engagibility study. ***OBlinks, OBHome*** and ***Levels*** are counts from the same study.

Surf ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
OBlinks	Total occurrences of outbound links in the website.	Increase	Numerator (**X**)
OBHome	Number of outbound links from Home page.	Increase	Numerator (**X**)
OBpages	Number of active HTML pages in the site ÷ Number of pages containing outbound links.	Decrease	Denominator (**÷**)
Menus	Total occurrences of all menus in site ÷ sum of different horizontal and vertical menus in site.	Increase	Numerator (**X**)
Levels	Number of levels below Home page.	Decrease	Denominator (**÷**)

Figure D.4 – *Values and requirements for the Surf Ratio Formula.*

Two columns are included to the right of the figure. These clarify formula requirement, indicating a predictable increase or decrease in the ratio as a result of increase in a formula value. Also indicated are the simple mathematical operators that can be used in the formula.

Indirect values

Two indirect values are included in Figure D.4. These are ***OBpages,*** and ***Menus***. ***OBpages*** is a quotient of HTML pages in the site and pages containing outbound links. By including both values, MRA considers ***OBpages*** is a more representative value for page impact in the formula. ***Menus*** is a product of the occurrences of menus in the site and the number of different menus.

The constructed Surf Ratio Formula is set out in Figure D.5.

D.3.2.2 Constructing the Surf Ratio Formula

Surf Ratio Formula

The Surf Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Surf Ratio Formula =

$$\frac{\{(OBlinks+x)\times 1\}^{1}\times\{(OBHome+x)\times 1\}^{1}\times\{(Menus+x)\times 1\}^{1}}{\{(OBpages+x)\times 1\}^{1}\times\{(Levels+x)\times 1\}^{1}\times C}$$

Where

$OBlinks$ = Total occurrences of outbound links in the website.

$OBHome$ = Number of outbound links from Home page.

$OBpages$ = Number of active HTML pages in the site ÷ Number of pages containing outbound links.

$Menus$ = Total occurrences of all menus in site ÷ sum of different horizontal and vertical menus in site.

$Levels$ = Number of levels below Home page.

x = a discontinuities variable and has a value of 1 or 0.

C = 10 = A Surf ratio constant arrived at when applying the formula.

Figure D.5– *Surf Ratio Formula.*

D.3.2.3 Applying the Surf Ratio Formula to five eCommerce websites

Previously determined counts appropriate to the Surf ratio for each website in the study (normalized on the basis of 100 page websites) are set out in Table D.**5**. The websites are represented by $\boldsymbol{v_1}$, $\boldsymbol{v_2}$, $\boldsymbol{v_3}$, $\boldsymbol{v_4}$ and $\boldsymbol{v_5}$.

Table D.5 - *Surf ratio values and individual ratios*

		eCommerce website study				
		Websites				
		BMIbaby	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**
		v_1	v_2	v_3	v_4	v_5
p(age) count		118	96	104	89	130
		Surf ratio values				
		(Normalised to 100 pages)				
OBlinks	x	108.47	711.46	199.04	98.88	98.46
OBHome	x	1.00	8.00	3.00	1.00	1.00
OBpages	÷	14.29	10.00	6.67	1.14	33.33
Menus	x	100.00	95.83	61.54	68.16	9.30
Levels	÷	5.00	2.00	4.00	2.00	3.00
Individual ratio		15.19	2727.26	137.80	296.56	0.92

For each of the websites the individual surf ratios are **15.19**, **2727.26**, **137.80**, **296.56** and **0.92**.

D.3.2.4 Surf Ratio – Target solution and validation

Table D.6 has two additional columns of values headed, **Target** (v_o), **and 1-page website** (v_m). These two columns are used for the purpose of testing the Surf Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.6 - *Table of calculated individual Surf ratios- Target added*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Surf ratio values					
			(Normalised to 100 pages)					
OBlinks	x	300.00	108.47	711.46	199.04	98.88	98.46	0
OBHome	x	3.00	1.00	8.00	3.00	1.00	1.00	0
OBpages	÷	6.67	14.29	10.00	6.67	1.14	33.33	1
Menus	x	100.00	100.00	95.83	61.54	68.16	9.30	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Individual ratio		428.57	15.19	2727.26	137.80	296.56	0.92	0.10

For the purpose of testing the formula two limits are set – a lower and an upper.

The lower limit is a 1-page website which is considered to be a worst case example. In this case there are no outbound links so, ***OBlinks*** and ***OBHome*** are both zero. ***OBpages*** and Menus are both 1 by calculation and there are no levels. These values are illustrated at the right of Table D.**6** in the column headed **1-page website**. The Surf Ratio Formula calculates a figure at **0.10** for this lower limit website.

For the upper limit a 100-page website is considered to be a target size. In this case it is considered that there would be two horizontal menus and one vertical menu on each page giving a total occurrences of 300 and a calculated value of 100 (300/3) for ***Menus***. In this case two outbound links are considered appropriate for the three menus. One additional outbound link from the body of each page is also included. This means that there are 3 outbound links on each page giving a total occurrences of 300 for ***OBlinks***. For ***OBpages*** an indirect value of 6.67 (100/15) is calculated using 100 pages in the website and dividing by 15 which is the page count for the site with the highest number of pages containing outbound links after sites $\boldsymbol{v_4}$ and $\boldsymbol{v_5}$ have been disregarded as outliers. In this case the count of outbound links on the Home page would also be 3, that is, ***OBHome*** is 3. In the target website there would be three levels below the Home page. These values are illustrated at the left of Table D.6 in the column headed **Target**. Using these values the Surf Ratio Formula calculates a target individual ratio as shown in Table D.6.

D.3.2.5 Analysis

An approach to interpreting these figures is to evaluate them using an acknowledged similarity graph formula (Johnsonbaugh, 2004) as shown in Table D.7. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios calculated by Metric Ratio Analysis are shown in Table D.8.

Table D.7 - *Website surf similarity (ss)*

$$ss(v,w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4| + |p_5 - q_5|$$

$ss(v_1, v_2)$ 621			
$ss(v_1, v_3)$ 140	$ss(v_2, v_3)$ 557		
$ss(v_1, v_4)$ 58	$ss(v_2, v_4)$ 656	$ss(v_3, v_4)$ 116	
$ss(v_1, v_5)$ 122	$ss(v_2, v_5)$ 731	$ss(v_3, v_5)$ 182	$ss(v_4, v_5)$ 92

$ss(v_o, v_1)$	203
$ss(v_o, v_2)$	425
$ss(v_o, v_3)$	140
$ss(v_o, v_4)$	241
$ss(v_o, v_5)$	321

A low value indicates website surf similarity.

Table D.8 - *Table of calculated individual Surf ratios - Scaled*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Surf ratio values					
			(Normalised to 100 pages)					
OBlinks	x	300.00	108.47	711.46	199.04	98.88	98.46	0
OBHome	x	3.00	1.00	8.00	3.00	1.00	1.00	0
OBpages	÷	6.67	14.29	10.00	6.67	1.14	33.33	1
Menus	x	100.00	100.00	95.83	61.54	68.16	9.30	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Individual ratio		428.57	15.19	2727.26	137.80	296.56	0.92	0.10
Scale 1-100		100.00	3.54	636.36	32.15	69.20	0.21	0.02

Using Johnsonbaugh's formula - $ss(v, w) = |p_1\text{-}q_1| \ldots + \ldots |p_5\text{-}q_5|$ - in conjunction with the values in Table D.5 website surf similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.7. From these calculations it can be seen that companies $\boldsymbol{v_1}$ and $\boldsymbol{v_4}$ are the most similar. However, the calculations do not indicate whether this similarity is rich or poor, i.e., whether the sites support or restrict engagibility through surfing. Furthermore, the similarity values do not suggest a target value that a website owner might seek to achieve in order to insure improved quality-of-product. Such a target is identified as part of Metric Ratio Analysis and is presented in Table D.6. The reader also will realise that the values returned by the similarity formula are for pairs of websites. An individual value for each website is missing. The Surf Ratio Formula addresses this by retuning an individual ratio for each website per Table D.6. Having identified a set of target values the similarity graph formula is revisited and website surf similarity is calculated for this target website. The results are presented in the lower panel of Table D.7.

The study has used Metric Ratio Analysis to calculate individual Surf ratios in order to compare the degree that the five websites in the study support outbound hyperlinking. The calculated individual ratios are **15.19**, **2727.26**, **137.80**, **296.56** and **0.92**. The study shows that an overall individual ratio of ***428.57*** is a target value for the website owners to seek to achieve. From this, the study concludes that site $\boldsymbol{v_4}$ is closest to the set's target and that its individual ratio of ***296.56*** is a minimum ratio that other sites need to target. Achieving this will provide their visitors with a similarly rich surfing experience.

One site ($\boldsymbol{v_2}$) has significantly exceeded the target value and from an inspection of the values in Table D.8 it is clear that the additional (excessive) functionality provided by ***OBlinks*** has precipitated this situation. MRA would suggest that this website owner have over invested and is including confusing functionality.

The five values used in the Surf Ratio Formula to calculate a website's Surf ratio rely on ten counts from a set of 67 counts, which have previously been established for all five websites in this study.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.3.3 Contribution ratio

The Contribution ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree that a website implements visitor contribution functionality.

Increasingly, websites are being created that rely on contributors to the website for content. Typically, auctioneering and property sales websites rely on site members to post items ‘For Sale’ or houses ‘For Rent or Sale’. Even websites that support a mailing list where all postings are archived are part of this content contribution process. In this case the archive becomes a rich content resource. So, the aim of this section is to derive a formula to calculate a figure (individual ratio) which represents the potential for website visitors to contribute to website content. To achieve this aim the selected group of previously established counts relating to content contribution criteria, are combined. These counts reflect a website’s design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether a new design will result in a website which supports visitor content contribution.

D.3.3.1 Contribution ratio values and predictor requirements

The formula used for calculating the *Contribution ratio* uses the principle of Metric Ratio Analysis and is based on content contribution activity functionality, occurrences of that functionality and the ease with which visitors can make a contribution to the site content.

The values that are used for deriving the Contribution Ratio Formula are set out in Figure D.6. ***CCOP*** is an indirect value which relies on counts from the website quality-of-product engagibility study. ***CCactivities***, ***Levels***, ***Reg_fields*** and ***Reg_Home*** are counts from the same study.

Contribution ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
CCOP	The Content Contribution Occurrences Product	Increase	Numerator (**X**)
CCactivities	Number of content contribution activity components in website	Increase	Numerator (**X**)
Levels	Number of levels below Home page	Decrease	Denominator (**÷**)
Reg_fields	Number of fields in site membership Registration Form	Decrease	Denominator (**÷**)
Reg_Home	Number of clicks from Home page to Registration Form	Decrease	Denominator (**÷**)

Figure D.6 – *Values and requirements for the Contribution Ratio Formula.*

Two columns are included to the right of the figure which clarify formula requirement, indicating a predictable increase or decrease in the ratio as a result of increase in a formula value. Also indicated are the simple mathematical operators used in the formula.

Indirect values

In order to better reflect the distribution of Content Contribution activities throughout the website, this research uses a Content Contribution Occurrences Product (***CCOP***). A Content Contribution Occurrences Product is the summation of the products of the occurrences of the Content Contribution activities at each level in the site and the level +1 of those occurrences. A typical example of how a value for a website Content Contribution Occurrences Product is derived is illustrated in Figure D.7.

Site level	Content Contribution occurrences accessed at this level	Calculation	Content Contribution Occurrences Product
Level 0	5	5 x (0 + 1)	5
Level 1	5	5 x (1 + 1)	10
Level 2	3	3 x (2 + 1)	9
Level 3	3	3 x (3 + 1)	12
Level 4	1	1 x (4 + 1)	5
Level 5	0	0 x (5 + 1)	0
Content Contribution Occurrences Product =			**41**

Figure D.7 – *Deriving a typical Content Contribution Occurrences Product.*

The figure sets out the number of levels in the site with the root level or Home page being level 0. For each level in the website, the occurrences of all Content Contribution activities at that level are shown. In the calculation the Content Contribution occurrences is used and the multiplier in the sum of the corresponding site level plus 1 (this 1 is added in order to overcome the difficulty of multiplying by zero as would otherwise be the case at level 0). The Content Contribution Occurrences Product is the summation of the calculations for each level. In this example ***CCOP*** = 41.

So, the equation for calculating indirect value ***CCOP*** is:

CCOP = The Content Contribution Occurrences Product =

(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6)

where, level is the Community activities occurrences for the level number and the multiplier is the website level +1.

The Content Contribution activities occurrences for the different site levels are returned by the ‘Occurrence of activity components’ table for each website. These are set out in Appendix C. The actual values returned for this ratio are all 0, so, there are no ***CCOP*** values for this ratio.

The constructed Contribution Ratio Formula is set out in Figure D.8.

D.3.3.2 Constructing the Contribution Ratio Formula

Contribution Ratio Formula

The Contribution Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Contribution Ratio Formula =

$$\frac{\{(CCOP+x)\times 1\}^{1}\times\{(CCactivities+x)\times 1\}^{1}}{\{(Levels+x)\times 1\}^{1}\times\{(reg\_fields+x)\times 1\}^{1}\times\{(reg\_Home+x)\times 1\}^{1}\times C}$$

Where

$CCOP$ = Total Content Contribution Occurrences Product.

$CCactivities$ = Number of content contribution activity components in website.

$Levels$ = Number of levels below Home page.

Reg_fields = Number of fields in site membership Registration Form.

Reg_Home = Number of clicks from Home page to Registration Form.

x = a discontinuities variable and has a value of 1 or 0.

C = 1 = A Contribution ratio constant arrived at when applying the formula.

Figure D.8 – *Contribution Ratio Formula.*

D.3.3.3 Applying the Contribution Ratio Formula to five eCommerce websites

Previously determined counts appropriate to the Contribution ratio for each website in the study are set out in Table D.9. The websites are represented by $\boldsymbol{v_1}$, $\boldsymbol{v_2}$, $\boldsymbol{v_3}$, $\boldsymbol{v_4}$ and $\boldsymbol{v_5}$.

Table D.9 - *Contribution ratio values and individual ratios*

		eCommerce website study				
		Websites				
		BMIbaby	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**
		v_1	v_2	v_3	v_4	v_5
p(age) count		118	96	104	89	130
		Contribution ratio values (Normalised to 100 pages)				
CCOP	x	0.00	0.00	0.00	0.00	0.00
CCactivities	x	0.00	0.00	0.00	0.00	0.00
Levels	÷	5.00	2.00	4.00	2.00	3.00
Reg_fields	÷	0.00	0.00	0.00	0.00	0.00
Reg_Home	÷	0.00	0.00	0.00	0.00	0.00
Individual ratio		0.20	0.50	0.25	0.50	0.33

These values can now be used in conjunction with the Contribution Ratio Formula to calculate the Contribution ratio for each website. As can be seen the website owners do not have a content contribution strategy and consequently the calculated ratios are meaningless.

D.3.3.4 Contribution Ratio – Target solution and validation

Table D.10 has two additional columns of values headed, **Target** (v_o), **and 1-page website** (v_m). These two columns are used for the purpose of testing the Contribution Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.10 - *Table of calculated individual Contribution ratios- Target added*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Contribution ratio values **(Normalised to 100 pages)**					
CCOP	x	30.00	0.00	0.00	0.00	0.00	0.00	0
CCactivities	x	5.00	0.00	0.00	0.00	0.00	0.00	0
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Reg_fields	÷	8.00	0.00	0.00	0.00	0.00	0.00	0
Reg_Home	÷	1.00	0.00	0.00	0.00	0.00	0.00	0
Individual ratio		6.25	0.20	0.50	0.25	0.50	0.33	1.00

For the purpose of testing the formula two limits are set – a lower and an upper.

