Usability evaluation for Business Intelligence applications: A user support perspective

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ABSTRACT

Business Intelligence (BI) applications provide business information to drive decision support. Usability is one of the factors determining the optimal use and eventual benefit derived from BI applications. The documented need for more BI usability research together with the practical necessity for BI evaluation guidelines in the mining industry provides the rationale for this study. The purpose of the study was to investigate the usability evaluation of BI applications in the context of a coal mining organization. The research is guided by the question: How can the existing usability criteria be customized to evaluate the usability of BI applications? The research design included user observation, heuristic evaluation and a survey. Based on observations made during user support on a BI application used at a coal mining organization a log of usability issues was compiled. The usability issues extracted from this log were compared and contrasted with general usability criteria from literature to synthesize an initial set of BI usability evaluation criteria. These criteria were used as the basis for a heuristic evaluation of the BI application used at the coal mining organization. The same BI application was also evaluated using the Software Usability Measurement Inventory (SUMI) standardized questionnaire. The results from the two evaluations were triangulated and then compared with the BI user issues again to contextualize the findings and synthesize a validated and refined set of criteria. The main contribution of the study is the usability evaluation criteria for BI applications presented as guidelines. These BI guidelines deviate from existing usability evaluation guidelines in that it emphasises the aspects of information architecture, learnability and operability.

KEYWORDS: Business intelligence, usability criteria, heuristic evaluation, decision support

CATEGORIES: H.5.2

1 INTRODUCTION

The purpose of Business Intelligence (BI) is to support managing the massive stocks and flows of business information around and within the organisation by firstly identifying and secondly processing the information into condensed and useful managerial knowledge and intelligence [1]. BI applications are consulted to obtain information that assist in making business decisions and to support a deeper understanding of the business and its driving forces. The benefits that can be derived from the use of BI applications include effectiveness [2]], i.e., faster and easier access to information, savings in information technology (IT) costs, greater customer satisfaction and improved competitiveness of enterprises [3]. The value of BI is determined by measuring the efficiency of BI personnel, effective allocation of available resources, quality of BI products [1] and user satisfaction [1] [4]. There is evidence that BI usability has not been well researched [5] [6] and more recent studies on the evaluation of BI fall short of mentioning usability as an attribute of BI applications [7] [8] [9] [10]. Furthermore, mobile interfaces, visualization, and human–computer interaction (HCI) design have been identified as promising research areas in the Web 3.0 era [6]. The context for the study is a coal mining organisation in the Mpumalanga province of South Africa. The primary researcher is an employee of the organization responsible for user support on the BI application namely Cognos7 Upfront [11]. In this role of providing BI support the researcher became aware of significant usability problems experienced by the users of the BI system.

To get an understanding of the extent of the problem the user support queries were logged and analysed to extract usability issues. The usability issues were then compared and contrasted with general usability principles from literature. This was done to synthesize an initial set of usability criteria for BI applications, since no specific BI Usability guidelines could be found in the research literature. The extracted criteria were used as the basis for a heuristic evaluation (HE) of the BI application used at the coal mining organisation. The usability of the BI application was also evaluated with a survey using the Software Usability Measurement Inventory (SUMI) standardised questionnaire

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[12]. The findings from the two evaluation methods (HE and SUMI) were compared and used to refine the initial set of guidelines for the usability evaluation of BI applications. Interaction design and usability research reinforces the mantra that we should look at user's behaviour rather that listen to what they say and what they say they do [13]. This justifies the deeper analysis of the user log to refine the guidelines published previously as part of this study [14].

The remainder of the paper is organized as follows. In Section 2 the relevant literature is reviewed, in Section 3 the research design is explained, in Section 4 the results and findings are presented with the discussion in Section 5. The paper concludes in Section 6.

2 BACKGROUND

2.1 Business Intelligence

In the current era of abundant data, it is accepted as implicit that data-driven decisions are the norm [10]. Decision support systems (DSS) can be defined as support for and improvement of managerial decision-making. This is achieved by means of collecting, storing and managing data to generate information for the sake of decision-making [15] [16]. Lin [17] defines BI as a tool used by enterprises to collect, manage and analyse structural and non-structural data and information by taking advantage of modern information technology (IT). The term BI denotes the integrated infrastructures used for management support. BI also encompasses components for data transformation (extraction, transformation, loading), data storage (data warehouses, data-marts, and/or operational data stores), and data analysis [18] [19] [20].

