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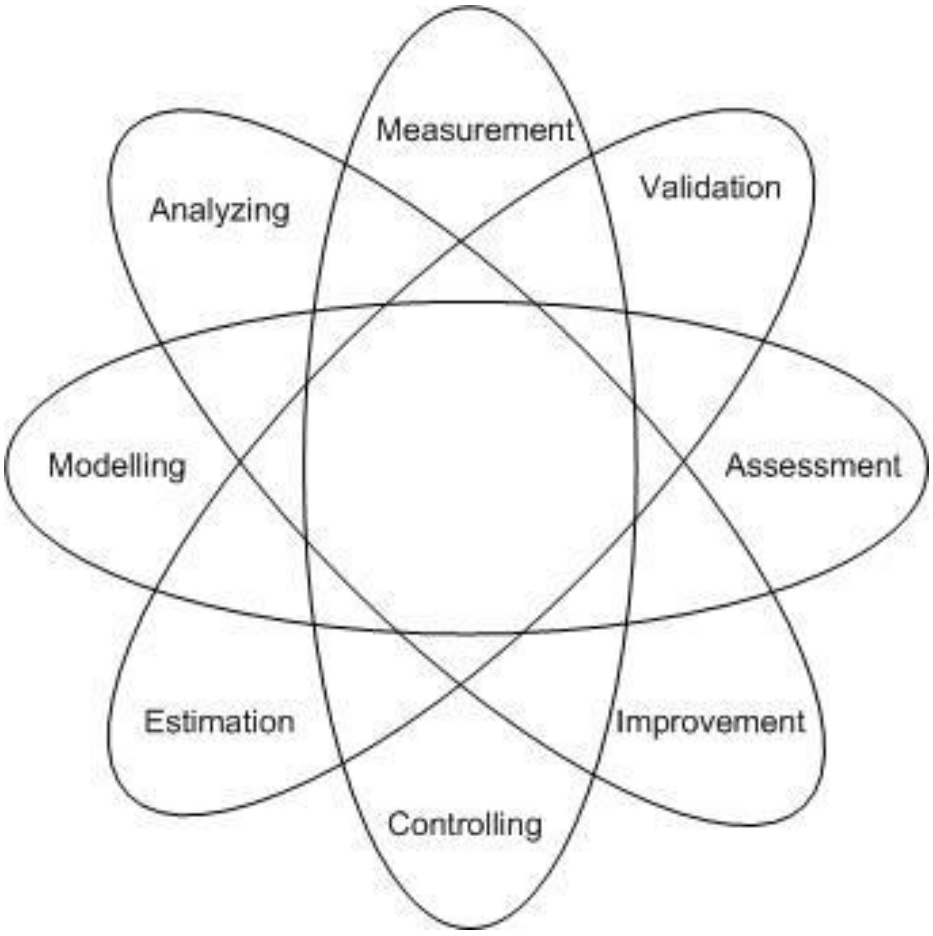
Software Measurement News

Journal of the Software Metrics Community



Editors:

Alain Abran, Manfred Seufert, Reiner Dumke, Christof Ebert, Cornelius Wille

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École de technologie supérieure
COSMIC
SM L@b

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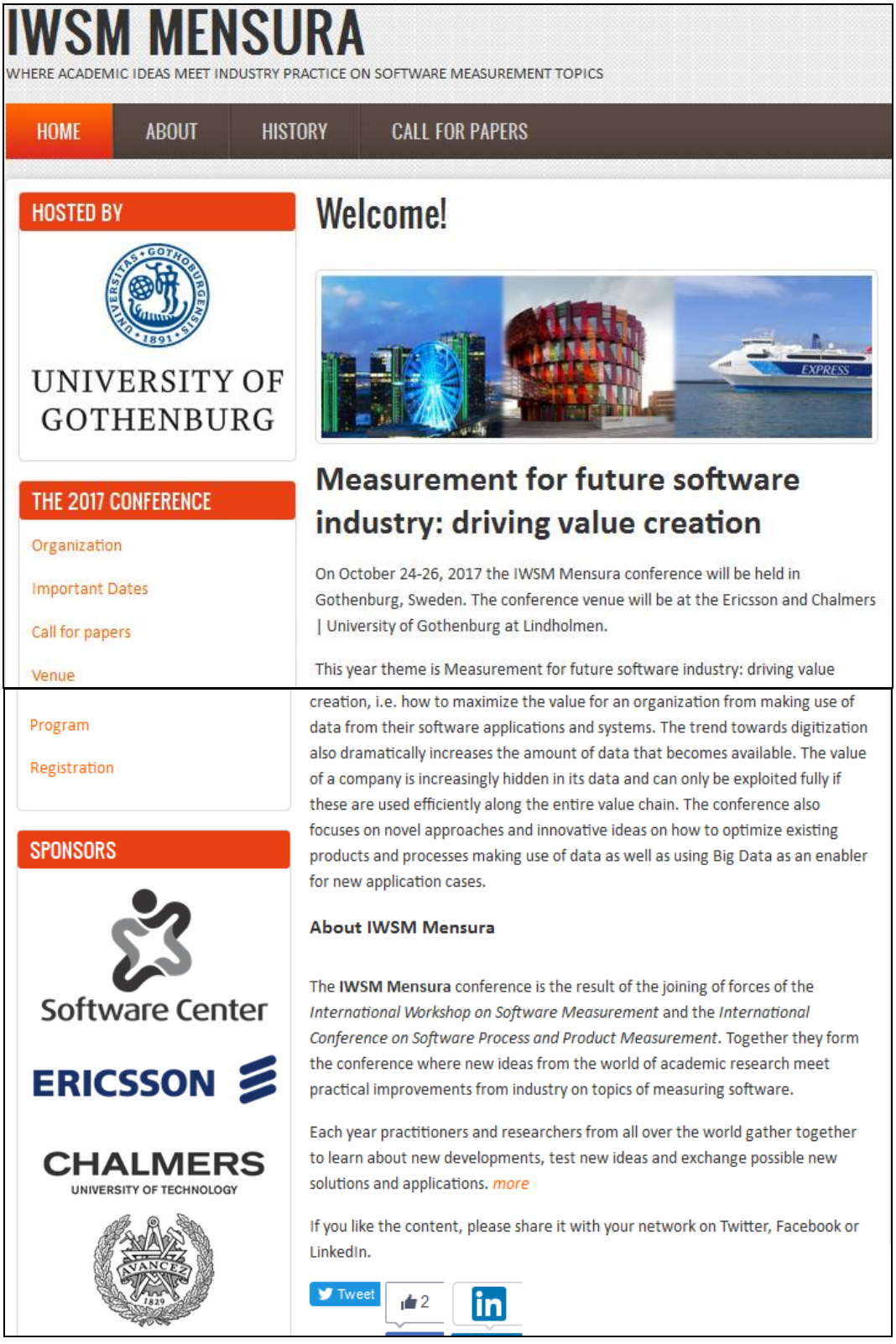
The journal is published in one volume per year consisting of two numbers.



http://www.iwsm-mensura.org.

Theme & scope

Software and IT measurement are keys for successfully managing and controlling software development projects. Data analytics and measurement are essential for both business and engineering. They enrich scientific and technical knowledge regarding both the practice of software development and empirical research in software technology. The conference focuses on all aspects of software measurement and data analytics.

This year focus is the **Value of Data**, i.e. how to maximize the value for an organization from making use of data from their software applications and systems. The trend towards digitization also dramatically increases the amount of data that becomes available. The value of a company is increasingly hidden in its data and can only be exploited fully if these are used efficiently along the entire value chain. Big data becomes an important keyword to deal with. The conference also focuses on novel approaches and innovative ideas on how to optimize existing products and processes making use of data as well as using Big Data as an enabler for new application cases.

Topics of interest

We encourage submissions in any field of software measurement, including, but not limited to:

- Practical measurement applications
- Data analytics in practice, e.g. Enterprise embedded solutions
- Usage of big data analytics for improving products and processes
- Quantitative and qualitative methods for software measurement
- Measurement processes and resources, e.g. agile or model-driven
- Empirical case studies
- System and software engineering measurement
- IT and project cost and effort estimation, e.g., cost, effort, defects
- Functional size measurement
- Data analytics and measurement in novel areas, e.g. ECU's or web services
- Measures for Cognitive Computing

Conference language

The language for the conference, workshops and special sessions is English.

see: http://www.iwsm-mensura.org.

Enterprise Computing Conference – ECC 2017

26. bis 27.04.2017 in Berlin
(25.04.2017 Pre-Conference)

Crowne Plaza Berlin City Centre
Nürnberger Str. 65, 10787 Berlin

Intelligente Algorithmen bestimmen zunehmend Produktions-, Verwaltungs- und Dienstleistungsprozesse. Auch Dinge des alltäglichen Lebens erfahren durch den Einsatz von intelligenten (smarten) Lösungen gravierende Veränderungen.

Entsprechende Beispiele beziehen sich auf das teilautonome Fahren, den verstärkten Einsatz natürlicher Sprache als Schnittstelle zu modernen Softwaresystemen, die Abwicklung des Bank- und Zahlungsverkehrs oder die allgegenwärtige Verbindung zu internetbasierten Lösungen. Damit einher geht eine allumfassende Integration privater, öffentlicher und industriell genutzter Softwaresysteme.

Neben der klassischen prozess- und funktionsorientierten Integration geht es dabei insbesondere um die Akquisition von Daten aus diversifizierten Quellen. Zunehmend wird diese Ressource als Treiber innovativer Lösungen bewertet, welche maßgeblich über die Markt- und Wettbewerbsposition eines Unternehmens entscheidet. Nahezu alle Branchen sind von den Auswirkungen der Digitalisierung betroffen. Für klassische IT-Anbieter resultieren daraus gravierenden Veränderungen. Es gilt die richtigen und vor allem nachgefragten Infrastrukturen bzw. IT-Lösungen am Markt bereitzustellen.

Mit dem Motto der ECC 2017 „*Wertschöpfung in der digitalen Wirtschaft*“ wollen wir diese Diskussion anregen und korrespondierende Entwicklungstendenzen aufzeigen. Dafür werden die folgenden Highlights geboten:

- World-Cafés zu den Themen „*API-Economy/-Management*“, „*Risiken unzureichender Datenqualität*“ und „*agile Servicebereitstellung*“.

- Moderierte Podiumsdiskussion „*Datenschutz und Datensicherheit als Treiber oder Bremse von Innovationen?*“

- Vertiefende Seminare zu aktuellen Herausforderungen im „*Data Science/Machine Learning*“, „*zPricing*“ und „*Open Data/API-Management*“.

- Pre-Conference (25.04.2016) Workshop „*Mainframe-Updates*“ mit namhaften Referenten wie Fabio Ottaviani (EPV) und Glenn Anderson (IBM).

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BSAO/BCloud 2017

(Qualitative und quantitative Bewertung)

see: **http://www-ivs.cs.uni-magdeburg.de/~gi-bsoa/2017/**

IWSM/Mensura 2016

5.-7.10.2016 HWR Berlin, Germany

Heidrich, J.; Vogelezang, F.: *Joined Conference of the 26th International Workshop on Software Measurement (IWSM) and the 11th International Conference on Software Process and Product Measurement (Mensura),* IEEE Computer Society, CPS, http://www.computer.org/cps, 2016

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Session 6A - Estimation

Bewertungsaspekte service- und cloudbasierter Architekturen (BSOA/BCloud2016)

(detaillierter Workshopbericht)

Andreas Schmietendorf[+], *Frank Simon*[#]

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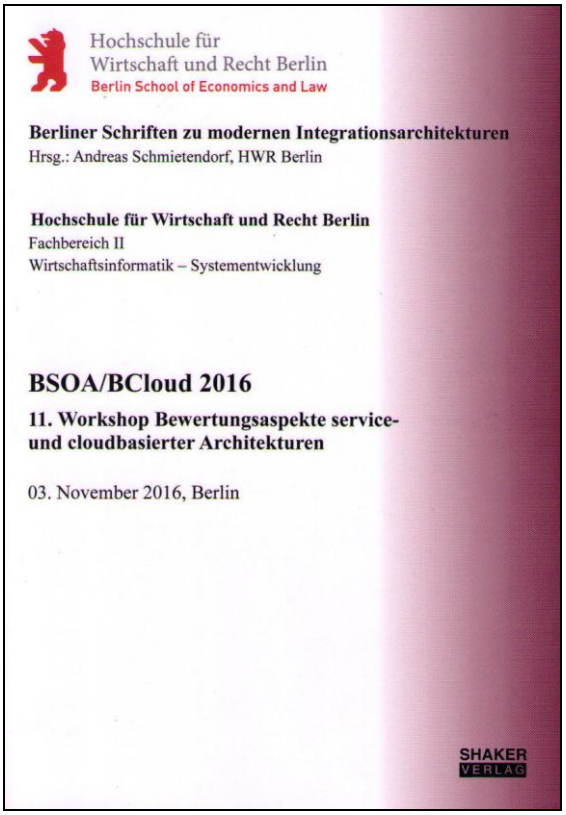

1. Hintergründe zur Veranstaltung

Obwohl heute vielfältige Methoden und Techniken zur Implementierung interoperabler Systeme existieren und deren Einsatz vergleichsweise einfach ist, kann die industrielle Reflektion der mit webbasierten Service APIs einhergehenden Möglichkeiten aktuell noch nicht überzeugen. Die Bereitstellung unternehmensintern akquirierter Informationen via Service APIs wird eher als ein Risiko, denn als Chance zur Bewältigung der Herausforderungen einer zunehmend digitalisierten Welt bewertet. Es stellt sich die Frage, inwieweit die Innovations- und Wettbewerbsfähigkeit der Unternehmen unter dieser „Abschottungspolitik“ leidet, wenn der kreative Umgang mit existierenden Informationen an den Unternehmensgrenzen Halt macht. Dies gilt umso mehr, wenn global gesehen Deutschland hier eine Sonderrolle einnimmt. Mit den sich aus diesen Potentialen und Risiken ergebenden Handlungsfeldern beschäftigte sich der am 03. November 2016 in Berlin durchgeführte Workshop. [Schmietendorf 2016].

2. Beiträge des Workshops

Die für den Workshop ausgewählten Beiträge reflektieren primär eine fach- bzw. branchenbezogene Auseinandersetzung mit den Möglichkeiten von über das Internet angebotenen Serviceschnittstellen (kurz Web APIs). Im Einzelnen beziehen sich diese auf Herausforderungen im Diskurs von Transportunternehmen, von Banken/Versicherungen aber auch von medizinischen bzw. pharmazeutischen Unternehmen. Darüber hinaus reflektieren ausgewählte Beiträge die zunehmenden Wechselwirkungen zu analytisch eingesetzten Datenbanklösungen. Dabei werden Möglichkeiten und Grenzen der Integration von Big Data Komponenten mittels Web APIs oder aber die Verwendung von Machine Learning Ansätzen (kurz ML) wie z.B. das Natural Language Processing (kurz NLP) untersucht. Die Beiträge finden sich im Tagungsband vgl. ([Schmietendorf 2016]).

Michael Binzen. Open Data / Open API – Herausforderungen für gewachsene Unternehmen

> Mit dem Spannungsfeld gewachsener Organisationsstrukturen im Zusammenhang mit den Herausforderungen einer umfassenden Digitalisierung beschäftigte sich die eingeladene Keynote.
> Im Folgenden finden sich einige interessante Kernaussagen:
>
> - Unternehmenskultur muss die Digitalisierung tragen können.
> - Motivation für die Mitwirkung bei den Mitarbeitern ist eine Grundvoraussetzung.
> - Kreative Lösungsansätze müssen gefunden werden (u.a. Design Thinking).
> - Der Bedarf an nutzenszentrierten und zielorientierten Lösungen.
> - Die interdisziplinäre Zusammenarbeit mit Partnern (Chancen) und Kunden (Bedürfnisse) ist ein wichtiges Hilfsmittel.

Frank Simon: PSD2: Status-Quo und Ausblick der APIs

> Mit der durch die Europäische Union verabschiedeten „Payment Service Directice 2.9“ (kurz PSD2) und den Auswirkungen auf die Bankenbranche beschäftigt sich dieser Beitrag. Im Mittelpunkt steht die „Zwangsöffnung“ von Banken zur API-basierten Bereitstellung von Kontoinformationen und von Überweisungsservices als wesentliche Voraussetzung für innovative Lösungen im Zahlungsverkehr, besonders für junge FinTech-Unternehmen.

Michael Knuth: Kann die Nutzung des API-Managements die Bereitstellung von geschäftsrelevanten Schnittstellen verbessern?

> Die Funktionen des Managements von veröffentlichten APIs über den gesamten Lebenszyklus stehen im Mittelpunkt dieses Beitrags. Im Detail vermittelt der Beitrag die Ergebnisse eines Tests der Open Source API-Management-Lösung WSO2. Untersucht werden benötigte Funktionen wie z.B. die Authentifizierung/Autorisierung, die Erzeugung/Freischaltung oder auch das Releasemanagemt von APIs.

