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Empirical Assessment of the Effectiveness of Business Intelligence Tools: Case of Free State Government Departments

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Abstract: In this paper, we employ a multi-pronged analytical approach (qualitative survey and factor analysis) to empirically analyze the usage and effectiveness of a widely used business intelligence tool, namely the Vulindela System (VS) in prominent service-oriented government departments (Provincial Treasury, Health and CoGTA) in the Free State province in South Africa. Using the novel Task Technology Fit theoretical framework proposed by Goodhue (1995) as an evaluation benchmark, we compute two principal component analysis (PCA) models to identify key latent features of the VS technology. We find evidence for both bi-directional and unidirectional links between the operational capacity, usability and functionality of the VS and executed tasks, productivity and decision-making capability of the main users. The empirical result suggest that the strength of VS lies in its ability to perform unstructured tasks, collate information, improve decision making and productivity but the operational capacity and functionality of the system is constrained due to incompatibility to meet user's task profile and inflexibility to execute new task demanded. Based on these findings, the reliability and usability of the VS can be improved by testing the system in different network environment and continuous development of new software, upgrade of operating systems.

Keywords: Business Intelligence tool, Information Technology, Principal Component Analysis, Task-Technology Fit, Vulindela System, Free State.

1. Introduction

Business Intelligence (BI) technologies are a key tool in decision-making processes within private and public sectors world-wide. In this context, BI is a grand, umbrella term that spans the people, processes and applications/tools to organise information, enable access to this information and leads to improved decisions and manage performance[1]. BI is mostly embedded into enterprise software and systems such as enterprise resource planning (ERP), customer relationship management system (CRM) and supply chain management (SCM). The challenge most organisations face is lack of a tool to evaluate the BI competences of these enterprise software and systems against the organization's decision-making processes and investments made towards their implementation [2]. Majority of the existing evaluation tools tend to focus on evaluating and selecting software packages and enterprise systems but not the intelligence criteria [3]. Secondly, they tend to focus on profit-based efficiency and therefore do not serve the needs of non-profit making organisations such as government service departments. Abstracting from the existing evaluation models, the effectiveness of BI tools to facilitate tasks, enhance productivity and aid decision making process can be described in different ways, based on the user's perspective, such as: user attitudes, information satisfaction, IS appreciation, information channel disposition, value, and

usefulness. Different models are used for different sectors and the problem statement to be investigated. The most commonly used empirical factors in these models are system quality, information quality, use or intension to use, user satisfaction and the organisational impact [2], [3].

There is a large body of research examining the viability, functionality and operational capability of BI tools using variety of evaluation models in the existing literature, however, most of these studies focuses on the successful implementation and application of BI tools in the private sectors (business enterprises) of advanced countries, while similar studies in the public sectors and/or developing countries, especially African countries remains scarce. Even so, few studies investigating the usage, importance and effectiveness of BI tools in Africa countries mostly rely on descriptive and/or qualitative evaluation method such as survey by administering set of questionnaires to main users. It is well known that feedback from surveys (or focused groups) tends to be objective and biased (Lin and Huang, 2008) [4] due to respondent's psychological and emotional state of mind, leading to an unreliable and inconclusive conclusion. At best, drawn inferences of the survey are typically viewed as anecdotal evidence, and also deficient of any diagnostic (or substantive) statistical tests to validate the reliability of the respondent's feedback and sampling adequacy of the administered survey questions.

Conversely, a number of studies have examined the usefulness of BI tools in South Africa's public and private sectors focusing on the organisational efficiency, generated operational revenue and productivity. Among these, Fujitsu (2006) [5] studied the impact of BI tools on the transportation, which involves both road (Translink Bus Company) and air (South African Airways) transports, and finds BI technology to be time-efficient, capable of processing complex (meta)data, generate high quality reports and error-free. While, Mosebi (2009) [6] found the usage of BIs as an innovative data-driven tool in both the public transport and the national carrier such as the South African Airways (SAA). Likewise, the Free State province (in South Africa) launched the implementation of BI technology, as a piloted project, to mitigate administrative challenges in companies managing subsidised public transport buses (Interstate buses).

