A Context-Based Business Intelligence Solution for South African Higher Education

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Abstract—This paper shows the results of a research based approach to the implementation of an integrated management information system in South African Higher Education. The paper aims to address and put into practice the theoretical foundations of information systems research and argue that a context-aware based business intelligence framework is suitable to respond to institutional decision making activities within the South African Higher Education sector. The study addressed the loopholes in managing higher education institutions by fact and also streamlines how integrated business intelligence tools and applications can bring organizational intelligence. The study employed a mixed method research approach, where information systems research methodologies especially the design science research methods in information systems, quantitative and qualitative techniques are solicited in applicable situations during the study.

Index Terms—management information systems, business intelligence, context-aware, technology acceptance model, mixed methods research

I. INTRODUCTION

The business intelligence theory is an umbrella term that refers to the skills, processes, technologies, applications and practices that are used to leverage an organization’s internal and external information assets to support and improve decision making activities [1]-[3]. Business intelligence solutions in higher education have gained momentum and according to [4] and the [5] more than a third of the United Kingdom’s Higher Education institutions use the IBM Cognos and even more institutions are adopting Business Intelligence Solutions. Business intelligence solutions give managers the visibility into institutional processes, forecast future behaviour of institutional processes and the ability to take proactive actions in areas where their organizations should improve in performance [1]. Business intelligence can be regarded as a driver for Management Information Systems, and in the higher education sector they present an opportunity to provide meaningful information about performance.

A number of higher education institutions are falling below the expected proficiency levels in terms of their student success rates, graduation rates, enrolment targets, staff retention etc. [2]. Universities should be able to measure, monitor and understand their performances and elicit the factors that play in student enrolment and tuition, staffing, finance, procurement and asset management [2]. Universities are therefore obliged to develop an information and communication technology (ICT) infrastructure that facilitate the university management to get meaningful information that will help them make correct decisions and create suitable conditions for the success. When data is scattered across the university as isolated silos, solving the success puzzle becomes a mystery or a mission impossible. Apart from leveraging existing technology investments, universities have to implement integrated ICT infrastructures that extract data from these silos and use analytics that will help the university management to make sense out of the data and make informed decisions [5]-[8].

Every higher education institution is unique, as envisaged by the different vision and mission statements they do possess. The uniqueness might be posed by the different mode of delivery of the courses, which is contact, distance or a hybrid form of delivery that consists of both distance and contact modes of delivery. The standardization of the ICT infrastructure that supports decision making processes in the higher education institutions is therefore dependant on the statutory obligations which the institutions have to comply [9]. In South Africa there are 23 public universities and each of these universities has to submit Higher Education Management Information System (HEMIS) statistics data to the Department of Higher Education and Training (DHET) three times a year. The public Higher Education Institutions (HEIs) rely financially on the subsidies and block grants given to them by the Department of Higher Education and Training (DHET). The HEMIS data is used by the DHET to allocate subsidies and block grants to the institutions.

Management Information Systems (MIS) form the basis of providing information for decision-making, policy formulation and provide information to support the execution of strategies within the higher education sector [10]. However, taking MIS as it is implies manoeuvring into a wide variety of information systems that fall into these systems. Examples include Decision Support Systems, Executive Information Systems among others. The theoretical framework for this study is informed by the field of Management Information Systems in the Higher education sector, particularly informed by the role

In this study we base our theoretical framework on the fact that it is incumbent upon business intelligence and analytics to provide theoretical and practical technological tools to Management Information Systems. This is done in terms of generally accepted research doctrines in the form of technology and information systems research paradigms in our case mixed methods research, and validating the quality of meta-inferences. This is a fundamental postulation to be made in this research study, because if the role of business intelligence is to be understood in its various incarnations, students, researchers and practitioners of MIS must have a broad understanding of business intelligence and its inherent predictive analytics characteristics.

The context-aware business intelligence framework to be developed remains theory unless put into use and tested for its adoption and use in the South African higher education. We therefore, implement the CABIF at the University of Venda, basically with the aim of covering most the theories, concepts and constructs mentioned. For this reason we included all the activities related to the implementation of the CABIF as decision-making processes, and test empirically and theoretically on the technology acceptance and adoption of the BI solution at the University of Venda. The Technology Acceptance Model (TAM) as theorised and published [12]-[14] form the basis for measuring business intelligence technology adoption and acceptance at university of Venda and any other university with BI technology in South Africa.