BI applications typically support querying, reporting, and multidimensional analysis of company data [18] [19] [21]. BI applications can be considered a performance management framework that help companies set goals, analyse progress, gain insight, take action, and measure success [21] [22] [23]. Gangadharan and Swamy [24] states that BI is a description of the result of an in-depth analysis of detailed business data that includes database and application technologies, as well as analysis practices. They furthermore argue that the scope of BI potentially encompasses knowledge management, enterprise resource planning, DSSs and data mining. According to Sahay and Ranjan [25] experts hold different views about BI. For example, data warehousing experts view BI as a technology platform for decision support whereas data mining experts include mining techniques and algorithms. Statisticians, on the other hand, view BI as a forecasting and multidimensional analysis tool. Towards an integrative view, Gangadharan and Swamy [24] define BI as the use of technology to collect and effectively use information to improve business potency. For a DSS to be successful, managerial decision-making is critically dependent upon the availability of integrated, high quality information organized and presented in a timely and easily understood manner [6] [23] [26].

Based on the literature presented here the following working definition is selected for the purpose of the study: BI is a set of DSSs that allows tactical and operational decision-makers to direct their actions according to the company strategy, thereby establishing a performance management framework that helps companies set their goals, analyse their progress, gain insight, take action, and measure their success. The focus of this study is on the front-end user interface of the BI application.

2.2 Usability

A review of the usability literature produced a number of usability principles [27], standards [28], guidelines [29] and rules [30]. Usability principles are abstract design rules with high generality and low authority [31]. Rogers, Sharp & Preece [28] refer to guidelines as a general term used for all forms of guidance; rules, in turn, are described as the low-level guidance that refer to a particular prescription to be followed. Heuristics are described as a general term used to refer to design and usability principles when applied to a particular design problem. Therefore it follows that principles are on a higher level of abstraction followed by guidelines and standards on lower levels, with standards being the most specific.

Usability ensures that interactive products are easy to learn, effective to use and enjoyable from the user's perspective. This culminates in the goals of effectiveness, efficiency, safety, utility, learnability and memorability [28]. The measurement of usability depends on the users, their needs (goals) and the context - three variables that are inconsistent and unstable in themselves [32]. The focus of HCI research has evolved over time [33]. The task and work related usability paradigm that focus on the achievement of behavioural goals in work settings [34] has been expanded beyond the instrumental to the holistic, aesthetic and hedonic user experience (UX) paradigm [35]. For the purpose of this study the basic difference between usability and user experience is based on the ISO FDIS 9241-210 [36] and is stated as follows:

- Usability is the extent to which a system, product or service can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use.
- User experience involves the user's subjective perceptions and responses that result from the use and/or anticipated use of a product, system or service.

Due to the context of using a BI application in a coal mining organization the research design will focus on usability criteria because UX criteria are less concrete [37]. However, given the importance of user experience as a more holistic approach to the user's engagement with the interactive computing devices [35] every effort was made to capture user's subjective perceptions and responses.

2.2.1 Usability evaluation methods used

The two usability evaluation methods used in this research were heuristic evaluation (analytical method) and surveys (empirical method). Heuristic evaluation involves a small number of experts inspecting the system, and evaluating the user interface against a list of recognized usability principles, named the heuristics [38]. De Kock, van Biljon & Pretorius [39] highlight the advantages of this evaluation method as being inexpensive, intuitive and relatively easy to implement. Additional factors that were taken into consideration for selecting heuristic evaluation were a pragmatic research strategy and the appropriateness of heuristic evaluation within the specific context. BI applications are often used at a location outside of a usability laboratory and it is therefore more feasible for a few experts to travel to the BI application site than for users to interrupt their work and travel to a laboratory.

Questionnaire driven surveys are a well-established technique for collecting demographic data and users' opinions [40]. Considering the context and the maturity of the method, a survey was chosen as an empirical evaluation method. Effort and skill are needed to ensure that questions are clearly worded (unambiguous and to the point) and that data collected can be analysed efficiently [28]. In this study a standardised questionnaire was used to avoid the pitfalls of designing a questionnaire. The SUMI questionnaire was selected since it provides a standardised way of measuring overall usability [12] and maps to a subset of the BI usability issues identified (see detailed explanation on mapping in Section 4.1).

Other questionnaires considered were the System Usability Scale (SUS), the Usefulness, Satisfaction, and Ease of use (USE) and the Questionnaire for User Interface Satisfaction (QUIS). The SUMI questionnaire was selected for this study because of its standardized design as well as its ability to provide an independent statistical analysis.

2.3 Usability in Business Intelligence

The purpose of an BI application is to deliver the right information to the right person at the right time [41]. In an organizational context the BI application supports the analysis and application of captured information in order to make strategic, tactical and operational decisions. Muriithi and Kotzé [42] state that the adoption and use of BI systems within the enterprise remains low despite the potential benefits of an effective BI system. For optimal adoption, the user needs to be able to interact with the application in such a way that the business decision is not inhibited by an overly complex user interface. The importance of this aspect of user interaction is listed as a critical success factor in the implementation of BI systems in an organization [43]. The complexity of any interface must be sufficient to present the full scope of information, while keeping the data extraction process as simple as possible [32]. This highlights the importance of applying usability principles to the design of BI application interfaces. The modern business environment is characterized by complexity and high pressure to perform, this impacts negatively on the business analyst's ability to master the BI application interface [44]. Therefore the usability of the BI application is essential to business performance.