Elsewhere, Dawson and van Belle (2013)[7] finds the BI technology as a reliable data warehouse and key catalyst that drives financial innovation, value-added products, and strong performance the financial sector in South Africa. While, Lutu and Meyer (2008) [8] focused on the use of BI tools in a provincial education department in South Africa, and found a notable improvement in the overall performance of both the main users and the education department. This finding suggests a linear correlation between the technology fit, users' requirements and performed tasks as predicted in most of theoretical models evaluating the successful implementation of BI tools, discussed in Section 2 of this paper.

Against this backdrop, this present study fills the research gap in the extant literature by using a multi-pronged analytical strategy to empirically analyze the effectiveness (and usefulness) of the of the commonly use BI technology in the public sector in South Africa, namely the Vulindela System (hereafter, VS) focusing on three prominent service delivery government departments, namely the Provincial Treasury, Department of Health and Cooperative Governance and Traditional Affairs in the Free State (FS) province in South Africa. On the other hand, the government departments in the Free State province (South Africa), tend to operate their enterprise software and systems in 'silos'. This makes it difficult to effectively interlink the existing BI technologies, and further aggravated by the fact that these systems were not designed for the challenging environments (especially infrastructural) the departments operate in. Consequently, decision making in the province is a lengthy and time-consuming process. In this context, findings from our analytical exercise would be able to equipped policy makers on how to integrate the implemented BI technologies as a single component to facilitate, among others, better service delivery,

durable infrastructure development, system communications and business innovations in the province. Similarly, our analytical exercise is relevant to ensure the implementation of effective policy decisions, improve aggregate productivity, seamless communication and transfer of information via reliable IT systems and enhance the delivery of the much needed quality services, to improve the general welfare of citizens and infrastructural development.

Our work contribute to the existing literature in several dimensions. Firstly, for the first time, unlike majority of previous studies evaluating the usage of BI tools in the public sector (and national departments), we focus on the sub-national sphere of government, that is, provincial government departments in a South African which has received little (or no attention) until now. Secondly, on methodological front, we make use of the qualitative survey method, by administering questionnaires to assess the usefulness of the VS relying on the experience of the main users, and obviate the common problem of unreliable or biased deductions by including multiple questions measuring the same construct (i.e. the observable characteristics of the VS) randomly in the administered questionnaire. However, we remedied the limitations by employing a factor analysis technique to unearth the unobserved (inherent) critical factors which encapsulate the weakness and/or strengths of implemented VS. This analytical method has become popular in extracting common components (factors) between small or large dataset of variables that defines or measures the same construct. To this end, we applied the principal component analysis (PCA) to provide an irrefutable empirical evidence on the success of implementation of the VS across the three provincial government departments. To carry out a robust evaluation of the VS technology as a BI tool, we applied the Task-Fit-Technology theoretical framework proposed by Goodhue [9]. By making use of the novel TTF framework together with factor analysis approach, we built two distinct TTF models (i.e. a 17-item and 12-TTF item models) to adequately match the VS technology features and the requirement of tasks executed. These models are then, factorised to extract latent components among the different measures of the construct (in this case, the VS technology).

The remainder of the paper is structured as follows: Next section provides a synoptic survey of different evaluation models for BI tools. Section 3 describes the different BI tools used in both the national and provincial (the Free State) government departments in South Africa. Section 4 outlines the research methodology employed, while the results are discussed in Section 5, and section 6 concludes.

2. Theoretical Models for Evaluating BI Tools

Research in the broader realm of Information Systems (IS) has resulted in development of wide-range of user's evaluation models aimed at assessing the extent to which the information systems in place effectively meet business tasks that need to be executed. These models also assess how the use of the information system influences the user's performance[10]. For example, to evaluate the effectiveness of BI systems, Davis et al. (1989) [11] developed the Technology Acceptable Model (TAM) [12] based on the hypothesis of Perceived Usefulness (PU) which referred to the degree to which system users believed that the continuous use of a particular system will enhance their overall job performance. In theory, TAM model asserts that users could choose to adopt a specific technology based on individual cost benefit consideration.