The lower limit is a 1-page website which is considered to be a worst case example. In this case there are no content contribution activities and consequently ***CCOP*** is 0. Being a 1-page website there are no levels below the Home page and there is no site registration involved. These values are illustrated at the right of Table D.10 in the column headed **1-page website**. So all of the 1-page website values are 0 and the Contribution Ratio Formula calculates a ratio for this lower limit at 1.

For the upper limit it is considered that a full five content contribution activities would be included and that there would be three levels below the Home page. It is considered that eight fields would be required for first time registration and that there would be just one click from the Home page to the Registration Form. Using these figures ***CCOP*** is calculated at 30 ((5*1)+(5*2)+(5*3)+(0*4)+(0*5)+(0*6)). These values are illustrated at the left of Table D.10 in the column headed **Target**. Using these values the Contribution Ratio Formula calculates a target individual ratio as shown in Table D.10.

So, the Contribution Ratio Formula will always return a positive value.

D.3.3.5 Analysis

An approach to interpreting these figures is to evaluate them using an acknowledged similarity graph formula (Johnsonbaugh, 2004) as shown in Table D.11. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios calculated by Metric Ratio Analysis are shown in Table D.12.

Table D.11 - *Website Contribution similarity (cs)*

$$cs(v,w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4| + |p_5 - q_5|$$

$cs(v_1, v_2)$ 3			
$cs(v_1, v_3)$ 1	$cs(v_2, v_3)$ 2		
$cs(v_1, v_4)$ 3	$cs(v_2, v_4)$ 0	$cs(v_3, v_4)$ 2	
$cs(v_1, v_5)$ 2	$cs(v_2, v_5)$ 1	$cs(v_3, v_5)$ 1	$cs(v_4, v_5)$ 1

$cs(v_o, v_1)$ 46
$cs(v_o, v_2)$ 45
$cs(v_o, v_3)$ 45
$cs(v_o, v_4)$ 45
$cs(v_o, v_5)$ 44

The similarities are meaningless because there is no Contriution functionality

Table D.12 - *Table of calculated individual Contribution ratios – Scaled*

eCommerce website study

Websites

		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Contribution ratio values **(Normalised to 100 pages)**					
CCOP	x	30.00	0.00	0.00	0.00	0.00	0.00	0
CCactivities	x	5.00	0.00	0.00	0.00	0.00	0.00	0
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Reg_fields	÷	8.00	0.00	0.00	0.00	0.00	0.00	0
Reg_Home	÷	1.00	0.00	0.00	0.00	0.00	0.00	0
Individual ratio		6.25	0.20	0.50	0.25	0.50	0.33	1.00
Scale 1-100		100.00	3.20	8.00	4.00	8.00	5.33	16.00

Using Johnsonbaugh's formula - $cs\ (v, w) = |p_1-q_1| \ldots + \ldots |p_5-q_5|$ - in conjunction with the values in Table D.9 website contribution similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.11.

However, in this instant the calculated results are meaningless because these website owners do no have a content contribution strategy.

Tables D.9 to D.12 are included to maintain consistency of presentation for this ratio.

The study has used Metric Ratio Analysis with a view to calculating individual Contribution ratios in order to compare the degree that the five websites in the study implement content contribution functionality. In the case of this engagibility ratio, none of the websites in the study employs a content contribution strategy and consequently no counts are available. So, although the formula has been constructed and tested it is not possible in this study to fully use it.

The study concludes that for websites in this business sector an individual ratio of ***6*** is an achievable design target. The extent that any of these websites might be enhanced and any decision to enhance can now be a more informed management decision.

The values used in the Contribution Ratio Formula to calculate a website's Contribution ratio rely on four counts from a set of 67 counts, which have previously been established for all five websites in this study. The Contribution Ratio also relies on an additional content contribution occurrences analysis which is completed after the 67 criteria counts have been determined.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.3.4 Commerce ratio

The Commerce ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree that a website implements mature eCommerce functionality.

Securing Return on Investment from eCommerce websites is a primary driver for all website owners. Measurements relating to converting browsing visitors to purchasers who revisit the site have been extensively written about. Measurement in these writings focuses on quality-of-use log file figures and similar statistics. So, the aim of this section is to derive a formula to calculate a figure (individual ratio) which represents the potential for website visitors to fully engage in eCommerce activity. To achieve this aim the selected group of previously established counts relating to website eCommerce criteria, are combined. These counts reflect a website's design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether a new design will result in a website which supports rich eCommerce engagibility.

D.3.4.1 Commerce ratio values and predictor requirements

The formula used for calculating the *Commerce ratio* uses the principle of Metric Ratio Analysis and is based on counts of the fields in the first time buyers Registration Form, the number of Add to Basket offers on the Home page, the number of these offers in the site, and number of pages containing Add to Basket offers. It is based on levels, links to supporting products, the pages that these links occur on, the number of clicks to the basket and the number of clicks to the checkout. The formula also includes a Commerce Occurrences Product which is an indirect value based on the occurrences of product offers throughout the different levels of the website. All of these combine as eleven values to create the formula.

The values used for deriving the Commerce Ratio Formula are set out in Figure D.9. $C_{om}OP$ is an indirect value which relies on counts from the website quality-of-product engagibility study and the other values are counts from the same study.

Commerce ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
Pfields	Number of fields in first-time buyer's Registration Form	Decrease	Denominator (÷)
HomeOffers	Number of *Add to Basket* offers on Home page	Increase	Numerator (**X**)
POffers	Number of *Add to Basket* offers in site	Increase	Numerator (**X**)
POpages	Number of pages containing *Add to Basket* offers	Increase	Numerator (**X**)
POlevel	Level below Home page containing first *Add to Basket* offer	Decrease	Denominator (÷)
SPlinks	Occurrences of links to supporting, non-catalogue products	Increase	Numerator (**X**)
SPpages	Number of pages containing supporting products	Increase	Numerator (**X**)
SPlevel	Level below Home page containing first link to supporting products	Decrease	Denominator (÷)
$\boldsymbol{Clicks_{to}B}$	Number of clicks from product offer to Basket	Decrease	Denominator (÷)
$\boldsymbol{Clicks_{to}C}$	Number of clicks from Basket to Checkout Form	Decrease	Denominator (÷)
$\boldsymbol{C_{om}OP}$	The Commerce Occurrences Product.	Increase	Numerator (**X**)

Figure D.9 – *Values and requirements for the Commerce Ratio Formula.*

Two columns are included to the right of the figure. These clarify formula requirement, indicating a predictable increase or decrease in the calculated ratio as a result of increase in a formula value. Also indicated are the simple mathematical operators that can be used in the formula.

Defining the formula predictors for ***POpages*** and ***SPpages*** is based on the principle that the more pages that contain Add to Basket offers the better the engagibility. Similarly, the more pages that contain links to supporting products the better the engagibility. In both instances, as the value increases so too will the Commerce ratio. This is different to the use of pages in other formula. Such difference is dictated by the different requirement of the ratio being studied. It is similar to the reality that some quality criteria have an inverse impact on different quality factors. For example, reusable code adds a loading dimension to the size of the product thereby reducing the program's efficiency - a negative effect. Alternatively, the same reusable code, which has been extensively tested and has been selected because of its know accuracy, improves the program's correctness and reliability– a positive effect.

Indirect values

One indirect value is used in the Commerce Ratio Formula. This is named the Commerce Occurrences Product (***ComOP***) and is a measure of the distribution of eCommerce occurrences (typically, *Add to Basket*) at the different site levels.

The Commerce Occurrences Product is the summation of the products of the occurrences of the Commerce activities accessed at each level in the site and the level+1 of those occurrences. A typical example of how a value for a website Commerce Occurrences Product is derived is illustrated in Figure D.10.

Site level	Commerce occurrences accessed at this level	Calculation	Commerce Occurrences Product
Level 0	1	1x (0 + 1)	1
Level 1	27	27 x (1 + 1)	54
Level 2	30	30 x (2 + 1)	90
Level 3	26	26 x (3 + 1)	104
Level 4	2	2 x (4 + 1)	10
Level 5	2	2 x (5 + 1)	12
Commerce Occurrences Product =			**271**

Figure D.10 – *Deriving a typical Commerce Occurrences Product.*

The figure sets out the number of levels in the site with the root level or Home page being level 0. For each level in the website, the occurrences of all Commerce activities accessed at that level are shown. In the calculation, the Commerce occurrences are used and the multiplier is the sum of the corresponding site level plus 1 (this 1 is added in order to overcome the difficulty of multiplying by zero as would otherwise be the case at level 0). The Commerce Occurrences Product is the summation of the calculations for each level. In this example ***ComOP*** = **271**.

The equation devised for calculating ***ComOP*** is:

$C_{om}OP$ = The Commerce Occurrences Product =
(level 0×1)+(Level 1×2)+(Level 2×3)+(Level 3×4)+(Level 4×5)+(level 5×6)
where, level is the Commerce occurrences for the level number and the multiplier is the website level +1.

The Commerce activities occurrences for the site levels are returned by the ‘Occurrence of activity components’ table of each website as set out in Appendix C.

The calculated Commerce Occurrences Products used for to calculate the individual Commerce ratios are:

		Un-normalised	**Normalised**
Target	v_o $C_{om}OP$ =	230	229.66
BMIbaby	v_1 $C_{om}OP$ =	271	229.66
CityJet	v_2 $C_{om}OP$ =	4	4.17
Eircom	v_3 $C_{om}OP$ =	43	41.35
Royal Tara	v_4 $C_{om}OP$ =	192	215.73
Sheila's Flowers	v_5 $C_{om}OP$ =	143	110.00
1-page website	v_m $C_{om}OP$ =	1	1.00

The constructed Commerce Ratio Formula is set out in Figure D.11.

D.3.4.2 Constructing the Commerce Ratio Formula

Commerce Ratio Formula

The Commerce Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Commerce Ratio Formula =

$$\frac{\{(HomeOffers+x)1\}^{1}\times\{(POffers+x)1\}^{1}\times\{(POpages+x)1\}^{1}\times\{(SPlinks+x)1\}^{1}\times\{(SPpages+x)1\}^{1}\times\{(ComOP+x)1\}^{1}}{\{(Pfields+x)1\}^{1}\times\{(POlevel+x)1\}^{1}\times\{(SPlevel+x)1\}^{1}\times\{(Clicks_{to}B+x)1\}^{1}\times\{(Clicks_{to}C+x)1\}^{1}\times C}$$

Where $Pfields$ = Number of fields in first-time buyer’s Registration Form.

$HomeOffers$ = Number of *Add to Basket* offers on Home page.

$POffers$ = Number of *Add to Basket* offers in site.

$POpages$ = Number of pages containing *Add to Basket* offers.

$POlevel$ = Level below Home page containing first *Add to Basket* offer.

$SPlinks$ = Occurrences of links to supporting, non-catalogue products.

$SPpages$ = Number of pages containing supporting products.

$SPlevel$ = Level below Home page containing first link to supporting products.

$Clicks_{to}B$ = Number of clicks from product offer to Basket.

$Clicks_{to}C$ = Number of clicks from Basket to Checkout Form.

$C_{om}OP$ = The Commerce Occurrences Product =
(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6), where,
level is the Commerce occurrences for the level number and the multiplier is the website level +1.

x = a discontinuities variable and has a value of 1 or 0.

C = 100000 = A Commerce ratio constant arrived at when applying the formula.

Figure D.11 – *Commerce Ratio Formula.*

D.3.4.3 Applying the Commerce Ratio Formula to five eCommerce websites

Previously determined counts appropriate to the Commerce ratio for each website in the study (normalized on the basis of 100 page websites) are set out in Table D.13. The websites are represented by v_1, v_2, v_3, v_4 and v_5.

Table D.13 - *Commerce ratio values and individual ratios*

		eCommerce website study				
		Websites				
		BMIbaby	CityJet	Eircom	Royal Tara	Sheila's Flowers
		v_1	v_2	v_3	v_4	v_5
p(age) count		118	96	104	89	130
		Commerce ratio values				
		(Normalised to 100 pages)				
Pfields	÷	22.00	22.00	26.00	35.00	27.00
HomeOffers	x	0.00	0.00	1.92	0.00	0.00
POffers	x	100.00	2.08	19.23	71.91	60.77
POpages	x	100.00	2.08	8.65	71.91	60.77
POlevel	÷	1.00	2.00	1.00	1.00	1.00
SPlinks	x	103.39	584.38	142.31	0.00	0.00
SPpages	x	100.00	95.83	61.54	0.00	0.00
SPlevel	÷	1.00	1.00	0.00	0.00	0.00
$Clicks_{to}B$	÷	1.00	1.00	1.00	2.00	2.00
$Clicks_{to}C$	÷	1.00	1.00	1.00	1.00	1.00
$C_{om}OP$	x	229.66	4.17	41.35	215.73	110.00
Individual ratio		10793.01	0.23	44.57	0.16	0.08

For each of the websites the individual commerce ratios are **10793.01**, **0.23**, **44.57**, **0.16** and **0.08**.

D.3.4.4 Commerce Ratio – Target solution and validation

Table D.14 has two additional columns of values headed, **Target (*v_o*)**, **and 1-page website (*v_m*)**. These two columns are used for the purpose of testing the Commerce Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.14 - *Table of calculated individual Commerce ratios – Target added*

eCommerce website study

Websites

		Target v_o	**BMIbaby** v_1	**CityJet** v_2	**Eircom** v_3	**Royal Tara** v_4	**Sheila's Flowers** v_5	**1-page website** v_m
p(age) count		100	118	96	104	89	130	*1*
Commerce ratio values (Normalised to 100 pages)								
Pfields	÷	22.00	22.00	22.00	26.00	35.00	27.00	22
HomeOffers	x	2.00	0.00	0.00	1.92	0.00	0.00	1
POffers	x	100.00	100.00	2.08	19.23	71.91	60.77	1
POpages	x	100.00	100.00	2.08	8.65	71.91	60.77	1
POlevel	÷	1.00	1.00	2.00	1.00	1.00	1.00	0
SPlinks	x	584.38	103.39	584.38	142.31	0.00	0.00	0
SPpages	x	100.00	100.00	95.83	61.54	0.00	0.00	0
SPlevel	÷	1.00	1.00	1.00	0.00	0.00	0.00	0
Clicks $_{to}$ *B*	÷	1.00	1.00	1.00	1.00	2.00	2.00	0
Clicks $_{to}$ *C*	÷	1.00	1.00	1.00	1.00	1.00	1.00	1
C $_{om}$ *OP*	x	229.66	229.66	4.17	41.35	215.73	110.00	1
Individual ratio		122007.42	10793.01	0.23	44.57	0.16	0.08	0.00

For the purpose of testing the formula two limits are set – a lower and an upper.

The lower limit is a 1-page website which is considered to be a worst case example. In this case the number of fields in first-time buyer's Registration Form is considered to be the minimum as indicated by the lowest in the set of five sites, i.e., 22. It is considered that the site is selling just 1 product and so, only needs a Home page. In this case there are no links to supporting products and consequently no supporting product pages or levels. There would be no clicks to Basket and just 1 click to Checkout on the Home page. These values are illustrated at the right of Table D.14 in the column headed **1-page website**. The Commerce Ratio Formula calculates a figure at 0 for this lower limit website.

