# Business Intelligence as a Service:
## A Vendor's Approach

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## ABSTRACT

*Demand for business intelligence (BI) applications continues to grow even at a time when demand for most information technology (IT) products is low, showing the importance of BI products for a modern organization. However, globalization changes the way organizations use BI, where geographic location and time independency is becoming more and more important. Gartner's hype-cycle on BI depicts the technology of BI as a Service as being almost on top of the hype cycle, indicating there are high expectations of this new technology. This research advances on existing literature on business intelligence and cloud computing from a development perspective by introducing the concept of business intelligence as a service (BIaaS). The most important deliverable is the BIaaS capability maturity model (CMM) that is introduced here. The BIaaS CMM explains the conceptual model of BIaaS by the creation of the first BIaaS capability model containing key capabilities of BIaaS. The capability model is further enhanced with maturity levels depicting the importance of each BIaaS capability, a maturity matrix suggesting a roadmap for BIaaS solution development, and a BIaaS assessment model introducing a tool for finding problem areas in existing BIaaS solutions. The developed BIaaS CMM ought to support (starting) BIaaS vendors to develop BIaaS solutions by providing an assessment tool for BIaaS solutions. The assessment outcome provides the current maturity of the BIaaS solution and also includes problem areas for solution improvement. The introduction of the CApability Maturity Positioning (CAMP) method for the development of a maturity matrix, which results in the BIaaS maturity model, is significantly different from conventional maturity modeling. To calculate the weight of each capability from the BIaaS capability model, a thorough product review of existing business intelligence and cloud computing products is performed. Analysis of the results and normalizing the outcome of that analysis together with the introduction of a calculation mapping, is input for the creation of the maturity matrix. The maturity matrix is the essential foundation for the developed business intelligence as a Service capability maturity model, which is the main deliverable of this research.*

*Keywords:* *BIaaS, Business Intelligence, Cloud Computing, Maturity Model, SaaS*

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## 1. INTRODUCTION

In the twenty-first century, organizations are dealing with a fast changing environment. The changing environment is mainly caused by globalization, where geography and time boundaries no longer limit organizational processes. To react on this globalization, technology vendors develop more and more advanced technologies to accommodate organizations and give them competitive opportunities in this changing environment (Kakihara & Sorenson, 2002). One essential component in organizational success and increasing their competitive position is Business Intelligence (BI) (Wixom, Watson, 2010). But also with BI, globalization is changing the way organizations use BI. Market researchers predict a steady shift in the way organizations use BI and it is driven by the upcoming Software as a Service (SaaS) solutions (Gartner, 2013). This shift results in BIaaS solutions, Business Intelligence offered as a service on the internet (e.g. BI that is geographically and time independent).

More and more BI vendors are exploring the BIaaS solution hype by improving their BI products with SaaS abilities and thereby developing BIaaS-like solutions. BI (in some form) already exists for decades and extensive knowledge is available from different studies, and also SaaS as we know it now, already exists for some years and researchers have followed this trend by doing research on SaaS and cloud computing. However, in contrast to BI and SaaS, combining these two together and offering BI as a Service (BIaaS) on the Internet is a quite young field of research, and therefore there is not a specific BIaaS model available that elaborates on what BIaaS solutions should entail or a best practice for BIaaS solution development. Taking this lack of clarity about BIaaS and the missing guideline for BIaaS solution development into account, this research focusses on defining BIaaS and its contents and the creation of a roadmap for BIaaS solution development.

Thomson and van der Walt (2010) outlined the essence for companies to invest in BI in the cloud. Their research conclusion stated that BIaaS solutions (i.e. BI solutions offered as services on the internet) will allow companies to reduce the cost of having a BI solution and also having access to the latest software which will give the business an edge on their competition. This opposed edge on the competition by having access to the latest software has long been supported by earlier research done for instance by Porter and Millar (1980), and somewhat more recently by Clemmons and Row (1991).