DeLone and Mclean [12] developed their model (D&M model) of IS that was used for process/casual model, measured the service quality and use and later replaced by intension to use. Gable et al., (2003) [20] IS impact model was developed based on the D&M model and perceived for measurement model to view the complete view of the system and success usage in all four dimensions.

More recently, Fourati et al. (2016) [2] used Task Technology Fit (TTF) and TAM to evaluate the use of BI tools by professionals and students. In the latter a model to identify

companies' understandings, expectations and needs in terms of BI systems is presented. In the same work, a model for evaluating the performance, user-friendliness, satisfaction, price and adaptability is presented. It emerged that user' experience was key in these issues. A related model is presented in [14] – it looks at BI's quality and performance and the results revealed the superiority of data quality in determining the performance of the BI.

2.1 The Task-Technology-Fit Theoretical Framework

One of most commonly used theoretical models for evaluating BI is the TTF model developed by Goodhue [9]. TTF is an established theoretical framework in information systems that enables the investigation of issues of fit of technology to tasks as well as performance. One significant focus of TTF has been on individuals to assess and explain information systems success and impact on individual performance. Goodhue and Thompson [10] proposed the technology-to-performance chain where characteristics of Information Technology (IT), tasks and individual users explain information system use and individual performance. TTF's thrust is that technology need to be willingly accepted as well as fit well with users and their corresponding tasks to prove its effectiveness. Further, TTF assumes that users will choose the technology based on its appropriateness for the tasks they intend to perform. By design, the TTF is based on four constructs of: task, characteristics, technology functionality and technology utilisation (*see, Figure 1*).

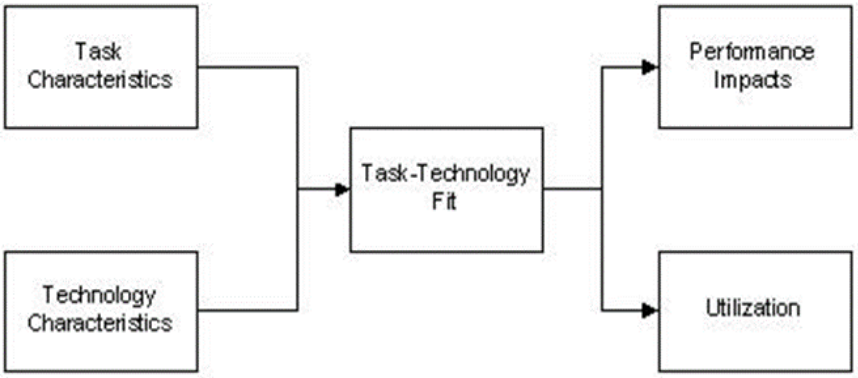

Figure 1. Conceptual Framework of the TTF Model [9]

With respect to task-technology fit elements, a number of studies have validate the task-technology fit items as a multidimensional evaluation tool for BIs capable of measuring intrinsic features of an information system technology and its fits, in terms of task requirement, functionality and interface of the information system, [9], [10]. As an effective organizational diagnostic tool, Goodhue and Thompson (1995) [9] developed twelve dimensions to measure a task-technology fit (TTF) using eight factors which are distributed among the TTF constructs of task, technology and individual characteristics respectively (*see, Table 1*).

Table 1: TFF Contributing Factors in the Adoption of IT [10]