For the upper limit a 100-page website is considered to be a target size. In this case it is considered that the 22 fields in first-time buyer's Registration Form (***Pfields***) is the most efficient as indicated by the minimum in the set of five sites. The number of *Add to*

Basket offers on Home page (***HomeOffers***) is considered to be 2 as indicated by the maximum competitive offering. It is considered that there would be 1 *Add to Basket* offer on each of the 100 pages in the site so, ***POffers*** is 100 and so too is ***POpages***. The first level below the Home page would contain *Add to Basket* offer, i.e., ***POlevel*** is 1. The site with the maximum number of links to supporting products in the five websites is considered to be a suitable target, so, ***SPlinks*** is set at 561 ÷ 96 ×100 = 584.38 and there are occurrences of these on all 100 pages. ***SPlevel*** is 1 as there would be *links to supporting product* offers at level 1. $\boldsymbol{Clicks_{to}B}$ and $\boldsymbol{Clicks_{to}C}$ are both set to 1 as this is the most efficient solution in the five websites in the study. The site with the maximum Commerce Occurrence Product is considered to be the target so, $\boldsymbol{C_{om}OP}$ is set at 271 ÷ 118 ×100 = 229.66. These values are illustrated at the left of Table D.14 in the column headed **Target**. The Commerce Ratio Formula calculates a positive figure at 122007.42 for this upper limit website.

Note: in these calculations 561 and 271 are the respective values for ***SPlinks*** and $\boldsymbol{C_{om}OP}$ before normalization.

So, the Commerce Ratio Formula will always return a positive value.

D.3.4.5 Analysis

An approach to interpreting these figures is to evaluate them using an acknowledged similarity graph formula (Johnsonbaugh, 2004) as shown in Table D.15. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios calculated by Metric Ratio Analysis are shown in Table D.16.

Table D.15 - *Website commerce similarity ($c_{om}s$)*

$$c_{om}s(v, w) = |p_1 - q_1| \ldots + \ldots |p_{11} - q_{11}|$$

$c_{om}s(v_1, v_2)$ 907			
$c_{om}s(v_1, v_3)$ 445	$c_{om}s(v_2, v_3)$ 545		
$c_{om}s(v_1, v_4)$ 289	$c_{om}s(v_2, v_4)$ 1047	$c_{om}s(v_3, v$ 506	
$c_{om}s(v_1, v_5)$ 409	$c_{om}s(v_2, v_5)$ 911	$c_{om}s(v_{3,}$ v 370	$c_{om}s(v_4, v_5)$ 136

$c_{om}s(v_o, v_1)$	483
$c_{om}s(v_o, v_2)$	428
$c_{om}s(v_o, v_3)$	846
$c_{om}s(v_o, v_4)$	771
$c_{om}s(v_o, v_5)$	891

A low value indicates website commerce similarity.

Table D.16 - *Table of calculated individual Commerce ratios - Scaled*

			eCommerce website study					
			Websites					
		Target v_o	BMIbaby v_1	CityJet v_2	Eircom v_3	Royal Tara v_4	Sheila's Flowers v_5	1-page website v_m
p(age) count		100	118	96	104	89	130	*1*
			Commerce ratio values (Normalised to 100 pages)					
Pfields	÷	22.00	22.00	22.00	26.00	35.00	27.00	22
HomeOffers	x	2.00	0.00	0.00	1.92	0.00	0.00	1
POffers	x	100.00	100.00	2.08	19.23	71.91	60.77	1
POpages	x	100.00	100.00	2.08	8.65	71.91	60.77	1
POlevel	÷	1.00	1.00	2.00	1.00	1.00	1.00	0
SPlinks	x	584.38	103.39	584.38	142.31	0.00	0.00	0
SPpages	x	100.00	100.00	95.83	61.54	0.00	0.00	0
SPlevel	÷	1.00	1.00	1.00	0.00	0.00	0.00	0
$Clicks_{to}B$	÷	1.00	1.00	1.00	1.00	2.00	2.00	0
$Clicks_{to}C$	÷	1.00	1.00	1.00	1.00	1.00	1.00	1
$C_{om}OP$	x	229.66	229.66	4.17	41.35	215.73	110.00	1
Individual ratio		122007.42	10793.01	0.23	44.57	0.16	0.08	0.00
Scale 1-100		100.00	8.85	0.00	0.04	0.00	0.00	0.00

Using Johnsonbaugh's formula - $c_{om}s\ (v, w) = |p_1 - q_1| \ldots + \ldots |p_{11} - q_{11}|$ - in conjunction with the values in Table D.13 website Commerce similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.15. From these calculations it can be seen that companies $\boldsymbol{v_4}$ and $\boldsymbol{v_5}$ are the most similar. However, the calculations do not indicate whether this similarity is rich or poor, i.e., whether the sites support or restrict engagible eCommerce. Furthermore, the similarity values do not suggest a target value that a website owner might seek to achieve in order to insure improved quality-of-product. Such a target is identified as part of Metric Ratio Analysis and is presented in Table D.14. The reader also will realise that the values returned by the similarity formula are for pairs of websites. An individual value for each website is missing. The Commerce Ratio Formula addresses this by retuning an individual ratio for each website per Table D.14. Having identified a set of target values the similarity graph formula is revisited and website commerce similarity is calculated for this target website. The results are presented in the lower panel of Table D.15.

The calculated individual ratios are **10793.01**, **0.23**, **44.57**, **0.16** and **0.08**. The study shows that an overall individual ratio of ***122007.42*** is a target value for the website owners to seek to achieve. The study shows that site v_1 is the closest site to the target in this set and that its individual ratio of ***10793.01*** is a minimum ratio that the other four sites need to target. Achieving this will provide their visitors with a similarly rich engagibility experience during eCommerce activity. Exceeding it will provide a new target for the other competitor sites.

The study does not conclude that sites v_2, v_3, v_4, and v_5 do no provide an engagable eCommerce experience for their visitors. These sites' engagibility is poor. But that is not to say that they are unsuitable for eCommerce. The study does demonstrate that more engagibility functionality is provided by a competitor site in the study and indicates the extent of that additional functionality.

The study also concludes that for websites in this business sector an individual ratio ***10793.01*** is a minimum design target and the ***122007.42*** is achievable. The extent that any of these websites might be enhanced and any decision to enhance can now be a more informed management decision.

The values used in the Commerce Ratio Formula to calculate a website's Commerce ratio rely on ten counts from a set of 67 counts, which have previously been established for all five websites in this study. The Commerce Ratio also relies on an additional Commerce occurrences analysis which is completed after the 67 criteria counts have been determined.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.3.5 Activities ratio

The Activities ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree that a website implements activity components.

The Activities ratio is the third quality-of-product ratio of Interactivity. Interactivity implies that visitor interaction will occur at the website. But for this interactivity to occur, activities (which support interactivity) must be provided during website design. So, the aim of this section is to derive a formula to calculate a figure (individual ratio) which represents the potential for website visitors to interact with a website. As part of defining the website criteria the research has identified what these activities should be and has grouped them as Core activities, Competitive and Innovative activities, Community activities, and Contribution activities. There are 35 activities in total required in this study. The Activities ratio measures the extent that these activities are implemented in the website design. The counts of these activities reflect a website's design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether the design will result in a website which is activity rich.

D.3.5.1 Activities ratio values and predictor requirements

The formula used for calculating the *Activities ratio* uses the principle of Metric Ratio Analysis and is based on activities, activity occurrences, hypertext pages and site levels. The formula reflects the theory that better website interactivity is achieved through the inclusion of appropriate activities (functionality) and the proximity of these to the website visitor - Functionality and Activity proximity. Using these elements, four values are combined in a formula which calculates an *Activities ratio*.

The values that are used for deriving the Activities Ratio Formula are set out in Figure D.12. ***AOP***, ***Activities*** and ***aPages*** are indirect values which rely on counts from the website quality-of-product engagibility study. ***Levels*** are counts from the same study.

Activities ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
AOP	The Activities Occurrences Product.	Increase	Numerator **X**
Activities	Number of **all** activity components in website.	Increase	Numerator **X**
aPages	Number of active HTML pages in the site ÷ Number of pages containing activities.	Decrease	Denominator ÷
Levels	Number of levels below Home page.	Decrease	Denominator ÷

Figure D.12 – *Values and requirements for the Activities Ratio Formula.*

Two columns are shown to the right of the figure. These clarify formula requirement, indicating a predictable ratio increase or decrease as a result of increase in a formula value. Also indicated are the mathematical operators that are used in the formula.

Indirect values

Three indirect values are used in the Activities Ratio Formula. The first is ***Activities*** which is a simple summation of all of the activity components in the website. The second is a ***aPages*** which is a quotient of HTML pages in the site and pages containing activities. The third is the Activities Occurrences Product (***AOP***).

In order to better reflect the distribution of activities throughout the website, this research uses an Activities Occurrences Product (***AOP***). An Activity Occurrences Product is the summation of the products of the occurrences of the activity at each level in the site and the level +1 of those occurrences. A typical example of how a value for a website Activities Occurrences Product is derived is illustrated in Figure D.13.

Site level	Activities occurrences accessed at this level	Calculation	Activities Occurrences Product
Level 0	1	1 x (0 + 1)	1
Level 1	46	46 x (1 + 1)	92
Level 2	140	140 x (2 + 1)	420
Level 3	87	87 x (3 + 1)	348
Level 4	0	0 x (4 + 1)	0
Level 5	0	0 x (5 + 1)	0
Activities Occurrences Product =			**861**

Figure D.13 – *Deriving a typical Activities Occurrences Product.*

The figure sets out the number of levels in the site with the root level or Home page being level 0. For each level in the website, the occurrences of all activities at that level are shown. In the calculation the activities occurrences is used and the multiplier is the sum of the corresponding site level plus 1 (this 1 is added in order to overcome the difficulty of multiplying by zero as would otherwise be the case at level 0). The Activities Occurrences Product is the summation of the calculations for each level. In this example ***AOP*** = 861.

So, the equation for calculating indirect value ***AOP*** is:

AOP = The Activities Occurrences Product =

(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6)

where, level is the Activities occurrences for the level number and the multiplier is the website level +1.

The Activities Occurrences for the different site levels are returned by the 'Occurrence of activity components' table for each website. These are set out in Appendix C.

The calculated Activities Occurrences Products used for to calculate the individual Activities ratios are:

	Un-normalised	Normalised
Target v_0 *AOP =*	2220	2220.34
BMIbaby v_1 *AOP =*	2620	2220.34
CityJet v_2 *AOP =*	309	321.88
Eircom v_3 *AOP =*	98	94.23
Royal Tara v_4 *AOP =*	448	503.37
Sheila's Flowers v_5 *AOP =*	861	662.31
1-page website v_m *AOP =*	0	0.00

The constructed Activities Ratio Formula is set out in Figure D.14.

D.3.5.2 Constructing the Activities Ratio Formula

Activities Ratio Formula

The Activities Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Activities Ratio Formula =

$$\frac{\{(AOP+x)\times 1\}^{1}\times\{(Activities+x)\times 1\}^{1}}{\{(aPages+x)\times 1\}^{1}\times\{(Levels+x)\times 1\}\quad\times C}$$

Where

AOP = The Activities Occurrences Product =

(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6)

where, level is the Activities occurrences for the level number and the multiplier is the website level +1.

$Activities$ = Total Number of **all** activity components in website.

$aPages$ = Number of active HTML pages in the site ÷ Number of pages containing activities.

$Levels$ = Number of levels below Home page.

x = a discontinuities variable and has a value of 1 or 0.

C = 1= An Activities ratio constant arrived at when applying the formula.

Figure D.14 – *Activities Ratio Formula.*

D.3.5.3 Applying the Activities Ratio Formula to five eCommerce websites

Previously determined counts appropriate to the Activities ratio for each website in the study (normalized on the basis of 100 page websites) are set out in Table D.17. The websites are represented by v_1, v_2, v_3, v_4 and v_5.

Table D.17 - *Activities ratio values and individual ratios*

		eCommerce website study				
		Websites				
		BMIbaby	CityJet	Eircom	Royal Tara	Sheila's Flowers
		v_1	v_2	v_3	v_4	v_5
p(age) count		118	96	104	89	130
		Activities ratio values (Normalised to 100 pages)				
AOP	x	2220.34	321.88	94.23	503.37	662.31
Activities	x	8.47	7.29	3.85	5.62	3.08
aPages	÷	0.85	1.04	0.96	1.12	0.77
Levels	÷	5.00	2.00	4.00	2.00	3.00
Individual ratio		4440.68	1126.56	94.23	1258.43	883.08

For each of the websites the individual activities ratios are **4440.68**, **1126.56**, **94.23**, **1258.43** and **883.08**.

D.3.5.4 Activities Ratio – Target solution and validation

Table D.18 has two additional columns of values headed, **Target (v_o), and 1-page website (v_m)**. These two columns are used for the purpose of testing the Activities Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.18 - *Table of calculated individual Activities ratios – Target added*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Activities ratio values					
			(Normalised to 100 pages)					
AOP	**x**	2220.34	2220.34	321.88	94.23	503.37	662.31	*0*
Activities	**x**	35.00	8.47	7.29	3.85	5.62	3.08	*0*
aPages	÷	1.00	0.85	1.04	0.96	1.12	0.77	*1*
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	*0*
Individual ratio		25903.95	4440.68	1126.56	94.23	1258.43	883.08	1.00

For the purpose of testing the formula two limits are set – a lower and an upper.

The lower limit is a 1-page website which is considered to be a worst case example. In this case there are no activities, there are no levels below the Home page and the Activity Occurrences Product (***AOP***) has a value of zero. So, ***aPages*** = 1 by calculation, ***Activities*** = 0; ***Levels*** = 0; and ***AOP*** = 0. These values are illustrated at the right of Table D.18 in the column headed **1-page website**. The Activities Ratio Formula calculates an individual ratio at 1 for this lower limit website.

For the upper limit a 100-page website is considered to be a target size and that activities would be available on all pages. So, ***aPages*** = 1 by calculation. In this case the maximum of 35 activities would be included and it is considered that there would be three levels below the Home Page in the target website (***Levels*** = 3). A value for the Activity Occurrences Product (***AOP)*** is based on the highest value of the five sites in this study, i.e., 2220.34. These values are illustrated at the left of Table D.18 in the column headed **Target**. The Activities Ratio Formula calculates a figure at 25903.95 for this upper limit website.

So, the Activities ratio will always return a positive value.

D.3.5.5 Analysis

An approach to interpreting these figures is to evaluate them using an acknowledged similarity graph formula (Johnsonbaugh, 2004) as shown in Table D.19. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios calculated by Metric Ratio Analysis are shown in Table D.20.

Table D.19 - *Website activities similarity (as)*

$$as(v,w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4|$$

$as(v_1, v_2)$ 1903			
$as(v_1, v_3)$ 2132	$as(v_2, v_3)$ 233		
$as(v_1, v_4)$ 1723	$as(v_2, v_4)$ 183	$as(v_3, v_4)$ 413	
$as(v_1, v_5)$ 1566	$as(v_2, v_5)$ 346	$as(v_{3,}\ v_5)$ 570	$as(v_4, v_5)$ 163

$as(v_o, v_1)$ 29
$as(v_o, v_2)$ 1927
$as(v_o, v_3)$ 2158
$as(v_o, v_4)$ 1747
$as(v_o, v_5)$ 1590

A low value indicates website activity component similarity.