II. PROBLEM STATEMENT

In South Africa given the shrinking government budget to higher education and the current economic environment, institutions need to provide high quality HEMIS data to attract government subsidy and block grants. The current harsh economic environment is not only affecting South African Higher education institutions, as [4] argued that, data integration capability is non-existent in most higher institutions, and given the fact that universities have large amounts of data at their disposal few university managers understand the benefits of BI. This situation has resulted in multiple data sources in institutions that often contradict each other and usually the data is just in raw form that is not of value in the institutional decision making activities [4], [15], [16]. The implementation of BI can have positive significant effects in the decision making processes of the institution [3], [4], [15]

The implementation of BI initiatives in Higher Education using the one-size-fit-all approach does not work [4]. The commonality in all BI implementations is the existence of a data warehouse, but designing a business intelligence requires an agile rather than a waterfall approach [4], [16], [17]. Critical to BI implementations are Information Systems research methodologies, which consider the business users among other elements [4], [16], [17]. In South Africa Higher Education institutions are required to submit five-year enrolment plans to the DHET depending on the HEMIS statistics. These statistics are used by the DHET to project and forecast on the grants and subsidies each institution will have to receive in the future. The question that might be raised is whether the institutions themselves can use the available technology resources to predict the subsidy and grants from the government. Even during their budget forecasting and elaboration processes do these higher education institutions factor in HEMIS statistics to predict the viability of the programmes and modules they are offering or intend to offer?

In response to the previous question, we argue that, the higher education institutions will only be able to forecast on the amount of government subsidy and grants they will receive if technological tools for predictive analysis of their current data assets are available. One might argue that the solution to this is simply the public higher education institutions must invest in off-the-shelf BI tools that have been used in higher education for the past decade, such as SAP Business Objects, IBM Cognos and Infobuilder, then implement them. This will be suicidal in that the context of each institution is unique and the one-size- fits all is not a pragmatic approach. Reference [8] presents the “Cycle of Continuous Improvement”, as a possible means of using BI to deliver information and communicate strategy to various stakeholders within higher education institutions. The BI technology can then be used strategically for performance management by connecting the institution’s strategy, retrieve and analyse data, and link with operational institutional processes in a continuous cycle.

However, to make management information systems usable as vehicles for decision-making processes and performance management in the Higher education sector particularly in the South African Higher Education sector is not an easy task. Selecting a technology and linking with the theoretical conceptions of the MIS field and evaluate the technology choice through empirical means is often unheard-of in HEIs. It is an overarching aim of this research to bring out the scientific nuggets that elucidate the fact, that Management Information Systems technology choices within higher education should be based upon IS theory and supported by a suitable academic practices.

III. AIMS AND OBJECTIVES

The aim of this study is to develop and implement a Context-Aware Business Intelligence Framework (CABIF) for the South African Higher Education sector. The aim is achieved by providing an accessible, secure management information system environment that achieves the following specific objectives:

- Leverage the collective knowledge of existing business intelligence systems in the South African higher education sector to accommodate a context-aware business intelligence framework for the sector;
- Establish practices and processes for HEMIS and Operational data provision to end users;
• Streamline data collection into a data warehouse by integrating transactional and reporting systems to take best advantage of the Business Intelligence tools and provide comprehensive reporting and analytics;

• Develop a web based University Management Information System Portal with dashboards which will be a place for university management to get information on the institution’s performance with regard to strategic objectives;

• To allow university management to view data and reports for which they can use for decision making, planning, quality assurance and/or policy formulation;

• Provide an estimate of government funding (subsidy) according to schools/faculties, departments and give future funding projections;

• Evaluate the end-users’ perceived adoption and acceptance of the rolled-out information system based on the developed business intelligence framework;

The BI solution will have to leverage collective knowledge of existing operational information systems to accommodate a university-wide management information system. The system will have to establish practices and processes for HEMIS and Operational data provision by standardizing the processes of data integration and dissemination on a web portal. In this process the information system will facilitate the establishment of a centralized system of official university data records that ensures legal compliance both for internal use and external reporting.

IV. RESEARCH QUESTIONS AND HYPOTHESES

Following the preceding statements and arguments in this research, the research questions for this study are as follows:

RQ1 What are the conceptual foundations of the business intelligence frameworks currently used in the South African public Higher Education Institutions, and are these technological entities theoretically and practically contextualised?