Components of the Task-Technology-Fit Model	
Data Quality	Measures the users' satisfaction about the currency of the data, the right data and the level of detail of the data. So the need for all the necessary data at the right level(s) of details that is current enough to fulfil the employee's tasks.
Locatability	Consider the ease of determining what data is available where and what the meaning of a data element is (and for calculations what is excluded or included).
Authorization	Measures if users are able to obtain the right authorization to access data necessary for the job easily.
Compatibility	Determine if data from two different data sources can be consolidated or compared without inconsistencies.
Ease-of-use/ Training	It is easy to learn how to use the system and it is convenient to use the system to access data, including the ease-of-use of hardware and software, and easy of obtaining of relevant training.
Production Timeliness (Currency)	Ascertain whether the system can provide relevant information to the task in a timely manner. Information up to date and reports delivered on time
System Reliability	Consider the reliability and dependability of the system, from users' perspective, to complete the task without system problems and system breakdowns.
Relationship with Users (Assistance and training)	The system fits the users' daily requirements and corporate goals and provides maximum support to its users in order to perform their tasks.
Level of detail	Completeness of Information
Meaning	Ease of determining what information is available and where, Ease to understand what data means
Presentation	Information displayed in a clear manner
Lack of Confusion	Understanding of the information and results of data stored in many forms

3. Application of Vulindela Business Intelligence Tool in Public Sector

South Africa has a 3-tier government system made up of national, provincial and local government respectively. At the national level, a number of government departments such as the (1) Department of Cooperative Governance and Traditional affairs; (2) Department of Provincial Treasury and (3) Department of Health, are in charge of various national-wide issues. The provincial government is made up of 9 department, which are replica of the national departments [15], [16].

Various Business Intelligence tools are used to make decision within government departments at national and provincial levels. Government departments make use information system (IS) that comprises of business intelligence features, which include: (i) Logistical Information System (LOGIS), (ii) Basic Accounting System (BAS) system, (iii) Personnel and Salary (PERSAL) system, and (iv) Management Information System (hereafter referred to as Vulindlela System). Vulindlela is a BI tool that interacts with other systems, as illustrated in Figure 2.

Provincial departments in Free State use BI technologies to improve strategic decision making processes to ensure the delivery of quality public service. Since the structure and operations of the provincial departments replicate those of the national departments, there is general uniformity in the approach used in the implementation of the Vulindlela System (VS) BI tool. The high level of autonomy of provincial government means that the implementation of VS within the Free State government departments is wholly the responsibility of the Province. Among the provincial government departments; the FS Provincial Treasury, FS Health and FS CoGTA (Cooperative of Governance and Traditional Affairs) viewed as critical service-oriented provincial departments. Thus, these provincial departments are prime candidates (i.e. as a case study) for the evaluation of the implemented VS technology. For instance, among the three provincial departments, the FS Treasury department, facilitates the effective and efficient management of assets, liabilities

and financial activities of the province as well as compliance with financial norms and standards of other departments.

Furthermore, the above-mentioned provincial departments have been using other BI-enabled information systems since 2006, as a: Basic accounting system (BAS), Personnel and salary system (PERSAL), Logistical information system (LOGIS) and VULINDELA systems (VS). However, the lack of integration and a streamline process of data / information, all these BI tools have failed to enhance both users and organisational performance (and/or productivity). There are cases where the same BI tool often produces different reports and data for decision making in the different departments. Nevertheless, given the high cost of implementing the BI technology across government departments, it is imperative that it is properly implemented across these departments, but the required technical know-how and expertise is deficient in these provincial departments.

