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Abstract

Purpose – Higher education institutions (HEIs) face a number of challenges in effectively managing and reporting on sustainability information, such as siloes of data and a limited distribution of information. Business intelligence (BI) can assist in addressing the challenges faced by organisations. The purpose of this study was to propose a BI framework for strategic sustainability information management (the Sustainable BI Framework) that can be used in HEIs.

Design/methodology/approach – The research applied the design science research methodology whilst using a South African HEI as a case study. The problems with sustainability information management were identified, and a theoretical framework was proposed. In addition, a practical BI software tool was developed as proof of concept to address these problems and to assist with the management of strategic sustainability information in an HEI.

Findings – The proposed sustainability BI tool was evaluated through heuristic and usability evaluations with senior management. The results indicated that the usability of the BI tool was positively rated and that the framework can assist in overcoming the constraints that HEIs face in effectively managing sustainability information.

Research limitations/implications – The research was limited to a single case. However, the theoretical framework was derived from and expanded on existing stakeholder theory, sustainability reporting theory and literature on BI dashboard development. The framework was implemented successfully in the Sustainable BI Tool prototype at the case study, and the results reveal in-depth information regarding information management for sustainability reporting in higher education.

Practical implications – The Sustainable BI Tool is a solution that integrates data from multiple areas of sustainability and provides a single integrated view of the information to stakeholders. The information is provided through performance dashboards, which provide predictive capabilities to enable management to report on sustainability and determine if the institution is meeting its strategic goals. The lessons learnt can also assist other HEIs considering implementing BI for sustainability reporting.

Social implications – Improved sustainability reporting for HEIs provided by the BI framework can improve the environmental and social impact of the educational community.

Originality/value – This study provides the most comprehensive framework for guiding the design of a BI tool to assist in effectively managing sustainability information in HEIs.

Keywords Business intelligence, Higher education, Sustainability reporting, Dashboards, BI framework, Strategic sustainability information

Paper type Case study

Introduction

The increased competition in the higher education sector has resulted in a need for faster and improved decision-making at all levels of an institution (Stocker, 2010). Higher

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education institutions (HEIs) globally have realised that the effective analysis of sustainability information can improve sustainability management can be used as a tool to measure sustainability efforts and manage long-term risks and opportunities (Posner and Stuart, 2013). Improved sustainability management includes the process of sustainability reporting. The increased awareness of sustainability is emphasised by the number of sustainability reporting frameworks being implemented (Institute of Directors, 2009; Pina, 2011). These frameworks provide institutions with guidelines on how to report on sustainability, and examples are the Global Reporting Initiative (GRI), ISO 14000 series; the Triple Bottom Line; and the Sustainability Tracking, Assessment and Rating System (STARS). STARS is a reporting framework specifically designed for HEIs in North America [Association for the Advancement of Sustainability in Higher Education (AASHE), 2011], and although the GRI reporting framework was designed for companies, it does have modifications for HEIs with an additional category for education.

One of the biggest challenges institutions face with managing sustainability is the collection, integration and reporting of sustainability information (Frost *et al.*, 2012). Compared with corporations, HEIs are still in the early stages of sustainability reporting, both in the number of HEIs reporting and the level of reporting (Alonso-Almeida *et al.*, 2014; Lozano and Huisingh, 2011). The majority of sustainability reporting efforts in HEIs have been restricted to institutions in developed countries, and those in the developing countries are falling behind. Two possible causes for this are the lack of access to data and accurate information (Haupt *et al.*, 2015; Pina, 2011; Velazquez *et al.*, 2005). In spite of the provision of several sustainability reporting frameworks, there has been limited progress to identify appropriate methods to support sustainability reporting efforts by HEIs in developing countries. Recent regulations for South African HEIs requiring mandatory sustainability reporting could assist in improving the future quality of sustainability data and information in the country [Department of Higher Education and Training (DHET, 2014)]. Bosire (2014) verified that governance practices are a key factor for effective sustainability management (including reporting), and these are outlined in the King III report, which is seen as the foundation for South African governance practices (Institute of Directors, 2009). Many HEIs in South Africa have realised the benefit of the STARS reporting framework (Pina, 2011).

For strategic management at HEIs to effectively manage and report on sustainability information, a tool is required that can effectively analyse data and provide management with the information required for decision-making (Goni *et al.*, 2013). Advances in information and communications technology (ICT) have improved the way in which management produces reports and makes decisions. These ICTs can and have been used to support the process of sustainability reporting. The internet is one such technology that has been used for internet-based sustainability reporting and is now integrated into daily operations of a large number of companies (Isenmann, 2004; Isenmann *et al.*, 2007). The online documents produced are then available to be pulled or automatically disseminated via email or other push technologies. The use of the internet and other ICTs facilitated three developments in the field of sustainability reporting:

(1) an integrated reporting system that includes not only environmental issues but also social and financial (Ahmed and Sundaram, 2012; Isenmann, 2004);

(2) support for different media and presentation styles to be included in the reports (Isenmann, 2004); and

(3) customisation of reports so that they are tailored to the individual organisation's needs (Isenmann, 2004; Isenmann *et al.*, 2011).

There has been a growing trend towards integrated corporate reporting and South Africa has been one of the most innovative countries in this regards (Coldwell and Joosub, 2015). The demand for flexibility and customisation of reports led to the emergence of stakeholder reporting, also referred to as stakeholder dialogue (Bengtsson and Ågerfalk, 2011; Isenmann *et al.*, 2011). The stakeholder dialogue approach provides mechanisms for key stakeholders to provide input and to fine tune reports to individual preferences. In terms of trends in software suites and tools for sustainability management, available products on the market vary in the breadth and depth of their offering (Mingay and Stokes, 2011). Some are emerging vendors and some are niche players (such as Greenstone, which concentrates exclusively on aggregation and reporting), and others (such as Microsoft and Oracle) are adding sustainability management and reporting tools to their enterprise resource planning (ERP) suites. However, the ERP software offering is in a low-key manner, providing only the core requirements for sustainability management.

Strategic management of sustainability requires more than just a reporting tool. Business intelligence (BI) is a readily available tool that easily enables the gathering, storing and processing of information. Both Pina (2011) and Bosire (2014) highlight the key role that BI tools play in effectively managing sustainability information in HEIs. The successful implementation of BI tools can ensure that management benefits from improved access to accurate and up-to-date information when desired. These tools can provide strategic management and other stakeholders with a complete view of the organisation, thus providing benefits such as the ability to enable faster, more accurate and more reliable decisions (Adelman *et al.*, 2005). However, traditional BI tools do not meet the requirements of strategic sustainability management, because the main focus of these tools is historical reporting and *ad hoc* queries, which falls under the domain of descriptive analytics. Descriptive analytics is a retrospective analysis that provides insight into what is currently happening and what has already happened (Kandogan, 2012) and is thus not suitable at a strategic level where the focus is on long-term strategy and decision-making where a more predictive approach is required (Hacklin and Wallnöfer, 2012).

Bosire (2014) identified infrastructure as a key factor for sustainability management and argues that BI forms a large part of this category, as it can provide benefits such as access to real-time sustainability information, improved sustainability reporting and strategic planning. BI supports improved data management and provides management with a constant stream of real-time information (Sabherwal and Becerra-Fernandez, 2011). The benefits of a properly implemented BI solution include integrated and improved information, time savings for data suppliers and for users, more and better information, improved decision-making capabilities and business processes, improved support for an organisation's strategic and tactical goals and improved organisational performance (Watson, 2009; Hočevar and Jaklič, 2010; Holsapple *et al.*, 2014).