Table D.20 - *Table of calculated individual Activities ratios - Scaled*

					eCommerce website study			
					Websites			
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
					Activities ratio values			
					(Normalised to 100 pages)			
AOP	x	2220.34	2220.34	321.88	94.23	503.37	662.31	*0*
Activities	x	35.00	8.47	7.29	3.85	5.62	3.08	*0*
aPages	÷	1.00	0.85	1.04	0.96	1.12	0.77	*1*
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	*0*
Individual ratio		25903.95	4440.68	1126.56	94.23	1258.43	883.08	1.00
Scale 1-100		100.00	17.14	4.35	0.36	4.86	3.41	0.00

Using Johnsonbaugh's formula - $as(v, w) = |p_1 - q_1| \ldots + \ldots |p_4 - q_4|$ - in conjunction with the values in Table D.17 website Activities similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.19. From these calculations it can be seen that companies $\boldsymbol{v_4}$ and $\boldsymbol{v_5}$ are the most similar. However, the calculations do not indicate whether this similarity is rich or poor, i.e., whether the sites support or restrict engagibility through the inclusion of activity components. Furthermore, the similarity values do not suggest a target value that a website owner might seek to achieve in order to insure improved quality-of-product. Such a target is identified as part of Metric Ratio Analysis and is presented in Table D.18. The reader also will realise that the values returned by the similarity formula are for pairs of websites. An individual value for each website is missing. The Activities Ratio Formula addresses this by retuning an individual ratio for each website per Table D.18. Having identified a set of target values the similarity graph formula is revisited and website activity similarity is calculated for this target website. The results are presented in the lower panel of Table D.19.

The calculated individual ratios are **4440.68**, **1126.56**, **94.23**, **1258.43** and **883.08**. The study shows that an overall individual ratio of ***25903.95*** is a target value for the website owners to seek to achieve. From this, the study concludes that site $\boldsymbol{v_1}$ is the closest site in this set to the target site and that its individual ratio of ***4440.68*** is a minimum ratio that the other four sites need to target. Achieving this will provide their visitors with a similarly rich engagibility experience through interactivity. Exceeding it will provide a new minimum target for the other competitor sites.

The sites in this study return Activities ratios well below the target ratio which indicates that they do not support visitor interactivity as defined by this research and that there is opportunity for these website owners to obtain better return on their investments.

The study concludes that for websites in this business sector an individual ratio ***25903.95*** is an achievable design target. The extent that any of these websites might be enhanced and any decision to enhance can now be a more informed management decision.

For the Activities ratio a total of 35 possible activities were identified and counted for each website in order to determine counts for 4 criteria. As part of this counting, the occurrences of these activities at each level of the website were manually counted and from these further indirect values were established.

Practice note

The Activities Occurrences Product (***AOP***) used for the target value in this calculation, uses the maximum ***AOP*** of the five websites in the study, i.e., 35. Future practice might refine this value by calculating a target ***AOP*** based on the average ***AOP*** of the websites being studied, or other calculated value.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.3.6 Assistive ratio (special needs)

The Assistive ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree that a website implements functionality to support special needs visitors.

The aim of this section is to derive a formula to calculate a figure (individual ratio) which represents the potential for website visitors with special needs to fully engage with the website. To achieve this aim the selected group of previously established counts relating to special needs criteria, are combined. These counts reflect a website's design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether a new design will result in a website which supports rich engagibility of those with special needs.

D.3.6.1 Assistive ratio values and predictor requirements

The study surrounding special needs and assistive solutions is vast and for this reason it would be possible to create a fuller set of ratios that are sub-ratios of the other seven ratios in this study. For example, a voice enabled website might be evaluated on the basis of a 'voice-enabled Sitebound links' sub-ratio, or on the basis of a 'voice-enabled Outbound links' sub-ratio. Or, a touch-enabled website might be evaluated on the basis of a 'touch-enabled Sitebound links' sub-ratio, or on the basis of a 'touch-enabled Outbound links' sub-ratio. Or the website might be evaluated on the basis of assistive support by way of text design and style. So, in this study the focus is a general ratio which combines all three. The formula used for calculating the *Assistive ratio* uses the principle of Metric Ratio Analysis and is based on voice, text and touch.

The values that are used for deriving the Assistive Ratio Formula are set out in Figure D.15. All of the values rely on direct counts from the website study.

Assistive ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
Pages	Number of Active HTML pages in the site	Decrease	Denominator ÷
Levels	Number of levels below Home page	Decrease	Denominator ÷
VoEpages	Number of voice enabled html pages in website	Increase	Numerator **X**
VoElinks	Total number of voice enabled hyperlinks in website	Increase	Numerator **X**
VoEactivities	Total number of voice enabled activity components in website	Increase	Numerator **X**
Images	Number of embedded images in website	Decrease	Denominator ÷
Alt_images	Number of embedded images with alt tags	Increase	Numerator **X**
BG_colour	Number of background colours on Home page	Decrease	Denominator ÷
Text_colour	Number of text colours on Home page	Decrease	Denominator ÷
Font_size	Number of font sizes on Home page	Decrease	Denominator ÷
Fonts	Number of fonts on Home page	Decrease	Denominator ÷
ToEpages	Number of touch enabled html pages in website	Increase	Numerator **X**
ToElinks	Total number of touch enabled hyperlinks in website	Increase	Numerator **X**
ToEactivities	Total number of touch enabled activity components in website	Increase	Numerator **X**

Figure D.15 – *Values and requirements for the Assistive Ratio Formula.*

Indirect values

There are no indirect values used for this ratio.

The constructed Assistive Ratio Formula is set out in Figure D.16.

D.3.6.2 Constructing the Assistive Ratio Formula

Assistive Ratio Formula

The Assistive Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Assistive Ratio Formula =

$$\frac{(VoEpages+x)^1 \times (VoElinks+x)^1 \times (VoEactiviies+x)^1 \times (Alt\_images+x)^1 \times (ToEpages+x)^1 \times (ToElinks+x)^1 \times (ToEactivities+x)^1}{(Pages+x)^1 \times (Levels+x)^1 \times (Images+x)^1 \times (BG\_colour+x)^1 \times (Text\_colour+x)^1 \times (Font\_size+x)^1 \times (Fonts+x)^1 \times C}$$

All formula values are multiplied by a weighting variable of 1. For clarity this variable is not shown.

Where

$Pages$ = Number of Active HTML pages in the site.

$Levels$ = Number of levels below Home page.

$VoEpages$ = Number of voice enabled html pages in website.

$VoElinks$ = Total number of voice enabled hyperlinks in website.

$VoEactivities$ = Total number of voice enabled activity components in website.

$Images$ = Number of embedded images in website.

Alt_images = Number of embedded images with alt tags.

BG_colour = Number of background colours on Home page.

$Text\_colour$ = Number of text colours on Home page.

$Font\_Size$ = Number of font sizes on Home page.

$Fonts$ = Number of fonts on Home page.

$ToEpages$ = Number of touch enabled html pages in website.

$ToElinks$ = Total number of touch enabled hyperlinks in website.

$ToEactivities$ = Total number of touch enabled activity components in website.

x = a discontinuities variable and has a value of 1 or 0.

C = 100000 = An Assistive ratio constant arrived at when applying the formula.

Figure D.16 – *Assistive Ratio Formula.*

D.3.6.3 Applying the Assistive Ratio Formula to five eCommerce websites

Previously determined counts appropriate to the Assistive ratio for each website in the study are set out in Table D.21. These counts have been normalized on the basis of 100 page sites. ***BG_colour***, ***Text_colour***, ***Font_size*** and ***Fonts*** are left unnormalised as they are not influenced by the page count. The websites are represented by v_1, v_2, v_3, v_4 and v_5.

Table D.21 - *Assistive ratio values and individual ratios*

		eCommerce website study Websites				
		BMIbaby v_1	CityJet v_2	Eircom v_3	Royal Tara v_4	Sheila's Flowers v_5
p(age) count		118	96	104	89	130
		Assistive ratio values **(Normalised to 100 pages)**				
Pages	÷	118.00	96.00	104.00	89.00	130.00
Levels	÷	5.00	2.00	4.00	2.00	3.00
VoEpages	x	0.00	0.00	0.00	0.00	0.00
VoElinks	x	0.00	0.00	0.00	0.00	0.00
VoEactivities	x	0.00	0.00	0.00	0.00	0.00
Images	÷	3191.53	2971.88	1770.19	2813.48	3536.15
Alt_images	x	2183.05	1619.79	604.81	811.24	1983.08
BG_colour	÷	7.00	8.00	4.00	4.00	4.00
Text_colour	÷	4.00	10.00	7.00	6.00	5.00
Font_size	÷	8.00	19.00	7.00	7.00	7.00
Fonts	÷	3.00	7.00	6.00	4.00	4.00
ToEpages	x	0.00	0.00	0.00	0.00	0.00
ToElinks	x	0.00	0.00	0.00	0.00	0.00
ToEactivities	x	0.00	0.00	0.00	0.00	0.00
Individual ratio		0.00	0.00	0.00	0.00	0.00

These values can now be used in conjunction with the Assistive Ratio Formula to calculate the Assistive ratio for each website. As can be seen, the website owners do not have an assistive strategy and consequently the calculated ratios are meaningless.

D.3.6.4 Assistive Ratio – Target solution and validation

Table D.22 has two additional columns of values headed, **Target** (***v_o***), **and 1-page website** (***v_m***). These two columns are used for the purpose of testing the Assistive Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.22 - *Table of calculated individual Assistive ratios – Target added*

					eCommerce website study			
					Websites			
		Target v_o	**BMIbaby** v_1	**CityJet** v_2	**Eircom** v_3	**Royal Tara** v_4	**Sheila's Flowers** v_5	**1-page website** v_m
p(age) count		100	118	96	104	89	130	*1*
					Assistive ratio values			
					(Normalised to 100 pages)			
Pages	÷	100.00	118.00	96.00	104.00	89.00	130.00	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
VoEpages	x	100.00	0.00	0.00	0.00	0.00	0.00	0
VoElinks	x	2200.00	0.00	0.00	0.00	0.00	0.00	0
VoEactivities	x	35.00	0.00	0.00	0.00	0.00	0.00	0
Images	÷	1770.19	3191.53	2971.88	1770.19	2813.48	3536.15	0
Alt_images	x	1770.19	2183.05	1619.79	604.81	811.24	1983.08	0
BG_colour	÷	4.00	7.00	8.00	4.00	4.00	4.00	1
Text_colour	÷	4.00	4.00	10.00	7.00	6.00	5.00	1
Font_size	÷	7.00	8.00	19.00	7.00	7.00	7.00	1
Fonts	÷	3.00	3.00	7.00	6.00	4.00	4.00	1
ToEpages	x	100.00	0.00	0.00	0.00	0.00	0.00	0
ToElinks	x	2200.00	0.00	0.00	0.00	0.00	0.00	0
ToEactivities	x	35.00	0.00	0.00	0.00	0.00	0.00	0
Individual ratio		5881.94	0.00	0.00	0.00	0.00	0.00	0.00

For the purpose of testing the formula two limits are desirable – a lower and an upper.

The lower limit is a 1-page website which is considered to be a worst case example. In this case there is 1 page which uses 1 BG_colour, 1 Text_Colour, 1 Font_size and 1 Font. So, in this case ***BG_colour*** = 1, ***Text_Colour*** = 1, ***Font_size*** = 1 and ***Font*** = 1. All other values are 0. These values are illustrated at the right of Table D.22 in the column headed **1-page website**. The Assistive Ratio Formula calculates an individual ratio of 0.00 for this lower limit.

For the upper limit a 100-page website is considered to be a target size and all pages would be voice enabled and touch enabled. So, ***Pages*** = 100, ***VoEpages*** = 100 and ***ToEpages*** = 100. In this case the maximum of 35 voice enabled activities and touch enabled activities would be included and it is considered that there would be three levels below the Home Page in the target website. These values are illustrated at the left of Table D.22 in the column headed **Target**. The four values ***BG_colour***, ***Text_Colour***, ***Font_size*** and ***Font*** are based on the minimum practice in the set of five websites in the study (these criteria are best kept to a minimum). The number of Images in the site is also based on the minimum practice in the set i.e., ***Images*** = 1770.19 and it is considered that all of these images would be specified with alternate text, i.e., ***Alt_images*** = 1770.19. In the target solution all links would be both voice enabled and touch enabled. Target values for voice enabled links and touch enabled links in a website are based on the link target values used in the Navigation and Surf ratios, (i.e., Navigation links = ***SBlinks + Home_Top + Search*** = 1400 + 400 + 100 = 1900 and Surf links = ***OBlinks*** = 300, giving a total links = 2200) – see Table D.2 and Table D.6. The Assistive Ratio Formula calculates a figure at 5881.94 for this upper limit website.

So, the Assistive Ratio Formula will always return a positive value.

D.3.6.5 Analysis

An approach to interpreting these figures is to evaluate them using an acknowledged similarity graph formula (Johnsonbaugh, 2004) as shown in Table D.23. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios calculated by Metric Ratio Analysis are shown in Table D.24.

Table D.23 - *Website assistive similarity ($a_{st}s$)*

$$a_{st}s(v, w) = |p_1 - q_1| \ldots + \ldots |p_{11} - q_{11}|$$

$a_{st}s(v_1, v_2)$	830						
$a_{st}s(v_1, v_3)$	3025	$a_{st}s(v_2, v_3)$	2247				
$a_{st}s(v_1, v_4)$	1789	$a_{st}s(v_2, v_4)$	997	$a_{st}s(v_3, v_4)$	1270		
$a_{st}s(v_1, v_5)$	565	$a_{st}s(v_2, v_5)$	987	$a_{st}s(v_3, v_5)$	3175	$a_{st}s(v_4, v_5)$	1938

$a_{st}s(v_o, v_1)$	6528
$a_{st}s(v_o, v_2)$	6053
$a_{st}s(v_o, v_3)$	5846
$a_{st}s(v_o, v_4)$	6687
$a_{st}s(v_o, v_5)$	6681

A low value indicates website assistive similarity.

Table D.24 - *Table of calculated individual Assistive ratios - Scaled*

eCommerce website study

Websites

		Target v_o	**BMIbaby** v_1	**CityJet** v_2	**Eircom** v_3	**Royal Tara** v_4	**Sheila's Flowers** v_5	**1-page website** v_m
p(age) count		100	118	96	104	89	130	*1*
					Assistive ratio values (Normalised to 100 pages)			
Pages	÷	100.00	118.00	96.00	104.00	89.00	130.00	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
VoEpages	x	100.00	0.00	0.00	0.00	0.00	0.00	0
VoElinks	x	2200.00	0.00	0.00	0.00	0.00	0.00	0
VoEactivities	x	35.00	0.00	0.00	0.00	0.00	0.00	0
Images	÷	1770.19	3191.53	2971.88	1770.19	2813.48	3536.15	0
Alt_images	x	1770.19	2183.05	1619.79	604.81	811.24	1983.08	0
BG_colour	÷	4.00	7.00	8.00	4.00	4.00	4.00	1
Text_colour	÷	4.00	4.00	10.00	7.00	6.00	5.00	1
Font_size	÷	7.00	8.00	19.00	7.00	7.00	7.00	1
Fonts	÷	3.00	3.00	7.00	6.00	4.00	4.00	1
ToEpages	x	100.00	0.00	0.00	0.00	0.00	0.00	0
ToElinks	x	2200.00	0.00	0.00	0.00	0.00	0.00	0
ToEactivities	x	35.00	0.00	0.00	0.00	0.00	0.00	0
Individual ratio		5881.94	0.00	0.00	0.00	0.00	0.00	0.00
Scale 1-100		100.00	0.00	0.00	0.00	0.00	0.00	0.00

Using Johnsonbaugh's formula - $a_{st}s\ (v, w) = |p_1 - q_1| \ldots + \ldots |p_{11} - q_{11}|$ - in conjunction with the values in Table D.21 website Assistive similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.23.

However, in this instant the calculated results are meaningless because these website owners do no have an assistive strategy as defined by Metric Ratio Analysis.

Tables D.21 to D.24 are included to maintain consistency of presentation for this ratio.

The study has used Metric Ratio Analysis with a view to calculating individual Assistive ratios in order to compare the degree that the five websites in the study implement special needs assistive functionality. In the case of this engagibility ratio, none of the websites in the study employs a complete assistive strategy and consequently too few counts are available at this time. So, although the formula has been constructed and tested it is not possible in this study to fully use it.