In a coal mining organisation the BI application needs to support the analysis of information captured in order to make timely strategic, tactical and operational decisions. To make informed decisions an integrated view by management requires that each business unit not only functions efficiently and effectively internally, but also understands how its activities and decisions impacts on the functions of other business units [45]. To support analysis and reporting tasks, the BI application should provide high quality data made accessible through intuitive interface technologies [46].

Many of the existing general usability criteria lists are oriented towards the design of the interface instead of assisting the performance of business activities [44]. It is therefore critical to build up sufficient knowledge and understanding of the context of use (the working environment) and this requires user involvement [9]. The fact that BI usability has not been adequately researched [7] [8] [9] [10] as discussed in Section 1 together with the lack of BI focused usability evaluation guidelines [44] provided the rationale for this study.

3 RESEARCH APPROACH

3.1 Context and research design

The research was executed at a mining organisation in the Mpumalanga province of South Africa. Information system users consult the IBM Cognos7 Upfront BI application [11] to gather information relevant to their tasks. The Cognos7 suite collates transactional data from the various Enterprise Resource Planning (ERP) site instances (11 collieries) into a consolidated data repository.

The research methods include indirect observation (during BI user support), expert evaluation (HE) and user based evaluation (SUMI survey). The research process flow is depicted in Figure 1 which depicts the numbered processes as follows:

- The literature review (1, 3)
- The observation of BI users (2, 4)
- Synthesis of usability evaluation criteria (5)
- Data collection method 1: user-based survey (6)
- Data collection method 2: expert-based HE (7)
- Survey findings (8)
- HE findings (9)
- Refined usability criteria (10)
- BI usability guidelines (11)

Note that the dotted line from the user issues (2) to the refined usability guidelines (11) indicates the process of revision based on the user perspective. The BI usability issues were identified through indirect user observation while the primary researcher was responsible for technical support on the application. The sample population was obtained from cube usage data