Several common challenges exist for BI including data quality (Ranjan, 2008; Otto and Reichert, 2010), complexity (Sabherwal and Becerra-Fernandez, 2011; Chen *et al.*, 2012), cost (Sabherwal and Becerra-Fernandez, 2011), information technology (IT) support (Lin *et al.*, 2009) and organisational alignment (Vural, 2006; Lin *et al.*, 2009). Another challenge associated with BI involves the complexity to implement and use the system (Sabherwal and Becerra-Fernandez, 2011). In developing countries such as South Africa, there is a low level of maturity for BI implementations (Bosire, 2014). The limited use of BI can be ascribed to a number of factors related to insufficient data, leading to poor information. Data in HEIs in these countries are often unavailable and incomplete (Bosire, 2014), and data integration capabilities are also limited (Guster and Brown, 2012).

The purpose of this paper is to report on a study that proposes a BI framework that can be adopted by HEIs for sustainability information management. The framework is implemented in a South African HEI, and a BI software tool was developed as proof of concept. The Design Science Research (DSR) methodology was used in conjunction with a South African case study. This paper forms part of a larger study where both the BI framework and the tool were evaluated. However, this paper only reports on the usability evaluation of the software tool as proof of concept. Five criteria identified by Jooste *et al.* (2014) were used for the evaluations. The findings showed that the usability of the tool was positively rated in all five criteria and that the proposed framework can successfully be used to design such a BI tool for sustainability information management in higher education.

The structure of the paper is as follows: the next section discusses the research methodology used. It is then followed by a review of the literature that formed a foundation for the design of the proposed framework and the architecture of the tool. The paper then proceeds to present the results of the evaluations and concludes with some discussions, recommendations and conclusions.

Research methodology and case study

The DSR methodology (Hevner, 2007) was the underlining research methodology followed in the larger study. The three research cycles of the DSR, the relevance cycle, the design cycle and the rigor cycle, were applied in this research in developing two artefacts. The first artefact produced was the BI framework for strategic sustainability information management in higher education (the Sustainable BI Framework for short), a theoretical framework to support strategic sustainability information management in HEIs. An extensive literature study was conducted to derive the theoretical framework. In conjunction with DSR, a case study was used. The case study used was a single case of an established HEI in South Africa where sustainability has been prioritised by strategic management (Nelson Mandela Metropolitan University, 2008). Large volumes of data relating to the sustainability of the institution are generated and recorded; however, the use of such data to manage sustainability at the strategic level is limited. The second artefact produced was a practical BI software tool, "Sustainable BI", which was developed to address problems with strategic sustainability information management.

During the problem investigation activity stage of the DSR, the researchers conducted semi-structured interviews with the relevant knowledgeable managers (the stakeholders). These interviews and secondary data sources were used to corroborate the findings of the literature review and were reported on in a previous paper (Haupt *et al.*, 2015). The interview results confirmed the literature that constraints to BI at the HEI were attributed to siloed data and information and poor sharing and communication of information. The main challenges were identified as being able to provide on-demand IT support to management when implementing a BI tool and aligning the implemented BI tool with the institution's organisational goals. The analysis of existing literature and the feedback from the interviews were used to specify and confirm the objectives and requirements for the two artefacts, Sustainable BI (the software tool) and the Sustainable BI Framework. Five criteria for evaluating the tool were identified based on previous work in the field of BI usability by Jooste *et al.* (2014). These criteria were used in the usability evaluations of the practical artefact, Sustainable BI. In total, 12 participants who were involved in sustainability information management at the case study were the participants in the usability evaluation.

Some authors (Gray *et al.*, 1995, Hahn and Kühnen, 2013) explain the need for publishing sustainability reports by using stakeholder theory. Stakeholder theory is used to identify the connections (or lack thereof) between stakeholder management and the achievement of traditional organisational goals or objectives such as profitability (Donaldson and Preston, 1995). In this view, the success of an organisation is linked to the involvement of various stakeholders in the organisation. This theory was therefore used in this study to both understand sustainability reporting and to guide the research process as recommended by Freeman, *et al.* (2004).

A business intelligence framework for sustainable higher education institutions

Muntean *et al.* (2013) proposed a BI architectural framework created specifically for HEIs, with six component layers, namely:

(1) the extract, transform and load (ETL) process layer;
(2) the data layer;
(3) the reporting layer;
(4) the analytical layer;
(5) the monitoring layer; and
(6) the presentation layer.

However, this framework is not comprehensive and does not consider the sources of data and the categories of sources. The framework was therefore extended in this study to a BI framework to support strategic sustainability information management in HEIs (the Sustainable BI Framework) to include two additional layers and all the stakeholders as recommended by stakeholder theory. The main stakeholders are the users, management and the IT team. The six steps for dashboard development were also included in the Sustainable BI Framework (Figure 1). The two additional layers are:

(1) the users; and
(2) the sustainability data landscape (sustainability components and data sources).

The proposed sustainability data landscape includes sustainability components based on the those recommended by STARS, the GRI frameworks for HEIs and the general recommended sustainability practice of HEIs (Sayed and Asmuss, 2013). The GRI and STARS frameworks both have four components that are similar but have slightly different names: environmental (GRI)/operations (STARS); economic (GRI)/planning and administration (STARS); social (GRI)/engagement (STARS); and educational (GRI)/academic (STARS).

The data layer consists of the institution's data warehouse that is used to store all sustainability data and that has been through the ETL process from the data sources (Muntean *et al.*, 2013). The data warehouse will also contain separate data marts making the querying of the data warehouse and analytical processes more efficient. The potential benefits in the data layer include the enhancement of data quality and consistency, as well as cost savings, as data marts can be consolidated. The reporting layer consists of *ad hoc* query and reporting capabilities, which form part of traditional BI tools (Muntean *et al.*, 2013). The *ad hoc* querying capability allows users to query a database to filter and select the desired data (Ong *et al.*, 2011). Queries can be created to find information to answer a specific question. Reports can also be generated to share the information that has been discovered, which enables access to more and better information and ultimately improved operational performance.