De Marco et al (2010) support the conclusion of Thomson and van der Walt (2010) on BIaaS solutions that reduce company costs, but they also seek to establish a conceptualization of the enabling factors in Business Intelligence as a Service solution adoption. Their main research objective was to propose a model containing enabling factors for the adoption of BIaaS solutions. They seek to expand on the Benlian, Hess and Buxmann (2009) model which is based on a theoretical framework including axioms from Transaction Cost Theory, Resource Based View and Theory of Planned Behavior.

Having outlined the benefits for companies to market BIaaS solutions, it is clear why analysts foresee a growth of investments companies will do in BIaaS solutions and therefore the importance for BI solution vendors to offer BIaaS solutions for their customers (Gartner (2013)).

The subject of this research is BI offered as a service in the cloud (BIaaS). A clear definition of cloud computing is therefore a necessity. For years many definitions of cloud computing have been made by a great variety of researchers, but they all seem to focus on certain aspects of technology (Bragg, 2009; Buyya, Yeo, Venugopal, 2008; Geelan, 2008; Gruman and Knorr, 2008; Hwang, 2008; McFedries, 2008; Milojicic, 2008; Baars and Spruit, 2012). Recently Ambrust et al (2009) tried to make a more comprehensive definition of cloud computing. They define Cloud Computing as both the applications delivered as services over the Internet and the hardware and systems software in datacenters that provide those services. The services themselves have long been referred to as Software as a Service (SaaS), therefore

the term SaaS will be used for services. The datacenter hardware and software is called a Cloud. BI in the cloud (BIaaS) is therefore Business Intelligence software solutions offered as a service in the Cloud.

Vaquero et al (2009) already underlined a downside of the current state of BIaaS research: a *complete* overview of all cloud computing features is not available in literature yet. Nevertheless they have made a good start in defining those cloud computing features that are available in literature. BI on the other side, exists already for quite some time and therefore more information about BI features is available. Langseth and Vivatrat (2003) did research on pro-active BI and summed up all the features of pro-active BI. Negash (2004) used the work of Langseth and Vivatrat (2003) to identify the features for BI in general. Although a lot of the BI features are identified in earlier research, more research has to be done to identify all BI features used nowadays.

This research complements the above, but it differs in that it finally will approach BIaaS from a vendor perspective. Two research questions thrive this research. The first research question: "*What are business intelligence as a service capabilities and how do they differ from conventional business intelligence capabilities?*" is partly answered by developing a capability model for BIaaS which gives a clear conceptual model of BIaaS. The major goal of this research is to assist vendors in developing BIaaS solutions. Therefore a second research question is formulated: "*How can business intelligence as a service capabilities be used to create a product portfolio roadmap for business intelligence as a service solution vendors?*" to find a roadmap for the development process of BIaaS solutions. By developing a Capability Maturity Model for BIaaS solutions accompanied with improvement steps, it aims to be of assistance for BIaaS vendors in the product management process. Vendors can use the introduced Capability Maturity Model and description as a guideline in their solution improvement process.

## 2. THE BIAAS CAPABILITY MODEL

To describe the competences of software, often the term *features* is used. A feature describes one specific technological task the software product or solutions can handle. For this research the term capability is used instead to describe the competences of BIaaS. A capability is a higher level construct of measurement than features, defined as 'a set of features'. More specifically, a capability is the ability of a solution to "*perform a set of co-ordinated tasks, utilizing technological resources, for the purposes of achieving a particular end result*" (Helfat & Peteraf, 2003, p. 1000).

BIaaS merges BI and cloud computing competences, therefore to develop a BIaaS model one has to understand the concepts of BI and cloud computing individually. Because the objective is to develop a capability model of BIaaS containing the most important capabilities of BIaaS, the first step in the creation of this model is to find the most important BI and cloud computing capabilities, which is done through a literature study.

### 2.1. Literature Study

BI and SaaS are both research domains that are well documented in today's scientific literature. Reviewing the scientific knowledge available from published journals and scientific articles can therefore provide a good overview of BI and cloud computing capabilities.