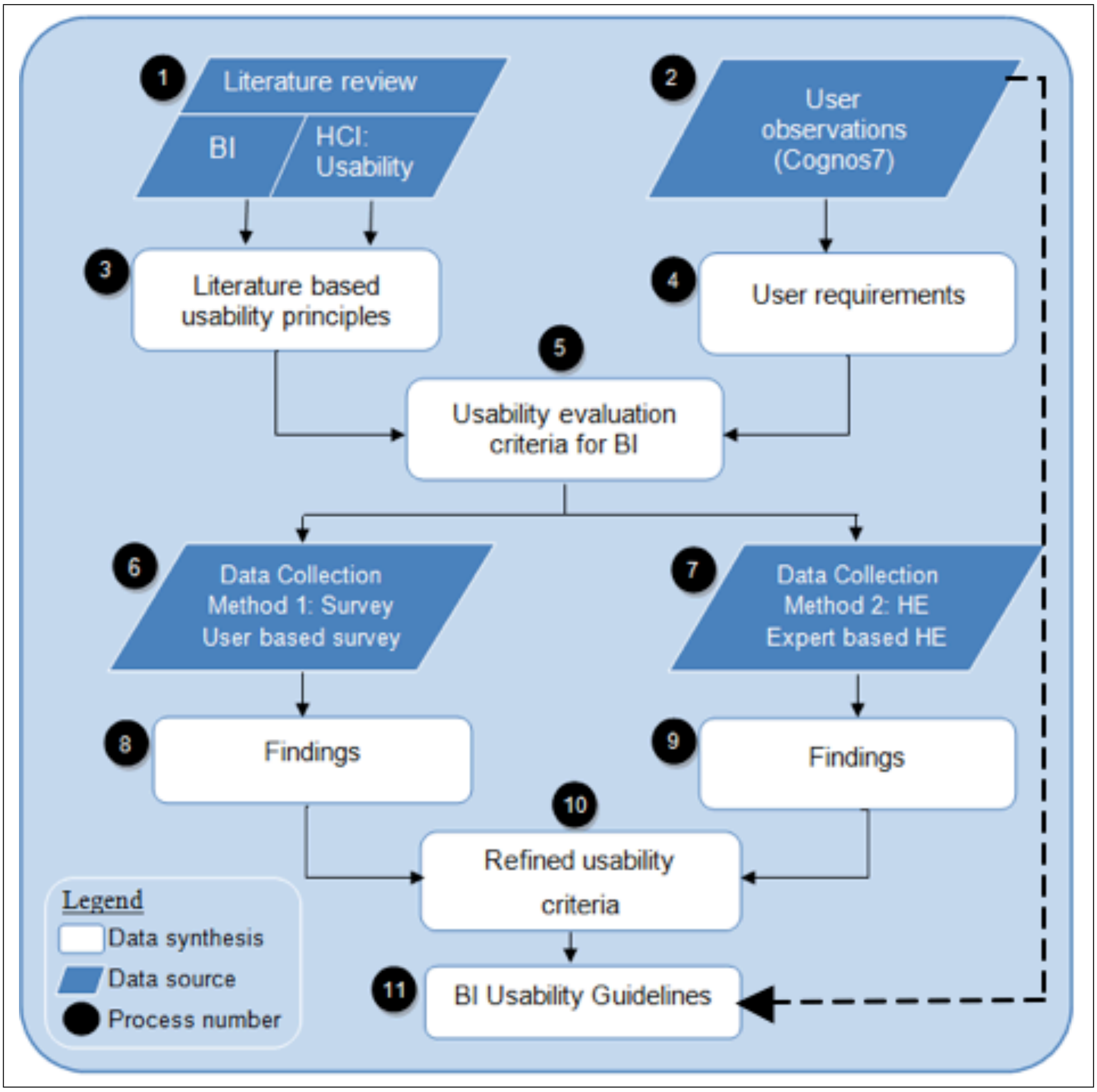

Figure 1: Research design process flow

to ensure all the participants did in fact make use of the application. The user issues identification started in 2010 and the data capturing was completed in 2012. Approval to conduct the study was obtained from the University of South Africa Ethical Clearance Committee.

The research instruments are the SUMI questionnaire used in the survey and the BI HE questionnaire developed by the researchers for this study. SUMI is a 50-item questionnaire for assessing the overall, perceived software-system usability. The SUMI questionnaire was developed by the Human Factors Research Group (HFRG) at the Cork University College [12].

4 RESULTS

4.1 Usability evaluation criteria for BI

From the literature review on usability and usability criteria a set of general usability criteria was synthesized from the ISO9241 standard as well as from usability researchers who proposed principles for evaluating usability namely Dix [47], Nielsen [29] and Tognazinni [48]. The ISO9241 standard and the seminal texts on usability informs guidelines that tend to focus on specific application areas, i.e., commerce [37] or learning [39], but none could be found for BI. From the sources mentioned above the following keywords were extracted as a basis for usability criteria: *User language, Visible instructions, Use of metaphors, Self-descriptiveness, Flexibility, Responsiveness, Controllability, Learnability, Efficiency, Familiarity, Predictability, Consistency, Error tolerance, Explore-able interface, Visible navigation, Customization, Task migration, Synthesizability, Help, Documentation, Satisfaction, System speed, System status display, Memorability, Colour blindness, Default values.*

These keywords were compared to, contrasted with and integrated with the user requirements derived from the researcher's log on usability problems to establish

Table 1: User-identified BI issues

Issue	Occurrence	Impact	Issue	Occurrence	Impact
Data access	61	M	Knowledge sharing	5	M
Training	27	L	Graphs	4	M
Data visibility	26	L	Links	4	L
Data calculations	11	M	Cube modifications	3	M
Data update	10	H	Data availability	3	H
Detail report	9	M	Data save	2	M
Additional data	7	H	Deletion	2	H
System speed	7	M	Data analysis	1	H
User discipline	7	H	Data format	1	L
Data display	6	L	Data incorrect	1	H
Data filter	6	L	KPI information	1	M
Data extraction	5	L			
Grand total			**209**		

an initial set of BI usability criteria. According to Albert and Tullis [40] the proper identification of usability issues should be based on an in-depth understanding of the product, keen observations of user behaviour and the ability to distinguish the real issues from false issues. As a BI support person the primary researcher met all three validity requirements in observing the users over a period of 18 months. The usability issues were identified based on frequency of occurrence and severity in terms of impact on the business goals and the user experience. Table 1 depicts the issues identified.

The list of user-identified BI usability requirements were determined as a result of the analysis of a log on usability issues mentioned by the observed BI application users. This list can be seen in Table 1. A user requirement was identified as a result of how frequently a specific request was listed in the usability issue log. The impact of a user requirement on the user's ability to complete a task was categorized as a severity impact factor of high (H), medium (M) or low (L). Note that 13 out of the 23 issues identified contain the word *data*, an aspect not directly addressed in any of the existing guidelines.

The usability issues from the researcher's log were mapped to the corresponding business intelligence attributes and usability principles to produce the synthesized user criteria presented in Table 4 (see Appendix). The mapping of the usability issues to usability criteria, the resulting evaluation criteria and the SUMI criteria are presented in Table 5 (see Appendix). The central criteria, i.e., common to all or relevant to BI, were extracted and used for the heuristic evaluation on Cognos7 (Upfront). Note that *knowledge sharing* and *decision support* have been added to the heuristic evaluation set proposed for BI evaluation.