Frederik Kramer, Markus Wirth, Stephan Klinger, Michael Becker, Julia Friedrich, Martin Schneider.: Zum Nutzen toolbasierter Wissensmanagementprozesse

> Der Wert des „Wissens“ steht im Mittelpunkt dieses Beitrags. Konkret beschäftigen sich die Autoren mit den Nutzenspotentialen bei klein- und mittelständischen Unternehmen (kurz KMUs). Dafür gehen sie auf eine im Diskurs eines mittelständischen IT-Dienstleisters durchgeführte explorative Fallstudienforschung ein.

Robin Rojowiec: API-basierte Nutzung von NLP-Services

> Die automatische Analyse und Klassifikation von Textdokumenten mit Hilfe von API-basiert angebotenen Machine Learning Algorithmen bilden den Hintergrund dieses Beitrags. Hier wird auf einen Test verschiedener Klassifizierungsansätze eingegangen, welche über die

Natural Language Classifier API und die Alchemy Language API in der Watson Developer Cloud der IBM zur Verfügung stehen.

Konrad Nadobny: Schnittstellen als Voraussetzung einer integrierten Informationsplattform zur Verbesserung des Planungsprozesses klinischer Studien

In diesem Beitrag geht der Autor auf die Informationsbedürfnisse, die zur Planung klinischer Studien benötigt werden, ein. Konkret geht es sowohl um formelle und semi-formelle als auch um informell zur Verfügung stehende Informationen, die einen historischen oder einen aktuellen Zeitbezug aufweisen. Mit Hilfe von Datenanalysen soll insbesondere die Rekrutierungsperformance in klinischen Studien verbessert werden.

Sandro Hartenstein: Vertrauenswürdige APIs für Gesundheitsanwendungen

Die Übertragung von Gesundheitsdaten via internetbasierter APIs impliziert hohe Anforderungen an die Vertrauenswürdigkeit derartiger Schnittstellen. Die Auswahl konkreter APIs erfordert dementsprechend messtechnisch erfassbare Kriterien (u.a. Data Quality, Security, Compliance), womit sich dieser Beitrag beschäftigt.

Jan Hentschel: Bewertung der Integration von Big Data Web APIs in Unternehmens-architekturen

Ausgehend von zunächst allgemein hergeleiteten Kriterien für die Auswahl von Web-APIs wird in diesem Beitrag insbesondere auf die speziellen Herausforderungen von derartigen Schnittstellen bei Big Data eingegangen. Eine beispielhafte Bewertung angebotener APIs beschäftigt sich mit den Möglichkeiten der Lösungen Oozie, Spark, HDFS und Flume.

Sebastian Kiepsch, Sebastian Herden, Anja Fiegler, Reiner Dumke: Entwurf von industrieübergreifenden Machine-Learning-Architekturen

In diesem Beitrag gehen die Autoren auf die Zusammenhänge zwischen Machine Learning, Big Data, Data-Mining und künstlicher Intelligenz ein. Auf der Grundlage der identifizierten Beziehungen wird der Bedarf einer industrieübergreifenden Machine Learning Architektur postuliert. Dafür werden zunächst die Anforderungen und in einem weiteren Schritt ein konzeptioneller Architekturvorschlag (Komponenten) vermittelt.

3. Ergebnisse des World Cafes

Themenstellung: API-Ecosystems verändern die Unternehmensorganisation

Immer mehr Unternehmen erkennen die Chance, ihre daten-, prozess- und algorithmenbezogenen Mehrwerte auch via Web-APIs zur Verfügung zu stellen. Über diese sehr leichtgewichtig einsetzbaren Schnittstellen lassen sich Zwischen- und Vorprodukte agil vertreiben, die dann – insbesondere bei Erfolg – zu einer zunehmenden Autonomie einzelner Organisations-Einheiten führen. Mit dieser Organisations-Modularisierung bietet sich allerdings auch die Möglichkeit, bestimmte Prozessschritte durch alternative fremde Organisationen realisieren zu lassen.

In Summe entsteht so ein globaler Wettbewerb von agil einsetzbaren Service-Modulen, in denen Unternehmensgrenzen nur noch eine untergeordnete Rolle spielen. Die sich daraus ergebenden Änderungen für eine jeweilige Organisation können mehr als disruptiv sein, sind aber in jedem Falle von höchster strategischer Bedeutung und sorgen daher ex ante bei der Mehrheit der Mitarbeiter für große Ängste, was häufig zur grundlegenden Ablehnung der Idee einer umfassenden API-fizierung führt.

Mit Hilfe des avisierten World-Cafes sollte dieser Trend diskutiert werden, wofür im Vorfeld 3 Fragen durch die Autoren dieses Berichts zur Verfügung gestellt wurden. Die folgende grob strukturierte Zusammenfassung der durch die Teilnehmer getätigten Aussagen (jeweils kursiv) stellt kein abgestimmtes Gruppenergebnis dar, sondern zeigt vielmehr die vielfältig auftretenden Sichtweisen.

1. Kann es sich ein Unternehmen leisten, sich grundsätzlich diesem Trend zu widersetzen, und welche Risiken gehen damit einher?
   Möglichkeiten einer API-fizierung:
   - *Bereitstellung offener Datenschnittstellen:*
     - *Neue Geschäftsfelder,*
     - *Neue Partner,*
     - *Konzentration auf das Kerngeschäft (Kompetenzfokussierung).*
   - *Sicherheitsdienste (Incident-API) --> Chance.*
   - *In der Zukunft richtet sich Fokus eher auf Leistungen (z.B. Mobilität) und weniger auf klassische Firmen (Marke, Besitz, …).*

   Risiken im Falle nicht bereitgestellter APIs:
   - *Für das Unternehmen gefährlich - für die Gesellschaft ggf. gut.*
   - *Verlust von Kunden bzw. potentiell erreichbaren Kunden.*
   - *Fehlender Zugang zu globalen Märkten, Daten und Ressourcen.*
   - *Verpasste Chance zum Prozess- und Informations-Alignment.*
   - *Isolation vs. Integration – Verlust der Innovationsfähigkeit,*
     Untergang durch fehlende Vernetzung.

   Risiken im Falle bereitgestellter APIs:
   - *Datenschutz und Datensparsamkeit als gesetzliche Anforderung.*
   - *Gefahr für eigene (IT-)Innovation durch bereitgestellte APIs.*
   - *Klärung des Grundes für eine API-fizierung (Kernfrage nach dem Mehrwert einer API) → Sicht der Nutzer und Partner.*
   - *Teilnahme am branchenspezifischen Wettbewerb.*

2. Wenn ein Verzicht auf die API-fizierung nicht möglich ist, wie können resultierende Änderungen den Mitarbeitern, die es effektiv betrifft, erläutert werden, damit sie es besser bewerten zu können?
   Vorteile/Möglichkeiten für betroffene Mitarbeiter aufzeigen:
   - *Reduktion der Arbeitszeiten (ggf. bei Lohnausgleich).*
   - *Perspektiven aufzeigen – Was kannst Du?*
     Angebot alternativer Aufgaben.
   - *Ansätze zur Arbeitserleichterung aufzeigen. „Den Mist macht der PC, das Tolle Du!“*
   - *Lebenslanges Lernen als Chance vermitteln.*
   - *Absicherung einer längeren Ausbildung.*
   - *Keine betriebsbedingten Kündigungen.*
   - *Innovative Ausgründungen (Spinn-offs) anbieten.*
   - *Crowd basierte Innovationen treiben (Berücksichtigung vielfältiger ggf. globaler Meinungen).*

   Technologische Argumentation:
   - *Show Cases bzw. Demos zeigen.*
   - *Gründe (Anwendungsfälle) für den API-Einsatz erläutern.*
   - *Prozessoptimierung & Vermeidung von Medienbrüchen.*
   - *Fehlervermeidung by Design.*

   Implikationen im Diskurs der Unternehmensstrategie:
   - *Klare Orientierung: Vision – Strategie – Maßnahme,*
     Change Management – Details klar nennen. Zielgruppenspezifische Aufbereitung.
   - *Unternehmen muss innovativ und wettbewerbsfähig sein.*
   - *Bessere Produkte / Leistungen für Endkunden.*
     Bedarf einer erhöhten Produktivität (Wirtschaftlichkeit).
   - *Es ist nur eine Verschiebung – beim API-orientierten Dienstleister werden vermutlich neue Stellen aufgebaut.*
   - *Fokussierung auf kreative (hoch bezahlte) Aufgaben.*
   - *API-fizierung führt zur Auflösung starrer Unternehmensgrenzen.*

Gesellschaftliche Auswirkungen:
- *Potentielle Gefahren eines Arbeitsplatzverlustes (Grundsicherung zum Erhalt des sozialen Status).*
- *Bsp.: Banken – es müssen Gesetze eingehalten werden.*
- *Verschiebung von benötigten Kompetenzen für den Job.*
  Veränderte Anforderungen an die Ausbildung bzw. das Studium.
  Kulturveränderung (knowledge management).
- *Widerspruch – persönliche Sicht vs. Unternehmenssicht.*

Risikoorientierte Aussagen (Gefahr der Demotivation):
- *„Erst kommt das Fressen, dann kommt die Moral." – B. Brecht*
- *Lohndruck/Leistungsdruck verdeutlichen.*
- *Ellenbogen-Kultur akzeptieren/tolerieren?*
- *Motivation vs. Herausdrängen (Hire & Fire).*
- *Geschäftsleitung macht einfach, ohne Erklärung - Eine große Anzahl von MA bekommt API-fizierung nicht mit.*
- *Ist Kreativität API-fizierbar?*

3. Was muss und kann gemacht werden, um die Mitarbeiter möglichst flächendeckend für die Idee zu gewinnen?
   Gestaltung des Veränderungsmanagements:
   - *„Bundeswehrmodell" – Überbrückungsgeld für Weiterbildung.*
     Verbesserung der Informationsqualität.
   - *Das Zeug verständlich machen (entmystifizieren) – Marketing.*
   - *Soziale Grundsicherung gewährleisten.*
   - *Belohnung für Beteiligung an „neuen Lösungen".*
   - *Profit-Sharing an Mitarbeiter.*

   Motivation/Begeisterung der Mitarbeiter:
   - *Verständnisprobleme, Zweifel und Sorgen einsammeln (ernst nehmen) und adressieren.*
   - *Persönliche Mehrwerte aufzeigen (z.B. lästige „Routine" Tätigkeiten abbauen).*
   - *Nützlichkeit auf private Anwendungen (z.B. DropBox-API) übertragen.*
   - *Fortbildung und Entwicklungsperspektiven vermitteln.*

   Mitwirkung über Unternehmensgrenzen hinaus:
   - *Spieltrieb fördern (vgl. Gamification).*
   - *Feedback (z.B. Blogs) und Mitwirkung (Collaboration).*
   - *Gemeinsame Vision erarbeiten.*
   - *Bildungspolitik ausrichten.*

   Wettbewerb als Chance für Innovation vermitteln:
   - *Globale Herausforderung des „Mind Change".*
   - *Kampf um die besten Köpfe – „war for talents".*
   - *Evidenzen zeigen (intern und extern).*
   - *Flexibilisierung der Arbeitswelt.*

   Klare Regeln für Beteiligung aufstellen (Gefahr der Demotivation):
   - *Zwang ausüben.*
   - *Alternativlosigkeit darstellen.*

4. Weitere Informationen

Auch für das Jahr 2017 ist die Durchführung eines BSOA/BCloud-Workshops vorgesehen. Weiterführende Informationen werden zeitnah unter der folgenden URL im Internet bereitgestellt: http://ivs.cs.uni-magdeburg.de/~gi-bsoa

5. Quellenverzeichnis

[Schmietendorf 2016] Schmietendorf, A. (Hrsg.): Tagungsband BSOA/BCloud 2016, in Berliner Schriften zu modernen Integrationsarchitekturen, Shaker-Verlag, Aachen, November 2016

6 Dank

Seit Gründung der BSOA-Initiative im Jahre 2006 erfährt diese vielfältige Unterstützung aus dem industriellen und wissenschaftlichen Bereich. Dem Gastgeber des Jahres 2016 und Hauptsponsor Zalando gilt unser Dank für die ausgezeichneten Rahmenbedingungen. Ebenso danken wir der T-Systems International GmbH (Berlin) und der Ultra Tendency UG (Magdeburg) für das Sponsoring. Ein herzlicher Dank geht an die beteiligten Medienpartner SIGS DATACOM GmbH aus Köln, dpunkt.verlag GmbH aus Heidelberg und an den Shaker Verlag GmbH aus Aachen. Organisatorische Unterstützung bei den vielfältig eingesetzten Websystemen zur Bewerbung der Veranstaltung erfuhr der Workshop abermals von Herrn Dr. Dmytro Rud von der Roche Diagnostics AG/Schweiz und von Herrn Kevin Grützner von der HWR Berlin.

7 Organisation

Der Workshop wurde in Kooperation zwischen der Hochschule für Wirtschaft und Recht Berlin, der Otto-von-Guericke-Universität Magdeburg (Softwaremesslabor) unter der Schirmherrschaft der ceCMG (Central Europe Computer Measurement Group) und in Partnerschaft mit der ASQF (Arbeitskreis Software-Qualität und Fortbildung) veranstaltet. Darüber hinaus erfährt die BSOA/BCloud-Initiative Unterstützung durch die GI (Gesellschaft für Informatik - Fachgruppe Softwaremessung- und Bewertung) und die DASMA (Deutschsprachige Interessengruppe für Softwaremetrik und Aufwandsschätzung).

Improving Software Quality-in-Use Model for Mobile Applications

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Abstract— *Mobile technology is an integral part of modern life. The mobile user interface (MUI) serves as the bridge between the application and the user. To ensure user satisfaction the MUI of any application needs to be evaluated before it reaches the end user. In this article we propose a quality-in-use model for the MUI adapted specifically to the needs of mobile applications. This work is an improvement on a previously published quality-inuse measurement model motivated by recent international standards ISO/IEC (25010: 2011, 25021: 2012, and 25022: 2015) and is adaptable to various applications. The proposed measurement models were validated both theoretically using the representational theory of measurement and empirically using controlled experiments.*

Keywords—*ISO 25000-SQuaRE; Mobile user interface; quality-in-use; quality measure elements; quality measure; quality characteristics; controlled experiment.*

1. Introduction

The ongoing challenge to characterize and measure software quality becomes even more urgent when the standard terminology is updated to reflect the latest trends in industry and academia. According to existing ISO standards, several quality characteristics are used to evaluate software applications. However from the end user perspective the important characteristics are those the user experiences while using the software: correctness, efficiency and usability that is, the “quality-in-use”.

Quality-in-use is based on the experience of using the software, rather than the properties of the software itself. More specifically, quality-in-use relates to how effectively and efficiently the software enables the user to achieve the intended tasks.

In (Alnanih, Ormandjieva, & Radhakrishnan, 2013) we proposed a new quality-in-use model based on ISO/IEC TR 9126-4: Quality-in-Use Metrics (ISO/IEC TR 9126-4: 2003). Since then, the ISO recognized a need for further enhancement of ISO 9126, primarily as a result of advances and changes in the IT field (Abran, Al Qutaish, and Habra, 2007). Consequently, the ISO developed the next generation of software product quality standards referred to as Software Product Quality Requirements and Evaluation (SQuaRE – ISO 25000) (ISO/IEC 25000: 2014). This series of standards replaced the outdated ISO 9126.

The goal of this paper was to improve our previously published quality-in-use model (Alnanih et al., 2013) by resolving the harmonization issues resulting from previous research terminology and coverage, based on the SQuaRE standards ISO/IEC 25010 (ISO/IEC 25010: 2011), 25021 (ISO/IEC 25021: 2012), and 25022 (ISO/IEC DIS 25022: 2015) (Abran et al., 2005). To validate the

measurements, the representational theory of measurement was applied ensuring that each measure accurately characterizes the attribute it claims to measure by showing that the representation condition is satisfied (Roberts, 1979) (Fenton and Bieman, 2014). The quality-in-use model was also validated empirically by determining statistically whether the meaning of the intended quality-in-use characteristics measured is satisfied,by comparing model performance with known data in a given environment (Fenton and Bieman, 2014).

The rest of the paper is organized as follows: In section 2, we state the motivation for the research. In section 3, we summarize related work on quality-in-use modeling. In section 4, the existing quality models and measurements are introduced. In section 5, we present our quality-in-use model for evaluating the MUI. In section 6, we describe the theoretical method used to validate the quality-in-use measurements. In section 7, we describe a case study involving social networking applications. Discussion of the results is given in section 8, and section 9 presents the summary.

2. Motivation

Mobile user interface (MUI) design is an important factor in determining success or failure in the highly competitive mobile market. Mobile devices can be now be used for performing a variety of tasks that were earlier only possible on a PC. Increasingly, with their mobile devices always in hand people are using many application services on the go. . However, as the technological sophistication of mobile devices has grown, MUI for applications are becoming more complex. The limited resources in terms of input and output capabilities, processing power, connectivity, and memory, in a mobile device as compared to a PC requires a different approach to design; one that is not a direct transfer from PC to mobile device. Also, the way an application is used in a mobile context can be totally different from a PC. On a mobile device, a user might be on the move and have only limited and possibly fragmented time to spend on a task [12]. Nevertheless, the MUI should allow the user to complete all relevant tasks. It must be a usercentered design that is both usable and useful. In addition, it must meet user needs for effective and efficient presentation of large volumes of information, including navigation within limited screen space.