This research question comes from the broader research aim of trying to scan and get information about the business intelligence solutions and frameworks currently used in the South African higher Education sector. The research question requires a classification of the scientific knowledge relating to current business intelligence applications and contextualize them in relation to theories and practices of IS research. After scanning and contextualizing the BI frameworks currently used as basis for management information systems in the South African public higher education sector, we then come up with a customized business intelligence from for the sector. This is because we assume that there is a hybrid of business intelligence applications and solutions within the sector and in some cases there might be no BI solutions at all. The business intelligence framework to be developed will be called the Context-Aware business intelligence framework (CABIF).

In order to develop CABIF we will be guided by the following research question:

RQ2 What Context-Aware business intelligence framework is suitable for the South African public higher education sector, and why?

This research question suggests analysing and deriving at the common entities that may constitute contexts within the higher education sector in South Africa. This question is grounded principally by the theoretical underpinnings behind business intelligence systems, context-aware and information systems. In pursuit of answering this research question we include, studying documentation from the South African higher education sector, including their statutory obligations. The data collected during the process of answering the first research question will also provide insight on how a context-aware business intelligence framework for the sector can be developed.

V. LITERATURE REVIEW

A. Overview of Management Information Systems and Business Intelligence

There is a dialectical relationship between Business Intelligence (BI) and Management Information Systems (MIS). It is incumbent upon business intelligence and analytics to provide theoretical and practical technological tools to Management Information Systems, and to do so in terms of generally accepted research doctrines in the form of technology and information systems research paradigms. The important aspect and variation to the study of business intelligence and analytics is its evolution. While the term intelligence in computing dates back in the 1950s being coined by artificial intelligence researchers [18] business intelligence became only popular in business and information technology communities in the 1990s [19]. As [20] argued that only in the late 2000s, business analytics was coined to represent the key analytical component in BI solutions.

The generation approach to the evolution of BI and analytics coupled by Context-Aware give another dimension to the contextual understanding of BI in various applications domain. How Context-Aware informs the development, implementation and the adoption of a business intelligence framework particularly in higher education constitutes a research gap. Information and communication technologies (ICTs) particularly decision support technologies that are the epicentre of MIS have reached distinguished maturity levels and the literature shifts to a new epoch in business intelligence and analytics technological progress, i.e., of the so-called convergent big data and big impact technologies, and observes its irruption as it merges with the remnants of the ongoing techno-age. The next issue that arises is the adoption of business intelligence according to geographical regions and application domain. While this research study appeals to the inherent international character of both the discipline of BI and MIS as well as the discourse about this subject field, this
research project is from Africa, particularly for South African Higher Education and maybe relevant to its peers among the larger cluster of the Southern African Regional Universities Association (SARUA). There is available, adequate and sufficient evidence to show that these countries do not have the absorptive capacity to benefit from international technology transfers [21]. South Africa [22] needs to improve her production competence and knowledge generation for technology transfers. If we take this postulate we need to outline the adoption of BI, Analytics and MIS technologies as drivers for decision making in South African Higher Education.

Finally, developing a BI framework, implementing and adopting it in Higher Education for research purposes depends on the research model, its data requirements and the vagaries of data collection. The BI framework and solution cannot be developed, implemented and adopted without understanding its acceptability by the end-users particularly in the use of the solution in their professional areas. Theories of Information Systems research will be studied and the ones used for this research highlighted. The field of information systems have evolved over the past 45 years of its existence [23]. The shift is from not only focussing on business needs of the organizations addressing major challenges of managing internal business processes and transaction data, but to integrate with data analysis and rapid decision making based on a large volume of data [19], [23]-[25]. It is acknowledged that such data analysis that involve time-critical decision making activities takes place outside the organization’s operational information systems.

B. Business Intelligence in Higher Education

Business intelligence can be successfully implemented and effectively used in higher education to make intelligent decisions that will enhance the student success rate [4]. According to [8], many institutions of higher education still have administrative information systems for student, finance, human resources and usually find it costly to provide data for decision making. The reason is that most operational information systems for HEIs are transactional in nature as they process transactions rather than provide information [4], [8]. To compile reports staff in most HEIs have get into laborious, time-consuming and costly routines of churning out the various information sets from transactional systems and interpret it into meaningful products.