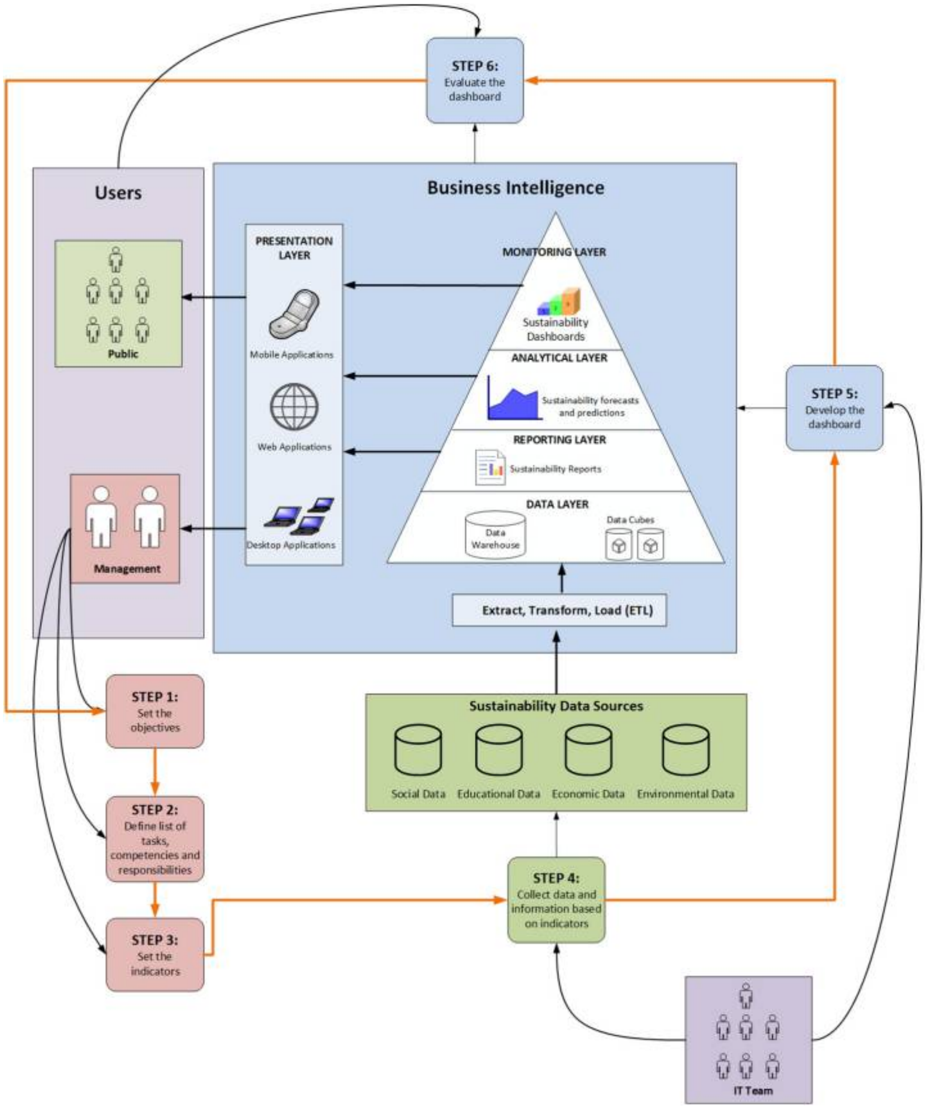

Figure 1.
Sustainable BI Framework

In the analytical layer, business analytics components extend the traditional BI components and represent the analytical and the monitoring capabilities (Muntean *et al.*, 2013). The analytical layer provides analytical tools, such as online analytical processing (OLAP), data mining, forecasting and predictive modelling, to find patterns and trends in the data. These capabilities can assist an institution in improving its decision-making qualities. OLAP involves developing data cubes from the data warehouse to reduce query time. These cubes enable users to easily perform the four basic OLAP operations, namely, roll-up or drill-up, drill-down, slice and dice and pivot. Data mining is used to find patterns in large sets of data through the use of complex algorithms (Ong *et al.*, 2011). Forecasting is the process of predicting future outcomes based on historical data (Han *et al.*, 2012). These capabilities are also the core capabilities of the business analytics field. These capabilities are all key components that enable predictive analytics and are key components that enable the creation of strategic intelligence.

The information created in the analytical layer is usually presented to management in the monitoring layer (Kourentzes *et al.*, 2014). The monitoring layer consists of performance dashboards and scorecards, which enable an institution to better manage and monitor their sustainability key performance indicators (KPIs) by providing real-time strategic information to management (Ong *et al.*, 2011). Dashboards and scorecards are a key element of the analytical and monitoring layers of the framework and should be used to present information to management to represent the status of KPIs and to easily identify trends, patterns and anomalies (Yigitbasioglu and Velcu, 2012). The presentation layer provides the platform through which all users access the information provided by the other layers through mobile, desktop or Web applications. Using this information, the institution can continuously make decisions to determine if it is on-track to meet the long-term goals identified in the institutional strategy (Muntean *et al.*, 2013).

The framework also incorporates the six-step process for the design and development of dashboards proposed by Caraiani and Dumitrana (2005), as follows:

(1) Set the objectives.

(2) Define the list of tasks, competencies and responsibilities.

(3) Set the indicators.

(4) Collect information based on the identified indicators.

(5) Develop the dashboard.

(6) Evaluate the dashboard.

Current BI tools used in HEIs do not support forecasting or predictive capabilities and are mostly historical (Bosire, 2014; Haupt *et al.*, 2015). In addition, they do not integrate multiple sustainability aspects and usually focus entirely on educational data. The main objective of a BI tool for HEIs is to provide relevant stakeholders with current and accurate strategic sustainability information, which will enable them to better monitor and manage sustainability efforts. Requirements for the tool proposed in this study were derived from the literature review and then verified by interviews with the relevant stakeholders (Levendal, 2015; Van Leeve, 2015), which are as follows:

- *Performance dashboards*: The information should be visualised using dynamic and interactive dashboards.
- *OLAP capability*: The information should be aggregated according to KPIs, but should support drill-down functionality to enable root-cause analysis and drill-up.
- *Filtering*: This is done at different levels of aggregation.
- *Forecasting*: The information should support forecasting for predictive modelling.
- *Reporting*: This is to support the sharing and integration of multiple aspects of sustainability information to ensure that the silo effect can be avoided.

When designing the dashboards, guidelines for dashboard design should be considered and several pitfalls should be avoided. An analysis of the literature identified three categories of guidelines for dashboard design:

- interaction, media, visualisation and feedback;
- aesthetics; and
- information detail, relevance and purpose.

Interaction, media, visualisation and feedback

Dashboards can enhance ease of use through engaging users by means of various interactions and visualisation techniques (Bremser and Wagner, 2013). These can include intuitive charts, dials, sliders, gauges and "traffic lights" that provide visual cues of information (Few and Edge, 2007). Visualisation should require minimal effort to impart the message to the user, should be coherent and allow the user to specify the level of detail they would like to view (Janes *et al.*, 2013). Visualisations should also minimize the time needed to understand what has been communicated. Designers should not make interaction with these visualisations necessary to understand the data (Janes *et al.*, 2013). Interaction should be optional and enforced only when the attention of the user is obtained and he/she wants to investigate further.

When designing a dashboard, the appropriate media (types of graphs) to display information should be used (Few, 2006). Choosing inappropriate media is one of the most common design mistakes on dashboards. If the media cannot be interpreted in a useful way without reading the associated numbers, then the media is of no use to the user; examples are using a graph when a table of numbers would work better or using the wrong type of graph for the data and their message.

Aesthetics

In dashboard design, the aesthetics of the dashboard are extremely important and the elements of the dashboard should be presented in a visually appealing way that can increase a user's interest in viewing the dashboard (Janes *et al.*, 2013). Colour is an important aspect of aesthetics and should be used effectively to highlight different aspects of the data (Few, 2006; Yigitbasioglu and Velcu, 2012). A common problem is the use of too many colours, especially bright colours. As dashboards are usually densely packed with information, the visual content should be as simple as possible. Too many colours can be visually assaulting. Overuse of colour can result in a loss of highlighting what is most important. Very bright colours or colours used for visual effect such as three-dimensional effect should be carefully considered, as they can distract the user or make it difficult to read (Few, 2006).

Information detail, relevance and purpose

Information in dashboards should be well-structured and should assist users to immediately recognise the indicators that need attention (Few and Edge, 2007). Dashboards should present only data that are relevant to the users' tasks, data questions and objectives and should avoid displaying excessive detail. In other words, the right data must be selected (Janes *et al.*, 2013). The appropriateness of the data can be determined by identifying the goal of what we want to study and why, as well as the relevance or focus. The goal will depend on whether the dashboard is strategic, tactical or operational (Eckerson, 2011). In operational dashboards, the level of detail is often more specific, for example, to determine whether an operation has dropped below an acceptable threshold (Eckerson, 2011; Few, 2006). Access to specific details of information is critical, and appropriate interactions need to be in place to move from high-level statistics to finer granularities. These interactions may also be realised by using drill-down or hovering capabilities to provide deeper levels of details on demand (Abdelfattah, 2013; Few, 2006).