This research was motivated by the need to assess the quality-in-use of mobile applications adapted specifically to the needs of users of mobile devices.

Quality-in-use is defined as “the degree to which a product or system can be used by specific users to meet their needs to achieve specific goals with effectiveness, efficiency and satisfaction and reduced risk in specific contexts of use” (ISO/IEC DIS 25022: 2015). Our previously published quality-in-use model QiU-4-MUI (Alnanih et al., 2013) was based on ISO/IEC 9126-4 (ISO/IEC TR 9126-4: 2003) which differs considerably from the latest ISO standard ISO 25022 (ISO/IEC DIS 25022.2: 2015). Only three of the fourteen ISO/IEC 9126-4 measurements remained the same in ISO/IEC 25022, four were modified, and seven were removed completely. Table 1 highlights the changes to ISO/IEC 9126-4 and the new standard ISO/IEC 25022.

The considerable differences between ISO 9126-4 (ISO/IEC TR 9126-4: 2003) and ISO/IEC 25022 (ISO/IEC DIS 25022.2: 2015) requires we bring up-to-date our previous quality-in-use model to ensure that the terminology on software product quality-in-use measurement is fully aligned with the latest ISO measurement terminology. One of the objectives of the ISO 25000 series (and what differentiates it from the outdated ISO 9126 series) was the harmonization of its contents with the software measurement terminology of ISO 15939 (ISO 15939: 2007) (Buglione and Abran, 2014). For example, what is referred to as a “quality measure element” in ISO/IEC 25022 and “quality measure” corresponds approximately to the classic concepts of “base measure” and “derived measure” in ISO 15939 (ISO 15939: 2007). In addition, the ISO 9126-4 terminology used in our previous model has to be aligned with ISO/IEC 25010 terms (i.e., “quality factors” renamed to “quality characteristics”) (ISO/IEC 25010: 2011).

TABLE 1. Quality-in-use measures in ISO 9126-4 and ISO/IEC 25022

ISO 9126-4 Quality Characteristics		ISO 9126-4 Quality Measure Name	ISO 9126-4	ISO 25022
Effectiveness	1.	Task effectiveness	√	√ (redefined)
	2.	Task completion	√	√ (renamed to Tasks completed)
	3.	Error frequency	√	
Productivity	4.	Task time	√	√ (categorized as an Efficiency measure)
	5.	Task efficiency	√	
	6.	Economic productivity	√	
	7.	Productive proportion	√	
	8.	Relative user efficiency	√	
Safety	9.	User health and safety	√	√ (redefined and renamed to User health and safety impact)
	10	Safety of people affected by use of system	√	√ (redefined)
	11	Economic damage	√	
Satisfaction	12	Satisfaction scale	√	
	13	Satisfaction questionnaire	√	√ (redefined and renamed to Overall Satisfaction
	14	Discretionary usage	√	√

Our objective was twofold: (1) to present our updated quality-in-use model, aligned with the ISO/IEC 25010, 25021, and 25022 and adapted specifically to MUI for mobile applications, and (2) to validate our quality model on social network applications available on both mobile and desktop platforms. In order to assess validity, two approaches were applied: (a) a theoretical approach (Alnanih et al., 2013), and (b) an empirical approach (Fenton and Bieman, 2014). Validity should ideally be measured using both approaches (Bhattacherjee, 2012). The theoretical approach is used to demonstrate that a quality measure is really measuring the purported quality characteristic; the empirical approach determines whether the measure is useful in that it relates to other variables in expected ways (as defined in the hypotheses) (Fenton and Bieman, 2014).

3. Related Work

The existing standards in the literature do not satisfy the requirements for measuring the quality-in-use of MUIs in the healthcare domain. In Table 2, we compare various standards, including ISO/IEC 25010 (ISO/IEC-25010:2011), ISO/IEC 25022 (ISO/IEC DIS 25022: 2015), ISO 9241-210 (ISO:9241-210: 2010), and ISO 9241-11(ISO 9241-11:1998), with respect to quality-in-use for designing UI for software (SW) and hardware (HW) in the healthcare domain, specifically for mobile devices for use in different contexts.

TABLE 2. Comparison of selected ISO standards

Standard	Criteria			
	SW/ HW	UI Design	UCD Method	Mobile Usage
ISO/IEC 25010	SW	√	×	×
ISO/IEC 25022	SW	√	×	×
ISO 9241-210	SW, HW	√	√	×
ISO 9241-11	SW	√	×	×
New Quality-in-use model	SW	√	√	√

The ISO/IEC 25010 quality-in-use characteristics are: effectiveness, efficiency, satisfaction, freedom from risk, and context coverage (ISO/IEC 25010: 2011). The quality model proposed for this standard is highly dependent on the domain, and its definition of quality too abstract for our purposes. So, we can not apply this standard as is, to the evaluation of the usability of MUI in applications.

ISO/IEC 25010 (ISO/IEC 25010: 2011) divides the notion of quality-in-use into usability-in-use, flexibility-in-use, and safety-in-use. In addition, it defines satisfaction-in-use as:

- Likeability: satisfaction of pragmatic goals
- Pleasure: satisfaction of hedonic goals
- Comfort: physical satisfaction
- Trust: satisfaction with security

Flexibility-in-use is defined as context conformity-in-use, context extendibility-in-use, and accessibility-in-use.

ISO/IEC 25022 measurement of quality-in-use provides the measures for the quality characteristics of the qualityin-use model. The quality measures included in this international standard were selected based on their practical value. They are not comprehensive, and users are encouraged to refine them as necessary (ISO/IEC DIS 25022.2: 2015).

ISO 9241-210:2010 outlines the basic phases of the human-centered design methodology. It defines the general process throughout the life cycle of computer-based interactive systems, but does not specify the precise methods applicable to an MUI for a specific environment. According to ISO 9241-11 (ISO 9241-11: 1998), usability is 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.

In (Nayebi, Desharnais, and Abran, 2012) the authors observed that the questionnaires and hands-on methods developed for mobile usability measurement do not consider the user interface features provided in the newest mobile operating systems that are gaining popularity. To improve the quality-in-use of mobile applications, there is a need to focus on who the users of a product are, what they want to use it for, and where and in what context it will be used. So, determining the user context is a critical step in systematic quality-in-use engineering.

We conclude that a new quality-in-use model and quality-in-use evaluation guidelines had to be derived, as the current standards do not meet the specific needs of MUI users. In the following section, we highlight the main topics that are important for an understanding of the quality model and quality measurement.

4. Quality Model and Measurements

Software products and software-intensive computer systems need to provide personal satisfaction, while continuing to improve business success, with high-quality software and systems that are safe and reliable. (ISO/IEC 25010:2011). The quality characteristics need to be specified, measured, and evaluated whenever possible using validated measures and measurement methods.

The new SQuaRE (Software Product Quality Requirements and Evaluation) series of standards consists of the following divisions:

- ISO/IEC 2500n - Quality Management Division,
- ISO/IEC 2501n - Quality Model Division,
- ISO/IEC 2502n - Quality Measurement Division,
- ISO/IEC 2503n - Quality Requirements Division,
- ISO/IEC 2504n - Quality Evaluation Division,

The quality models listed above together serve as a framework to ensure that all characteristics of quality are considered from the perspective of each stakeholder. A brief description of ISO/IEC 25010, 25021 and 25022 is presented below.

The International Standard (ISO/IEC 25010: 2011) defines a product quality model composed of eight characteristics that relate to the static properties of software and dynamic properties of the computer system. The model is applicable to both computer systems and software products.

The ISO/IEC 25010 standard also defines a quality-in-use model composed of five characteristics that relate to the outcome of interaction when a product is used in a particular context. Quality-in-use measures the outcome of interaction between user and system. This system model is applicable to the complete human-computer system, including both computer system and software products. The final quality-in-use can be measured when a system is implemented and used in the environment intended for its purpose The ISO/IEC 25010, and ISO/IEC 25022 standard definitions of the quality-in-use characteristics are as follows: Effectiveness measures the accuracy and completeness with which goals can be achieved. Efficiency measures the level of effectiveness achieved to the expenditure of resources. Relevant resources can include mental or physical effort, time, materials or financial cost. Freedom from risk measures the risk of operating the software or computer system over time, conditions of use and the context of use. Satisfaction measures the extent to which users are free from discomfort and their attitudes towards the use of the product. Satisfaction can be specified and measured by subjective rating on scales such as: liking for the product, satisfaction with product use, acceptability of the workload when carrying out different tasks, or the extent to which particular quality-in-use objectives (such as efficiency or learnability) have been met. Context of use includes users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a system, product or service is used.

Standard ISO/IEC 25021:2012 defines an initial set of quality measure elements (QME) used through the product life cycle for the purpose of SQuaRE. A number of QME for quality measures that quantify some of the characteristics and subcharacteristic constitute an initial list to be used during the construction of the quality measures as referenced in ISO/IEC TR 9126-2, ISO/IEC TR 9126-3 and ISO/IEC TR 9126-4. In order to understand and indicate quality (sub) characteristics, quality measure (QM) is defined and then the QME are defined. A measurement function is applied to a QME to generate the QM. A measurement method must be applied to a property to define and identify a way to quantify a QME (ISO/IEC FDIS 25021: 2012).

Our new quality-in-use model and quality-in-use evaluation/decision making criteria are introduced next.

5. A Quality-in-Use Model for MUI

In this section we present an improvement to our new quality-in-use model tailored specifically to the MUI design process. The model is meant to assist the designer to evaluate the mobile application in terms of its ability to execute work-related tasks with: i) increased effectiveness, productivity, efficiency, and satisfaction; and ii) increased safety, through error reduction, by restricting the use of the UI to the available options,as well as making the UI more pleasant to use and easier to manipulate; and iii) reduced cognitive load on the user, through a reduction in the number of navigation-related actions.

In our approach, the quality-in-use characteristics are delineated through several layers in a hierarchical structure (see Fig.1). The root of the proposed new quality-in-use model is divided into objective and subjective characteristics.

Objective characteristic measurements are derived from quality measure elements applied to the measurement function in order to collect quantitative data based on the results of the user during conduction of the test. By doing so, we make sure that different users produce the same measures, regardless of whether they are measuring product or resources as the quantification of the objective

is based on numerical rules (ISO/IEC 15939:2007). This consistency of measurement is considered very important (Fenton and Bieman, 2014).

Subjective characteristic measurements can vary with the person measuring, and reflect the judgment of the measurer. Subjective characteristics are indicated by ratings on an ordinal scale in post questionnaires that users complete after conducting the test in order to collect qualitative data based on their experience using the application. Thus the quantification of subjective characteristics involves human judgment (ISO/IEC 15939:2007), (ISO/IEC DIS 25022.2: 2015).

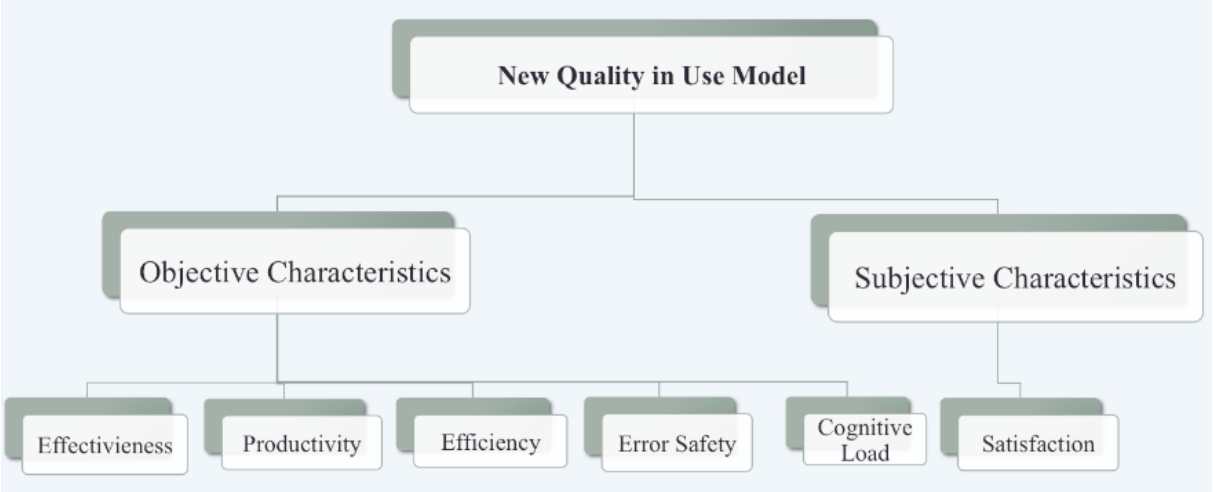


Fig. 1. New quality-in-use characteristics

The characteristics of the new quality-in-use model are defined as follows:

• Effectiveness which is quantified using the quality measure task completion ratio defined as the minimum number of actions required to complete a task in a specified context, divided by the number of clicks recorded. An effective MUI dsign on limited screen space would assist the user to perform tasks with a minimal number of right actions, which leads to increased user effectiveness. The unit of measurement is actions per task;

• Productivity which is quantified using the quality measure task productivity defined as the number of actions performed in a specified context of use relative to the time taken by the user to complete the task. A productive MUI design guides the user to selecting the correct actions in less time by choosing appropriate icons or symbols, thus increasing user productivity in a specified context of use. The unit of measurement is actions per second;

• Efficiency which is quantified using the quality measure cost effectiveness defined as the effectiveness of the user in completing the task in a specified context of use, achieved in a certain time. An efficient MUI design visualizes task information as what is happening and what is about to happen within the limited capability of a mobile screen; task visibility increases user effectiveness in performing the task while minimizing time. The unit of measurement is actions per second;

• Error safety (error prevention and recovery from error) is concerned with minimizing the number of errors during completion of tasks by users, considering the limited input capability of the mobile device, ie. tapping or touching the screen. It is quantified using the quality measure error free task completion which is the portion of correct actions in each task performed in a specified context of use. Error safety requires the MUI designer to provide the user with evidence of closure, using direct manipulation interactions, thus satisfying user expectations when engaging in a dialogue on MUI. The unit of measurement is errors per action;

• Cognitive load (task navigation) is defined as the level of the cognitive load of users with which tasks can be achieved in a specified context of use and depends on three factors: task complexity, screen size or shape factor, and the way the designer has organized information on the various screens. Moving from screen to screen adds to the cognitive load of the user. For a given user task, each screen view is weighted by the number of actions performed on that screen, which must be minimized to keep the user focused on the task at hand, but sufficient in number to increase user confidence in using the application while reducing the likelihood of the user losing interest while performing a task. It is quantified using the quality measure task navigation defined in terms of the number of views required to complete each task relative to the number of actions in a specified context of use. The unit of measurement is views per actions;

• Satisfaction is defined as user level of enjoyment as a result of interacting with the application in a specified context of use, in terms of learning, and using the application, performing a particular task, finding the features, understanding the navigation process, recovering from error, and performing a task anywhere and at any time. Satisfaction is measured by subjective ratings on a Likert scale that quantify the strength of user subjectively expressed attitudes or opinions. The process of quantification can be accomplished in a number of ways, for example, by using an attitude scale based on a questionnaire (ISO/IEC DIS 25022.2: 2015).

Table 3 presents the definitions of some quality measurement elements including measurement unit and method.

TABLE 3. Definition of some quality measure elements

QME	Definition
A	The minimum number of actions required to complete a task, measured by the number of clicks recorded.
C	The number of correct actions a user is required to take to complete a task, measured by the number of clicks recorded.
X	The number of incorrect actions that a user performs when completing a task involving risk, recorded to help assess the level of safety of the MUI, measured by the number of incorrect clicks recorded
T	Duration of task, time between start to finish of a specified task of software, recorded to help assess whether or not the MUI is sufficiently usable and simple. Measured in seconds.
V	The number of screen views involved in performing a task. Measured by the number of screen views recorded.

Table 4 presents the proposed quality measures and measurement functions for quality-in-use objective characteristics.

TABLE 4. Quality measure and measurement functions for quality-in-use characteristics

Quality Characteristics	Quality Measure	Measurement Function
Effectiveness	Task completion ratio	= A / (C + X)
Productivity	Task productivity	= C / T
Efficiency	Cost efficiency	= ((A / (C+X)) / T
Error Safety	Error free task completion	= 1- (X / (C + X))
Cognitive Load	Task navigation	= V/ (C + X)

Fig. 2 presents the quality measure used to indicate the quality-in-use objective characteristics, along with the interpretation of the measurement data,and the relation between the property to quantify, the measurement method and QME.

As suggested in ISO/IEC 2022 and depending on the context other quality measures may be necessary; these will be addressed in future work.