The literature study is conducted using the structured approach proposed by Webster and Watson (2002). The process starts by finding new capabilities from the major contributions in the BI and cloud computing research domain using the most common scientific journal and article databases and search engines (i.e. Google Scholar, Citeseer). The capabilities found from the reviewed literature are inserted into a database. References to the corresponding scientific journals and articles are connected to the capabilities. More literature is subsequently found by backward and forward

reviewing. *Backward reviewing* is determining prior articles that could be of interest by using the citations from the articles found in the first step. *Forward reviewing* uses the article itself to determine other articles that cited the articles from the first step (Webster & Watson, 2002).

During the literature research fifty-five business intelligence and thirty cloud computing scientific papers and articles are studied resulting in forty-six business intelligence and thirty-seven cloud computing capabilities. Analysis on the most significant capabilities from the capability database—i.e. capabilities with the highest amount of references—together with supporting literature and the input from experts, identified the key capabilities of BI and cloud computing. The analysis extracted twenty-seven business intelligence and nineteen cloud computing key capabilities from the capability database.

## 2.2. Focus Areas

Strongly coherent capabilities are grouped into *focus areas* containing capabilities supporting a specific area in their domain.The BI focus areas are formed after a structured expert group session. A group of five experts on BI were all individually asked to form coherent groups of capabilities with the capabilities from the literature research. After individually forming the focus areas, a groups discussion was setup to discuss each other's outcomes. The experts then together reached consensus and developed the focus areas with corresponding names resulting in the BI focus areas *data gathering, data management, data processing, data analysis*, *consumerization* and *alerting*. These strongly coherent capability groups are also partly supported by the main BI areas proposed by Elena (2011).

The focus areas for the cloud computing capabilities are formed using a different approach. Much like product software that is hosted on the premise of companies or individuals, also Software as a Service is a software model (Mietzner, Leymann, 2008). Focus areas exist in current software development literature, which can be enriched with a service component which was not included in the former software models. For the development of the cloud computing focus areas, we followed Dennis, Wixom and Tegarden (2002). They conclude that every application system—including a cloud computing solution—can be divided into four general functions: data storage, access logic, application logic and presentation logic. Renaming these four functions, taking the definitions into account and adding the service component of SaaS, provides us with the following five cloud computing focus areas: *data storage, accessibility, application logic, usability* and *service*.

## 2.3. Combining BI with Cloud Computing

Key capabilities of BI and cloud computing are extracted from literature and grouped into focus areas. Unfortunately there is not one technique available from capability modeling literature to combine the focus areas with corresponding capabilities into one capability model. However, analyzing the meaning (definition), contents and focus areas of BI and cloud computing provides a fortunate outcome. BI refers to computer-based techniques providing historical, current and predictive views of business operations (Elena, 2011), cloud computing on the other hand is a software model (Abdat, Spruit & Bos (2011); Spruit & Abdat (2012)) containing different capabilities and different focus areas than BI. Concludingly, BI and cloud computing capabilities and focus areas can be integrated next to each other, together forming the BIaaS capability model. The integration of BI and cloud computing, resulting in the BIaaS capability model is shown in Figure 1. The BIaas capability model includes all BI and cloud computing focus areas and the key capabilities from the literature research. "BI" and "CC" in Figure 1 provide the origin of each focus areas. A matrix form is chosen to visualize al focus areas and capabilities in one compact overview.

*Figure 1. The BIaaS capability model*


## 3. THE BIAAS MATURITY MODEL

Paulk et al. (1993:1) stated about process improvement in software organizations: "Setting sensible goals for process improvement requires an understanding of the difference between immature and mature software organizations". The same is true for developing new software products and the maturity of the developed products. Maturity describes a "state of being complete, perfect or ready" (Simpson & Weiner, 2011). To reach a desired state of maturity, an evolutionary transformation path from an initial to a target stage needs to be progressed (Fraser, Moultrie, Gregory, 2002). Maturity Models (MMs) are used to guide this transformation process.