Architecture of a business intelligence dashboard tool for higher education institutions

The architecture of the Sustainable BI Tool incorporated all the framework components, namely, the operational data sources, the ETL process, the data layer, the reporting, analytical and monitoring layers and the presentation layer (Figure 2). Data across multiple sustainability categories were included. Tableau was used for the presentation, reporting, analytical and monitoring layers, as it is a leader in BI software (Gartner, 2014). Tableau was used to create the dashboards to visualise the information, and these dashboards can be viewed via the presentation layer through Tableau Online, Tableau's online cloud platform. However, BI does not provide a data platform; therefore, Microsoft SQL Server was used as the data platform. Several tools were used in the reporting, analytical and monitoring layers. The Sustainable BI Tool supports the creation of both CSV reports, typically viewed in Microsoft Excel, and PDF reports, typically viewed in PDF readers such as Adobe Acrobat Reader. Although Tableau allows the creation of predictive models, Tableau's predictive capabilities are limited; therefore, the statistical program R was used to create the predictive models.

Operational data sources represent the lower layer of the architecture. An ETL process was conducted using SQL server integration services on the data sources, which were then loaded into the data warehouse into three data cubes, the integrated tertiary software (ITS) students' cube, the higher education management information system (HEMIS) students' cube and the environmental cube. The cubes were created in SQL server analysis services. These cubes were selected as they encapsulate multiple aspects of sustainability in HEIs. The ITS students cube' contains data regarding students and student activity. The HEMIS students' cube stores historic data regarding students and student activity. The environmental cube contains data about the electricity and water usage.

Capabilities of sustainable business intelligence

The tool, Sustainable BI, was developed as a desktop solution to support all the required capabilities for a BI solution: *performance dashboards; OLAP capabilities; forecasting capabilities; reporting and filtering capabilities.*

The Sustainable BI Tool provides performance dashboards to allow users to encapsulate multiple sustainability aspects and to monitor key metrics and KPIs. A single view is provided per subject area, such as water usage (Figure 3). The OLAP capabilities allow different views of the data according to the levels of aggregation. A high-level aggregated view allows management to determine if there is a problem with operations that require action. A low-level aggregation allows management to identify the root cause of the problem. A drill-down can be created by setting up information hierarchies. For example, in the educational sustainable category, faculty, department and qualification level are important dimensions for student enrolments. If there are a large number of applications in a certain faculty, then management can drill-down into that faculty to view the applications and department as well as the qualification level.

The Sustainable BI Tool uses the R software tool to provide a prediction and forecasting capability based on historical information. These forecasting capabilities, for example, the prediction of electricity usage and enrolments at the university, can enable strategic management to determine if they are on course to meet strategic sustainability goals. A summary of the enrolment forecasting models outline which measures were used, the time