The values used in the Assistive Ratio Formula to calculate a website's Assistive ratio rely on 17 counts from a set of 67 counts, which have previously been established for all five websites in this study.

Practice note

This study of the application of Metric Ratio Analysis to website measurement illustrates that a lower number of formula values or indirect values is more desirable. In this example voice enabled pages, text presentation and touch enabled links are all being measured. In practice, it might be more appropriate to use three separate calculations for these.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.3.7 Community ratio

The Community ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree that a website implements functionality to support common interest visitors.

Website owners and designers are conscious of the value that a sense of community adds to a website. Providing functionality that repeatedly encourages common interest visitors to "revisit" and to "belong" is the foundation of their strategy. So, the aim of this section is to derive a formula to calculate a figure (individual ratio) which represents the potential for website visitors to fully engage in common interest community activity. To achieve this aim the selected group of previously established counts relating to website community criteria, are combined. These counts reflect a website's design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether a new design will result in a website which supports rich community engagibility.

D.3.7.1 Community ratio values and predictor requirements

The formula used for calculating the *Community ratio* uses the principle of Metric Ratio Analysis and is based on community activities, community activity occurrences, hypertext pages in the website, hypertext pages containing those activities, and site levels. The formula reflects the theory that better common interest engagibility will be achieved through the inclusion of appropriate community activities (functionality) and the proximity of these activities to the website visitor – that is, Functionality and Community Activity proximity. Using these elements, four values are combined in a formula which calculates a *Community ratio*.

The values that are used for deriving the Community Ratio Formula are set out in Figure D.17. ***CPages*** and ***COP*** are indirect values that rely on counts from the website quality-of-product engagibility study. ***CActivities*** and ***Levels*** are counts from the same study.

Community ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
COP	The Community Occurrences Product.	Increase	Numerator **X**
CActivities	Number of community activity components in website.	Increase	Numerator **X**
CPages	Number of active HTML pages in the site ÷ Number of pages containing community activities.	Decrease	Denominator **÷**
Levels	Number of levels below Home page.	Decrease	Denominator **÷**

Figure D.17 – *Values and requirements for the Community Ratio Formula.*

Two columns are included to the right of the figure. These clarify formula requirement, indicating a predictable increase or decrease in the ratio as a result of increase in a formula value. Also indicated are the simple mathematical operators that can be used in the formula.

Indirect values

The two indirect values that are used in this set are ***CPages*** and ***COP***. ***CPages*** is a quotient of HTML pages in the site and pages containing Community activities. By including both values, MRA considers ***CPages*** is a more representative value for page impact in the formula.

To better reflect the distribution of Community activities throughout the website, the research calculates and uses a Community Occurrences Product (***COP***). A Community Occurrences Product is the summation of the products of the occurrences of the Community activities at each level in the site and the level +1 of those occurrences. A typical example of how a value for a website Community Occurrences Product is derived is illustrated in Figure D.18.

Site level	Community Activity occurrences accessed at this level	Calculation	Community Occurrences Product
Level 0	1	1 x (0 + 1)	1
Level 1	26	26 x (1 + 1)	52
Level 2	65	65 x (2 + 1)	195
Level 3	0	0 x (3 + 1)	0
Level 4	0	0 x (4 + 1)	0
Level 5	0	0 x (5 + 1)	0
Community Occurrences Product =			**248**

Figure D.18 – *Deriving a typical Community Occurrences Product.*

The figure sets out the number of levels in the site with the root level or Home page being level 0. For each level in the website, the occurrences of all Community activities at that level are shown. In the calculation the Community activity occurrences is used and the multiplier is the sum of the corresponding site level plus 1 (this 1 is added in order to overcome the difficulty of multiplying by zero as would otherwise be the case at level 0). The Community Occurrences Product is the summation of the calculations for each level. In this example ***COP*** = 248.

So, the equation for calculating indirect value ***COP*** is:

COP = The Community Occurrences Product =

(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6)

where, level is the Community Activity occurrences for the level number and the multiplier is the website level +1.

The Community Activity occurrences for the different site levels are returned by the ‘Occurrence of activity components’ table for each website. These are set out in Appendix C.

The calculated Community Occurrences Products used for to calculate the individual Community ratios are:

	Un-normalised	**Normalised**
Target v_o *COP* =	329	328.81
BMIbaby v_1 *COP* =	388	328.81
CityJet v_2 *COP* =	248	258.33
Eircom v_3 *COP* =	18	17.31
Royal Tara v_4 *COP* =	7	7.87
Sheila's Flowers v_5 *COP* =	4	3.08
1-page website v_m *COP* =	0	0.00

The constructed Community Ratio Formula is set out in Figure D.19.

D.3.7.2 Constructing the Community Ratio Formula

Community Ratio Formula

The Community Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Community Ratio Formula =

$$\frac{\{(COP + x) \times 1\}^1 \times \{(CActivities + x) \times 1\}^1}{\{(CPages + x) \times 1\}^1 \times \{(Levels + x) \times 1\}^1 \times C}$$

Where

COP = The Community Occurrences Product =

(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6)

where, level is the Community activity occurrences for the level number and the multiplier is the website level +1.

$CActivities$ = Number of community activity components in website.

$CPages$ = Number of active HTML pages in the site ÷ Number of pages containing community activities.

$Levels$ = Number of levels below Home page.

x = a discontinuities variable and has a value of 1 or 0.

C = 1= A Community ratio constant arrived at when applying the formula.

Figure D.19 – *Community Ratio Formula.*

D.3.7.3 Applying the Community Ratio Formula to five eCommerce websites

Previously determined counts appropriate to the Community ratio for each website in the study (normalized on the basis of 100 page websites) are set out in Table D.25. The websites are represented by v_1, v_2, v_3, v_4 and v_5.

Table D.25 - *Community ratio values and individual ratios*

		eCommerce website study				
		Websites				
		BMIbaby	CityJet	Eircom	Royal Tara	Sheila's Flowers
		v_1	v_2	v_3	v_4	v_5
p(age) count		118	96	104	89	130
		Community ratio values (Normalised to 100 pages)				
COP	x	328.81	258.33	17.31	7.87	3.08
CActivities	x	0.85	1.04	0.96	1.12	0.77
CPages	÷	0.93	1.09	16.67	33.33	50.00
Levels	÷	5.00	2.00	4.00	2.00	3.00
Individual ratio		59.63	123.78	0.25	0.13	0.02

For each of the websites the individual community ratios are **59.63**, **123.78**, **0.25**, **0.13** and **0.02**.

D.3.7.4 Community Ratio – Target solution and validation

Table D.26 has two additional columns of values headed, **Target** (v_o), **and 1-page website** (v_m). These two columns are used for the purpose of testing the Community Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.26 - *Table of calculated individual Community ratios – Target added*

					eCommerce website study			
					Websites			
		Target	BMIbaby	CityJet	Eircom	Royal Tara	Sheila's Flowers	1-page website
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
					Community ratio values (Normalised to 100 pages)			
COP	x	328.81	328.81	258.33	17.31	7.87	3.08	0
CActivities	x	10.00	0.85	1.04	0.96	1.12	0.77	0
CPages	÷	1.00	0.93	1.09	16.67	33.33	50.00	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Individual ratio		1096.05	59.63	123.78	0.25	0.13	0.02	1.00

For the purpose of testing the formula two limits are set – a lower and an upper.

The lower limit is a 1-page website which is considered to be a worst case example. In this case there are no community activities, there are no levels below the Home page and the Community Occurrences Product (***COP***) has a value of zero. So, ***CActivities*** = 0, ***Levels*** = 0 ***COP*** = 0 and ***CPages*** is 1 by calculation. These values are illustrated at the right of Table D.26 in the column headed **1-page website**. The Community Ratio Formula calculates a value at 1 for this lower limit website.

For the upper limit a 100-page website is considered to be a target size and all pages would contain community activities. In this case all 10 Community activities would be included. It is also considered that there would be three levels below the Home Page in the target website. A value for the Community Occurrences Product (***COP***) is calculated based on the maximum value of the five sites in this study. That is, 388 ÷ 118 ×100 = 328.81. It is considered that the number of pages containing community activities would be 100 so, ***CPages*** is 1 by calculation (100/100). These values are illustrated at the left of Table D.26 in the column headed **Target**. The Community Ratio Formula calculates a positive figure at ***1096.05*** for this upper limit website.

D.3.7.5 Analysis

An approach to interpreting these figures is to evaluate them using an acknowledged similarity graph formula (Johnsonbaugh, 2004) as shown in Table D.27. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios calculated by Metric Ratio Analysis are shown in Table D.28.

Table D.27 - *Website Community similarity ($c_{ty}s$)*

$$c_{ty}\, s(v,w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4|$$

$c_{ty}\, s(v_1, v_2)$ 74			
$c_{ty}\, s(v_1, v_3)$ 328	$c_{ty}\, s(v_2, v_3$ 259		
$c_{ty}\, s(v_1, v_4)$ 357	$c_{ty}\, s(v_2, v_4$ 283	$c_{ty}\, s(v_3, v_4$ 28	
$c_{ty}\, s(v_1, v_5)$ 377	$c_{ty}\, s(v_2, v_5$ 305	$c_{ty}\, s(v_{3,}\ v_5$ 49	$c_{ty}\, s(v_4, v_5$ 23

$c_{ty}\, s(v_o, v_1)$ 11
$c_{ty}\, s(v_o, v_2)$ 81
$c_{ty}\, s(v_o, v_3)$ 337
$c_{ty}\, s(v_o, v_4)$ 363
$c_{ty}\, s(v_o, v_5)$ 384

A low value indicates website community component similarity.

Table D.28 - *Table of calculated individual Community ratios - Scaled*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Community ratio values					
			(Normalised to 100 pages)					
COP	x	328.81	328.81	258.33	17.31	7.87	3.08	0
CActivities	x	10.00	0.85	1.04	0.96	1.12	0.77	0
CPages	÷	1.00	0.93	1.09	16.67	33.33	50.00	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Individual ratio		1096.05	59.63	123.78	0.25	0.13	0.02	1.00
Scale 1-100		100.00	5.44	11.29	0.02	0.01	0.00	0.09

Using Johnsonbaugh's formula - $c_{ty}s(v, w) = |p_1\text{-}q_1| \ldots + \ldots |p_4\text{-}q_4|$ - in conjunction with the values in Table D.25 website Community similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.27. From these calculations it can be seen that companies $\boldsymbol{v_4}$ and $\boldsymbol{v_5}$ are the most similar. However, the calculations do not indicate whether this similarity is rich or poor, i.e., whether the sites support or restrict engagibility through the inclusion of community components. Furthermore, the similarity values do not suggest a target value that a website owner might seek to achieve in order to insure improved quality-of-product. Such a target is identified as part of Metric Ratio Analysis and is presented in Table D.26. The reader also will realise that the values returned by the similarity formula are for pairs of websites. An individual value for each website is missing. The Community Ratio Formula addresses this by retuning an individual ratio for each website per Table D.26. Having identified a set of target values the similarity graph formula is revisited and website Community similarity is calculated for this target website. The results are presented in the lower panel of Table D.27.

Table D.28 presents a full set of calculated individual ratios. Also, for ease of comparison Table D.28 includes the 1-100 scaled conversion of the individual ratios.

The calculated individual ratios are **59.63**, **123.78**, **0.25**, **0.13** and **0.02**. The study shows that an overall individual ratio of ***1096.05*** is a target value for the website owners' to seek to achieve. From this, the study concludes that site $\boldsymbol{v_2}$ is the closest site to the target in this set and that its individual ratio of ***123.78*** is a minimum ratio that the other four sites need to target. Achieving this will provide their visitors with a similarly rich engagibility experience using common interest functionality. Exceeding it will provide a new target for the other competitor sites.

The study concludes that common interest functionality provided by sites $\boldsymbol{v_3}$**,** $\boldsymbol{v_4}$**,** and $\boldsymbol{v_5}$ is very low and these website owners could gain from a review of their strategy to include community functionality.

The study also concludes that for websites in this business sector an individual ratio ***1096.05*** is an achievable design target. The extent of enhancement that might be targeted and any decision to enhance can now be a more informed management decision.

The values used in the Community Ratio Formula to calculate a website's Community ratio rely on four counts from a set of 67 counts, which have previously been established for all five websites in this study. The Community ratio also relies on an additional community activities occurrences analysis which is completed after the 67 criteria counts have been determined.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.3.8 Competitive ratio

The Competitive ratio is defined in the Taxonomy of Engagibility ratios as:

> The degree that a website supports a unique visitor perspective.

This ratio addresses a website owner’s requirement to achieve competitive advantage by engaging visitors through competitive and innovative activity on their website. So, the aim of this section is to derive a formula to calculate a figure (individual ratio) which represents a website’s potential to offer visitors a unique perspective when they visit. This perspective or experience relies on the presence in the website of a set of competitive and innovative activities and this study requires 10 such activities – 5 competitive activities and 5 innovative activities. To achieve this aim the selected group of previously established counts relating to these competitive and innovative activities, are combined. These counts reflect a website’s design and so it follows that this formula can be used with website design data (i.e., data available before the existence of the website artefact) in order to determine whether a new design will result in a website which supports engagibility through a unique visitor experience.

D.3.8.1 Competitive ratio values and predictor requirements

The formula used for calculating the *Competitive ratio* uses the principle of Metric Ratio Analysis and is based on competitive and innovative activities, occurrences of these activities, hypertext pages and site levels. The formula reflects the theory that a more competitive website will be achieved through the inclusion of appropriate activities (functionality) and the proximity of these activities to the website visitor - Functionality and Activity proximity as shown in Figure D.20. Using these elements, four values are combined in a formula which calculates a *Competitive ratio*.

The values that are used for deriving the Competitive Ratio Formula are set out in Figure D.20. ***CiOP***, ***CiActivities*** and ***CiPages*** are indirect values that rely on counts from the website quality-of-product engagibility study. ***Levels*** are counts from the same study.

Competitive ratio values			
Value or Indirect value name	**Value description**	**Formula requirement:**	
		Predictor As Value increases, calculated ratio will	**Operator**
CiOP	The Competitive +Innovative activities Occurrences Product.	Increase	Numerator **X**
CiActivities	Number of Competitive + Innovative activity components in website.	Increase	Numerator **X**
CiPages	Number of active HTML pages in the site ÷ Number of pages containing Competitive + Innovative activities.	Decrease	Denominator ÷
Levels	Number of levels below Home page.	Decrease	Denominator ÷

Figure D.20 – *Values and requirements for the Competitive Ratio Formula.*

Two columns are included to the right of the figure. These clarify formula requirement, indicating a predictable increase or decrease in the ratio as a result of increase in a formula value. Also indicated are the simple mathematical operators that can be used in the formula.

Indirect values

Three indirect values are used in this set. These are ***CiPages***, ***CiActivities*** and ***CiOP***. ***CiPages*** is a quotient of HTML pages in the site and pages containing Competitive and Innovative activities. By including both values, MRA considers ***CiPages*** is a more representative value for page impact in the formula. ***CiActivities*** is a simple sum of the competitive activities and the innovative activities in the website.

To reflect the distribution of Competitive + Innovative activities throughout the website, this research uses a Competitive + Innovative Occurrences Product (***CiOP***). A Competitive + Innovative Occurrences Product is the summation of the products of the occurrences of the Competitive and Innovative activities at each level in the site and the level +1 of those occurrences. A typical example of how a value for a website Competitive + Innovative Occurrences Product is derived is illustrated in Figure D.21.