The set of evaluation criteria is depicted in Column C of Table 5, as derived from Table 4. The SUMI questionnaire was selected since the SUMI criteria are a subset of the BI criteria. Note that the criteria *familiarity, predictability, consistency* and *satisfaction* were not included in the BI user issues column because users were not observed to have problems related to these criteria. Nevertheless, those are fundamental usability criteria and were included in the final set of criteria. The goal of the heuristic evaluation was to test the proposed set of BI usability criteria. The post-test survey was conducted as a control measure to triangulate with the findings of the heuristic evaluation. The aim of the triangulation was to confirm or reject the existing criteria and identify new criteria if necessary. The results from the heuristic evaluation are presented in Section 4.2, the results from the survey in Section 4.3 and the comparison of results in Section 4.4.

4.2 Heuristic evaluation

Four expert evaluators served as the sample for the heuristic evaluation. Three of the four expert usability evaluators that participated in this study have established themselves in the field of usability and are currently employed by the University of South Africa; the fourth usability expert that participated was obtained in-house from the researcher's organization. The sample consists of both genders and includes participants in their 30s, 40s, 50s and 60s. The individual scores of the heuristic evaluation evaluators are depicted in Table 2. A Global (mean) score of 50.7% was achieved for the application's usability taking all the category scores into consideration.

Table 2: Heuristic evaluation scores

	Efficiency	Affect	Learnability	Helpfulness	Control	Global
Evaluator						
A	60.0	60.0	53.3	53.3	60.0	58.9
B	51.1	46.6	53.3	46.6	42.8	48.6
C	55.6	53.3	46.6	46.6	51.4	52.6
D	44.4	40.0	40.0	33.3	42.9	42.9
Average	52.8	50.0	48.3	45.0	49.3	50.7

Furthermore, three of the evaluators scored *efficiency* higher than *learnability* and *helpfulness*. Notably there is a large difference between the highest

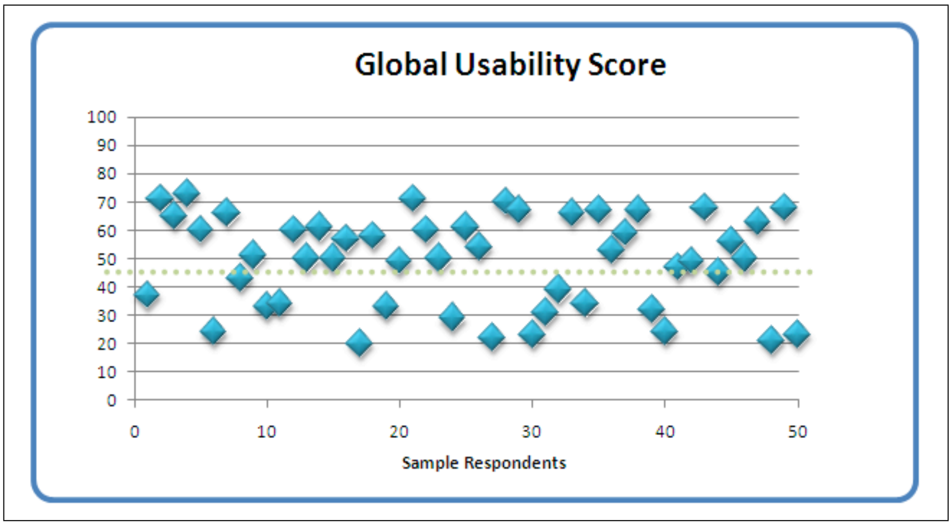

Figure 2: Global usability score

global score of 58.9 and the lowest of 42.9 for Global (overall usability). This supports earlier findings on the importance of selecting appropriate experts and monitoring the differences in evaluation scores to ensure valid feedback [39]. In this case the HE results are triangulated with the survey results to mitigate individual evaluators influence.

4.3 SUMI survey

Fifty-eight Cognos7 (Upfront) users on different managerial levels[1], served as the sample for the SUMI questionnaire. The sample composition allowed for evaluation of the different perceptions across various management levels at a mining organization. The users selected for participation had a Cognos sign-on and all of the users had previously made use of the application. Users were identified from a data log regarding the application usage listing particular cubes that each of the users consulted during a six month period. Table 6 (see Appendix) summarises the SUMI scores including the number of respondents that answered questions about each category, the mean score for the category, the standard deviation for the category, as well as the upper and lower fences for the category. From these results the BI application is positioned relative to other BI system applications. According to the independent analysis of the data [49], Cognos7 Upfront scored slightly better than the evaluation averages for other BI system applications.

As can be seen from Table 6, all the mean scores for the usability attributes lie between 45% and 51%, this implies that the largest variance between the scores is only 4.74%, which in turn indicates that the perception regarding the usability measures are not notably different for different attributes. Figure 2 depicts the distribution of scores with regard to the overall usability perception of the application expressed by the respondents.