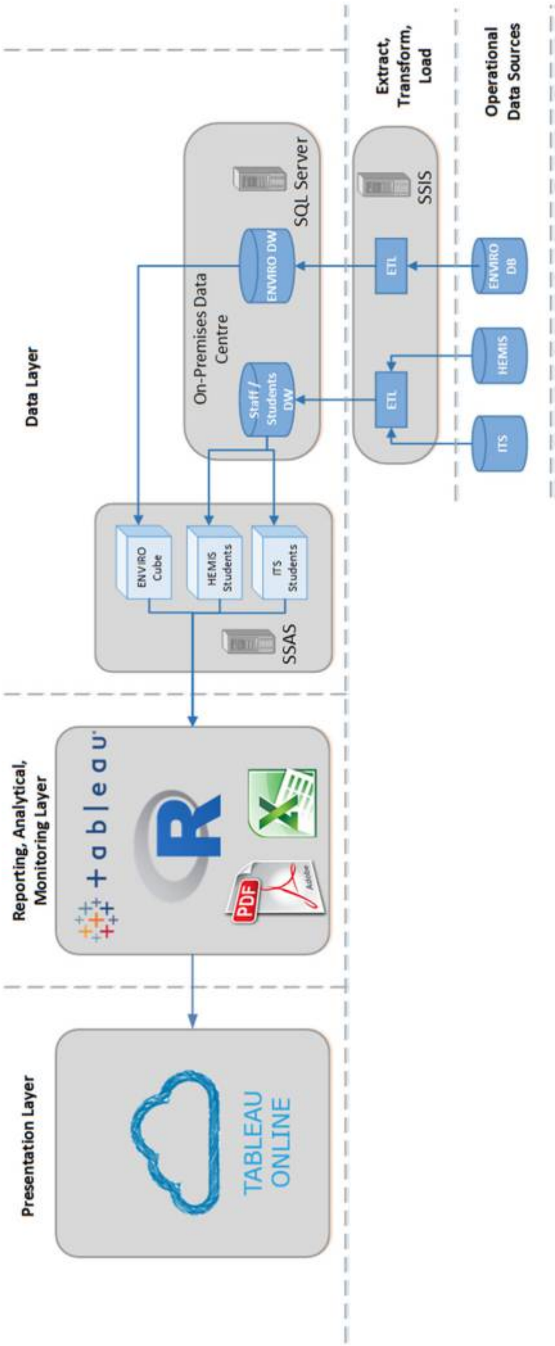

Figure 2.
Sustainable BI Tool architecture

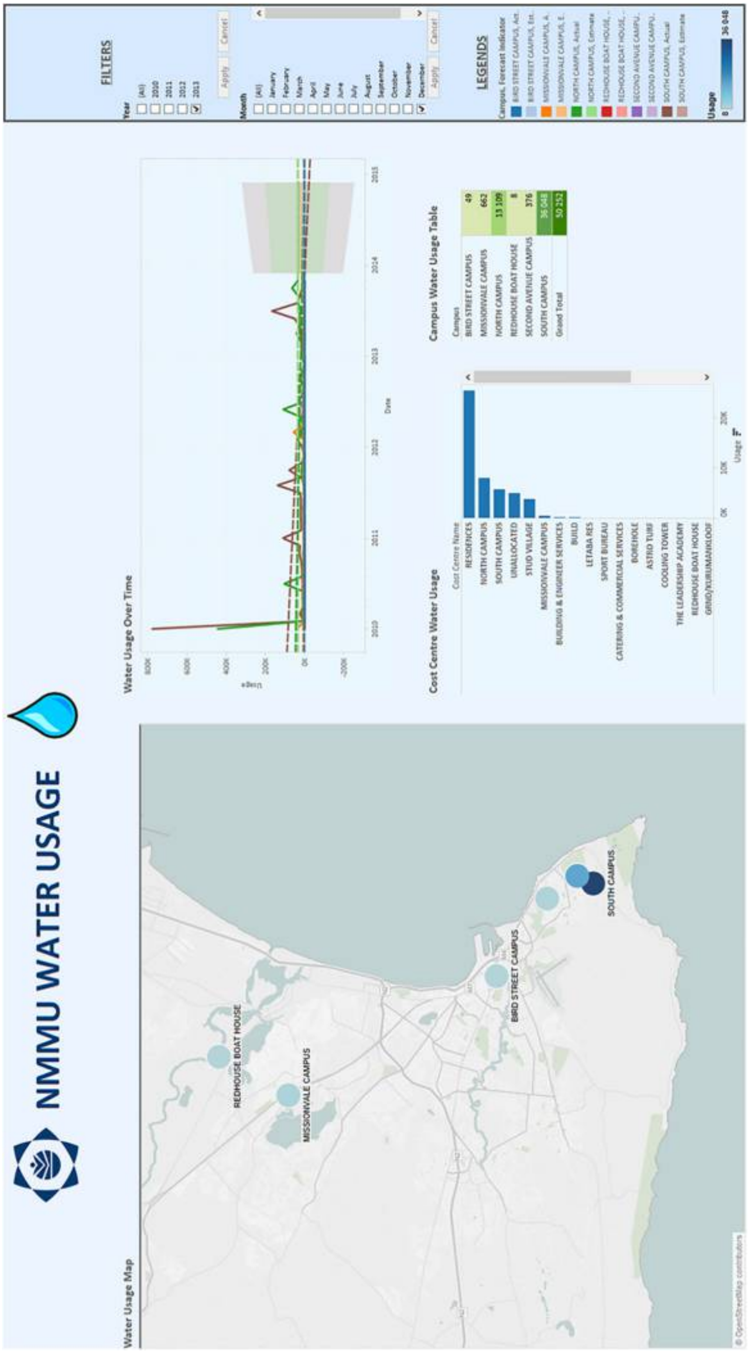

Figure 3.
Environmental
dashboard in
sustainable BI

period of the data the forecast is based on and the time period for which the forecast should be provided.

Reports can be created within the Sustainable BI Tool in CSV and PDF format and shared with other users for sustainability reporting. Filtering provides users with the capabilities to refine the viewed information and remove irrelevant information. The Sustainable BI Tool provides filtering capabilities using a toolbar, which provides radio buttons and checkboxes from which users can select the required information. The filtering features use interactive, coordinated dashboard components, where a selection on one component filters all other components of the dashboard (Figure 4).

Evaluation of the tool sustainable business intelligence

This paper reports on the two separate evaluations of the Sustainable BI Tool that were conducted. A heuristic evaluation (HE) was conducted first and is an informal usability evaluation in which feedback is gathered from users regarding a particular system according to several heuristic characteristics (Nielsen and Molich, 1990). The HE was used to gain an early understanding of the usability issues of the Sustainable BI Tool to address them prior to the usability evaluation. Issues identified in the HE were then addressed, and the tool was modified accordingly. After this, a full usability evaluation was conducted. All evaluations were conducted on desktop personal computers as the tool was designed for this platform.

Figure 4.
Filtering information in sustainable BI

Heuristic evaluation of the Sustainable Business Intelligence Tool

Procedure and participants. Nielsen and Landauer (1993) and Nielsen (1992) argue that an HE should be performed by at least three experts. Thus, the HE of the Sustainable BI Tool was conducted with five expert participants to ensure that most heuristic issues could be found. These participants all had more than five years' experience in working with BI, two of who are BI researchers. Therefore, all participants were considered as intermediate or expert BI users. They also had more than three years' expertise in user interface design. Each participant was provided with a task list outlining tasks that they were required to complete, which covered the broad capabilities of Sustainable BI described in the previous section.

A list of ten heuristics, identified by Forsell and Johansson (2010), was provided to the participants together with an explanation of each (Table I). These heuristics were selected as they are suited for evaluating information visualisation tools such as performance dashboards. For each issue, identified participants were asked to record the related heuristic and give a severity rating from 0 to 4 (0 = I don't agree that this is a usability problem at all; 1 = cosmetic problem only: need not be fixed unless extra time is available on project; 2 = minor usability problem: fixing this should be given low priority; 3 = major usability problem: important to fix, so should be given high priority; 4 = usability catastrophe: imperative to fix this before product can be released).

Results of heuristic evaluation. The HE identified 21 issues with Sustainable BI (Table II), all of which were addressed and modifications made to accordingly. The *information coding* (*H1*) heuristic had the highest number of issues ($f = 8$) of which three had a rating of 4. These issues were related to the lack of measurement units and data labelling on some graphs, and the problem with the scaling of the axes of the graphs. The tool was modified to address the issues related to *H1* by adjusting the *y*-axis to enable users to better identify fluctuations and trends and by including the units of measurement on the graph axis.

The second highest frequency of issues identified ($f = 4$) was for the *consistency* heuristic (*H6*); however, the severity ratings for consistency were generally low. The issues with *consistency* included the inconsistency in the use of terms "pass rate" and "success rate", as well as inconsistent labelling. The *data set reduction* (*H10*) heuristic had the third largest

#	Heuristic	Description
H1	Information coding	Represent information using the correct visual objects
H2	Minimal actions	Enable the user to accomplish tasks using the least number of actions possible. All unnecessary actions should be removed
H3	Flexibility	Be flexible by providing users with multiple ways to accomplish a goal
H4	Orientation and help	Provide the user with functions to control the levels of detail of information, redo/undo actions and represent additional information
H5	Spatial organisation	Use space optimally while ensuring that all information is legible
H6	Consistency	There should be consistency in design
H7	Recognition rather than recall	The user should not have to memorise large amounts of information to carry out tasks
H8	Prompting	Provide appropriate prompts to assist the user
H9	Removing the extraneous	All extraneous information considered to be a distraction and not required should be removed from the dashboard
H10	Data set reduction	User interface support of data set reduction

Source: Forsell and Johansson (2010)

Table I.
Heuristic criteria

Heuristic	Problem description	Evaluator no.	Severity rating	Frequency count (*f*)
H1 (information coding)	Decrease value of *y*-axis on electricity usage graph to better show fluctuations in usage	P3	4	8
	Provide unit measurements on graphs	P1	4	
	No units of measurement on electricity and water usage graphs	P5	4	
	Change axis values on "*over time*" graph	P1	3	
	Units of measurement are not provided Difficult to determine if electricity usage is measured in watts or rand	P4	3	
	No data labels on pie charts	P1	2	
	Graphs do not have labels on data points. Need to hover over data points to see values	P4	2	
	Pie charts should have data labels	P2	1	
H2 (minimal actions)	Difficult to navigate between dashboards. User has to navigate back home to go to another dashboard	P4	3	1
H4 (orientation and help)	Provide a home button	P3	2	1
H5 (spatial organisation)	Too much blank space on graduations dashboard	P2	2	2
	Date filters on electricity and water dashboards take up too much space. Dropdowns would be better	P5	2	
H6 (consistency)	Unsure of the difference between pass rate and success rate	P5	3	4
	Inconsistent use of caps and non-caps	P3	1	
	Inconsistent use of terms pass rate and success rate	P3	2	
	Graph labels are inconsistent	P2	1	
H9 (remove the extraneous)	Remove decimal points	P1	1	2
	Three numbers after decimal point unnecessary	P5	1	
H10 (data set reduction)	Provide more filters such as gender and race	P3	4	3
	Should be more filters than academic year	P2	3	
	Provide additional filters	P1	3	
Total issues				21

Table II.
Heuristic evaluation problem descriptions

number of issues (f = 3) and all were high severity (3 or 4) and were related to the lack of dedicated filters, which required users to select that specific field on the provided graphs. Participants of the HE preferred having dedicated filters for fields such as race, gender and nationality, and so these dedicated filters were incorporated for all additional fields.

Usability evaluation of the Sustainable Business Intelligence Tool

After improvements recommended by the HE were made to the software, a usability evaluation was conducted.