The development process of the BIaaS capability maturity model (CMM) is setup using the CMM development framework proposed by de Bruin, Rosemann, Freeze and Kulkarni

*Table 1. Properties of maturity models (Lahrmann & Marx, 2010)*

| Property | Description |
|---|---|
| Maturity concept | Three different maturity concepts (or understandings of maturity) can be distinguished (Mettler & Rohner, 2009). People (or workforce) capability defines "the level of knowledge, skills, and process abilities available for the performing an organisation's business activities" (Curtis, Hefley, Miller, 2010). Process maturity defines "the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective" (Paulk et al., 1993). Object (or technology) maturity defines the respective level of development of a design object (Gericke, Rohner, Winter, 2006) |
| Dimension | Dimensions are specific capability areas, process areas, or design objects structuring the field of interest. They should be exhaustive and distinct (de Bruin et al., 2005; Mettler & Rohner, 2009). Each dimension is further specified by measures (practices, objects, or activities) at each level (de Bruin et al., 2005; Fraser, Moultrie, Gregory, 2002). |
| Level | Levels are archetypal states of maturity of a certain dimension or domain. Each level has a distinguishing descriptor providing the level's intent and a detailed description (Lahrmann & Marx, 2010). |
| Maturity principle | MMs can be continuous or staged. Continuous MMs allow a scoring of activities at different levels. Therefore, the level can be either the (weighted) sum of the individual scores or the individual levels in different dimensions. Staged models require the compliance with all elements of one level (Fraser, Moultrie, Gregory, 2002). They specify a number of goals and key practices to reach a predefined level. Staged MMs reduce the levels to the defined stages, whereas continuous MMs open up the possibility of specifying situational levels. |
| Assessment | The assessment approach can be qualitative using descriptions or quantitative using e.g. Likert-like scales (Fraser, Moultrie, Gregory, 2002). |

(2005) and will use the MM characteristics from Table 1 as a reference. The CMM development framework consists of six phases; *scope, design, populate, test, deploy and maintain.* Only the first three phases of the framework are used in this research, the latter three are related to the actual usage of the developed maturity model, which is out of scope for this study and is left for further research.

## 3.1. Scoping the CMM

The first phase of the CMM development framework is to determine the scope of the desired CMM (Bruin et al., 2005). The most significant decision that needs to be made in the scoping phase is the focus of the model, which refers to the domain the CMM would be targeting and be applied in, distinguishing the proposed model from other existing models.

The BIaaS CMM as proposed in this research focuses on the newly introduced BIaaS concept. The BIaaS CMM tend to be used especially by BIaaS vendors using it to assess their own and competitor's BIaaS solutions, probably during the development phase of a newly introduced BIaaS solution or the improvement process of an existing BIaaS solution. The BIaaS CMM maturity concept is therefore technology oriented and depicts the respective maturity level of the BIaaS solution (Gericke, Rohner, Winter, 2006). The software product manager (SPM) of the BIaaS vendor is most likely to use the CMM, as he or she has the best overview of the development process (Ebert, 2007).

The BIaaS CMM is be used in three ways during the development process, each of which having different software product management purposes. The first usage is to assess the currently existing (or just developed) BIaaS solution to provide the SPM the maturity of its BIaaS solution, where from the market readiness can be derived. Secondly it is used to assess its own and competitor's BIaaS solutions, providing the SPM information about its own solution in contrast to its competitors. Product positioning can be derived from this information and can be used for marketing purposes. The third and maybe most important usage of the BIaaS CMM

are the improvement steps that are provided by the model. The latter functionality of the BIaaS CMM provides the SPM an informed improvement approach of the assessed BIaaS solution. Each of these ways of using the BIaaS CMM can be an essential part of the development roadmap of the BIaaS solution.

## 3.2. Designing the CMM

The second phase of the CMM development framework is to determine a design or architecture for the model. The design phase provides (1) *why* the model would be applied, (2) *how* the model can be applied to varying solutions, (3) *who* needs to apply the model and (4) *what* can be achieved through applying the model (Bruin et al., 2005). (1) Vendors see the potential of providing BIaaS solutions to their customers, but need an approach for the development process. (2) The BIaaS CMM provides problem areas which aid (3) SPM's at BIaaS vendors creating (4) roadmaps for their BIaaS solutions.