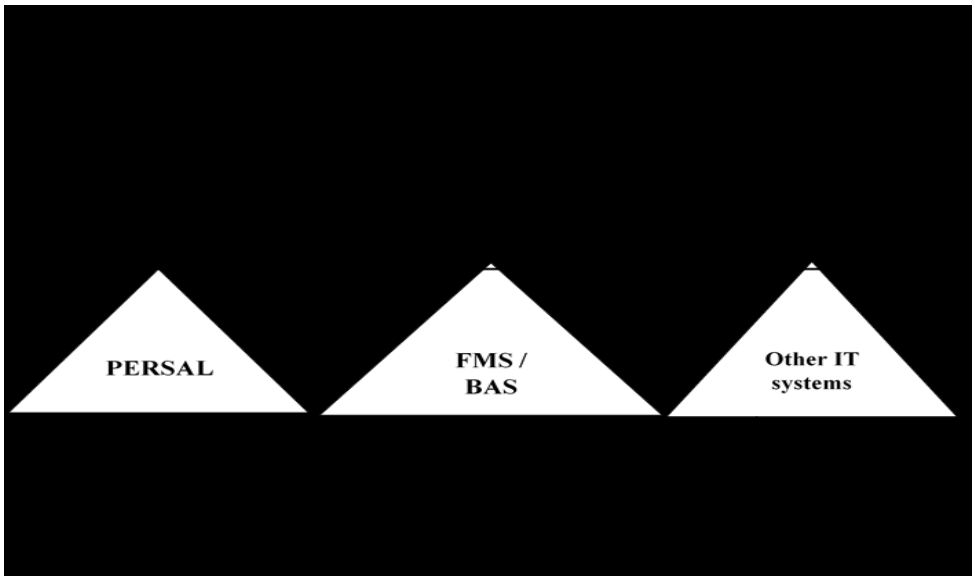

Figure 2: The Vulindlela System Platform.
Source: Department of National Treasury, South Africa

4. Methodology

4.1 Research Design and Sampling Strategy

To achieve our empirical aim, we used a mixed-method research design consisting of a qualitative survey and empirical method (principal factor analysis) within the TTF theoretical framework. The two main data collection instruments used are: (i) administered questionnaires designed based on a five-point Likert scale approach (via electronic mail), and (ii) unstructured interview sessions with middle-level managers in the focal three provincial departments, consistent outlined procedure for surveys by Bryman et al. 2014 [17]. We also applied a descriptive intrinsic case study and ideographic approach [17] to concentrate on the salient features of BI tools effectiveness that are unique to government departments. On sampling strategy, the entire population of main users of the VS (BI tool) were considered, and the entire population of the middle-level managers working in the three departments were targeted for the interview. Since, a total of ten (10) users responded to the questionnaire and ten (10) managers were interviewed, our sample size is 10.

4.2 Data Collection and Analysis

As previously mentioned, to examine the effectiveness of the VS technology in the focal provincial departments, we make use of the qualitative survey method (via questionnaires and interviews) to collate data. Notably, the survey method only deal with observable factors – main users' experience – of the measured construct, which is the VS technology.

However, to draw a conclusive inference on the usage of the VS technology, we adopt a factor analysis approach in combination with the TTF theoretical model framework proposed by Goodhue (1995) [9] comprising of a twelve (12) dimensions to measures introduced by Goodhue and Thompson (1995) [9] (*see, Table 1*) on the premise that the use of a IS technology is determined by the link (good fit) between the technology features, task requirement and facilitated task. On the empirical approach, two principal factor analysis (PCA) models were constructed within the TTF modelling framework consisting of a 17-item and 12-item TTF models, to evaluate the same construct (VS technology).

Our empirical multiple-pronged empirical approaches are justifiable on two grounds: Firstly, the factor analysis allows us to identify common (unobservable or latent) factors measuring the effectiveness of the BI tool. Secondly, the factor analysis validates the anecdotal evidence of the qualitative survey, in order to draw a conclusive inference on the strength and weakness tool. Besides, in our case, the results from the factor analysis is used to reinforce the deduced anecdotal evidence of the qualitative survey, which is our main contribution to the strand of literature evaluating the usage and successful implementation of BI tools in the public sector (or government departments).

Finally, we obviate spurious inferences, reduce error variance and subjectivity of the respondent's feedback; random questions measuring the same construct were included in the administered survey questions, while the Spearman rho correlation analysis, KMO and Cronbach Alpha tests was used to validate the internal consistency and sampling adequacy of the questionnaires (converted to a scaled index variables) in the built TTF models.

5. Discussion of Results

The data analysis results of both the survey and factor analysis are discussed in this section. The analysis of the results focusing on the inferences obtained from the estimated Principal Component Analysis (PCA) model[1].