As information in higher education institutions originates from different databases as separate data silos which are not integrated in any way, it requires a significant size of effort to extract and turn it into something useful and meaningful. In this scenario, there is no synergy of data provision activities, as various individual staff members can repeat the same manual data extraction and analysis procedures and routines already executed by other members of staff [8]. The planning process for implementing BI in small or medium sized businesses can at times seem overpowering but the problem is even tougher when BI is applied to higher education, particularly if the institution is public in nature [4], [26].

As [4] hinted that the path for attaining success in applying business intelligence tools for many institutions, principally small and medium sized institutions, may well be a jerky one. The understanding of the benefits and operational characteristics of BI applications is not a problem restricted to just University executives, but rather to IS professionals [4]. There is also a skills gap in the training of business intelligence professional as, [27] reports about the loopholes in the BI training process and suggested adding important hands-on projects designed to help the students link a particular BI framework to a prevailing database project. The success stories within BI certainly show that BI can massively increase efficiency in higher education. However, it seems as if each BI application will in fact be a little different because no two institutions operate in the same manner, have the same business niche including having the same strategic objectives[4], [27].

The higher education sector view BI as a solution with much promise in regard to adding much needed efficiency in all levels of decision making [4]. However, there seems to be some misperceptions as to what essentially set up a BI system. According to [28] deceptively everyone is tagging any kind of Higher Education reporting system a business intelligence solution. One large drive for BI in Higher Education is the amount of incongruent data sources and the time required to process integrated reports [4], [27], [28]. According to [28], the National University of Health Sciences (NUHS) needed to increase its enrolment reporting process and opted for a business objects BI solution forking out USD$200,000 and took two years of planning before roll-out was feasible. The BI solution adopted at NUHS was not aligned with the BI best practices, methods and techniques, which normally would encompass a custom solution and use a top down holistic approach, rather than focusing on one particular aspect of the business [4], [28].

We cannot fully reject or abandon the implementation process at NUHS, as focusing on one facet at a time might provide a means of breaking the problem into more manageable modules. A peril in this methodology is that the communication among those units might not be properly weighed. Tarleton State University face with the demands for information ranging from compliance, student retention, decision-making; enrolment planning and reporting deployed WebFOCUS BI technology [8]. The BI enabled an efficient and effective distribution of information among a large network of users within the institution. The Office of the Higher Education Commission in Thailand deployed a BI solution to generate an executive decision support information system to effectively and efficiently allocate resources to approximately 1.75 million students in 2008 [29]. Generally most higher education institutions including South African HEIs want to upturn enrolment, throughput, retention and student success while holding costs,
increasing affordability, safeguarding academic standards and refining teaching and learning standards [8], [22].

We advocate that before any BI solution is implemented it is important to have a thorough understanding of the context of each of the university. Business intelligence applications are computational agents therefore we advocate for the incorporation of Context-Aware in the BI framework to be adopted by each institution. We also argue that the key factors affecting enrolment, student success, retention and academic standards should be considered especially when measuring their impact against strategic objectives.

C. Context-Aware

Context-awareness is a very vital computing paradigm, and according to [30], [31] “context is any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the integration between the user and an application, including the user and the application themselves”. Latest advances in Context-Aware embrace the addition of such systems to the more advanced situation-aware systems [30]. One of the crucial matters in mobile Context-Aware is the pool of information from several nodes in mobile networks [30], [32]. Applications may exploit the gathered contexts from different sources in order to provide enhanced services such as environmental monitoring, security surveillance, contextual and situational inference and reasoning. Context collection refers to a process that a collector gathers context in quality and quantity from sources and other collectors in a computing system [30]-[32]. Reference [31] argued that, “Context refers to the current values of specific contextual ingredients that represent a user activity or situation” [30].

In academic circles, the Context-Aware paradigm has been widely researched and applied in the mobile and robotic computing environments [30]-[35]. Generally, in the Context-Aware archetype applications perceive and react to varying environments in an unattended fashion. To allow for behavioural adaptation, a context-aware application must dynamically obtain context data from diverse functional spaces in the real world, such as homes, shops and persons [35]. According to [35], “the ultimate goal of Context-Aware is to provide information and assistance for the applications to make appropriate decisions in the Right manner, at the Right time and in the Right place (3R)” (p.57). The context cradle can be a hardware sensor or a software process (e.g. web service or legacy database) that engenders context data, or a virtual source of an assortment of such sensors and processes whose context data is assimilated through a precise access point [18], [35].