Usability evaluation method, target sample and task list. Previous research studies suggest that five participants in a usability evaluation are sufficient to determine any major issues and to determine whether the system was usable (Nielsen and Landauer, 1993; Lewis, 1995). However, more recent literature has revealed that 5 participants are inadequate and that 10-12 participants is more desirable (Lindgaard and Chattratichart, 2007; Tullis and Albert, 2013). So, 12 participants were invited to take part in the usability evaluation of Sustainable BI and were representative of the actual intended users of the proposed system. The 12 participants who were invited to participate were selected based on their job profile, which had to be related to sustainability information management, and all 12 accepted. Some were directly responsible for the management of sustainability at the strategic level whilst others were in senior management positions in the management information systems division. In this way, participants with the appropriate competency level were selected.

The 12 participants were required to perform several tasks using the tool and to answer questions relating to each task. The goal of the usability evaluation was to identify all possible usability issues. The tasks that were performed covered the main capabilities of the Sustainable BI Tool. *Filtering* enabled the participant to select information based on specific criteria. *Drilling-down and drilling-up* enabled the participants to view information from different levels of detail. *Forecasting* enabled the participants to predict future outcomes based on historic data, whereas *creating reports* enabled the participants to share information with others.

Research instruments, criteria and procedure. All participants were required to provide consent to participate in the usability evaluation and to complete a biographical questionnaire. Instructions were provided to the participants through a written information form and a task list.

Five evaluation criteria were identified by Jooste *et al.* (2014), which are relevant for evaluating BI solutions, namely, visibility, flexibility, learnability, operability and error control and help. *Visibility* measures the systems' ability to provide clear and well-structured information, instructions, navigation options and system statuses at all times. The *flexibility* criterion evaluates to what extent the user feels in control of and is able to customise the application for individual or collaborative usage. *Learnability* is described as the extent to which the software enables users to learn the application. *Operability* refers to the degree to which a software product is easy to operate and control. The error control and help criterion measures the ability of the system to prevent and recover from errors and provide help to the user when required. The criteria of effectiveness and efficiency was added as it is relevant for any IT applications (ISO, 2008; Tullis and Albert, 2013). Effectiveness is defined as the extent to which the software can allow a user to accurately complete a given task (Preece *et al.*, 2011). *Efficiency* is described as the degree to which the product performs as expected, thereby enabling users to complete their task successfully (Rubin and Chisnell, 2008; Tullis and Albert, 2013). Efficiency can be quantified as the amount of effort required by users to complete a given task.

Upon completion of the task list provided in the usability evaluation, participants were required to complete a post-test questionnaire. The quantitative section of the questionnaire contained several statements where participants were required to rate to what extent they agree with the statement according to a five-point Likert scale, where 1 is strongly disagree and 5 is strongly agree. The following statistical ranges were applied when analysing the scores: negative ($\mu < 2.6$); neutral ($2.6 \geq \mu \leq 3.4$) and positive ($\mu > 3.4$). Each statement was related to one of the seven usability criteria. The post-test questionnaire also included a section with open-ended questions where users could provide qualitative feedback regarding the positive and negative features of the tool.

Results from the usability evaluation. The age range of the participants varied, with 17 per cent of participants between the ages of 18 and 30, 42 per cent between the ages of 31 and 40 and 42 per cent over the age of 40. The majority (77 per cent) of the participants qualified for usability evaluation. In total, 54 per cent of participants had more than five years' experience in using BI tools, 8 per cent had four to five years' experience in using BI tools and 15 per cent had one to two years' experience in using BI tools. The remaining participants had less than one year of experience in using BI tools. The frequency of use of BI tools varied considerably between participants, with 38 per cent of participants using BI tools daily, 8 per cent of participants using BI tools weekly, 23 per cent of participants using BI tools monthly, 15 per cent of participants using BI tools annually and the rest of the participants had never used BI tools.

The visibility section consisted of four separate statements, all of which were rated positively (Figure 5). The highest rated visibility statement was "*The information is displayed in an uncluttered and well-structured manner*" (μ = 4.62), followed by "*The application communicates the system status at all times*" (μ = 4.54) and "*Instructions are visible and self-explanatory*" (μ = 4.54). The overall mean score for the four statements was positive (μ = 4.52). This result indicates that participants perceived the information provided to be highly visible. The flexibility section consisted of two statements, with both receiving positive ratings (μ = 4.5), showing that participants were satisfied with the flexibility aspect of the tool (Figure 6).

Learnability consisted of three statements, all of which were rated positively (Figure 7), indicating that participants felt that the tool was easy to learn. The overall mean learnability score was also positive (μ = 4.38) and indicates that the prototype was *easy to learn to use*. Error control and help consisted of two statements of which both were rated positively (Figure 8). The overall mean for error control and help was also positive (μ = 4.04), although it had the lowest mean score of all the seven criteria. All eight statements related to operability were rated positively, and the overall mean score was positive (Figure 9). The highest rated