Site level	Competitive + Innovative occurrences accessed at this level	Calculation	Competitive + Innovative Occurrences Product
Level 0	0	0x (0 + 1)	0
Level 1	17	17 x (1 + 1)	34
Level 2	83	83 x (2 + 1)	249
Level 3	41	41 x (3 + 1)	164
Level 4	0	0 x (4 + 1)	0
Level 5	0	0 x (5 + 1)	0
Competitive + Innovative Occurrences Product =			**447**

Figure D.21 – *Deriving a Competitive and Innovative Occurrences Product.*

The figure sets out the number of levels in the site with the root level or Home page being level 0. For each level in the website, the occurrences of all Competitive and Innovative activities at that level are shown. In the calculation, the Competitive + Innovative occurrences is used and the multiplier is the sum of the corresponding site level plus 1 (this 1 is added in order to overcome the difficulty of multiplying by zero as would otherwise be the case at level 0). The Competitive + Innovative Occurrences Product is the summation of the calculations for each level. In this example ***CiOP*** = 447.

So, the equation for calculating indirect value ***CiOP*** is:

CiOP = The Competitive + Innovative Occurrences Product =

(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6)

where, level is the Competitive + Innovative activities occurrences for the level number and the multiplier is the website level +1.

The Competitive + Innovative activities occurrences for the different site levels are returned by the 'Occurrence of activity components' table for each website. These are set out in Appendix C.

The calculated Competitive and Innovative Occurrences Products used for to calculate the individual Competitive ratios are:

		Un-normalised	Normalised
Target v_o	*CiOP* =	1808	1807.63
BMIbaby v_1	*CiOP* =	2133	1807.63
CityJet v_2	*CiOP* =	11	11.46
Eircom v_3	*CiOP* =	80	76.92
Royal Tara v_4	*CiOP* =	195	219.10
Sheila's Flowers v_5	*CiOP* =	447	343.85
1-page website v_m	*CiOP* =	0	0.00

The constructed Competitive Ratio Formula is set out in Figure D.22.

D.3.8.2 Constructing the Competitive Ratio Formula

Competitive Ratio Formula

The Competitive Ratio Formula is constructed by arranging counts and indirect values that cause an increase in the calculated ratio as numerators, and by arranging counts and indirect values that cause a decrease in the calculated ratio as denominators. The constructed formula is:

Competitive Ratio Formula =

$$\frac{\{(CiOP+x)\times 1\}^{1}\times\{(CiActivities+x)\times 1\}^{1}}{\{(CiPages+x)\times 1\}^{1}\times\{(Levels+x)\times 1\}^{1}\times C}$$

Where

$CiOP$ = The Competitive + Innovative Occurrences Product =
(level 0x1)+(Level 1x2)+(Level 2x3)+(Level 3x4)+(Level 4x5)+(level 5x6)
where, level is the Competitive + Innovative activity occurrences for the level number and the multiplier is the website level +1.

$CiActivities$ = Number of Competitive + Innovative activity components in website.

$CiPages$ = Number of active HTML pages in the site ÷ Number of pages containing Competitive + Innovative activities.

$Levels$ = Number of levels below Home page.

x = a discontinuities variable and has a value of 1 or 0.

C = 1 = A Competitive ratio constant arrived at when applying the formula.

Figure D.22 – *Competitive Ratio Formula.*

D.3.8.3 Applying the Competitive Ratio Formula to five eCommerce websites

Previously determined counts appropriate to the Competitive ratio for each website in the study (normalized on the basis of 100 page websites) are set out in Table D.29. The websites are represented by v_1, v_2, v_3, v_4 and v_5.

Table D.29 - *Competitive ratio values and individual ratios*

eCommerce website study

Websites

		BMIbaby v_1	**CityJet** v_2	**Eircom** v_3	**Royal Tara** v_4	**Sheila's Flowers** v_5
p(age) count		118	96	104	89	130
		Competitive ratio values				
		(Normalised to 100 pages)				
CiOP	x	1807.63	11.46	76.92	219.10	343.85
CiActivities	x	4.24	3.13	1.92	2.25	1.54
CiPages	÷	0.85	50.00	3.13	1.49	1.27
Levels	÷	5.00	2.00	4.00	2.00	3.00
Individual ratio		1807.63	0.36	11.83	164.94	139.30

For each of the websites the individual competitive ratios are **1807.63**, **0.36**, **11.83**, **164.94** and **139.30**.

D.3.8.4 Competitive Ratio – Target solution and validation

Table D.30 has two additional columns of values headed, **Target** (v_o), **and 1-page website** (v_m). These two columns are used for the purpose of testing the Competitive Ratio Formula and to obtain a target ratio for the upper limit and are now explained.

Table D.30 - *Table of calculated individual Competitive ratios – Target added*

			eCommerce website study					
			Websites					
		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Competitive ratio values					
			(Normalised to 100 pages)					
CiOP	**x**	1807.63	1807.63	11.46	76.92	219.10	343.85	0
CiActivities	**x**	10.00	4.24	3.13	1.92	2.25	1.54	0
CiPages	÷	1.00	0.85	50.00	3.13	1.49	1.27	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Individual ratio		6025.42	1807.63	0.36	11.83	164.94	139.30	1.00

For the purpose of testing the formula two limits are set – a lower and an upper.

The lower limit is a 1-page website which is considered to be a worst case example. In this case there are no competitive or innovative activities, there are no levels below the Home page, and the Competitive + Innovative activity Occurrences Product (***CiOP***) has a value of zero. ***CiPages*** is 1 by calculation. These values are illustrated at the right of Table D.30 in the column headed **1-page website**. The Competitive Ratio Formula calculates a value at 1.00 for this lower limit website.

For the upper limit a 100-page website is considered to be a target size. In this case all 10 Competitive + Innovative activities would be included and it is considered that there would be three levels below the Home Page in the target website. It is considered that a target website would need to at least match the best offering of a competitor website. So, a value for the Competitive + Innovative activity Occurrences Product (***CiOP***) is calculated based on the highest value of the five sites in this study. That is, 2133 ÷ 118 × 100 = 1807.63. It is considered that the number of pages containing competitive and innovative activities would be 100 so, ***CiPages*** is 1 by calculation (100/100). These values are illustrated at the left of Table D.30 in the column headed **Target**. The Competitive Ratio Formula calculates a figure at 6025.42 for this upper limit website.

D.3.8.5 Analysis

An approach to interpreting these figures is to evaluate them using an acknowledged similarity graph formula (Johnsonbaugh, 2004) as shown in Table D.31. This optional interpretation is included here for future similarity and business clustering analysis. Scaled individual ratios as calculated using Metric Ratio Analysis are shown in Table D.32.

Table D.31 - *Website competitive similarity ($c_i s$)*

$$c_i\, s(v, w) = |p_1 - q_1| + |p_2 - q_2| + |p_3 - q_3| + |p_4 - q_4|$$

$c_i s(v_1, v_2)$	1849						
$c_i s(v_1, v_3)$	1736	$c_i s(v_2, v_3)$	116				
$c_i s(v_1, v_4)$	1594	$c_i s(v_2, v_4)$	257	$c_i s(v_3, v_4)$	146		
$c_i s(v_1, v_5)$	1469	$c_i s(v_2, v_5)$	384	$c_i s(v_3, v_5)$	270	$c_i s(v_4, v_5)$	127

$c_i s(v_o, v_1)$	8
$c_i s(v_o, v_2)$	1853
$c_i s(v_o, v_3)$	1742
$c_i s(v_o, v_4)$	1598
$c_i s(v_o, v_5)$	1473

A low value indicates website competitive activity similarity.

Table D.32 - *Table of calculated individual Competitive ratios - Scaled*

eCommerce website study

Websites

		Target	**BMIbaby**	**CityJet**	**Eircom**	**Royal Tara**	**Sheila's Flowers**	**1-page website**
		v_o	v_1	v_2	v_3	v_4	v_5	v_m
p(age) count		100	118	96	104	89	130	*1*
			Competitive ratio values **(Normalised to 100 pages)**					
CiOP	**x**	1807.63	1807.63	11.46	76.92	219.10	343.85	0
CiActivities	**x**	10.00	4.24	3.13	1.92	2.25	1.54	0
CiPages	÷	1.00	0.85	50.00	3.13	1.49	1.27	1
Levels	÷	3.00	5.00	2.00	4.00	2.00	3.00	0
Individual ratio		6025.42	1807.63	0.36	11.83	164.94	139.30	1.00
Scale 1-100		100.00	30.00	0.01	0.20	2.74	2.31	0.02

Using Johnsonbaugh's formula - $c_i s(v, w) = |p_1 - q_1| \ldots + \ldots |p_4 - q_4|$ - in conjunction with the values in Table D.29 website Competitive similarity is calculated for all of the websites in the study. The results are presented in the top panel of Table D.31. From these calculations it can be seen that companies **v_2** and **v_3** are the most similar. However, the calculations do not indicate whether this similarity is rich or poor, i.e., whether the sites support or restrict engagibility through the inclusion of Competitive and Innovative components. Furthermore, the similarity values do not suggest a target value that a website owner might seek to achieve in order to insure improved quality-of-product. Such a target is identified as part of Metric Ratio Analysis and is presented in Table D.30. The reader also will realise that the values returned by the similarity formula are for pairs of websites. An individual value for each website is missing. The Competitive Ratio Formula addresses this by retuning an individual ratio for each website per Table D.30. Having identified a set of target values the similarity graph formula is revisited and website Competitive similarity is calculated for this target website. The results are presented in the lower panel of Table D.31.

The calculated individual ratios are **1807.63**, **0.36**, **11.83**, **164.94** and **139.30**. The study shows that an overall individual ratio of ***6025.42*** is a target value for the website owners' to seek to achieve. From this, the study concludes that site **v_1** is the closest site to the target in this set and that its individual ratio of ***1807.63*** is a minimum ratio that the other four sites need to target. Achieving this will provide their visitors with a similarly rich engagibility experience through a competitive and innovative activities strategy. Exceeding it will provide a new target for the other competitor sites.

The study concludes that competitive and innovative functionality provided by sites ***v_2*, *v_3* *v_4*,** and ***v_5*** is very low and these website owners could gain from a review of their strategy to include competitive and innovative functionality.

The study also concludes that for websites in this business sector an individual ratio ***6025.42*** is an achievable design target. The extent of enhancement that might be targeted and any decision to enhance can now be a more informed management decision.

The values used in the Competitive Ratio Formula to calculate a websites Competitive ratio rely on 5 counts from a set of 67 counts, which have previously been established for all five websites in this study. The Competitive Ratio also relies on an additional Competitive + Innovative Occurrences analysis which is completed after the 67 criteria counts have been determined.

Section D.4 presents a complete set of charts and Kiviat diagrams for the engagibility calculations in the website study.

D.4 Website engagibility illustrated

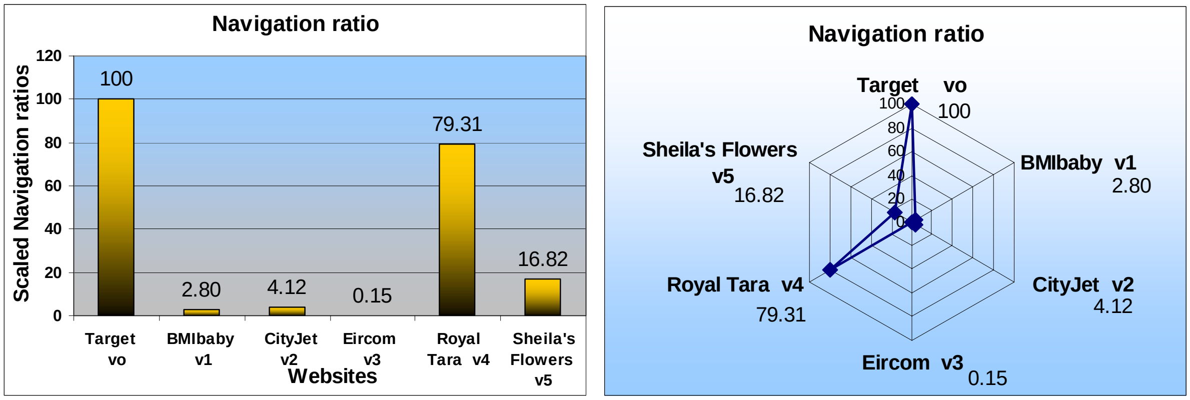
This section presents charts which illustrate the scaled Individual ratio, Characteristic Quotient and Engagibility Index of each website in the eCommerce study.

D.4.1 Engagibility individual ratios illustrated – by ratio

To support the analysis of the individual ratios two different charts for each ratio are illustrated in Figures D.23 to D.30. Both charts use the same data, so, they illustrate the same results in formats that support different illustration. Data for the charts is the scaled individual ratios from the scaled tables in Section D.3. Chart ***a*** presents the results as a column chart and chart ***b*** presents the same data as a Kiviat diagram.

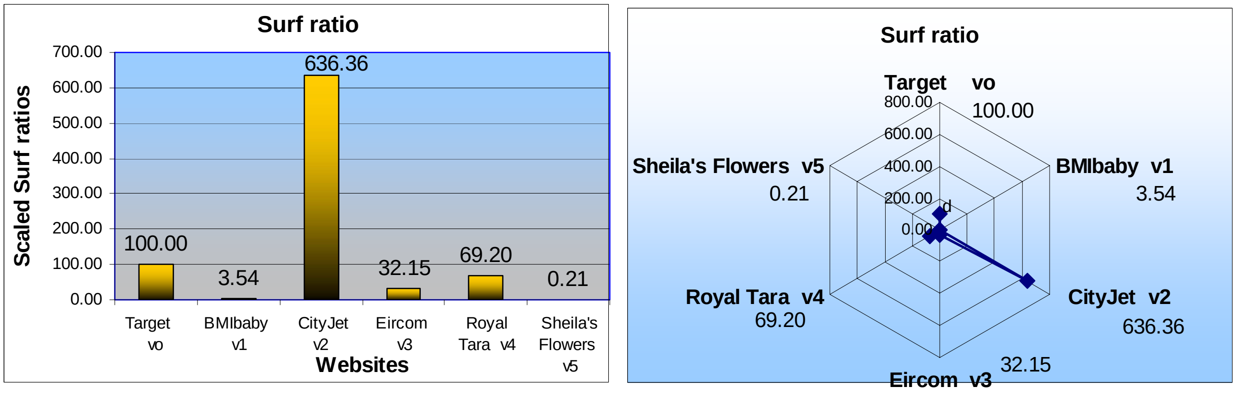
The column chart consists of a horizontal and a vertical axis. Vertical columns, one for the target solution and one for each of the websites in the study are positioned on the horizontal axis. The target solution column v_o is always positioned at the left of the diagram and the website columns are consistently positioned from left to right following the sequence v_1, v_2, v_3, v_4 and v_5. This reflects the presentation of data in the various tables in Section D.3. The vertical axis is divided into units of 20, commencing with 0 at the intersection of the two axes and reaching 120 at the top (the maximum required is 100). The height of each column is terminated in accordance with the scaled individual ratio of its corresponding website. The column for the target website is always terminated at 100. Readability and interpretation are supported by displaying the calculated value of the scaled ratio on each column. For each website these columns show the progress that has been made (and is still to be made) towards achieving engagibility as defined for a target website.

The Kiviat diagram consists of six axes, one for the target solution and one for each of the websites in the study. The target solution axis v_o is always positioned towards the apex (north) of the diagram and the website axis are consistently positioned in a clockwise direction from the apex following the sequence v_1, v_2, v_3, v_4 and v_5. Each axis is divided into units of 20, commencing with 0 at the centre of the diagram and reaching 100 at its outer perimeter. A marker is positioned on each axis. The target marker is the scaled target individual ratio. This target is always 100. The marker on each website's axis is the scaled individual ratio for that website. Readability and interpretation are supported by the irregular polygon created by joining the markers. For each website these markers show the progress that has been made (and is still to be made) towards achieving engagibility as defined for a target website.