Furthermore, stage definitions needs to be developed to define the maturity levels of the CMM (Paulk et al., 1993). Defining maturity stages can be done either by using a top-down or bottom-up approach. With using the top-down approach, definitions are written first and then the measures are developed to fit the definitions. With the bottom-up approach the requirements and measures are determined first and then definitions are written to reflect these (Bruin et al., 2005). The BIaaS capability model already introduces the conceptual model of BIaaS, therefore the top-down approach is used in this research. Taking the maximum number of capabilities used per focus area in the BIaaS capability model (hence maximum items per focus area in CMM) into account, an eight-scale maturity level will best fit the CMM.

A maturity level is a well-defined evolutionary plateau toward achieving a mature software solution. Representation of maturity as a series of one-dimensional linear stages is widely-accepted and has formed the basis for assessment in many existing tools (Bruin et al., 2005). Each maturity level indicates a level of solution maturity. Historically labels are added to the levels of maturity used in CMMs (Paulk et al., 1993). However, IS literature on CMM refers to *process* maturity instead of *product* maturity, and software product maturity is often measured by code or module formula's that is not relevant for this current research. Therefore new maturity stages are introduced that refer to the maturity of the BIaaS solution taking market readiness into account. Table 2 provides the maturity stages that are used in the BIaaS CMM. Typically eleven levels of maturity are used in maturity modeling (zero up to maturity ten), however, the focus areas of the BIaaS Capability Model have an average population of five capabilities (smallest contain two and largest contain six). For the purpose of readability and usability of the BIaaS CMM, a nine scale maturity model is used (zero up to maturity eight).

Maturity level zero indicates that the assessed solutions is incomplete and therefore is not a BIaaS solution. The solution has not all of the basic capabilities that a BIaaS solution must have. Maturity levels one up to three indicate a BIaaS solution that is becoming ready to be offered as a BIaaS solution but is not having all of the average capabilities current BI and SaaS solutions have. Maturity level four and five, *ready* and *ready+*, are seen as the average maturity of a BIaaS solution. These levels indicates that the assessed BIaaS solution is ready for the vendor to be offered as a complete BIaaS solution on the market, including the most popular BI and SaaS capabilities that are currently used in BI and SaaS solutions. Levels six, seven and eight are the evolving BIaaS maturity levels that indicate more maturing BIaaS solutions that finally have the most advanced capabilities currently known on the market.

## 3.3. Capability Comparison

The CMM uses maturity levels to indicate the solution maturity by means of capability implementation. A requirement for using this method for measurement of solution maturity is that one can compare capabilities with each

*Table 2. Maturity stages of the BIaaS CMM*

| Stages | Definitions |
|---|---|
| Level-0: Not implemented | The solution is not BIaaS, it does not contain all the vital capabilities for a BIaaS solution. The solution is incomplete. |
| Level-1: Initial | The initial capabilities of BIaaS are implemented. The current state is a foundation for every BIaaS solution, but needs further improvement to be of any value. |
| Level-2: Basic | A basic level is obtained were the fundamental capabilities are in place. The solution is working as a basic BIaaS solution. |
| Level-3: Evolved | The solution is evolving and is becoming a nearly complete BIaaS solution. More improvements are recommended before offering it for public use. |
| Level-4: Ready | The most commonly used capabilities currently available are implemented. The solution is ready to be offered as a BIaaS solution. |
| Level-5: Ready+ | The most commonly used capabilities currently available are implemented. |
| Level-6: Maturing | The solution is maturing and includes additional competitive capabilities. |
| Level-7: Qualitative | The solution includes all qualitative capabilities. |
| Level-8: Mature | The solution includes all BIaaS capabilities currently available. |

other. When comparing entities with each other, some system should be in place where comparison is possible. Common comparisons are <, > and =. However, to use such comparisons on capabilities, it must be clear which capability is more important than one other. A problem arises when one wants to introduce a comparison for capabilities, because from literature it is not clear whether one particular capability is more important than another one. So how do you find out? The answer is that there is not one particular way to state that one capability is more important than another capability, only if the first capability is necessary for the second capability to exist. When using logic representations; with current literature one can only state about two capabilities $C_1$ and $C_2$: $C_1 \rightarrow C_2$ (if $C_1$ then also $C_2$). This is not sufficient for the development of the BIaaS CMM, where it is necessary to introduce the comparisons > and <, so that can be stated $C_1 > C_2$ ($C_1$ is more important than $C_2$). Current literature does not yet provide a recipe for this problem.