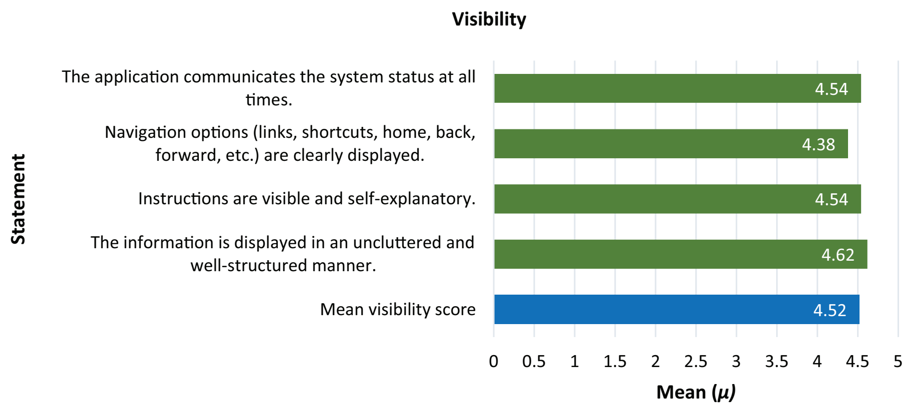

Figure 5.
Visibility of sustainable BI

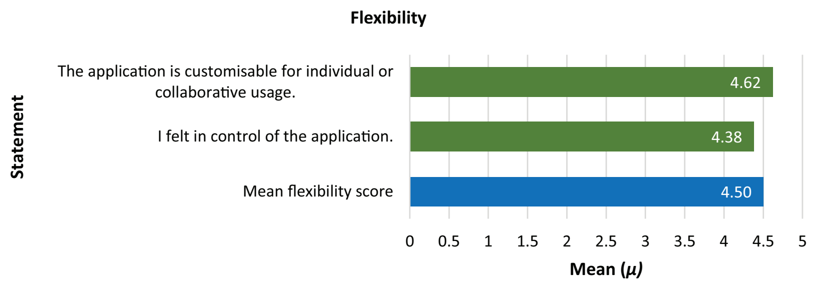

Figure 6.
Flexibility of sustainable BI

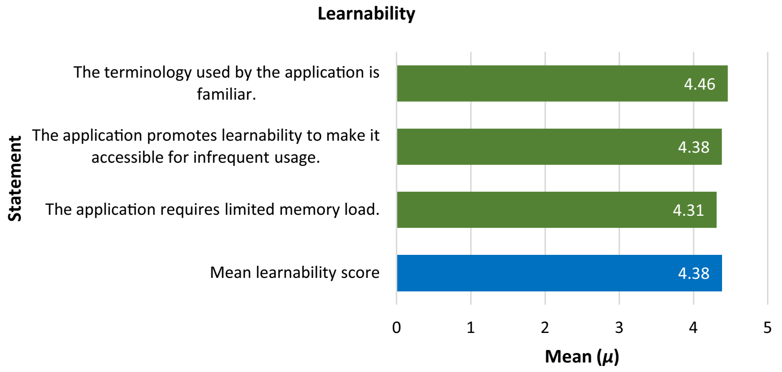

Figure 7. Learnability of sustainable BI

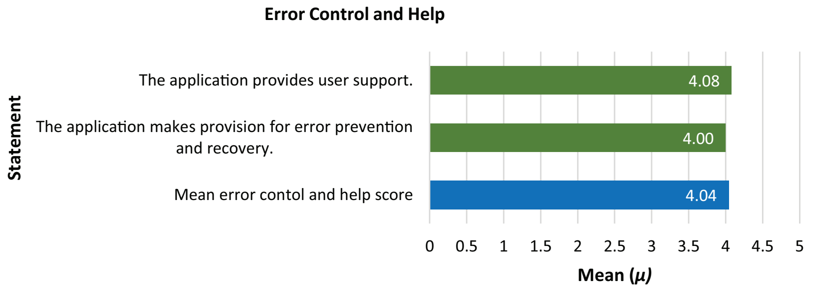

Figure 8. Error control and help of sustainable BI

statements were "*I have the option to save data views on the application*" (μ = 4.92) and "*The application allows knowledge sharing and exporting data*" (μ = 4.92). This was followed by "*The application behaviour is consistent*" (μ = 4.85*)* and "*There is information visualisation functionality*" (μ = 4.85*)*. The lowest ranked statement, although positively rated, was "*The system displays a hierarchical map to determine data granularity level*" (μ = 4.54*)*. These results show that participants were very satisfied with the operability of the Sustainable BI Tool. Participants were required to answer questions for each task in the task list based on the results provided by the Sustainable BI Tool. Effectiveness was measured by the number of correct answers provided by the participants and by the effectiveness section in the post-test questionnaire. Both statements in the effectiveness section received a positive mean rating (μ = 4.69) and were "*I could effectively complete tasks and scenarios using the system*" and "*I could complete all the tasks successfully using the system*" (Figure 10).

The participants' task-related answers revealed whether the tasks were successfully completed. Three tasks had a success rate of 100 per cent, another three tasks had a success rate of 92 per cent and one of the tasks had a success rate of 85 per cent. The high success rates of the tasks, together with the results of the effectiveness section in the questionnaire, suggest that the tool is effective. Efficiency consisted of three statements, all receiving positive ratings (Figure 11). The highest rated statement was "*The application provides a rapid response rate*" (μ = 4.77). The results show that participants were satisfied with the efficiency of the tool in accomplishing the required tasks.

Discussion of the results from the usability evaluation. Participants also provided a rating to represent to what extent they perceived that the tool could assist in realising the benefits of BI identified by literature (Figure 12). Participants rated the prototype positively for all

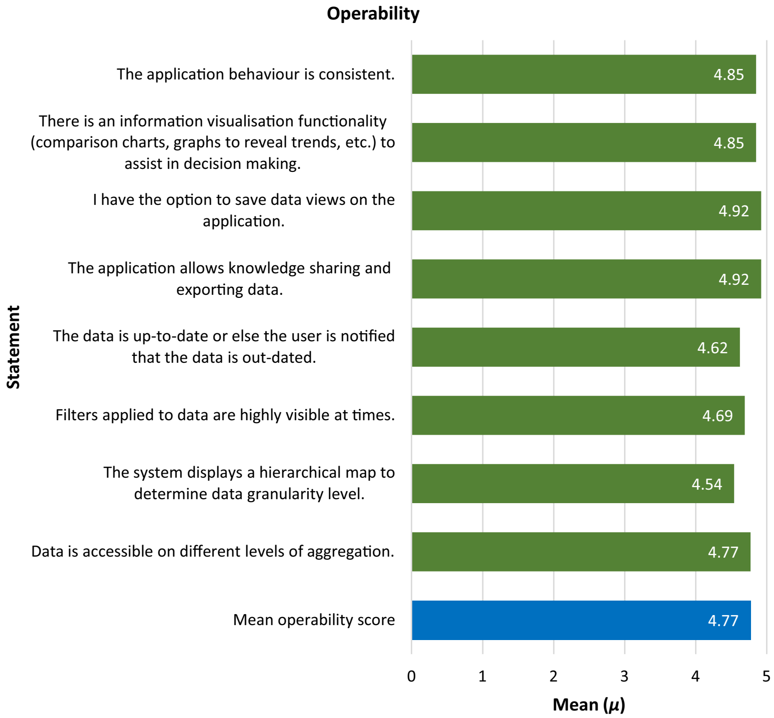

Figure 9.
Operability of sustainable BI

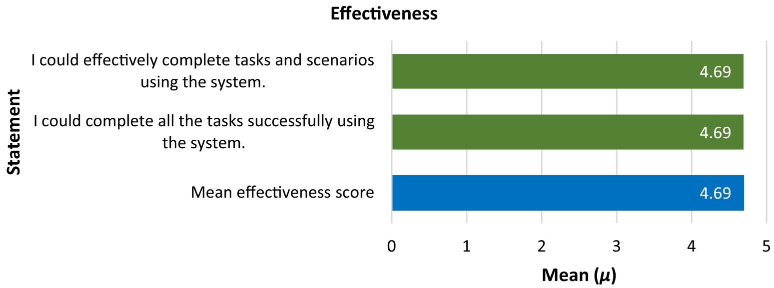

Figure 10.
Effectiveness of sustainable BI

five benefits of BI that were identified in the literature (Watson, 2009; Hočevar and Jaklič, 2010; Holsapple *et al.*, 2014), namely, integrated information, improved organisational performance, improved support for managing strategic goals, improved decision-making and more and better information. This finding therefore supports these previous studies. Several participants indicated that they would make use of the Sustainable BI prototype in future. The results therefore confirmed that the Sustainable BI prototype could assist management in realising the potential benefits.

The positive aspects and negative aspects identified in the post-test questionnaire (Tables III and IV) were grouped into related themes using thematic analysis and an approach identified by Braun and Clarke (2006). Participants identified that the tool was

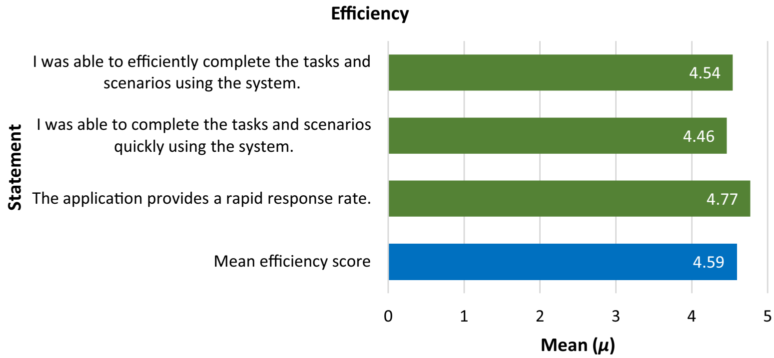

Figure 11.
Efficiency of sustainable BI

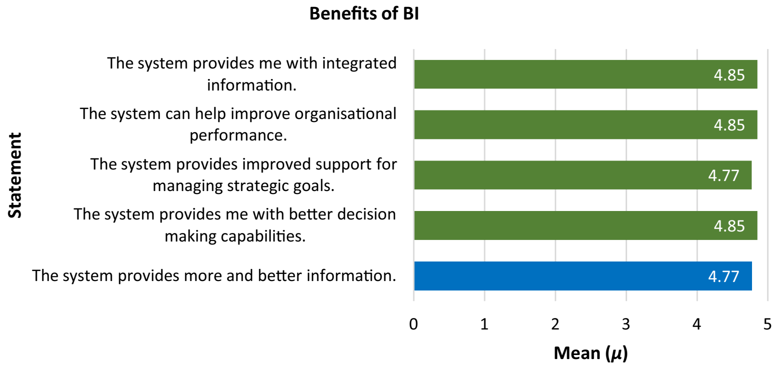

Figure 12.
Benefits of sustainable BI

Positive aspect	Frequency (f)
Sustainable BI is intuitive and easy to use	3
Forecasting and drill-down capabilities are very useful	2
Allows for improved decision-making	2
Enables transformation of raw data into useful information	2
Good way to visualise data (identify trends)	2