VI. ANSWERS TO THE RESEARCH QUESTIONS

Most of the South African universities (Thirteen of the 23 public universities) are using the Higher Education Data Analyser (HEDA) and the remaining universities are using other Business Intelligence Software packages. Some universities do not have any BI solution in place. The other BI solutions that are being used in South African universities include SAP Business Objects at the University of Pretoria and Vaal University of Technology, Microsoft Business Intelligence Suite at the University of Stellenbosch, Infobuilder and IBM Cognos at the University of Witwatersrand. Some universities are integrating analytics into their in-house operational information systems and hiring local companies to develop these additional modules for them. The University of Western Cape is one such example and they are paying development costs to the tune of R 1 200 000.00. Where universities are not using HEDA they have skilled personnel in these specialized areas or they have integrated analytics into their operational information systems, meaning that they have budgeted for these costs.

Most of the universities don’t have any theoretical foundations behind the implementation of their BI systems. They did rely on the vendors, and the marketing of these products at technology expositions and conferences. In this research we argued that it is important for universities to align their BI solutions with their common goals. Using design science research we designed a context-aware business intelligence framework for the South African Higher education sector. We deduced common entities in the sector and come-up with a solution as indicated in Fig. 1. We have actually seen that deduced from the data obtained from the Department of Higher Education and Training the universities that have high quality data have HEDA in place as it has assisted them in data quality issues, which has been and still pose a challenge most South African Universities. In our research we recommend the implementation of the HEDA system it is the only commercial web information portal which analyse and report on HEMIS data. The Data Warehouse Architecture used in HEDA is not dependent on a specific operational system but integrates with any operational system currently used in the higher education landscape.

Figure 1. Context-aware business intelligence framework for south african higher education
Currently, the South African Universities’ Central Administrations and individual academic entities maintain student, staff, space and asset records in a variety of ways. Core employee information, such as personal demographics, appointments and tenure are captured using the Integrated Tertiary Information System (ITS). This entails that the staff, students, space, assets and financial information is captured directly into the ITS. Some directorates and departments with technical skills have built their own independent database systems. They import data from central operational systems and expand it to address the reporting needs of their respective units. This whole process of dealing with institutional data in many cases has resulted in data inconsistencies and raise questions about how best to enhance data quality, accuracy, security, ease and timeliness of reporting while increasing cost effectiveness.

The context-aware business intelligence framework demonstrated in Fig. 1 shows an example on how universities can develop, implement and maintain an integrated Management Information System. The context-aware business intelligence framework can also facilitate and monitor the development of communication processes which ensure the accuracy of data within the institutions. One of the processes that are indispensable and advocated for in the CABIF is to identify data formats that support strategic decision-making, institutional planning, policy development and quality management activities within the universities. Through the current administrative information systems and the developed data warehouse the MIS personnel can conduct research concerning staff, students, and facilities within the higher education institutions in order to establish trends, provide information for enrolment planning and policy formulation as well as supporting academic reviews by providing student demographic and academic performance data. As is demonstrated in the Framework the CABIF will work with various datasets such as Higher Education Management Information Systems (HEMIS) data, excel spreadsheets and other institutional operational data from other legacy systems. The point of convergence of all the data from various systems, and formats will be the institutional data warehouse.

VII. CONCLUSIONS AND FUTURE RESEARCH

The research identified that every higher education institution is different and has its own set of measurement for success. Furthermore any BI framework should be designed in such a way that it effectively supports the execution of strategic objectives of the institution. To incorporate performance management in the BI technology it should be able to support scorecards, drill downs, dashboards, and should convert data into useful information for decision-making and reporting. The use of predictive analytics and automated retrieval of institutional information from anywhere is also an added important characteristic to be included in the BI technology. Generally most higher education institutions in South African HEIs want to upturn enrolment, throughput; retention and student success while holding costs, increasing affordability, safeguarding academic standards and refining teaching and learning standards.

In the near future the research will include a selected software solution to test the developed CABIF as a case study at the University of Venda. The TAM will be deployed to validate the user adoption and acceptance of the selected technology.

REFERENCES


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