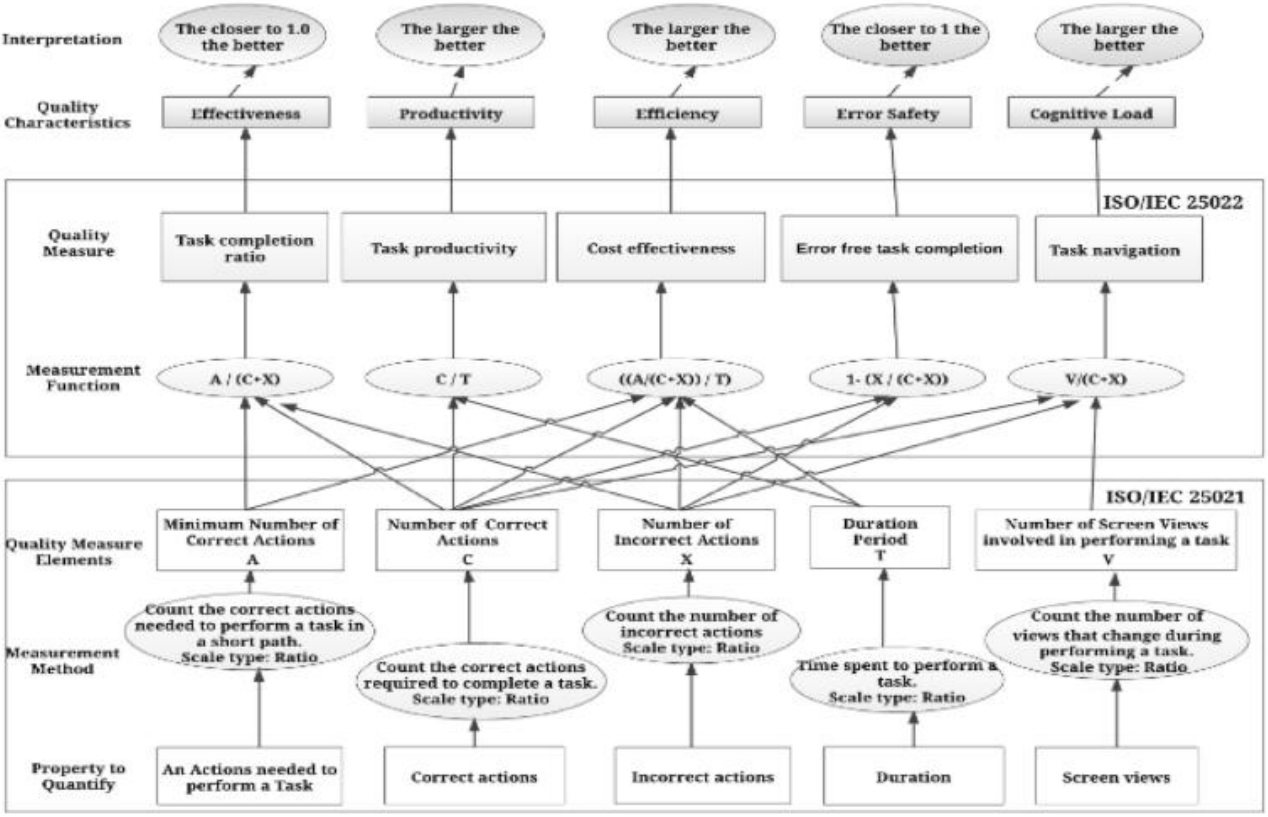


Fig. 2: New quality-in-use model for MUI

Our quality-in-use measurement model is classified into five objective characteristics. From the ISO 25021 guidelines we derive the corresponding five properties to quantify that represent the source of the quality-in-use measurement input. A measurement method (a logical sequence of operations required to quantify the property) is developed for each property.

The result of applying the measurement method is a value assigned to the corresponding quality measurement element (QME), which is the most important component of a quality measure. Based on ISO 25022, a measurement function is defined to combine two or more QME into a formula that is used to assign a value to the corresponding quality measure. The values of the quality measures, with their interpretations, represent the quantification of the five quality characteristics.

In the following section, we describe the theoretical approach to the proposed measurements validation.

6. Theoretical Validation of the New Quality-in-Use Model for MUIs

Theoretical assessment of validity focuses on how well the idea of a theoretical construct is translated into or represented in an operational measure. This type of validity is called translational validity (or representational validity), and consists of two subtypes: face and content validity. Translational

validity is typically assessed using a panel of expert judges, who rate each item (indicator) on how well they fit the conceptual definition of that construct, and a qualitative technique called Q-sort (Bhattacherjee, 2012).

Face validity refers to whether an indicator seems to be a reasonable measure of its underlying construct "on its face". For example, the frequency of one's attendance at religious services seems to make sense as an indication of a person's religiosity without a lot of explanation (Bhattacherjee, 2012). Content validity is an assessment of how well a set of scale items matches the relevant content domain of the construct it is attempting to measure (Bhattacherjee, 2012).

In this section, we examine measurement validation both the process of ensuring that we are measuring what we say we are measuring, so that we satisfy the representation condition, and the process of demonstrating the usefulness of a measure, by applying the characteristics and the quality measures that explain what you are measuring is what we say you are measuring. The validity of a measurement is defined intuitively as the extent to which the measurement reflects the real meaning of the concept under consideration. Consequently, intuition is the starting point for all measurement. Validating measurements is enormously important, as this step guarantees the correctness not just of the data, but of decisions taken based on their analysis in a specific environment. The theoretical validity of the measurement methods proposed in this paper is guaranteed by the representational theory of measurement (Fenton & Bieman, 2014), (Roberts, 1979).

This theory provides a theoretical basis for treating quality-in-use characteristics as mathematical objects and investigates them by means of formal analysis. This means that domain-specific knowledge is used to prove that quality-in-use measurements satisfy certain conditions about individual judgments, such as preferences, which make the measurement possible. An example of such an empirical relation would be the following preference: "A user performing a task on UI1 is more effective than a user performing the same task on UI2." In this case, the empirical relation "more effective than" is mapped to a numerical relation between the effectiveness values corresponding to UI1 and UI2 expressed by the symbol >. The ability to incorporate intuition and observation as representational conditions of measurement is the notion underlying our proposed theoretical validation of the measurements.

In this section, we demonstrate theoretically that our measurements reflect the empirical understanding of the quality characteristics of the entities we observe (such as effectiveness of the MUI), and that our measurement functions preserve the relationships (such as "more effective than") that we see among empirical entities. The representational condition ensures that the quality measure values calculated using a measurement function reflect the empirical understanding of the quality characteristic we observe, such as effectiveness. For instance, the measurement function A / (C + X) is used to quantify the quality measure for task completion ratio that characterizes the effectiveness of user interfaces. Please note that effectiveness is an ordinal scale type measure, hence the measurement goal here is to rank the user interface in terms of the task completion ratio on the scale [0…1]. For example, if we expect MUI_1 to be more effective than MUI_2 then the task completion ratio of MUI_1 has to be greater than the task completion ratio of MUI_2. There are two important criteria that a representation condition must meet: tracking and consistency. Tracking validates whether or not a change in the quality characteristic at different times is accompanied by a corresponding change in the measurement data. Consistency complements the tracking criterion by ensuring that the direction of change is the same for both the quality characteristic we observe empirically and its measurements. The theoretical validation of the quality measures for the new quality-in-use model is described below:

1. ***Task completion ratio:*** Based on the meaning of effectiveness, the closer the task completion ratio value is to 1.0, the better the user level of effectiveness in performing a task. For example, let the minimum number of actions required to perform a task be 3 (A = 3). If user 1 completes the task in three actions (C = 3), then the task completion ratio (User 1) = 3/3 = 1, which is excellent, and what we expect. In this case, the level of effectiveness is high, as the user has performed the task with a minimum number of required actions. If User 2 performs the same task in four actions (C = 4), the effectiveness of User 2 will be lower than the

effectiveness of User 1 (for instance, compare the task completion ratio of User 2 which is 3/4 and User 1, which is 1: 3/4 < 1). This is again what we expect, and makes sense, because if the user performs the task in a minimum number of required actions (short path), he will be more effective than if he performs the task in a larger number of actions (long path).

2. ***Task productivity:*** Based on the meaning of productivity, the larger the task productivity value, the better the productivity of the user performing the task. For example, if C = 3 and T = 10 seconds for User 1, then task productivity (User 1) = 3/10 = 0.3. In this case, this user's productivity is greater than that of User 2, who performs the same task with C = 3, but with T = 20 seconds, and so his task productivity (User 2) = 3/20 = 0.15. If we increase the time elapsed, the productivity will decrease.

3. ***Cost effectiveness:*** Based of the meaning of efficiency, the larger the cost effectiveness value, the better the efficiency. For example, if effectiveness = 1 (the highest value) for User 1 and T = 10 seconds, then cost effectiveness (User 1) = 1/10 = 0.1. In this case, User 1 efficiency is greater than that of User 2, who performs the same task in the same time, T = 10 seconds, but this user is less effective (0.75): cost effectiveness (User 2) =0.75/10 = 0.075), which is a decrease in efficiency.. If the user performs the task with the highest possible effectiveness value (1), but takes more time (20 seconds), then efficiency = 1/20 = 0.5, which is also a decrease in efficiency.

4. ***Error free task completion:*** The ability to successfully complete a task with no errors is essential in hospital environments to ensure safe use of medical software related to the caregiving task. The larger the error-free task completion value, the better the error safety level; the highest level of error safety corresponds to error-free task completion. For instance, if X = 0 for User 1, and C = 3, error-free task completion (User 1) = 1- (0/3) = 1. In this case, the error safety of User 1 is greater than the error safety of User 2, who performs the same task with X = 1 and C = 3 where error-free task completion = 1- (1/(3+1)) = 0.75. If we increase the number of incorrect actions to 1, the level of error safety decreases.

5. ***Task navigation:*** Based on the meaning of cognitive load, a decrease in level is better than an increase. So, the higher the task navigation value, the greater the reduction in cognitive load. For example, if the user completes a task with no errors (X = 0), in three correct actions (C = 3), on three views (V = 3), task navigation = 3/3 = 1. This is interpreted as a perfect score, as the user performed one action in each view, which minimizes the cognitive load. If we increase the number of incorrect actions to 1 and decrease the number of views to 2, the level of the cognitive load will increase, because the user has to perform two or three actions in one screen view.

These calculations establish the theoretical validity of the quality-in-use measurements, as required by the representational theory of measurement. We have seen how the measurement assigns a representation or mapping from an observed (empirical) relation to some numerical relation. The purpose of performing the mapping is to be able to manipulate measurement data and use the results to draw conclusions about the empirical entity. The qualityin-use QME are on an absolute scale type, because the measurement is made simply by counting (actions, views, etc.), and there is only one possible measurement mapping, namely the actual count (Fenton & Bieman, 2014). All arithmetic analysis of the resulting counts is meaningful on an absolute scale type; therefore, all mathematical and statistical operations are meaningfully applied on the quality-in-use measurement data, including those described in section 5.

While translation validity examines whether a measure is a good reflection of its underlying construct, criterionrelated validity examines whether a given measure behaves the way it should, given the theory of that construct.

In section 7, quality-in-use measurements are validated empirically through a carefully controlled experiment.

7. Controlled Experiment: Quality-in-use empirical evaluation for MUI v.s. DUI for social applications

Empirical assessment of validity examines how well a given measure relates to one or more external criteria, based on empirical observations. This type of validity is called criterion-related validity and examines whether a given measure behaves as expected, given the theory of that construct. This assessment is based on quantitative analysis of observed data using statistical techniques (Bhattacherjee, 2012).

In this section, we provide empirical evidence that the quality-in-use measurement model is effective on a wellunderstood problem (such as the use of a mobile device vs. a desktop computer) and in a familiar environment, such as social networking, and is of the same nature as any other application that can be applied in any context. In (Alnanih et al., 2013) we empirically evaluated the social application Twitter. In this paper we evaluated the improved qualityin-use model on Facebook, LinkedIn and Twitter, reportedly the most popular social networking sites used by students and educators.

The empirical study presented in this section involved a controlled experiment, in which the quality-in-use characteristics of Facebook, LinkedIn, and Twitter social applications were evaluated on a DUI and an MUI used by the same participant in the same environment, in order to measure the effects of applying the proposed quality-in-use characteristics to DUI and MUI quality assessment.

The goal of the experiment was expressed as a set of hypotheses to be tested. Hypotheses, relating to the objective characteristics of the quality-in-use model (effectiveness, efficiency, productivity, error safety, cognitive load) were formulated and investigated empirically.

Sample hypotheses for the above objective characteristics follow:

> HYP0: There is no significant difference between the effectiveness of the Facebook app using an MUI and the effectiveness of the same Facebook app using a DUI.
>
> HYP1: There is a significant difference between the effectiveness of the Facebook app using an MUI and the effectiveness of the Facebook application using a DUI.

7.1 Experimental Data

Participant samples consisted of students registered in a software engineering development process course, SOEN 6611, during the summer of 2013 at Concordia University. Three groups were formed, selected randomly for each application, one group per social network: Facebook (20), LinkedIn (15), and Twitter (20). For each social network, two user interfaces were compared: mobile (MUI) and desktop (DUI). Each student performed the same set of tasks on the assigned social network, once using the DUI and once using the MUI, in random order such that approximately half of the students in a group experimented first with the MUI and then with the DUI, while the other half performed the tasks first on the DUI first and then on the MUI. The test was conducted one participant at a time in a closed lab. The independent variables in the study were the quality measures (A, C, X, T, and V) of the two UI for the Facebook, LinkedIn, and Twitter applications. The dependent variables were the quality-in-use characteristics (Fig.2).

Prior to conducting the formal evaluation a list of materials to be used during testing was prepared as suggested by Dumas and Redish (1999), and included the following:

1) Task list: A list of tasks normally performed on a daily basis was prepared for test participants such as search for a friend, follow a friend, write a comment, or send a message.
2) Objective measure (paper log): The QME (A, C, X, T, and V) for each participant for each UI type were recorded in a paper log.

8. Results of Empirical Study

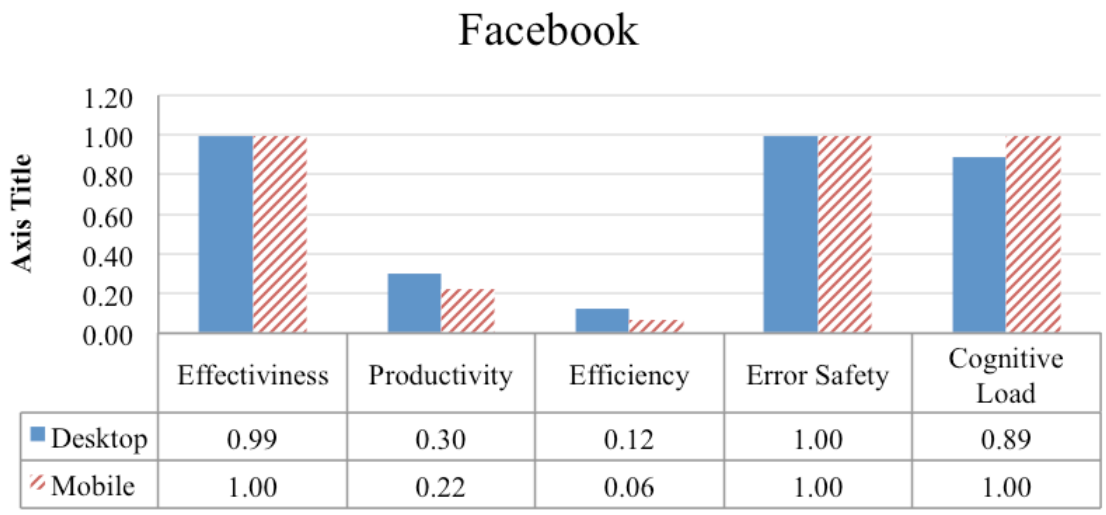
The objective characteristics of our quality-in-use model provided measures relating to effectiveness, productivity, efficiency, error safety, and cognitive load for:

- 20 graduate students performing 4 tasks on a DUI and an MUI for the Facebook application;
- 15 graduate students performing 4 tasks on a DUI and an MUI for the LinkedIn application;
- 20 graduate students performing 4 tasks on a DUI and an MUI for the Twitter application.

The raw data for the empirical study were tabulated in MS Excel for each of the participant groups. The dependent variables were calculated separately for each task. The mean of all 4 tasks, for each participant group, and for each characteristic was used to compare the quality-in-use of both the DUI and MUI. The data are presented in two separate tables. Each table shows the results for the 5 objective characteristics for all 4 tasks and all participants. The mean and median values are the same for each characteristic in the two tables., Since the data are normal we relied on the mean as each characteristic lies within the 95% confidence interval.

8.1 Facebook

Fig. 3 shows graphically improvement based on the mean for DUI compared to MUI for the productivity and efficiency characteristics. The cognitive load of the MUI was better than DUI.