When taking the consumer market into account, market forces decide which capabilities are important for the consumer. It is reflected in the capabilities that vendors put in their offered solutions, which implies that consumers want these capabilities in their purchased solutions. By using this market information, a comparison can be obtained using quantitative analysis. Therefore, we introduce a new method for positioning capabilities, the CApability Maturity Positioning method: CAMP. This method consists of a product review where the top most currently available BI and cloud computing solutions are reviewed and analyzed to develop a comparison technique for BIaaS capabilities. To increase the phenomenon of market forces, only the top most vendors of BI or cloud computing solutions, who develop solutions for commercial purposes, are taken into account for the product review.

## 3.4. CApability Maturity Positioning (CAMP) Method

Literature and practice are put together by introducing the CApability Maturity Positioning method (CAMP). The method contains of a product review and analysis, where current top-solutions are examined and tested on the availability of capabilities from the capability model (i.e. in this case the BIaaS capability model). For the product review twenty cloud computing and thirty-three BI solutions are

examined. The product review is conducted to find the possibility to compare capabilities with each other. Comparing capabilities with each other is important for the development of the BIaaS capability maturity model.

The product review is conducted by examining cloud computing and BI solutions (by either installing or using a trial account), consult product documentation and (where possible) interview solution experts. For every solution the capabilities that are implemented in or for the solution are checked and stored in a specially developed database which can be consulted for the quantitative analysis which is performed after the review.

To increase the phenomenon of market forces, only the top most vendors of BI and Cloud computing, who develop BI and cloud computing solutions for commercial purposes, are taken into account for the product review. To find these vendors it is useful to take advantage of the available market researches performed by commercial research institutes. Therefore, the selection of solutions is made by taking the top companies designated by Gartner Research Institute in their Magic Quadrant of business intelligence platforms, which is published every year. This suggests the top companies producing BI or cloud computing solution platforms and are thereby the best choice to find the most evolved BI solutions currently on the commercial market. The solutions that are selected for the product review from each vendor are the newest and most complete solutions provided by those vendors.

### 3.4.1. BI Products

Thirty-three BI solutions are reviewed from seventeen companies. While conducting the product review, a irregularity raised among the BI capabilities found per solution. For instance SAS scattered their BI capabilities over multiple solutions, each having their own specific abilities and a product can function as an addition to another product, resulting in each product to have different BI capabilities. However, TARGIT on the other hand offers their customers one BI solution including their whole variety of BI capabilities. The outcome of the analysis can be distorted while conducting the quantitative analysis on all the solutions separately, knowing not all solutions are relatively the same. Therefore a different approach is used for the analysis of the BI solutions, namely a quantitative analysis taking the outcome per vendor (i.e. summary of capabilities implemented per vendor) into account. The analysis per vendor gives a better outcome of the analysis because the capabilities found per vendor are relatively the same, thereby suggesting they are comparable. Table 3 summarizes the outcome of the product review per BI capability.

### 3.4.2. Cloud Computing Solutions

The same approach is used as for the BI products, examining twenty solutions from nine companies. Table 4 provides the total appearance of each capability in the cloud computing solutions.

### 3.4.3. Quantitative Analysis

Analysis on the sum of appearances introduced in Table 3 and Table 4 can provide a comparison when we sort the capabilities on the total number of appearance in the reviewed solutions. However for the CMM it is equally important to know the levels of importance, referring to the maturity levels of the CMM. To find these levels, another analysis is performed using IBM's SPSS statistical analysis tool and the analysis methods proposed by Field (2009).