Table III.
Positive aspects of sustainable BI identified by participants

Negative aspect	Frequency (f)
Response times are slow	3
Information does not all fit on one screen (dashboards too wide)	2
Filters should be at the top of the dashboard not the side	2

Table IV.
Negative aspects of sustainable BI identified by participants

intuitive and easy to use ($f = 3$). Participants liked the forecasting and drill-down capabilities ($f = 2$) and that the tool allows for improved decision-making ($f = 2$), enables transformation of raw data into useful information ($f = 2$) and that the dashboards provide a good way to visualise data and identify trends ($f = 2$). These aspects all align directly with the requirements for a BI tool in supporting strategic sustainability information in higher education. Negative aspects included slow response times of the Sustainable BI Tool ($f = 3$), which could be attributed to the volatility of the internet connection in South Africa and the fact that the tool is cloud-based. On the other hand, connection issues could not have been that seriously, as from the task success metrics, it is evident that participants could complete the tasks efficiently. Other negative aspects were related to information not fitting on a single screen-space because of the width of the dashboards ($f = 2$) and that filters should have been located at the top of the dashboards ($f = 2$) (Table IV).

Discussion of overall results

The study confirmed through the literature (Bosire, 2014) and interviews held in the larger study (Haupt *et al.*, 2015) that there is a low level of maturity of BI implementations in HEIs in South Africa. The literature review reported on in this paper identified five criteria proposed by Jooste *et al.* (2014) for evaluating BI solutions. These were extended with two additional criteria of effectiveness and efficiency. The Sustainable BI Framework (Figure 1) was used to develop the Sustainable BI Tool as a proof of concept of the framework. The evaluations used different stakeholders as participants. The usability evaluation results confirmed that the seven criteria used in this study can be used for evaluating BI tools required for sustainability reporting. The HE revealed important usability issues in the tool that led to modifications to the software so as to improve its usability. Information coding had the highest frequency of usability issues, thus supporting the study of Forsell and Johansson (2010), who propose using it as a heuristic for evaluating BI tools. The Sustainable BI Tool was modified to make improvements based on the HE results.

In total, 12 participants took part in the usability evaluation of the improved tool and rated all seven criteria (visibility, flexibility, learnability, error control and help, operability, effectiveness and efficiency) positively, showing that overall, they were satisfied with the usability of the tool. The evaluations also revealed that the tool can provide and share up-to-date integrated strategic sustainability information based on the strategic KPIs identified by management. Interactive and dynamic dashboards were used with real-time information. The Sustainable BI Tool can provide historic information and forecasting capabilities to provide predictions. The information provided by the Sustainable BI Tool encapsulates all the components of sustainability by integrating the data sources and can be used to create reports that can be used for sustainability reporting as required by legislation. The visualised information is combined into a high-level of granularity, but refining capabilities enable users to view information at lower levels to identify causes of specific problems. The participants also confirmed that the benefits of BI reported in previous literature (Holsapple *et al.*, 2014; Hočevar and Jaklič, 2010; Sabherwal and Becerra-Fernandez, 2011; Watson, 2009), particularly for HEIs (Bosire, 2014; Pina, 2011), can be met by the tool.

The quantitative results were confirmed by the qualitative, open-ended comments of participants. However, in spite of the generally positive results, several constraints were encountered during the implementation. One of these was related to poor internet access, which impacted response times and difficulties with gaining access to quality data and ICT support, as reported by previous literature (Otto and Reichert, 2010; Lin *et al.* (2009); Ranjan, 2008). This finding is of importance to developing countries where infrastructure such as low bandwidth and poor internet access can limit the potential benefits of using BI tools for sustainability reporting.

Limitations and implications

Existing frameworks for sustainability reporting provide organisations with guidelines on how to report on sustainability but do not provide the software or BI tools to produce integrated sustainability reports that consider all the stakeholders and allow for strategic predictive analysis. Previous studies of BI frameworks designed specifically for HEIs (Bosire, 2014; Muntean *et al.*, 2013) are limited and do not consider the steps required for dashboard development or the details of the data sources in the four components of sustainability at an HEI. Also, they do not provide guidelines for the design of sustainability dashboards. Here, it might be useful to describe the conceptual approaches and ICT tools (including already existing prototypes) in terms of ICT-based sustainability reporting in HEI.

A limitation of the study was that the framework was implemented at one HEI only. However, the proposed framework can be used by all HEIs to guide the design of a BI system for strategic sustainability management, as it is a generic framework that incorporates different types of sustainability-related data sources. The framework is not specific to one HEI. The framework is also not specific to one country or to developing countries, even though the tool was only implemented at one HEI in South Africa.

The DSR methodology followed produced two artefacts for supporting strategic sustainability information management and reporting at HEIs. The theoretical artefact was the Sustainable BI Framework (Figure 1), which was an extension of existing theory and is a valuable contribution of this study. It provides a theoretical foundation for the design and implementation of a BI tool to support effective strategic sustainability information management. This framework highlights the various components essential for such a BI tool and the steps required to develop dashboards. The framework also provides guidance for the design of integrated sustainability dashboards in a BI tool.

Overall, the findings have practical implications as the Sustainable BI Framework can be utilised by ICT staff to plan the implementation of a BI tool at HEIs. Designers of BI tools can use the design guidelines proposed to design dashboards that have high usability. The findings also revealed that a BI tool that has high usability can achieve the expected benefits. The Sustainable BI Tool, which is an implementation of the BI framework, is a BI tool that can assist strategic management at HEIs to better accomplish sustainability efforts. The tool encapsulates data from multiple categories of sustainability and provides an integrated view of this information. The results of the usability evaluation revealed that the Sustainable BI Tool was very successful in assisting strategic management at the case study in managing strategic sustainability information. The dashboards provided by the tool encapsulate both educational and environmental aspects of sustainability. This information is provided through performance dashboards with predictive capabilities to enable management to forecast whether the institution is on track to meet its long-term goals. In this way, HEIs can reduce the impact of the environment on the local community and ensure the future sustainability of the institution. The results revealed in-depth, valuable insight into the issues that can be expected when designing and implementing a BI tool in an HEI. These issues relate to technical, usability and management issues. Some of the issues identified were related to infrastructure (e.g. internet speed) that may not be relevant in developed countries. However, some of the other issues such as those relating to dashboard design and filtering could be applicable to other countries. Additional research is required to investigate if there are any potential issues that are country-specific. Culture, for example, could influence choice of colour and navigation issues.

Future research could investigate the adoption of the framework in other cases of HEIs or the impact of the usability ratings on the perceived benefits of BI. Comparisons between HEIs in developing countries and developed countries should be researched. A primary challenge of HEIs in the future is to prioritise data quality, integration and management support of this into their strategy.

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