	Effectiviness	Productivity	Efficiency	Error Safety	Cognitive Load
Desktop	0.99	0.30	0.12	1.00	0.89
Mobile	1.00	0.22	0.06	1.00	1.00

Fig. 3. Objective characteristics for all tasks for the DUI-based and MUI-based Facebook

In order to investigate the statistical significance of the observed differences in the objective characteristics: productivity, efficiency, and cognitive load, and since there are two conditions (one using DUI, and one using MUI) for the same participants, the data are paired. Consequently, we used the paired student t-test for data analysis.

Table 5 shows the t-test values and P-values for each characteristic. The hypotheses were verified for each characteristic, based on t-test and P-values, with the critical value approach of the t-Test at 19 degrees of freedom, $\alpha = 0.025$ for the two-tailed test, and a critical level of $t = \pm 2.09$. Our decision rule was to reject the null hypothesis if the computed t statistic was less than -2.09 or more than 2.09.

TABLE 5. Paired t-test and P-value for all objective characteristics for Facebook

	Effectiveness	Productivity	Efficiency	Error Safety	Cognitive Load
P-value	0.35	0.00	0.00	0.62	0.00
T-value	-0.96	16.31	14.23	-0.50	-32.83

From the P-value approach of the t-test, the P-values for effectiveness and error safety were 0.35 and 0.62, respectively. Therefore, we failed to reject the null hypothesis. Our conclusion was that there is no significant difference between DUI and MUI for the effectiveness, and error safety characteristics.

P-values of the t-test for productivity, efficiency and cognitive load were 0.00, 0.00, and 0.00 respectively, and therefore the null hypothesis is rejected. Since the t-values for productivity, and efficiency fall in the positive region, we can conclude that the DUI for accessing Facebook is better than the MUI based on these characteristics. The t-test value of -32.82 for cognitive load falls in the negative critical region, and we concluded that MUI is better than DUI for this characteristic.

Discussion of the Facebook controlled experiment:

The controlled experiment for Facebook, conducted with 20 graduate students, showed that productivity and task efficiency favour DUI over MUI. Since productivity and task efficiency depend on time, unlike the other characteristics, and since most of the tasks evaluated depended on the input features, entering input by tapping on a mobile platform was slower than typing on a keyboard,. In addition, we note the Facebook application contains many features easier to perform on a desktop than a mobile device.

For effectiveness and error safety our results showed no significant difference between the MUI and DUI. There was a trend toward superiority of the mobile given the negative direction of the t-value although the result did not attain statistical significance (see table 5). For cognitive load the result confirmed that accessing Facebook through a mobile device is better than a desktop. This indicates better task navigation through the MUI and a reduction in the cognitive load for students, as there were fewer actions in each view,and the incorrect actions were all within the same range.

8.2 LinkedIn

Fig. 4 shows graphically improvement based on the mean for DUI compared to MUI for error safety. In addition the cognitive load for the MUI for LinkedIn was better than the DUI.

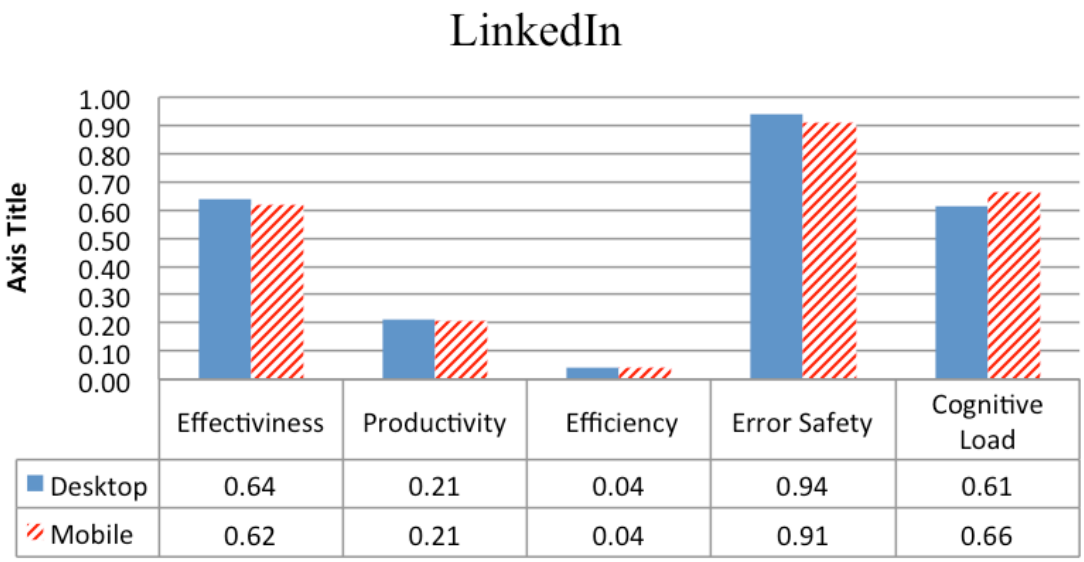


Fig. 4. Objective characteristics for all tasks for the DUI-based and MUI-based LinkedIn

The paired student t-test was used for analysis of the data to investigate the statistical significance of observed differences in error safety and cognitive load. Table 6 shows t-test and P-values for each of the characteristics. The hypotheses were verified for each characteristic, based on t-test and P-values, with the critical value approach of the ttest at 14 degrees of freedom, α =0.025 for the two-tailed test, and a critical level of t = ± 2.09. Our decision rule was to reject the null hypothesis if the computed t statistic was less than -2.14 or more than 2.14.

TABLE 6. Paired t-test and P-value for all objective characteristics for Linkedin

	Effectiveness	Productivity	Efficiency	Error Safety	Cognitive Load
P-value	0.59	0.79	0.70	0.09	0.18
T-value	0.55	0.28	0.39	1.83	-1.41

From the P value approach of the t-test, the P-value for all the characteristics was bigger than alpha. Therefore, we failed to reject the null hypothesis. Our conclusion was there was no significant difference between DUI and MUI for the objective characteristics of LinkedIn.

Discussion of the LinkedIn controlled experiment:

The controlled experiment for LinkedIn, conducted with 15 graduate students, showed that there was no significant difference between using DUI and MUI for all five objective quality-in-use characteristics. Although the participant sample was small, we expected this result from real life use of LinkedIn.

8.3 Twitter

Fig. 5 shows graphically improvement based on the mean for MUI compared to DUI for the productivity, efficiency, and cognitive load.

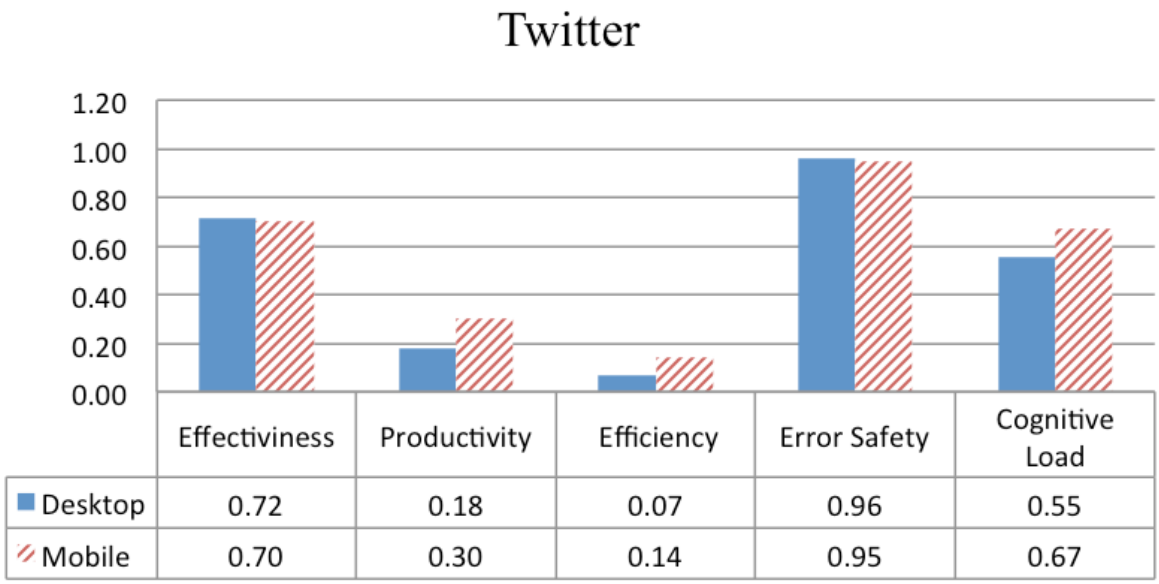


Fig. 5. Objective characteristics for all tasks for DUI-based and MUI-based Twitter

The paired student t-test was used for data analysis to investigate the statistical significance of the observed differences in productivity, efficiency, and cognitive load. Table 7 shows the t-test and P-values for each of the characteristics.

The hypotheses were verified for each characteristic, based on t-test and P-values, with the critical value approach of the t-Test at 14 degrees of freedom, $\alpha = 0.025$ for the two-tailed test, and a critical level of $t = \pm 2.09$. Our decision rule was to reject the null hypothesis if the computed t statistic was less than -2.09 or more than 2.09

TABLE 7. Paired t-test and P-value for all the objective characteristics for Twitter

	Effectiveness	Productivity	Efficiency	Error Safety	Cognitive Load
P-value	0.72	0.03	0.05	0.37	0.01
T-value	0.35	-2.27	-2.06	0.90	-2.70

From the P value approach of the t-Test, the P-values for effectiveness and error safety were 0.72, and 0.37, respectively. Therefore, we failed to reject the null hypothesis. Our conclusion was that there was no significant difference between the DUI and MUI for effectiveness and error safety characteristics.

P-values of the t-test for productivity, efficiency and cognitive load were 0.03, 0.05, and 0.01 respectively, and the null hypothesis was therefore rejected. Since the t-values for productivity, efficiency, and cognitive load fall in the negative region, we concluded that MUI for accessing Twitter was better than DUI based on these characteristics.

Discussion of the Twitter controlled experiment:

The controlled experiment with Twitter, conducted with 20 graduate students, showed that productivity, efficiency and cognitive load favoured MUI over DUI. In real-life experience of using the Twitter application, users prefer to access the application and follow their friends on a mobile device, rather than a desktop. We draw this conclusion from the results of the empirical study, which showed that the productivity and efficiency of using the MUI is better than the DUI. Also the cognitive load in

MUI is better than DUI where the limited the number of actions in each view of the MUI helped reduce the cognitive load compared with the DUI. The other factors were rated equally in the DUI and MUI.

Threats to validity: Potential problems with empirical studies are classified in terms of categories of threats to validity. Wohlin et al. (2012) describe four cateories of threats to validity:

1) Conclusion validity refers to the statistical relationship between independent and dependent variables to confirm a theory in a controlled experiment. Our experimental study has conclusion validity as we applied the paired student t-test to our data (see section 8) generating measures of association that indicate the closeness of behavior associated with the two variables.

2) Construct validity. We theoretically validated all five measurements in a narrow sense, which means a measure is valid if it reflects the real meaning of the concept under consideration (see section 6).

3) Internal validity. A study has internal validity if the treatment actually caused the effect shown in the dependent variables (Fenton & Bieman, 2014). Since an independent variable can be manipulated to affect the outcome, and the outcome, or result, is, in turn, given by values of the dependent variable, this means that the value of the dependent variable is affected by altering the value of one or more of the independent variables.

4) External validity. The results of the controlled experiment can be generalized to anyone accustomed to working with a moble device. It is clear from the above discussion,that both theoretical and empirical validation, as defined in this paper, are necessary and complementary.

9. Conclusion

The purpose of this paper was to improve our previous quality-in-use model (Alnanih et al., 2013) based on the latest international standards. The new quality-in-use model for evaluating any software for mobile application is the out come of merging ISO/IEC 25010, 25021, and 25022 Our main contribution in this paper was to update and design valid measurement methods as a foundation for collecting and analyzing data on the new quality-in-use model for MUIs in several social networking applications.

We tested the model with 55 graduate students comparing the usability of different social applications on both desktop and mobile devices. Further research is required to design additional quality measures for each quality-in-use characteristic of our new quality-in-use model. To addresses whether a quality measure does, in fact, measure the quality characteristic it is purported to measure in the ways expected, we carried out two types of validation: theoretical and empirical. We tested the model with 20,

20 graduate students respectively for Facebook, LinkedIn, and Twitter applications. The results of the controlled experiment confirm that there was no difference between the DUI and MUI for the characteristics of effectiveness and error safety for all three applications. However, for the Facebook application productivity and efficiency favor the DUI, while in Twitter they favor the MUI. The new characteristic introduced in the new quality-in-use model confirms that cognitive load in Facebook and Twitter favor MUI.

We anticipate our results will improve the quality of MUI measurement in terms of responding intelligently to contextual changes. Directions for future work include extensive testing of different types of applications, and implemention of the proposed quality-in-use model as a mobile application to assist developers for quality-in-use evaluation of new MUI. Due to the complexity of designing an MUI it is anticipated that measuring software qualityin-use automatically will be a significant challenge (Atoum and Bong, 2015); we will take up the challenge in future research work.

References

Abran, A., Al-Qutaish, R. E., & Desharnais, J. M. (2005). Harmonization issues in the updating of the ISO standards on software product quality. Metrics News, 10(2), 35-44.

Abran, A., Al Qutaish, R., Desharnais, J., & Habra, N. (2007). ISO-based Models to Measure Software Product Quality. Institute of Chartered Financial Analysts of India (ICFAI)-ICFAI Books

Alnanih, R., Ormandjieva, O., & Radhakrishnan, T. (2013). A New Quality-in-Use Model for Mobile User Interfaces. Proceedings of the 23nd International Workshop on Software Measurement, IWSM-MENSURA, pp. 165-170. IEEE.

Atoum, I., & Bong, C. H. (2015). Measuring Software Quality-in-Use: State-of-the-Art and Research Challenges. arXiv preprint arXiv:1503.06934.

Bhattacherjee, A. (2012). Social Science Research: Principles, Methods, and Practices. http://scholarcommons.usf.edu/oa_textbooks.

Buglione, L., & Abran, A. (2014, October). Measurement Process: Improving the ISO 15939 Standard. In Software Measurement and the International Conference on Software Process and Product Measurement (IWSMMENSURA), 2014 Joint Conference of the International Workshop on (pp.136-140). IEEE.

Desharnais, J. M., Abran, A., & Suryn, W. (2011). Identification and analysis of attributes and base measures within ISO 9126. Software Quality Journal, 19(2), 447-460.

Dumas, J. S., & Redish, J. (1999). A practical guide to usability testing. Intellect Books.

Fenton, N., & Bieman, J. (2014). Software metrics: a rigorous and practical approach. CRC Press.

ISO/IEC TR 9126-2:2003 (2003) Software Engineering – Product Quality - Part 2: External Metrics, Geneva: International Organization for Standardization.

ISO/IEC TR 9126-3:2003 (2003) Software Engineering – Product Quality - Part 3: Internal Metrics, Geneva: International Organization for Standardization.

ISO/IEC TR 9126-4:2003 (2004). Software Engineering – Product Quality – Part 4: Metrics, Geneva: International Organization for Standardization.

ISO/IEC 25000:2014 (2014). Software Engineering – Software Product Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE, Geneva: International Organization for Standardization.

ISO/IEC-25010:2011 (2011). Systems and Software Engineering – Systems and Software Quality Requirements and Evaluation (SQuaRE) – System and Software Quality Models. Geneva, Switzerland: International Organization for Standardization.

ISO/IEC 25021:2012 (2012). System and Software Engineering - Systems and Software Product Quality Requirements and Evaluation (SQuaRE) – Quality measure elements ISO/IEC JTC1/SC7/WG6.

ISO/IEC DIS 25022.2 (2015). Systems and Software Engineering –Systems and Software Quality Requirements and Evaluation (SQuaRE) –Measurement of Quality-in-Use ISO/IEC JTC1/SC7/WG6.

ISO 9241-11:1998 (1998). Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs) – Part 11: Guidance on Usability.

ISO:9241-210:2010 (2010). Ergonomics of human–system interaction — Part 210: Human-centered design for interactive systems, International Organization for Standardization (ISO). Switzerland.

ISO/IEC 15939:2007 (2007) Systems and Software Engineering – Measurement process. International Organization for Standardization, Geneva.

Nayebi, F., Desharnais, J. M., & Abran, A. (2012, April). The state of the art of mobile application usability evaluation. In CCECE (pp. 1-4).

Roberts, F. (1979). Measurement theory, encyclopedia of mathematics and its applications (Vol. 7). Massachusetts: Addison-Wesley Publishing Company.

Value-Based Measurement: the project 'holy grail'

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Abstract. The well-known SaaS acronym moved along the years from being 'Service as a Software' to more recently 'Software as a Service', where software is becoming the commodity to a service (sometimes) IT-based. What a customer decides to buy is a 'service experience' and measuring his/her perceived value becomes fundamental for any evaluation and/or estimating for properly take the right project decisions and therefore allocate a proper amount of assets for staffing that project. This paper discusses the impacts of looking to 'service projects' including a 'software project', implying a wider measurement plan with different drivers to take into account.