[1] Distribution: four (4) technical users, ten (10) super users, eight (8) managers, and thirty-six (36) general users.

The graph in Figure 2 shows well-distributed scores for the sample group, indicating that the average score obtained is not a result of the high number of poor scores, but rather as the result of the severity of the poor scores. Further analysis of the usage confirms that the type of user (supply chain, engineering or information management) significantly affect perceptions regarding the usefulness of BI applications on at least the 10% level of significance with supply chain users finding it more useful than engineering users. However, frequency of use and length of use did not significantly affect perceptions on the usefulness of BI applications.

4.4 Triangulation of findings

To triangulate the findings, the results from the heuristic evaluation (Table 2) were mapped to the results from the survey according to the constructs measured with some explanations for the similarities and differences proposed in the last column of Table 7 (see Appendix) by also considering the user issues.

The heuristic evaluation and the survey results concurred (maximum 6.3% variance) on measuring the usability of the application in terms of the criteria of *efficiency, effectiveness, learnability, control* and *helpfulness*. The heuristic evaluation provided useful explanations for some of the findings but overall the findings confirmed the importance of the criteria for BI. The following criteria are not covered by the SUMI fixed response but were found to be important for BI applications; as a result they were included in the refined set of criteria for the heuristic evaluation:

- Reporting formats such as providing the data dimensions completely and consistently
- Up-to-date accessible data
- Training required
- Application speed

The importance of these issues were confirmed by the open-ended responses at the end of the SUMI questionnaire where the terms *current, accessible data, reporting formats* and *application speed* were mentioned.

Table 3: BI usability guidelines

Functional grouping	Usability guideline
Visibility	The information should be displayed in a uncluttered and well-structured manner. Instructions should be visible and self-explanatory. Navigation options (links, shortcuts, home, back, forward, etc.) should be clearly displayed. The application should communicate the system status at all times (idle, processing, etc.).
Flexibility	The user should feel in control of the application. The application should be customisable for individual or collaborative usage.
Learnability	The application should limit the memory load. The application should promote learnability to make it accessible for infrequent usage. The terminology used should be familiar to the users.
Error control and help	The application should make provision for error prevention and recovery. The application should provide help on demand and make provision for user support. Application training should be available (initial training and refresher courses).
Operability	The system should display a hierarchical map to determine data granularity level. Reporting formats should include the relevant data dimensions. Cube dimensions should be easy to identify, select and view. Data should be accessible on different levels of aggregation. Filters applied to data should be highly visible at all times. The data should be up-to-date or else users should be notified that the data is out-dated. The application should allow knowledge sharing and exporting data. Users should have the option to save data views on the application. KPI and business support notifications should be possible. There should be information visualisation functionality (comparison charts, graphs to reveal trends, etc.) to assist in decision making. User application password resets should be automated by the use of email address. The application should provide a rapid response rate. The application behaviour should be consistent.

Furthermore, the importance of training and providing user support was reiterated.

5 DISCUSSION

The results from the standardised SUMI provide support for the reliability of the heuristic evaluation constructs in that the findings are similar; this must be seen in the context of different evaluator groups (expert evaluators versus regular users) for each instrument. The unique issues identified in the survey were the significant influence of the type of user and the fact that frequency of use and length of use did not significantly affect perceptions on the usefulness of the BI application. The heuristic evaluation provided unique insights such as the difference between the highest scoring attribute (7.8%), namely *efficiency* and the lowest scoring attribute, namely *helpfulness*. In addition, there was a significant difference between the average scores of the highest scoring heuristic evaluation expert (58.9%) and the lowest scoring heuristic evaluation expert (42.9%).

5.1 Usability evaluation guidelines for BI applications

The final set of BI Usability evaluation guidelines (Table 3) was synthesized from the original set of BI user criteria (Table 1 and Table 4) through mapping those to literature (Table 5) and then validating those with the heuristic evaluation and the SUMI based survey. The BI guidelines proposed earlier in this study [14] were refined through a deeper analysis of the user issues as discussed in section 4.1, triangulation with the findings from the heuristic evaluating and the survey as well as a comparison with a recent BI usability evaluation study by Scholtz, Calitz & Snyman [50], to propose the new set of guidelines for the usability evaluation of BI applications as depicted in Table 3.

The triangulating of the findings from the survey and the HE is limited by the fact that not all the BI usability criteria were covered by the SUMI questionnaire. In those cases the validation relied only on the findings of the heuristic evaluation and the open-ended questions at the end of the SUMI questionnaire. The criteria are presented as guidelines since HE was found appropriate in the BI application context but the criteria can also be used in other design or evaluation methods.