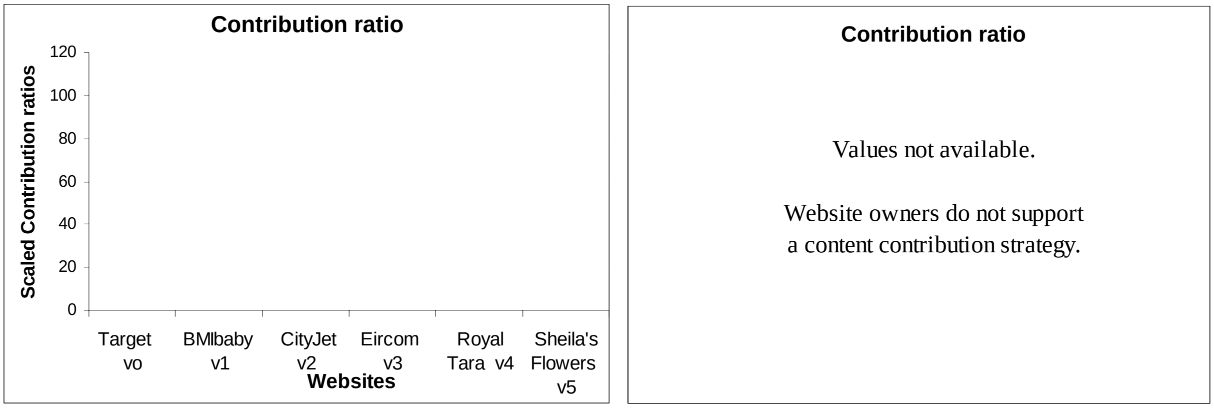
a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.23 – *Charting the Navigation ratio.*



a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.24 – *Charting the Surf ratio.*

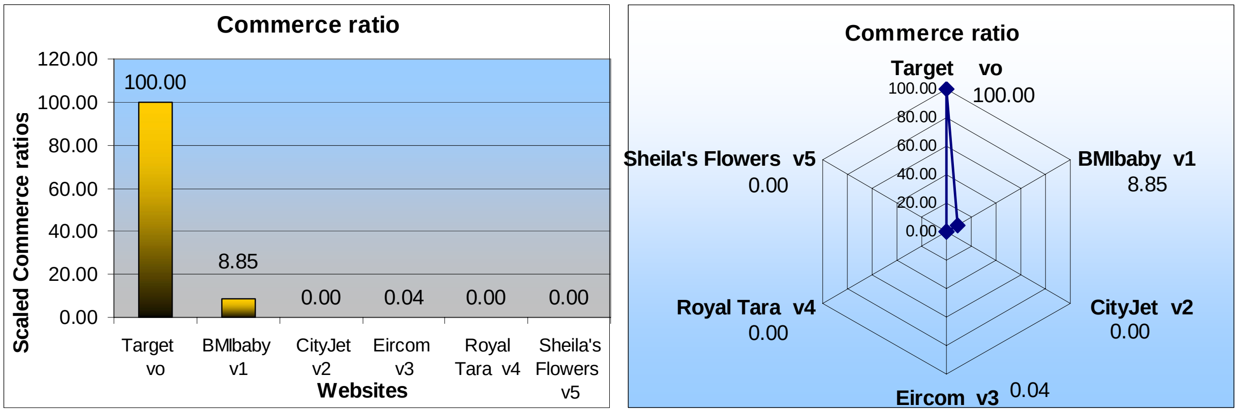


Values not available.

Website owners do not support a content contribution strategy.

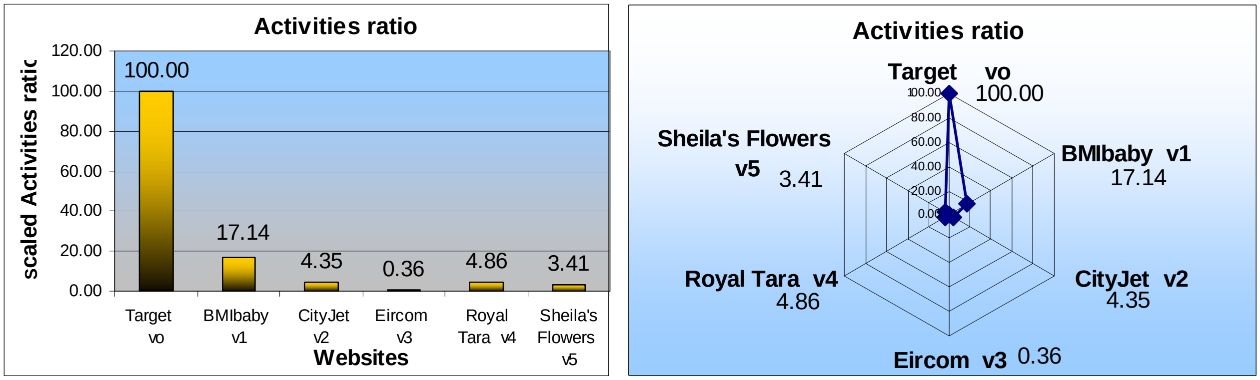
a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.25 – *Charting the Contribution ratio.*



a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.26 – *Charting the Commerce ratio.*

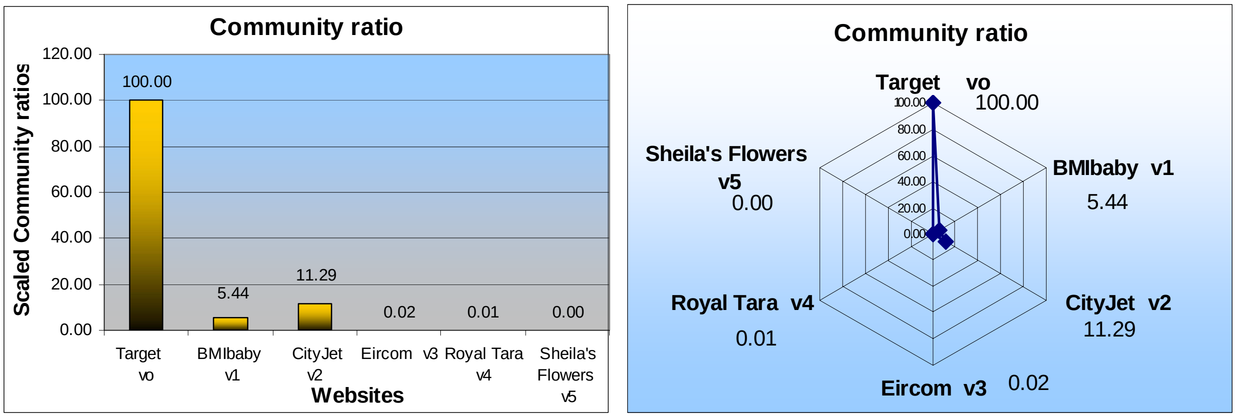


a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.27 – *Charting the Activities ratio.*

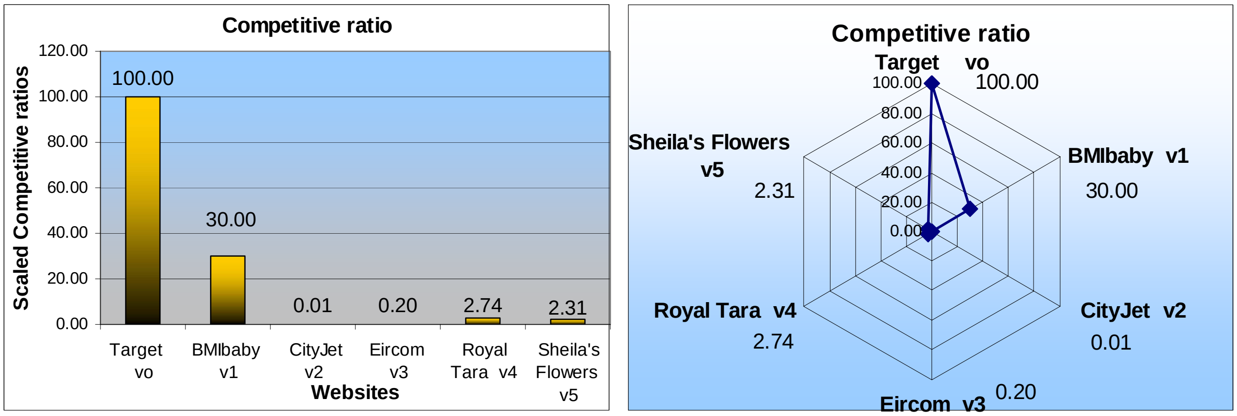
a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.28 – *Charting the Assistive ratio.*



a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.29 – *Charting the Community ratio.*

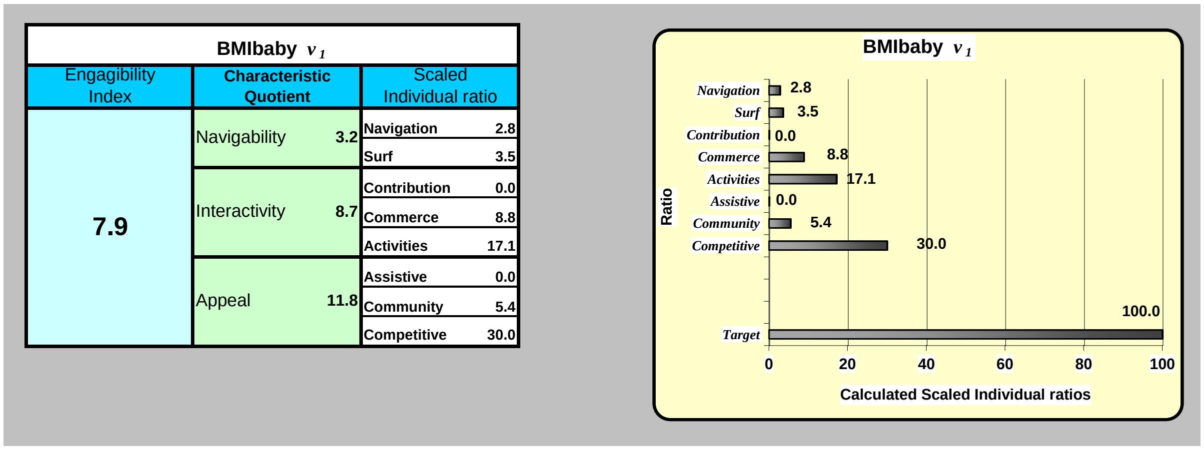


a *– Column diagram* ***b*** *– Kiviat diagram*

Figure D.30 – *Charting the Competitive ratio.*

D.4.2 Engagibility individual ratios illustrated – by website

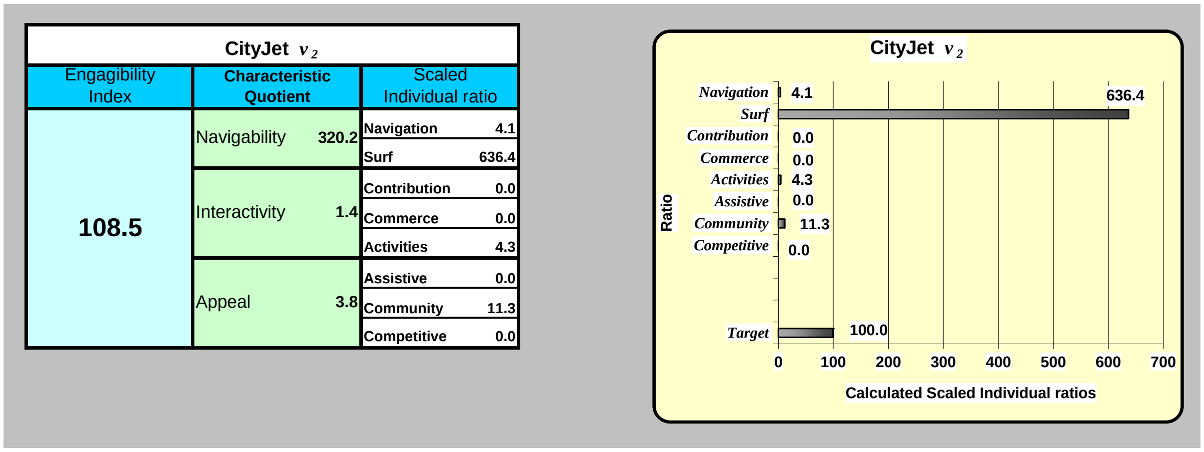
Results for each of the five websites in the study are now summarised and charted in a tabulated summary named the Engagibility Index Card. All values in this card are calculated to one decimal place. Ratios, as calculated in Section D.3, are set out in the columns headed Scaled Individual ratio - Figure D.31 to Figure D.35. Using these results, the Characteristic Quotient values are calculated as simple averages for Navigability, Interactivity and Appeal. Then taking a simple average of these three, the Engagibility Index for each website is calculated. The results are supported by a graphical illustration of all eight of each website's calculated Scaled individual ratios. The illustration shows how the website performs relative to the target of 100.



BMIbaby v_1

Engagibility Index	Characteristic Quotient		Scaled Individual ratio	
7.9	Navigability	3.2	Navigation	2.8
			Surf	3.5
	Interactivity	8.7	Contribution	0.0
			Commerce	8.8
			Activities	17.1
	Appeal	11.8	Assistive	0.0
			Community	5.4
			Competitive	30.0

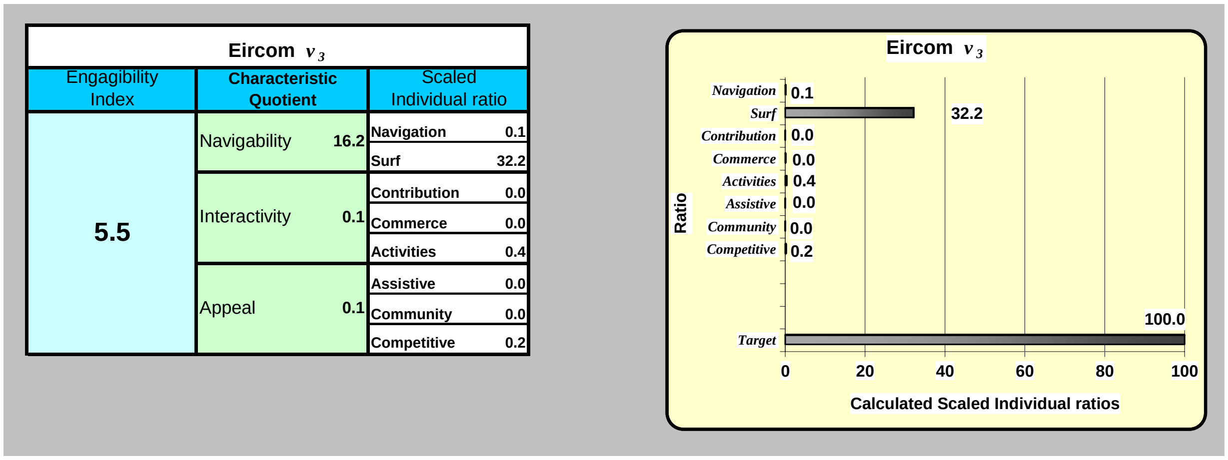
Figure D.31 - *Engagibilty Index Card* - **BMIbaby v_1**



CityJet v_2

Engagibility Index	Characteristic Quotient		Scaled Individual ratio	
108.5	Navigability	320.2	Navigation	4.1
			Surf	636.4
	Interactivity	1.4	Contribution	0.0
			Commerce	0.0
			Activities	4.3
	Appeal	3.8	Assistive	0.0
			Community	11.3
			Competitive	0.0