Keywords: Value, Intangibles, Service Project, Non-Functional Requirements (NFR), Users' perception.

1. Introduction

In the '80s and '90s 'SaaS' was a well-known acronym meaning 'Service as a Software', where the software was paid by a customer and the related services were offered in bundle with it. During last years, the two 'S' letters swapped, and the new business model for many organization is to offer a (free) software for selling the related services [1]. Thus, for software/service-intensive organizations (SIOs), the interesting business question should be: what a customer is buying now? What are the assets needed to organize and staff a project and how to measure them? Which is the right asset combination for creating 'value' to our customer? And last, but not least, what about the so-called 'User Experience'? Let's start from a couple of ITIL/ISO 20000 definition, starting from 'service': '*a means of delivering **value** to customers by facilitating outcomes customers want to achieve without the ownership of specific costs and risks*'[2]. Thus 'value' – as in Figure 1 – can be represented as the logical summation of 'what' the customer wants (utility – in the software world, FURs) and the 'how' and 'how much' a service must deliver its outcomes (warranty – in the software world, NFRs) to the final users. As in the picture, availability, capacity, continuity and security are the 'vital few 'characteristics to be designed, realized and run in operation for a customer. And it's interesting to observe that they are characteristics included also in the internal/external (software product) quality model defined in the ISO 25010 standard [4].

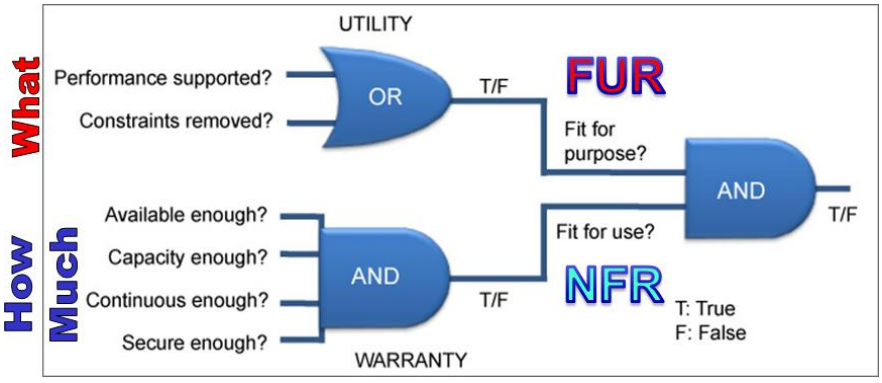


Fig. 1 – Service Value: Utility (FUR) + Warranty (NFR)

But there is also a second definition for 'value' in the ITIL Service Strategy core guide [3], as depicted in Figure 2:

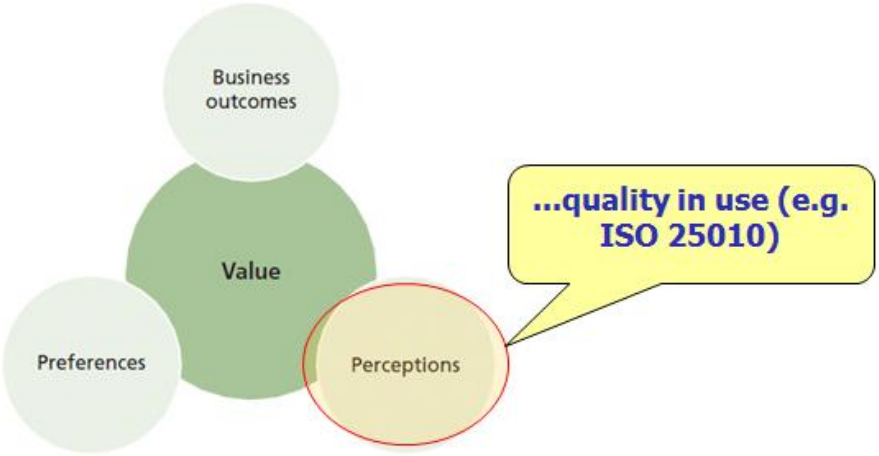


Fig. 2 – Service Value: Preferences (Customer/Business) + Business Outcomes + Perceptions (Users)

The three components moves from the 'what' a customer wants (*preferences*) but shouldn't skip the users' viewpoint (*perception*), that's more and more something to strictly involve from the Design phase on, also for allocating the right budget for a project. Also here, the 'quality in use' list of characteristics and sub-characteristics is again yet defined in the ISO 25010 standard, stressing the user's role.
Thus the basic question for SIOs shall be more and more if they are working on a project where software is the 'core' component or not and consequently, what should be measured and monitored for a proper management of such project.

The paper is structured as follows. Section 2 proposes the scenario for an IT project, depicting which should be the measurable entities and related attributes. Section 3 discusses ways to track and analyze data in value-chain, moving from good old tools, too often not applied, as the Balanced Scorecard. Last but not least, Section 4 proposes some conclusions and next actions that could be taken, in order to reduce and minimize estimation errors in projects.

2. Software or Service? That's the (*scope*) question!

The first question when dealing with something is to define its working scope and of course the attributes/characteristics for such 'object of interest' (OoI). Using the 'Pareto rules' proportion, we could affirm that a product (system) in a PLC (Product Life Cycle) could use 20% of its resources during the whole lifetime for being developed and approximately the other 80% for being maintained across the years for creating and maintaining 'value' for its customers and users. Figure 3 shows what a project scope should be, representing 'virtual barriers also in well-known maturity & capability models (MCM) as CMMI, where 16 out of 22 processes are quite the same comparing the 'DEV' and the 'SVC' constellations. Figure 3 overlaps a further concept that is 'maintenance': ISO 14764 [7] proposed such two-levels taxonomy with four types (corrective, preventive, adaptive, perfective), some of them more affording into the 'DEV' side, some others more in the 'SVC', that would express the enhancements for that project [5].

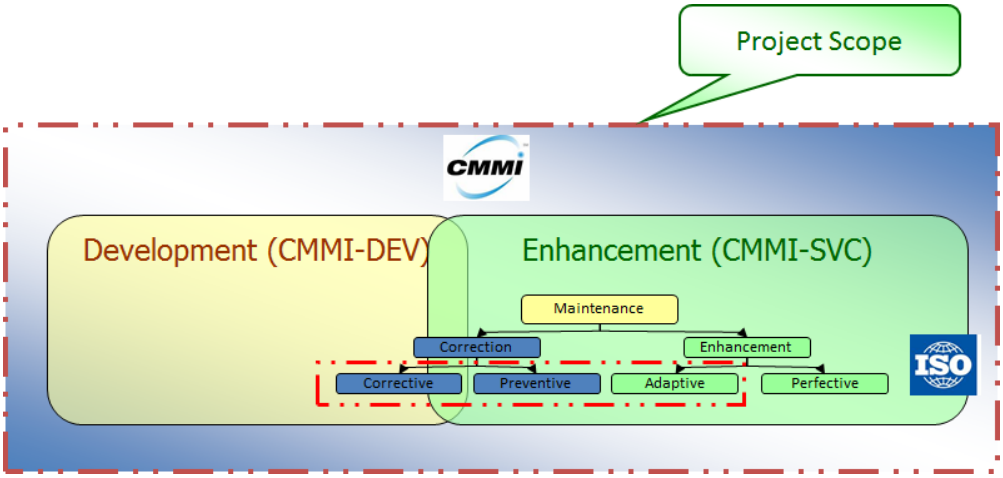


Fig. 3 – The (real) project scope and the DEV/SVC integration into a project 'continuum'

In the industrial world many SIOs decides to have a DEV team and separately another SVC team for the operational phase, not looking to the 'continuum' of such entity (the project) along its lifetime. In this way, the concrete risk is to do not manage a project in an efficient and effective way.
And a concrete risk is the way projects are managed from the contractual viewpoint. Often SIOs are dealing with contracts paid by a cost per functional size unit (*fsu*) – whatever the FSM method applied – the risk is that some 'zero FP' activities needing some working hours or days would not be paid and therefore the next 'planning game' between a provider and its customer will fail more and more. The provider will progressively reduce the attention on providing a sufficient 'quality' level for its project outcomes (since not properly paid), where 'quality' means NFRs plus 'user perception' and the customer reaction in the next contract will be to lower prices using the same contractual 'money' (using a *fsu* as a 'project size', while a whatever 'fsu' is only a sizing unit for the software product for its functional side, not for any kind of project outcome agreed between parts). As in the EAM (Entity-Attribute-Measure) analysis [6], each measure can describe only one attribute for a measurable entity at a time.

E – Entity	(software) **product**	(software) **product**	(software) **project**
A – Attribute	Code Length	Functionality	Time Progress
M - Measure	**Lines of Code**	**Function Point**	**% burned effort**

Table 1 – EAM classification: Function Points and LOC

Thus, this would explain in a very simple and effective way the coverage level for a measurement plan and that a linear correlation between measures for the same entity should not be assumed (e.g. the 'backfiring' conversion of LOCs into FPs – adding LOCs to a module not necessarily will correspond to more functionalities, that's the reason why Albrecht was asked to create a new method for sizing software applications [8]. Thus, what about most interesting attributes for a service project?

3. How to represent and measure the project value?

The project is not its product(s): we can use product measures for managing it, but looking to the whole value chain and considering measuring also organizational *assets* (meant as the summation of resources and their own capabilities), not only products/outcomes. Instead of 'reinventing the wheel', it could be better to look to well-known solutions, scalable to the level of complexity of your own organization, as well as a Balanced Scorecard (BSC). As in Figure 4, several measures and KPIs have been yet explored and are used for the Financial, Customer and Internal Process perspectives,

but very few on the 'Learning & Growth' one, that can be split in two separate sub-perspectives: Innovation & Infrastructure and People [9][13].

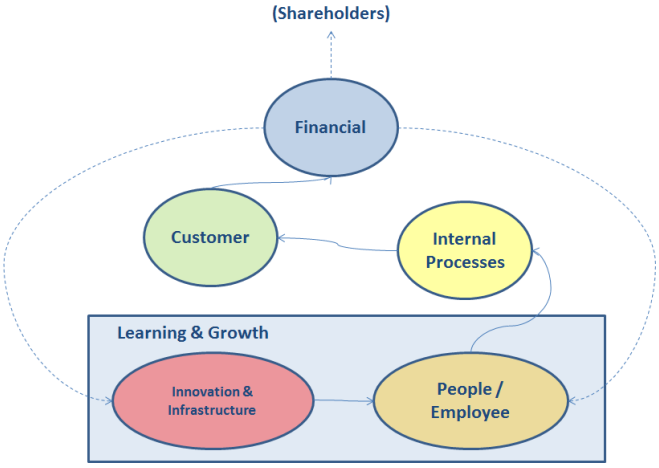
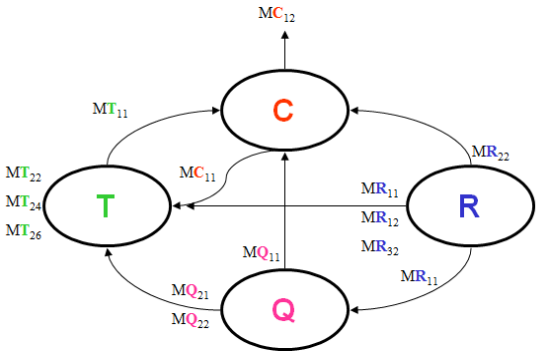


Fig. 4 – The BSC perspectives (L&G split in two)

Rotating the BSC schema 90° right, you would obtain the well-known Porter's Value Chain 0: thus the earlier drivers are the ones often where value could be exploited more and better, as it would be a sort of 'waterfall' cycle. A sort of unexplored zone is the 'people' related one and a plenty of good suggestions could come from books [11] or technical guides [12], leading to understand that the working time cannot deal only with PCs and computers, but mostly with people and its motivations and way to work within a SIO. Users' perceptions are more and more important for rating the overall project value and taking corrective/improvement actions. But often they are wrongly managed in measurement terms. Figure 5 shows a typical rating on Amazon.com for a book with two different results and potential perception on that book. The 4.7 average value calculated on 68 reviews could not necessarily match with the percentage distribution of the Likert-scale adopted: using a mean average, a 5-stars review would weight more than a 1-star review. Again, using an odd (and not a pair) ordinal scale could address a reviewer in rating the central value. Since perception is what arrives first, many people will look before to the stars rating (on the left) and will forget the percentage distribution (on the right). Supposing to have a balanced distribution of ratings between 1 and 5, a manager would be addressed to do not take any action, since the average value would be perceived mostly as 'not bad', even if several 1 or 2-stars ratings could have been perceived. The same would happen daily looking at the same measurement mechanism in any service rating, from booking an hotel on Expedia or rating a restaurant by TripAdvisor.

Fig. 5 – Dealing with User Satisfaction: right or wrong measurement?

Again, another way to keep value for all the project's stakeholders is to properly monitor it using a reasonable number of measures by viewpoint/perspective (e.g. C: Cost; T:Time; Q:Quality; R:Risk) and use not only a base measure for its own informative inner value, but also in conjunction with other ones, returning more information (e.g. whatever kind of productivity calculation is a ratio between a size unit for products/services and its related working time).



Time	• MT_{11} – Milestone Dates • MT_{22} – Problem Report Status • MT_{24} – Change Request Status • MT_{26} – Test Status
Cost	• MC_{11} – Earned Value • MC_{12} – Cost
Quality	• MQ_{11} – Defects • MQ_{21} – Defect Containment • MQ_{22} – Rework
Risk	• MR_{11} – Staff Experience • MR_{12} – Staff Turnover • MR_{22} – Functional Change Workload • MR_{32} – Resource Utilization

Fig. 6 – The Balancing Multiple Perspectives (BMP) approach 0

BMP (Balancing Multiple Perspective) [16] is a technique reinforcing what the generic BSC schema could ask to measure in a Strategy Map moving from each of the interesting drivers. BMP would address also another related goal: a plan of measure is not a measurement plan and the SIOs historical data are fundamental to improve estimates. Different sources but the same message: for instance, the ISO 15939 standard [17] stresses such request with the MEB (Measurement Experience Base) concept, while in the Service domain, ITIL speaks of a SKMS (Service Knowledge Management System) using the four KM (Knowledge Management) waves as the visual idea to describe the logical measurement flow in any organization (data, information, knowledge, wisdom).

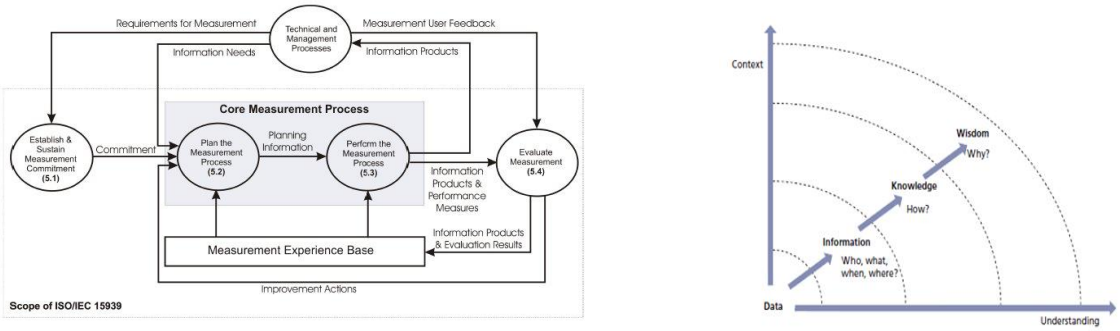


Fig. 7 – ISO 15939 process (*left*) and the ITIL four KM waves (*right*)

Moving from data to wisdom could be the way a 'big data' or an immature SIO could work (gathering useless data has a cost anyway), while moving from wisdom to data could be the way a 'smart data' approach or an more mature SIO could work (think before to what it is really need, applying the 5W+2H approach: who, what, why, where, when, how, and last not least, how much).

4. Conclusions and Next Steps

'*You cannot control what you cannot measure*' [18], but you cannot measure what you cannot define and finally you cannot define what you cannot know. The KM/HR driver could be one of the first sources of data/information for many SIOs to explore in order to measure the earlier drivers in the organizational value chain, allowing exploiting better results and creating and sustaining value to customers and its users. A user is not necessarily its customer (the so-called business) and a project contains more and more a series of non-software based deliverables. Exploring and designing more the 'quality in use' side of any service (IT or not IT related) becomes vital for the project sustainability over time, reducing the high rate of project failures, as in many business reports/statistics available on the web.