When relating the guidelines to the SUMI constructs, it has to be noted that effectiveness and efficiency are composite constructs, i.e., efficiency is the result of optimal navigation, information architecture, processing speed and other criteria, and therefore it is not presented as an independent grouping. Furthermore, the guidelines are defined on a more detailed level to minimise subjectivity and therefore affect has been excluded.

The refined set of BI criteria is different from the general usability criteria in the inclusion of *decision-making support, knowledge sharing* criteria and the focus on *information architecture.* The knowledge sharing criteria aligns with suggestions for closer integration between BI systems and knowledge management based on a metadata repository, which capture knowledge and insights accumulated during the usage of BI tools [51].

Scholtz, Calitz & Snyman [50] investigated the use of collaborative business process modelling (CBPM) software and hardware for improving the usability of CBPM projects. They proposed operability, satisfaction, effectiveness, efficiency, learnability, understandability and attractiveness as usability metrics. Comparing those metrics to the categories in our guidelines, *learnability* and *operability* correspond directly while *error control* and *help* map to their category of *understandability.*

Visibility and *flexibility* contribute to *effectiveness, efficiency* and *satisfaction* but a direct mapping is problematic since our focus is on the user perspective as gained from user observations and thus our guidelines are on a lower (more detailed) level of granularity. However, this makes these guidelines useful for incorporation as BI specific extensions to existing usability guidelines. *Attractiveness* as usability metric [50] relates to user experience that has been scoped as future research. Undeniably, aesthetics and visual appeal are important but for the sake of parsimony the guidelines focus on the core issues in an area where the user satisfaction seems to be determined by effectiveness and efficiency [4].

Initially it was believed that 4 to 5 users could identify up to 85% of the usability problems [52], but a more recent study [53] claims that between 8 and 12 evaluators are required to identify 80% of the problems. Therefore the heuristic evaluation is limited by having only four evaluators. Nonetheless this is mitigated by the triangulation with the survey results and the findings from the user identified usability issues captured over a period of two years.

Finally, the need for initial training followed by ad hoc training on request was highlighted. This is a managerial issue and thus not listed as an evaluation guideline. However, it was noted that BI users should be encouraged to master the BI system and take ownership of consulting the system for information instead of contacting application support for information.

6 CONCLUSION

The purpose of this study was to provide a set of refined usability evaluation guidelines for BI applications. Based on a previous study [14] a set of BI usability evaluation criteria was presented. In this study that set of guidelines was re-evaluated in terms of a deeper analysis of the user identified BI usability issues, those insights were triangulated with the findings from the heuristic evaluating and the survey and interrogated in terms of more recent BI usability evaluation literature.

In response to the research question ("How can existing usability criteria be customized to evaluate the usability of BI applications?") the importance of *efficiency, effect, learnability, helpfulness* and *control* was confirmed but the focus on *information architecture, reporting format* and *operability* was highlighted. This set of BI usability heuristic evaluation guidelines is the main contribution of the study. These guidelines differ from existing general usability guidelines in the added coverage of operability which relates to reporting formats, data quality, accessibility and processing speed as required in the mining context. Data quality and processing speed may have been considered as functionality requirements before but given their importance in BI decision support these have become usability criteria. Secondary contributions include the identification of BI user identified usability issues with severity ratings (Table 1). Furthermore, the analysis of user issues provided recommendations for training and best practices to support the individual users in the productive use of the BI system in an environment that emphasizes safety, productivity, profitability and sustainability.

Mining companies have to embark on sustainable cost management programs to become and remain lowest-quartile-cost producers. Strategies include improved efficiency through technology and the use of analytics to uncover the true cost drivers [54]. These strategies are not unique to the mining industry but further research is needed to confirm if the BI Usability guidelines presented in this paper would be transferable to other industries such as the automotive or pharmaceutical. Further research is also needed to investigate the user experience of BI application users towards providing more concrete guidelines on design for aesthetically pleasing and enjoyable BI applications.