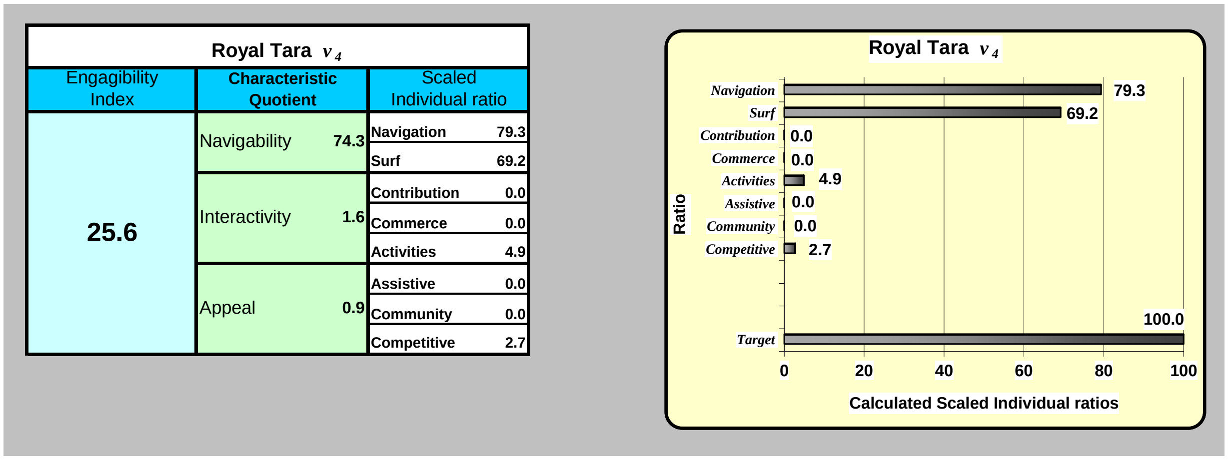
Figure D.32 - *Engagibilty Index Card* - **CityJet v_2**



Eircom v_3

Engagibility Index	Characteristic Quotient		Scaled Individual ratio	
5.5	Navigability	16.2	Navigation	0.1
			Surf	32.2
	Interactivity	0.1	Contribution	0.0
			Commerce	0.0
			Activities	0.4
	Appeal	0.1	Assistive	0.0
			Community	0.0
			Competitive	0.2

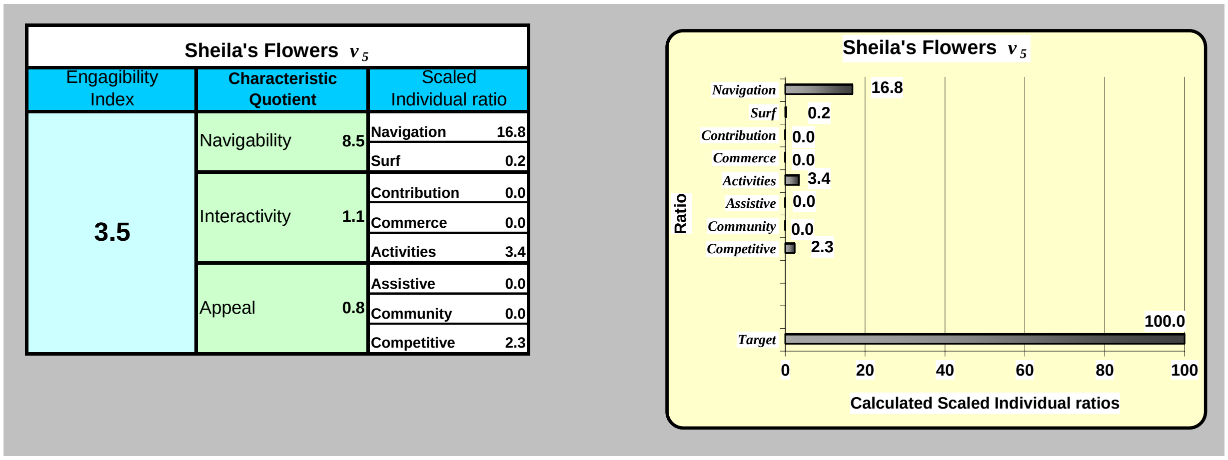
Figure D.33 - *Engagibilty Index Card* - **Eircom v_3**



Royal Tara v_4

Engagibility Index	Characteristic Quotient		Scaled Individual ratio	
25.6	Navigability	74.3	Navigation	79.3
			Surf	69.2
	Interactivity	1.6	Contribution	0.0
			Commerce	0.0
			Activities	4.9
	Appeal	0.9	Assistive	0.0
			Community	0.0
			Competitive	2.7

Figure D.34 - *Engagibilty Index Card* – **Royal Tara v_4**



Sheila's Flowers v_5

Engagibility Index	Characteristic Quotient		Scaled Individual ratio	
3.5	Navigability	8.5	Navigation	16.8
			Surf	0.2
	Interactivity	1.1	Contribution	0.0
			Commerce	0.0
			Activities	3.4
	Appeal	0.8	Assistive	0.0
			Community	0.0
			Competitive	2.3

Figure D.35 - *Engagibilty Index Card* – **Sheila's Flowers v_5**

Evaluators could create a Kiviat diagram for each website's Index card. Such a diagram would further illustrate a website's total achievement and progress towards the target solution. However, in this study, some results are so close to 0 that their markers would overlap to the extent of being indistinguishable from each other. So, for this reason, Index Card Kiviat diagrams are not presented.

D.4.3 Charting the Website Engagibility Index

An overall aim of this thesis is to demonstrate a mathematical expression of a website quality factor for benchmark comparison purposes. So, for website engagibility, Figure D.36 graphically presents the mathematical expression of engagibility, that is, the Engagibility Index for the five sites in the eCommerce website study for comparison against a target website.

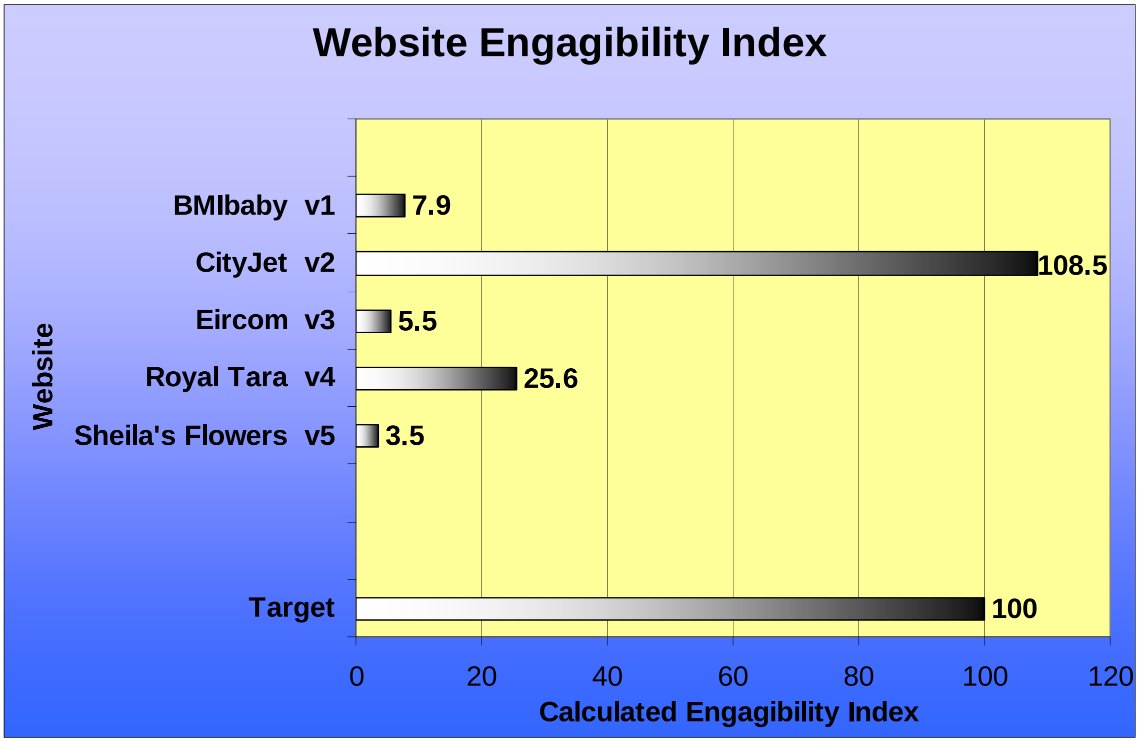


Figure D.36 – *Website Engagibilty Index chart.*

D.4.4 Summary

The individual ratio charts (by ratio) presented in Figures D.23 to D.30 illustrate how each of the five websites in the eCommerce study performs on the scale of 0-100 relative to the target website. Each chart visually benchmarks how much engagibility is present for an individual ratio for each website – by ratio. An evaluator can see how much more individual ratio engagibility might be achieved relative to competitor sites.

The individual ratio chart (by website) presented in Figures D.31 to D.35 is an individual card for each site and summarises how all of a website's scaled individual ratios perform relative to the desired target of 100. This is illustrated in a bar chart to the right of the card. It clarifies for an evaluator what has been achieved, and what might be achieved, for each individual ratio for each website – by website. To the left of the card the scaled individual ratio values are tabulated and used, first to calculate a simple average for the Characteristic Quotient and then to calculate a simple average for the Engagibility Index for the website. This satisfies the hypothesis relating to mathematically expressing website quality, in the context of engagibility.

Figure D.36 presents a benchmark comparison of each of the five website's Engagibility Index relative to the target of 100. Website owners and evaluators can see from this the Metric Ratio Analysis overall measurement of how much engagibility is present in each site and how much more might be achieved.

D.5 Conclusion

This Appendix illustrates how a quality-of-product comparative value for a website's engagibility can be calculated. Five eCommerce websites were studied in order to compare each website with competitor offerings.

The Appendix has fully implemented and illustrated the Metric Ratio Analysis approach to measuring website quality. It has determined eight sets of ratios and in each set has completed a benchmark analysis for each site.

In addition to using the engagibility ratios in an enhancement strategy where the website owner needs to identify where enhancement might improve return on investment, the ratios can also be used to quantify other website engagibility perspectives. For example, they might be used in a quality-of-production perspective for estimating cost and duration of a proposed project based on historical data for similar website development projects. Or the ratios might be used in a quality-of-procurement perspective for comparing a proposed website with those of competitors.

The theory underpinning Metric Ratio Analysis combined with graph theory could be further researched with a view to further mathematically classifying any website.

A significant future research issue should address corresponding ratios for quality-of-use. These two sets of ratios – quality-of-product and quality-of-use – are self supporting, so being able to numerically quantify both is desirable.

Further studies are needed in order to determine the universal criteria that should be included when measuring any aspect of website quality. At this stage of the research the focus is on using criteria that are specifically derived from quality-of-product. Further research into quality-of-use might identify patterns of usage that can provide feedback to the design process thereby enabling enhancement of the quality-of-product criteria.

A theory and practice of website engagibility

Ronan Fitzpatrick MSc CEng MBCS CITP

PhD Appendix E
Research publications

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Supervisor: **Professor Peter Smith** - Dean of School
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Supervisor: **Professor Brendan O'Shea –** Head of School
School of Computing, Dublin Institute of Technology.

July 2007

Published Papers

Paper	Review rigor
Fitzpatrick, R. and Higgins, C. (1998). Usable software and its attributes: A synthesis of software quality, European Community law and human-computer interaction, In: People and Computers XIII. Proceedings of HCI'98 Conference, Springer, London, UK	Full paper was triple blind reviewed.
Fitzpatrick, R. (2000a) Interpreting quality factors for the World Wide Web, Irish Academy of Management Conference, September 2000, Dublin, Ireland	(Extended abstract).
Fitzpatrick, R. (2000b) Additional Quality Factors for the World Wide Web, Proceedings of the Second World Congress for Software Quality, Yokohama; Union of Japanese Scientists and Engineers, Tokyo, Japan	Full paper was double blind reviewed.
Fitzpatrick, R. (2001) Strategic Drivers of Software Quality: Beyond external and internal software quality, Second Asia-Pacific Conference on Quality Software, Proceedings of APAQS 2001, Hong Kong; IEEE Computer Society Press, California, USA	Reviewed on the basis of originality, contribution, technical and presentation quality, and relevance to the conference.
Fitzpatrick, R. (2003a) Quality Challenges in E-Commerce Web sites, Workshop paper for Exploring the Total Customer Experience: Usability Evaluations of (B2C) E-Commerce Environments at INTERACT 2003: Ninth IFIP TC 13 International Conference on Human-Computer Interaction, September 2003, Zurich, Switzerland	Peer-reviewed by a committee consisting of international HCI-colleagues with research expertise in research-methodologies and e-commerce environments.
Fitzpatrick, R. (2003b) The Software Quality Star: A conceptual model for the software quality curriculum, Workshop paper for Closing the Gaps: Software Engineering and Human-Computer Interaction at INTERACT 2003: Ninth IFIP TC 13 International Conference on Human-Computer Interaction, September 2003, Zurich, Switzerland	Paper was reviewed by the workshop chairs [2] and accepted.

Fitzpatrick, R., Smith, P. and O'Shea, B. (2004a) Software Quality Revisited, Proceedings of the Software Measurement European Forum (SMEF 2004, Rome), Istituto di Ricerca Internazionale S.r.l., Milan, Italy, p307/315, ISBN 88-86674-33-3	Program Committee reviewed the abstract and the final paper.
Fitzpatrick, R., Smith, P. and O'Shea, B. (2004b) Software Quality Challenges, Proceedings of the Second Workshop on Software Quality at the 26th International Conference on Software Engineering (ICSE 2004), Edinburgh, Scotland, IEE, Stevenage, Herts, UK	Evaluated according to the relevance and originality of the work and to the ability to generate discussions between the participants of the workshop.
Fitzpatrick, R., Smith, P. and O'Shea, B. (2005) Website engagibility: A step beyond usability, proceedings of parallel session "Quality models for Human Computer Interaction" 3rd international conference on Universal Access in Human-Computer Interaction, HCI International 2005, Las Vegas, Lawrence Erlbaum Associates, New Jersey, USA	Invited paper reviewed by session chair and accepted.

A theory and practice of website engagibility

Ronan Fitzpatrick MSc CEng MBCS CITP

PhD Appendix F

Proposed MRA Axioms

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School of Computing, Dublin Institute of Technology.

July 2007

Axioms that the general MRA formulae comply with:

Axiom		MRA compliance
Property 1.	MRA must not assign the same calculated ratio to all websites (after Weyuker/S&I)	YES
Property 2.	There exist only a countable number of websites with a given calculated ratio (after Weyuker/S&I)	YES
Property 3.	MRA must not assign a unique calculated ratio to every website (after Weyuker)	YES
Property 4.	There exist websites that have equal calculated ratios but have different values associated with them (after Weyuker/S&I)	YES
Property 5.	The calculated ratio of a website formed by concatenation must be insensitive to the calculated ratios of the concatenating websites (restyled after Weyuker/S&I)	YES
Property 6.	MRA must be insensitive to the ordering of the websites components (after Weyuker/S&I)	YES
Property 7.	MRA must be insensitive to renaming changes of the website design elements (after Weyuker/S&I)	YES
Property 8.	MRA must not assign the same calculated ratio to a website when one of its values is changed	YES
Property 9.	MRA must not assign a calculated ratio of zero in the absence of a value	YES
Property 10.	MRA must be sensitive to the effects of indirect values	YES
Property 11.	MRA must be sensitive to the higher significance order among values	YES
Property 12.	MRA must be sensitive to the saturation effects of over including values	YES