"*Price is what you pay. Value is what you get.*"
Warren Buffet (Businessman, 1930-)

References

[1] Kurleto M., Software-as-a-Service or Service-as-a-Software, 21/01/2016, URL: https://goo.gl/ijjVSG

[2] Axelos, ITIL Glossary and Abbreviations, 2011, URL: https://goo.gl/6tkdvp

[3] Axelos, ITIL v3 2011: Service Strategy, 2011, URL: https://goo.gl/Ya9CKh

[4] ISO/IEC, IS 25010:2011: Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- System and software quality models

[5] Buglione L., Abran A., von Wangenheim C.G., Caffery F.M., Hauck J.C.R. (2015) Software or Service? That's the Question!, In: Kobyliński A., Czarnacka-Chrobot B., Świerczek J. (eds) Software Measurement. Lecture Notes in Business Information Processing, vol 230. Springer, Cham, pp.30-45, URL: https://goo.gl/rfYzuS

[6] Buglione L., Ebert C., Estimation, Encyclopedia of Software Engineering, Taylor & Francis Publisher, June 2012, ISBN: 978-1-4200-5977-9

[7] ISO/IEC, IS 14764:2006 - Software Engineering -- Software Life Cycle Processes – Maintenance

[8] Albrecht A., Measuring Application Development Productivity, Proceedings of the IBM Applications Development Symp., Monterey, CA (USA), Oct.14-17, 1979, URL: https://goo.gl/rNjj9M

[9] Reo D., Quintano N. & Buglione L., ESI Balanced IT Scorecard Infrastructure & Innovation Perspective, ESI-1999-TR-043, December 1999

[10] Porter M.E., Competitive Advantage: Creating and Sustaining Superior Performance, Free Press, 1998

[11] Demarco T., Lister T., Peopleware: Productive Projects and Teams, 3rd Ed., 2013, Addison-Wesley

[12] Curtis B., Hefley B., Miller S., People Capability Maturity Model (P-CMM), v2.0, July 2009, Technical Report, CMU/SEI-2009-TR-003, URL: https://goo.gl/qwrNde

[13] Buglione L., Abran A. & Meli R., How Functional Size Measurement supports the Balanced Scorecard framework for ICT, FESMA-DASMA 2001 (4th European Conference on Software Measurement and ICT Control), Heidelberg, Germany, May 8-11, 2001, pp. 259-272, URL: https://goo.gl/fq6MiJ

[14] Version One, 10th Annual State of Agile Report, 2016, URL: https://goo.gl/tBmUHz

[15] Standish Group, Factors of Value Research Report, URL: https://www.standishgroup.com

[16]Buglione L. & Abran A., Multidimensional Project Management Tracking & Control - Related Measurement Issues, Proceedings of SMEF 2005, Software Measurement European Forum, 16-18 March 2005, Rome (Italy), pp. 205-214, URL: https://goo.gl/80YQt1

[17] ISO/IEC, IS 15939:2007 - Systems and software engineering -- Measurement process

[18] Demarco T., Controlling Software Projects: Management, Measurement, and Estimates. Prentice Hall, 1986

Heidrich, J.; Vogelezang, F.:

IWSM/Mensura 2016

Joined Conference of the 26th International Workshop on Software Measurement (IWSM) and the 11th International Conference on Software Process and Product Measurement (Mensura), IEEE Computer Society, CPS, http://www.computer.org/cps, 2016

This proceedings are available at the IEEE online publishing service.

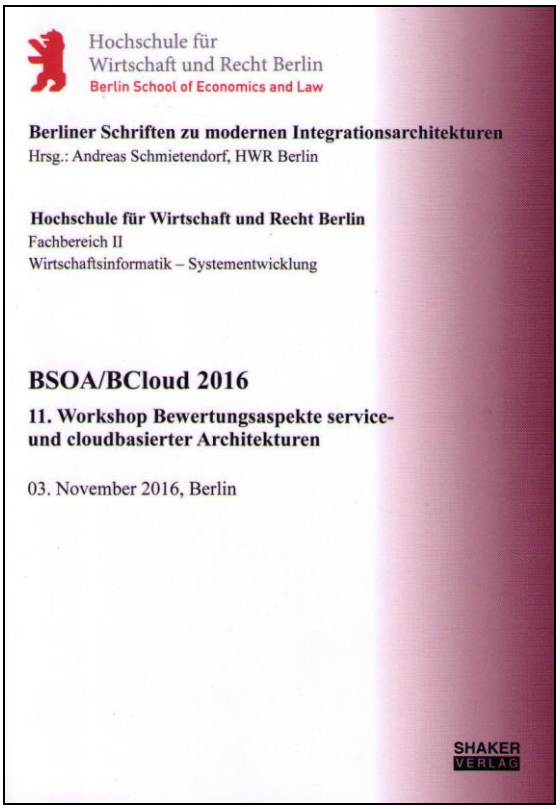
Schmietendorf, A.; Simon, F.:

BSOA/BCloud 2016

11. Workshop Bewertungsaspekte serviceorientierter Architekturen
3. November 2016, Berlin

Shaker Verlag, Aachen, 2016 (112 Seiten), ISBN 978-3-8440-2108-0

The book includes the proceedings of the BSOA/BCloud 2016 held in Berlin in November 2015, which constitute a collection of theoretical studies in the field of measurement and evaluation of service oriented and cloud architectures.

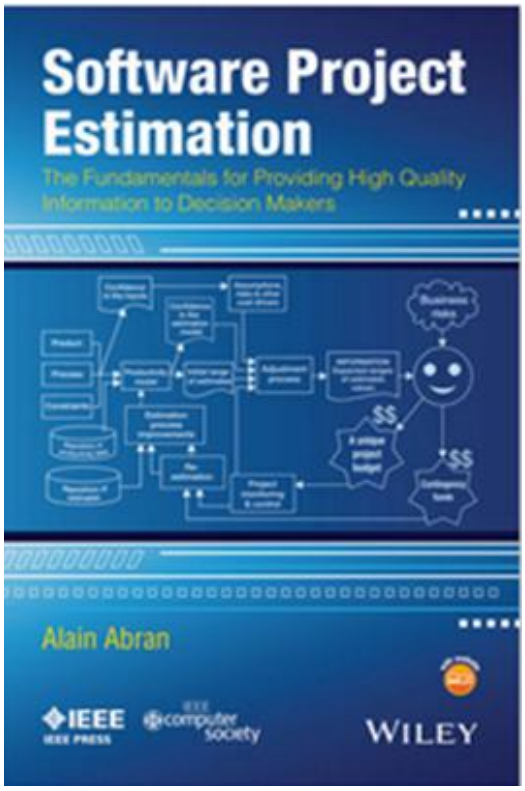


Abran, A.:

Software Project Estimation: The Fundamentals for Providing

High Quality Information to Decision Makers

Wiley IEEE Computer Society Press, 2015 (288 pages), ISBN 978-1-118-95408-9



This book introduces theoretical concepts to explain the fundamentals of the design and evaluation of software estimation models. It provides software professionals with vital information on the best software management software out there.

- End-of-chapter exercises
- Over 100 figures illustrating the concepts presented throughout the book
- Examples incorporated with industry data

Seufert, M.; Ebert, C, Fehlmann, T.; Pechlivanidis, S.; Dumke, R. R.:

MetriKon 2015 - Praxis der Softwaremessung

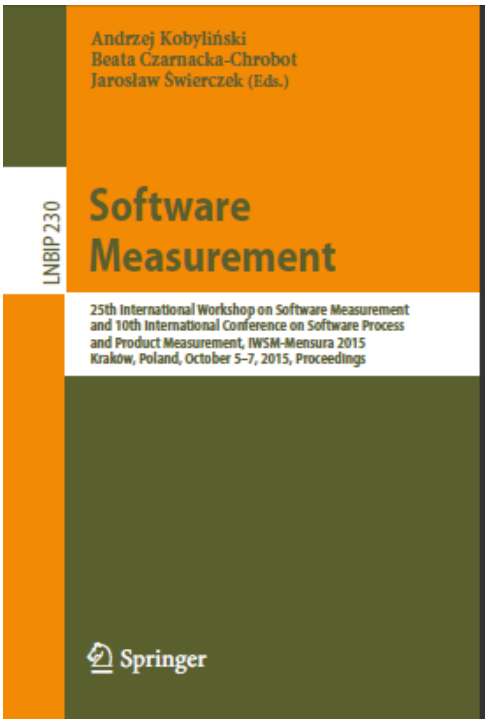
Tagungsband des DASMA Software Metrik Kongresses
5. - 6. November 2015, IBM, Köln

Shaker Verlag, Aachen, 2015 (272 Seiten)

The book includes the proceedings of the MetriKon 2015 held in Cologne in November 2015, which constitute a collection of theoretical studies in the field of software measurement and case reports on the application of software metrics in companies and universities.

Andrzej Kobylinski, Beata Czarnacka-Chrobot, Jaroslaw Swierczek

IWSM/Mensura 2015



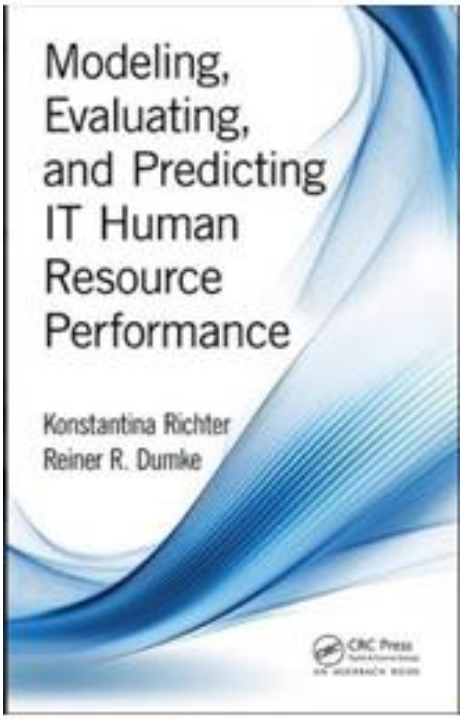
25th International Workshop on Software Measurement and 10th International Conference on Software Process and Product Measurement, Krakow, Poland, October 5-7, 2015

This book includes some chosen papers of the measurement conference in the LNBP Springer seiries.

Konstantina Richter, Reiner Dumke:

Modeling, Evaluating and Predicting IT Human Resource Performance

CRC Press, Boca Raton, Florida, 2015 (275 pages)



This book explains why it is essential to account for the human factor when determining the various risks in the software engineering process. The book presents an IT human resources evaluation approach that is rooted in existing research and describes how to enhance current approaches through strict use of software measurement and statistical principles and criteria.

Schmietendorf, A. (Hrsg.):

Eine praxisorientierte Bewertung von Architekturen und Techniken für Big Data

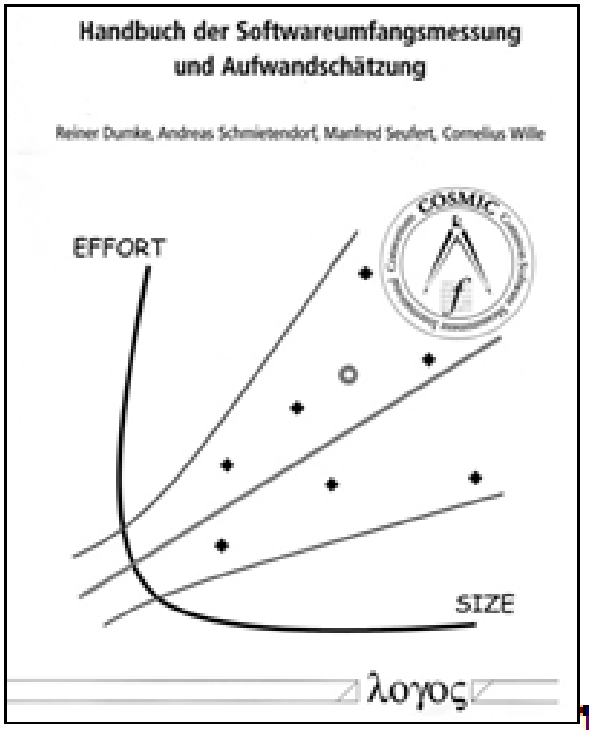
(110 Seiten) Shaker-Verlag Aachen, März 2015 ISBN 978-3-8440-2939-0

This book describes the system aspects of Big Data software infrastructures form a industrial/ practical point of view.

Dumke, R., Schmietendorf, A., Seufert, M., Wille, C.:

Handbuch der Softwareumfangsmessung und Aufwandschätzung

Logos Verlag, Berlin, 2014 (570 Seiten), ISBN 978-3-8325-3784-5



This book shows an overview about the current software size measurement and estimation approaches and methods. The essential part in this book gives a complete description of the COSMIC measurement method, their application for different systems like embedded and business software and their use for cost and effort estimation based on this modern ISO size measurement standard.

Software Measurement & Data Analysis Addressed Conferences

January 2017

SWQD 2017:
Software Quality Days
January 17-20, 2017, Vienna, Austria
see: https://2017.software-quality-days.com/

February 2017

ICSEFM 2017:
19th International Conference on Software Engineering and Formal Methods
February 2 - 3, 2017, Melbourne, Australia
see: https://www.waset.org/conference/2017/02/melbourne/ICSEFM

ISEC 2017:
9th Innovation in Software Engineering Conference
February 5 - 7, 2017, Jaipur, India
see: http://isec2017.in/

Big Data Car Cata 2017:
Automobilwoche Konferenz
February 15, 2017, Munich, Germany
see: http://www.automobilwoche-konferenz.de/

March 2017

REFSQ 2017:
22th International Working Conference on Requirements Engineering: Foundation for Software Quality
February 27- March 2,, 2017, Essen, Germany
see: https://refsq.org/2017/welcome/

ISMA 2017:
13th ISMA Conference of the IFPUG
March 5 - 7, 2017, Mumbai, India
see: http://www.ifpug.org/?lang=de

ICDSE 2017:
International Conference on Data Science and Engineering
March 11 - 12, 2017, Dubai, UAE
see: https://www.waset.org/conference/2017/03/dubai/ICDSE

ICST 2017:
10th International Conference on Software Testing, Verification & Validation
March 13 - 17 , 2017, Tokyo, Japan
see: http://aster.or.jp/conference/icst2017/

April 2017

ICSA 2017:	**12th International Conference on Software Architecture** April 5 - 7, 2017, Gothenburg, Sweden see: http://icsa-conferences.org/2017/
BigDataService 2017:	**IEEE BigDataService 2017** April 6 - 8, 2017, San Francisco, CA, USA see: http://big-dataservice.net/
FASE 2017:	**20th International Conference on Fundamental Approaches to Software Engineering** April 22 - 29, 2017, Uppsala, Sweden see: http://www.etaps.org/index.php/2017/fase
ICPE 2017:	**8th ACM/SPEC International Conference on Performance Engineering** April 22-26, 2017, L'Aquila, Italy see: https://icpe2017.spec.org/
WOSP 2017:	**Third Workshop on Challenges in Performance Methods for Software Development** April 22, 2017, L'Aquila, Italy see: https://wosp-c.spec.org/
SOFTENG 2017:	**International Conference on Advances and Trends in Software Engineering** April 23 - 27, 2017, Venice, Italy see: https://www.iaria.org/conferences2017/SOFTENG17.html
ICAMDS 2017:	**International Conference on Applied Mathematics and Data Science** April 27-28, 2017, Xi'an, China see: http://www.icamds.com/
iqnite 2017:	**Software Quality Conference** April 24 26, 2017, Düsseldorf, Germany see: https://www.iqnite-conferences.com/de/
CeCMG 2017:	**Enterprise Computing Conference** April 26 - 27, 2017, Berlin, Germany see: http://www.cecmg.de/
ENASE 2017:	**11th International Conference on Evaluation of Novel Approaches to Software Engineering** April 28 - 29, 2017, Porto, Portugal see: http://www.enase.org/

May 2017

ASQ 2017:	**International Conference on Quality and Improvement (ASQ)** May 1 - 3, 2017, Charlotte, NC, USA see: https://asq.org/wcqi/index.aspx
EMEA 2017:	**PMI Global Congress 2017 - EMEA** May 1 - 3, 2017, Rome, Italy see: http://congresses.pmi.org/emea2017
STAREAST 2017:	**Software Testing Analysis & Review Conference** May 7 - 12, 2017, Orlando, FL, USA see: http://stareast.techwell.com/
eMetrics 2017:	**eMetrics Summit** May 15 - 18, 2017, San Francisco, USA see: https://www.emetrics.org/sanfrancisco/2017/
OSS 2017:	**International Conference on Open Source Systems** May 22 -23, 2017, Buenos Aires, Argentina see: http://oss2017.lifia.info.unlp.edu.ar/
ICSE 2017:	**38th International Conference on Software Engineering** May 20 - 28, 2017, Buenos Aires, Argentina see http://icse2017.gatech.edu/
MSR 2017:	**17th Working Conference on Mining Software Repositories** May 20 - 21, 2017, Buenos Aires, Argentina see: http://2017.msrconf.org/#/home
ICPC 2017:	**25th International Conference on Program Comprehension** May 22 - 23, 2017, Buenos Aires, Argentina see: http://icpc2017.unibas.it/
ODSC 2017:	**Open Data Science Conference East** May 3 - 5, 2017, Boston, USA see: https://www.odsc.com/boston
CIbSE 2017:	**20th Iberoamerican Conference on Software Engineering** May 22 - 23, 2017, Buenos Aires, Argentina see: http://cibseconference.org/
ECASE 2017:	**First International Workshop on Establishing a Community-Wide Infrastructure for Architecture-Based Software** May 20 - 28, 2017, Buenos Aires, Argentina see: http://design.se.rit.edu/ECASE/
ICGSE 2017:	**12th International Conference on Global Software Engineering** May 22 - 23, 2017, Buenos Aires, Argentina see: https://www.facebook.com/ICGSEconference/
XP 2017:	**18th International Conference on Agile Software Development** May 22-26, 2017, Cologne, Germany see: https://www.xp2017.org/