5.1 Descriptive Statistics Analysis: Survey Questionnaires.

To empirically assess the Vulindlela System (VS) as a useful BI for decision-making; we begin our analysis by considering the descriptive statistics of survey questions, relying on the commonly used statistics, namely the mean (m) and standard deviation (σ) values[2]. By imposing a selection criteria of m values greater than ≥ 3 gives a σ values varying between 0.76 – 1.39. This inference confirms the extent to which the surveyed questions accurately capture the inherent features that uniquely define the VS. Next, the importance of the survey questions underlying the TTF constructs which defines the VS is evaluated considering, m values ≥ 4. In this context, the usefulness of the VS as decision-making BI can be mainly ascribed to seven (7) tasks, which relates to survey questions 9, 11, 16, 17, 5, 8 and 13. The identified (top) seven tasks that encapsulate the usefulness of VS are as follows, the system: **(1)** provides accurate information (m = 4.37 and $\sigma = 0.76$), **(2)** produces quality data (m = 4.21 and $\sigma = 0.79$), **(3)** provides timely data processing (m =

[1]For brevity and to save space; only synoptic overview of the both the survey and PCA models results are discussed here. Detailed results on descriptive statistics, correlation matrix, inter-item correlation, pattern matrix, communalities, Eigen values of extracted latent factors, and diagnostic tests performed are available from the authors upon request.

[2] The descriptive statistics (mean and standard deviations) result is available upon request from the authors.

4.21 and $\sigma = 0.92$), **(4)** produces reports easily (m = 4.16 and $\sigma = 0.69$), **(5)** supports completion of unstructured tasks (m = 4 and $\sigma = 0.88$), (6) solves non-routine tasks (m = 4 and 1.05), and (7) improves productivity (m = 3.95 and $\sigma = 1.08$).

5.2 Empirical Results

Beginning with the analysis of the results obtained from the estimated PCA model for the 17-TTF item (administered questionnaires). The solution of the PCA shows a total of six (6) latent factors, which cumulatively explained roughly 81% of the variance in the data. The inference on the extracted factors validated by the large Eigenvalues greater than one, keeping with Kaiser criterion [18].

In the context of evaluating the effectiveness of the VS, the first three factors explained about 21%, 18% and 14%, whereas the remaining three factors explained about 13%, 10% and 6% of the variance in the data, respectively. Note, we supress e coefficients of factor loadings less than 0.3 identify key unobservable factors that accurately capture (and evaluate) the usage (i.e., strength and weakness) of the VS[3]. Based on the significant factor loadings, these six latent factors are the main features that largely defines effectiveness of the VS as a decision-making BI tool, albeit with varying specificities. Notably, the extracted six factors are associated with: (1) *productivity (or performance) enhancement* (factor 1), (2) *system functionality* (factor 2), (3) *task execution* (factor 3), (4) *perform non-routine task* (factor 4), (5) *operational capability* (factor 5) and (6) *decision making and system flexibility* (factor 6).

The results of the PCA model for the 17-TTF items revealed some interesting innate features of the VS technology across the focal three provincial departments. For instance, factor 1 (*performance enhancement*); the capability of the VS to improve user's productivity (or performance), and execute structured task are some of the crucial features of the system. On *system functionality* (factor 2), the usefulness of the diverse functions provided by the system emerged as a significant benefit derived from the system. Nonetheless, the system compatibility to different task and solving non-routines also matter, to a lesser extent. Another main advantage of the VS as a decision-making BI relates to its ability to easily execute tasks, and the perceived error-free feature of the system as reflected by factor 3 (*task execution*). The ability to execute non-routine task is a prominent valuable feature of the system as reflected by factor 4.

Considering the *operational capability* of the VS (factor 5), the quick responsiveness of the system to data request and its compatibility with task profile emerged as notable features. Apart from this, the flexibility of the system to perform new task as well as being a user-friendly information system are viewed as equally important features of the VS as indicated by the sixth latent factor. On the contrary, a closer look at the result reveal some common drawbacks of the VS among the extracted six factors. These inadequacies include: inability to perform unstructured and non-routine tasks (factors 2, 3 and 6); inability to meet the demand of new tasks (factors 3 and 5); difficulty in drawing reports (factors 1, 4 and 6).