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APPENDIX A

Table 4: Mapping of Business Intelligence (BI) issues

A	B	C	D
User requirement	**BI attribute**	**Usability principle**	**Synthesised user criteria**
Highest level information must be visible	Hierarchical display of data	*Information architecture*	*Map of data landscape*
Page needs to be displayed clearly and uncluttered	Page display	*Information architecture*	*Clear page display*
Navigational buttons must be visible	Navigational display	*Visible navigation*	*Visible navigation*
Task icons must be visible and logical	Task pane display	*Information architecture*	*Visible and logical icons*
Cube name must be identifiable	Page layout	*Information architecture*	*Visible cube name*
Cube dimensions should be displayed clearly	Page layout	*Legibility*	*Visible cube dimensions*
Easy exploration of cube dimensions	Cube navigation	*Navigation*	*Ease of cube navigation*
Easy viewing of cube measures	Cube navigation	*Information architecture*	*Visibility of cube measures*
Data should be accessible in the optimal format	Data availability	*Efficiency*	*Data availability*
Data should be up to date	Data quality	*Effectiveness*	*Data quality*
Possibility to export data	Data export	*Flexibility*	*Flexibility to export data*
Types of export formats need to be sufficient	Data export	*Flexibility*	*Flexibility to export data to multiple formats*
Data must be legible	Information presentation	*Information architecture*	*Legible information*
Show requests progress	System status display	*Robustness (Observability)*	*Observability - appropriate system feedback*
Data dimensions must be visible	Information presentation	*Information architecture*	*Visible data dimensions*
Data measures must be formatted clearly	Information presentation	*Effectiveness*	*Correct data format*
Graphical displays of data required (graphs)	Information presentation	*Information architecture*	*Graphical presentation of information*
Assist with data analysis	Reveal trends and patterns	*Help*	*Auto trend analysis*
The screen must not present too much information	Page layout	*Information architecture*	*Display should prevent information overload*
Make use of terminology users are familiar with	User's language	*User's language*	*User's language*
Task buttons required to carry out work effectively	Functionality to support user tasks	*Efficiency*	*Adequate functionality to support user tasks*
Request for increased system speed	System response rate	*Latency reduction*	*Adequate system response rate*
Users need to be able to save views on cubes	'Save view' functionality - Customisation	*Customisation*	*Customization of views on cubes*
Request to share views on cubes with other users	Knowledge sharing functionality required	*Effectiveness*	*Collaboration with other users*
Training required	Learnability reduces training required	*Learnability*	*Learnability; Training*
Require optional hover explanation of icons	System explorability	*Self-descriptiveness*	*Self-descriptiveness and optional explanations*
Cannot remember how to complete task	Support to assist user memory	*Memorability*	*Memorability*
Sign on required	System security/Control	*Control*	*Control*
User locked out	System security/Control	*Control*	*Control*

Table 5: Usability criteria mapped

A	B	C	D
Usability principles	**BI user issues**	**Heuristic evaluation**	**Usability**
Literature	**Observation**	**Criteria**	**SUMI**
User's language, visible instructions, use of metaphors, self-descriptiveness	User vocabulary, legibility, task icons, visible, affordance	Instructions visible and self-explanatory	Helpfulness
Flexibility, responsiveness		Flexibility	
Controlability	Control	Control	Control
Learnability	Learnability	Learnability	Learnability
Efficiency	Efficiency	Efficiency	Efficiency
Familiarity, predictability		Expected behaviour	
Consistency		Consistent behaviour	
Error tolerance		Error prevention, tolerance	
Explorable interface, visible navigation	Explorable interface, visible page and system navigation	Visible system/page navigation (colour blindness)	
Customization, task migratability, synthesizability	Customization, formatted data export	Customization	Customization
Help, documentation	Training, manuals	Helpfulness	Helpfulness
Satisfaction		General satisfaction	Affect
System speed; system status display	Speed, display	Visibility of system status	
Memorability	Memorability	Memorability	
	Decision support (operability in terms of data requirements)	Support decision-making	
	Knowledge sharing	Support knowledge sharing	

Table 6: SUMI scores per usability principle

	Global	Efficiency	Affect	Helpfulness	Control	Learnability
No. cases	50	50	50	50	50	50
Mean	49.28	46.28	50.26	50.08	45.52	47.12
Standard dev.	16.24436	17.74219	16.99557	14.00414	16.20688	17.40237
Upper fence	81.11894	81.25469	83.57132	77.52811	77.28548	81.22864
Lower fence	17.44106	11.70531	16.94868	22.63189	13.75452	13.01136

Table 7: Triangulation of survey and heuristic data by usability principles

Principle	**SUMI**	**HE**	**Var**	**Findings**
Efficiency	46.5	52.8	6.3	Explanations for this discrepancy could be the limited exposure of the expert usability evaluators to the application; the simple task that the usability experts were requested to perform, thereby not facing the problems normal users would experience and the expert evaluators' extensive interaction with and understanding of applications.
Affect	50.3	50.0	0.3	This is confirmation of the SUMI score, therefore indicating a similar perception by the majority of the users that make use of the application, and expert evaluators.
Control	45.5	49.3	3.8	The difference in scores may be contributed to the advanced knowledge the expert evaluators possess with regards to the inner workings of an information systems which made them expect less of the application.
Helpfulness	50.1	45.0	5.1	Expert evaluators scored this variable considerably lower than the survey participants. This could be attributed to the expert evaluators' higher expectations of helpfulness due to their knowledge of usability standards or the expert evaluators' inability to consult technical expertise as the users tested in survey would consult the help desk.
Learnability	47.1	48.3	1.2	This usability principle scored a low variance of results, indicating a similar perception from both groups. Notably the SUMI findings based on regular application users, scored slightly lower, even though they have had ample time to master the application and support was provided. This suggests the application is difficult to learn.