June 2017

SERA 2017:
15th ACIS Conference on Software Engineering Research, Management and Applications
June 7 - 9, 2017, London, UK
see: http://www.acisinternational.org/sera2017/

EJC 2017:
27th International Conference on Information Modeling and Knowledge Bases
June 5 - 9, 2017, Krabi, Thailand
see: http://www.tut.fi/en/ejc/ejc-2017/index.htm

ICWE 2017:
International Conference on Web Engineering
June 5 - 8, 2017, Rome, Italy
see: http://icwe2017.webengineering.org/

SPICE 2017:
16th International SPICE Conference
June 9 - 10, 2017, Dublin, Ireland
see: http://www.spiceconference.com/

EASE 2017:
20th International Conference on Empirical Assessment in Software Engineering
June 15 - 16, 2017, Karlskrona, Sweden
see: http://ease2017.bth.se/

VDA Automotive SYS Conference 2017:
Quality Management for Automotive Software-based Systems and Functionality
June 19 - 21, 2017, Berlin, Germany
see: http://vda-qmc.de/fileadmin/redakteur/Software/sys/Call_for_Presentations_Automotive_SYS_Conference_2017.pdf

ICSEA 2017:
19th International Conference on Software Engineering Advances
June 21 - 22, 2017, Vienna, Austria
see: https://www.waset.org/conference/2017/06/vienna/ICSEA

IMMM 2017:
International Conference on Advances in Information Mining and Management
June 25 - 29, 2017, Venice, Italy
see: https://www.iaria.org/conferences2017/IMMM17.html

ICWS 2017:
IEEE 24th International Conference on Web Services
June 25 - 30, 2017, Hawaii, USA
see: http://icws.org/2017/

CLOUD 2017:
IEEE 10th International Conference on Cloud Computing
June 25 - 30, 2017, Hawaii, USA
see: http://www.thecloudcomputing.org/2017/

SERVICES 2017:
IEEE 13th World Congress on Services
June 25 - 30, 2017, Hawaii, USA
see: http://www.servicescongress.org/2017/

July 2017

LNCS 2017:	**Eight International Symposium on Software Quality** July 3 - 6, 2017, Trieste, Italy see: http://sq.covenantuniversity.edu.ng/?utm_source=researchbib
SAM Summit 2017:	**Conference on Software Asset Management** July, 10 - 12, 2017, Chicago, USA see: http://www.ecpmedia.com/samsummit.html
ICDM 2017:	**IEEE International Conference on Data Mining** July 12 - 16, 2017, New York, USA see: http://www.data-mining-forum.de/
SERP 2017:	**15th International Conference on Software Engineering Research and Practice** July 17 - 20, 2017, Las Vegas, Nevada, USA see: http://americancse.org/events/csce2017/conferences/serp17
DMIN'17:	**12th International Conference on Data Mining** July 17 - 20, Las Vegas, USA see: http://americancse.org/events/csce2017/conferences/dmin17
ICOMP'17:	**18th International Conference on Internet Computing and internet of Things** July 17 - 20, Las Vegas, USA See: http://americancse.org/events/csce2017/conferences/icomp17
ABDA'17:	**4th International Conference on Advances in Big Data** July 17 - 20, Las Vegas, USA see: http://americancse.org/events/csce2017/conferences/abda17
EEE'17:	**4th International Conference on e-Learning, e-Business, Enterprise Information Systems, and e-Government** July 17 - 20, Las Vegas, USA see: http://americancse.org/events/csce2017/conferences/eee17
GCC'17:	**13th International Conference on Grind, Cloud, and Cluster Computing** July 17 - 20, Las Vegas, USA see: http://americancse.org/events/csce2017/conferences/gcc17
MCCSIS 2017:	**International Conference on Big Data Analytics, Data Mining and Computational Intelligence** July 21 - 23, 2017, Lisbon, Portugal see: http://bigdaci.org/
ICSOFT 2017:	**12th International Conference on Software and Data Technologies** July 24 - 26, 2017, Madrid, Spain see: http://www.icsoft.org/

August 2017

AGILE 2017:

Annual North American Agile Conference
August 7 - 11, 2017, Orlando, FL, USA
see: https://www.agilealliance.org/agile2017/

Euromicro DSD/ SEAA 2017:

Software Engineering & Advanced Application Conference
August 30 - September 1, 2017, Vienna, Austria
see: http://dsd-seaa2017.ocg.at/index.html

September 2017

ESEC/FSE 2017:

European Software Engineering Conference and **Symposium on the Foundation of Software Engineering**
September 3 - 8, 2017, Paderborn, Germany
see: http://esec-fse17.uni-paderborn.de/

QEST 2017:

14th International Conference on Quantitative Evaluation of Systems
September 5 - 7, 2017, Berlin, Germany
see: http://www.qest.org/qest2017/

RE 2017:

24th IEEE International Requirement Engineering Conference
September 4 - 8, 2017, Lisbon, Portugal
see: http://re2017.org/

EuroAsiaSPI^2 2017:

24th European Systems & Software Process Improvement and Innovation Conference,
September 5 - 8, 2017, Ostrava, Czech Republic
see: http://2017.eurospi.net/

Big Data 2017:

Big Data Analysis and Data Mining
September 7 - 8, 2017, Paris, France
see: http://datamining.conferenceseries.com/

October 2017

ODSC 2017:
Open Data science Conference Europe
October 13 - 14, 2017, London, UK
see: https://www.odsc.com/london

IWSM-MENSURA 2017:
Common International Conference on Software Measurement
October 24 - 26, 2017, Gothenburg, Sweden
see: http://www.iwsm-mensura.org/

ASE 2017:
Automated Software Engineering
October 30 - November 4, 2017, Urbana-Champain, Illinois
see: http://www.ase2017.org/

November 2017

CSEE&T 2017:
30th Conference on Software Engineering Education and Training
November 7 - 9, 2017, Savannah, Georgia
see: http://www.cseet2017.com/index.html

BSOA/BCloud 2017:
12. Workshop Bewertungsaspekte Service-orientierter und Cloud-Architekturen
November, 2017, Berlin, Germany
see: http://www-ivs.cs.uni-magdeburg.de/~gi-bsoa/

ASQT 2017:
Arbeitskonferenz Softwarequalität, Test und Innovation
November 9 - 10, 2017, Graz, Austria
see: http://www.asqt.org/

ESEM 2017:
11th International Symposium on Empirical Software Engineering & Measurement
November 9 - 10, 2017, Toronto, Canada
see: https://sravyapolisetty.github.io/ESEM/cfp.html

December 2017

PROFES 2017:
International Conference on Product Focused Software Process Improvement
November 29 - December 1, 2017, Innsbruck, Austria
see http://www.profes-conferences.org/

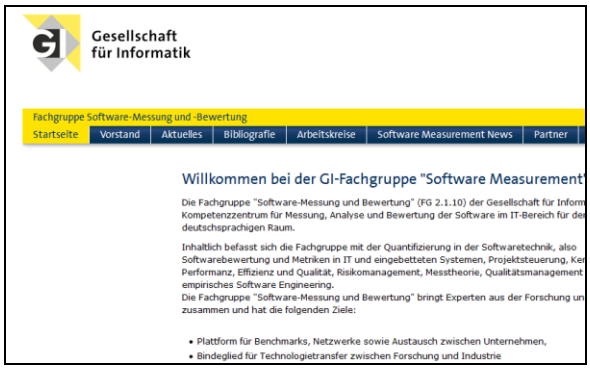
see also: Conferences Link of **Luigi Buglione (**http://www.semq.eu/leng/eveprospi.htm**)**

COMMUNITIES

GI-Fachgruppe Software-Messung und Bewertung

http://fg-metriken.gi.de/

(Measurement News Online)



Common Software Measurement International Consortium

http://cosmic-sizing.org

Deutschsprachige Anwender-gemeinschaft für Software-Metrik und Aufwandschätzung

http://www.dasma.org

International Software Bench-marking Standard Group (ISBSG)

https://www.isbsg.org

Central Europe Computer Measurement Group (ceCMG)

http://www.cecmg.de

Metrics Association's International Network (MAIN)

http://*www.mai-net.org*

Finnish Software Measurement Association (FISMA)

http://www.fisma.fi/in-english/

Netherlands Software Metrics users Association (NESMA)

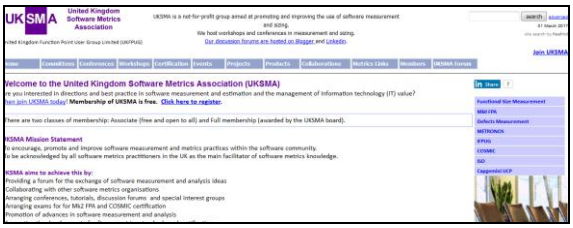
http://www.nesma.org/

Asociacion Espanola de Metricas de Software

http://www.aemes.org/

United Kongdom Software Metrics Association (UKSMA)

http://www.uksma.co.uk



Gruppo Utenti Function Point Italia - Italian Software Metrics Association (GUFPI - ISMA)

http://www.gufpi-isma.org

Anwenderkonferenz Software-qualität und Test (ASQT)

http://www.asqt.org

MEASUREMENT SERVICES

Software Measurement Laboratory (SML@b)

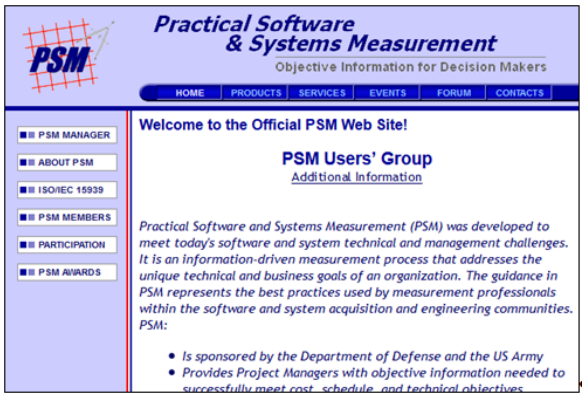
http://141.44.17.27/cms/index.php/en/home/forschung/106-smlab

International Function Point Users Group (IFPUG)

http:www.ifpug.org

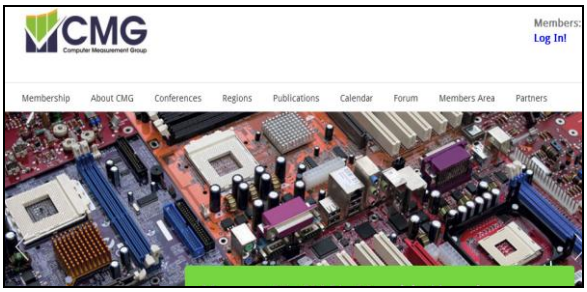
Practical Software & Systems Measurement

www.psmsc.com/:



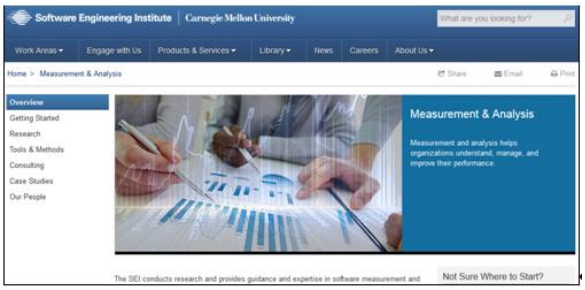
Computer Measurement Group (CMG)

http://www.cmg.org



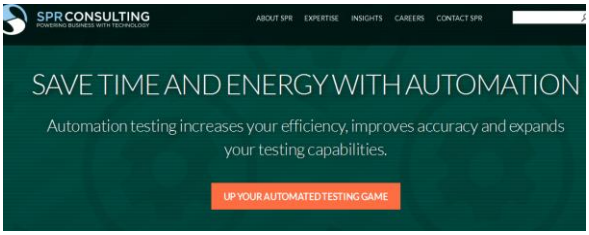
Software Engineering Institute (SEI)

www.sei.cmu.edu/measurement/



Software Productivity Research (SPR)

•*http://www.spr.com/*



McCabe & Associates

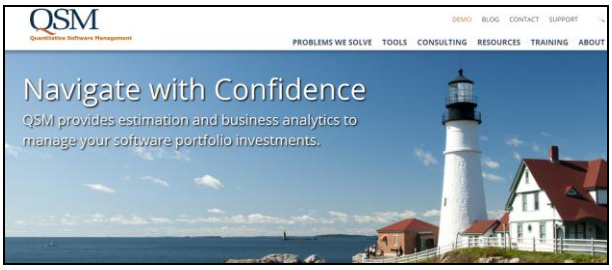
http://www.mccabe.com

SQS Gesellschaft für Software-Qualitätssicherung

http://www.sqs.de

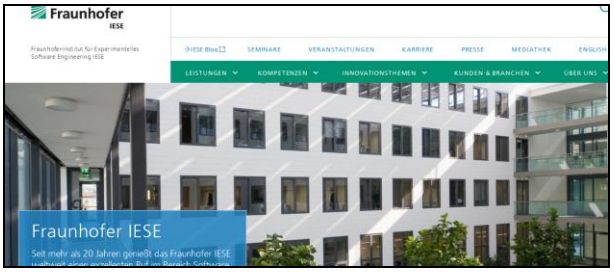
Quantitative Software Management

http://www.qsm.com/



Fraunhofer Institute for Experimental Software Engineering (IESE)

https://www.iese.fraunhofer.de/



National Institute of Standards and Technology (NIST)

https://www.nist.gov/el

SOFTWARE MEASUREMENT INFORMATION

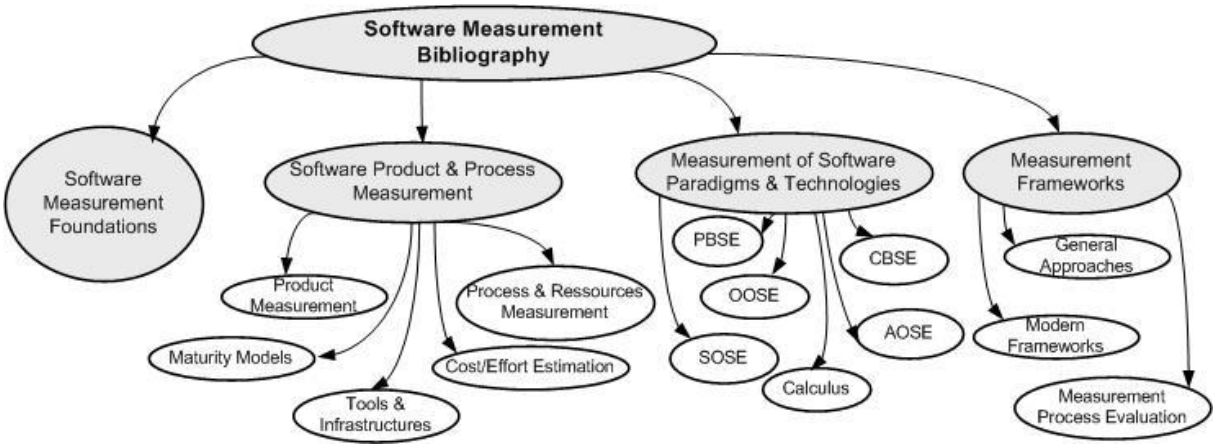
Software Measurement Bibliography

See our overview about software metrics and measurement in the Bibliography at

http://fg-metriken.gi.de/bibliografie.html

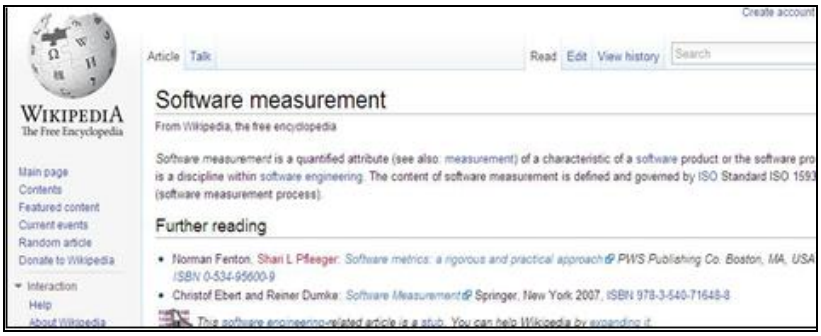
including any hundreds of books and papers

Bibliography Structure:



Software Measurement & Wikipedia

Help to qualify the software measurement knowledge and intentions in the world wide web:



Software Engineering Body of Knowledge (SWEBOK)

http://*www.swebok.orgI*

Project Management Body of Knowledge (PMBOK)

http://www.pmbook.org

SOFTWARE MEASUREMENT NEWS

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