5.3 Evaluating the Vulindlela System Using Constructed 12-TTF Items

Goodhue and Thompson (1995) [9] proves that TTF theoretical model is a ‘‘technology-to-performance chain’’ model, in which technology utilization rely on the fit between the technology and the tasks it supports it. Hence, a perceived good-fit TTF model is expected to identify the link between the perceived capabilities of an information system, facilitated task and the user's competence[19]. Based on this assertion, we grouped survey questions and respondent's feedback with similar characteristics into a 12-item TTF instruments, as

[3] The results of the PCA model for the 17-TTF items is available upon request from the authors.

alternative measures to evaluate the VS as a BI technology in the second PCA model. This allow us to gain more insight on the effectiveness (or the usage) of the VS as a BI tool.

The descriptive statistics revealed that, out of the 12-TTF item; the top three features of the VS are *Currency* (CU), *Accessibility* (AC) and *Ease of Use* (EU) due to sizeable *m* values of 14.3, 8.33, and 6 respectively. In contrast, the values of obtained σ for *CU* generally low suggesting a less dispersion of this measurable instrument from the sample mean compared to the higher σ values (>7) for both *AC* and *EU*, implying a relatively wide dispersion. Further, a joint analysis of the sampling adequacy and internal consistency of the 12-TTF items using the KMO and Cronbach Alpha test shows a values of 0.5 and 0.89 for the KMO and Cronbach Alpha diagnostic tests respectively, confirming the reliability (internal consistency) and ability of the twelve TTF instruments to adequately.

Having establish the factorability of the constructed 12-item TTF constructs; the association among these instruments was assessed using the Spearman rho ranked correlation analysis. Most notably, the correlation analysis revealed a statistically significant and positive bi-directional (two-way or feedback effect) association among the following all TTF constructs. In all cases, the positive correlations are statistically significant at 5% or 10% level. On the basis of this inference, a considerable improvement in the data quality, locatability, system reliability and accessibility will not only affect the functionality of the VS, but also enhance user's productivity and the overall performance of the organization using the system. Equally important, the quality of report, data presentation and information gathered using the system has a significant influence on the usage of the system and its future roll-out to other provincial departments.

6. Conclusion and Recommendation.

From the onset, in this paper, we set out to empirically examine the effectiveness VS technology – a commonly used BI tools in three provincial departments (Treasury, Health and CoGTA) in the Free State (South Africa).

We add value to the existing literature evaluating the usage and implementation of BI tools in the public sector by employing a multi-pronged analytical approach consisting of a qualitative survey and factor analysis were employed within the TTF theoretical framework. To the best of our knowledge, this is the first attempt, to assess the successful implementation of the widely used BI tool, i.e. the VS technology in South Africa and explicitly focusing on provincial service-oriented provincial government departments. The correlation (Spearman rho) analysis suggest the existence of both bi-variate (feedback) and univariate (one-way) linear relationships between several components of the VS technology associated with operational capacity, usability and functionality of the system and executed tasks, productivity and decision-making process of main users.

Furthermore, the results of the survey and factor analysis corroborates one another, uncovering some novel features about the VS technology, summarised as follows: First, the strength of VS as a decision making BI tool can be associated with the system's ability to perform unstructured tasks, collate quality information, enhance decision making and productivity. In contrast, the operational capacity and functionality of the system is limited, in part, due to VS inflexibility to execute new tasks and relative difficulty in using the System to perform daily tasks. Second, there is a strong (in) direct interlink between the operational capacity and functionality of the VS technology, and the shortcomings of system can be linked to its incompatibility to meet user's task profile and inflexibility to execute new task demanded.

Based on these findings, for policy design, we assert that the reliability and usability of the system can be significantly improved by providing comprehensive technical trainings to all users of the VS in the focal provincial departments, testing the system in different network environment and continuous development of new software, upgrade of operating

systems (platforms). These changes will not improve the functionality, security, compatibility (operating with latest web applications / software) and operational capability of the system but also provide the users with array of advance technological features as well as the opportunity to work outside their offices by making use of web-based applications, which in turn, improves daily productivity / performance.

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