Calculation output by SPSS provides the *mean* and *standard deviation*. However, these calculations are made under the assumption of a normal distribution, therefore this needs to be confirmed first. Techniques are available to show normality, like histograms, normal P-P/Q-Q plots or boxplots (see Figure 2 and Figure 3). There are also methods to calculate and proof with a predefined probability that your results are normally distributed. A method to proof the distribution is significantly (>95%) normal is the Kolmogorov-Smirnov (K-S) test (Field, 2009), which is calculated in Figure 4

*Table 3. Summarized outcome of the product review per BI capability*

| Capability | # | Capability | # |
|---|---|---|---|
| Analytics | 16 | Forecasting | 13 |
| Automated exception detection | 3 | Information management | 6 |
| Automatic learning and refinement | 1 | Intelligent warehousing | 4 |
| Business process embedded | 5 | Master data management | 8 |
| Collaboration | 14 | OLAP | 15 |
| Data mining | 14 | BI alerting | 7 |
| Data modeling | 6 | Reporting | 16 |
| Data preprocessing | 9 | Secure data delivery | 11 |
| Data quality | 11 | Segmentation and clustering | 7 |
| Data transformation | 7 | Self-service BI | 13 |
| Data visualization | 14 | Data independency | 4 |
| Data warehousing | 12 | Text mining | 9 |
| Data follow-through workflow | 2 | Usability | 12 |
| ETL | 13 | | |

and Figure 5. Note that the significance (Sig.) of the K-S test less than 0.05 indicates deviation from normality.

The K-S test significance (Sig.) is for both outcomes 0.200, which is higher than the threshold of 0.05. The results from Table 5 are therefore normally distributed with a probability of 95% ($p < 0.05$). Using the calculations of the mean and standard deviation, we can group all key capabilities into levels of importance. The level of a key capability can calculated by taking the value of the result ($x_i$) from Table 3 or Table 4 and map it to the ranges provided in Table 5, where $\mu$ is the mean and $s$ is the standard deviation. The levels from Table 5 are used for the calculation of the maturity levels in the BIaaS CMM by mapping all the results

*Table 4. Summarized outcome of the product review per cloud computing capability*

| Capability | # | Capability | # |
|---|---|---|---|
| Data center | 19 | Multi-tenancy | 10 |
| Resource alocation | 7 | Hosted service | 15 |
| Internet centric | 20 | Data protection | 13 |
| Resource optimization | 6 | Virtualization | 14 |
| Vendor controlled | 17 | Scalability | 18 |
| Automatic adoption | 4 | Configurability | 9 |
| Monitoring | 11 | User friendliness | 10 |
| Time and location independent | 20 | QoS | 15 |
| Payment model | 18 | Competitive costs | 2 |
| SLA | 10 | | |

*Figure 2. Histogram for the sum of BI capabilities from product review*

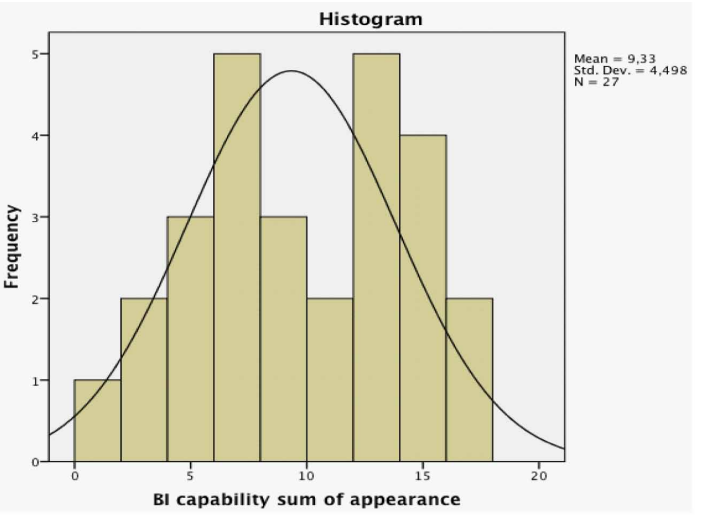


*Figure 3. Histogram for the sum of cloud computing capabilities from product review*

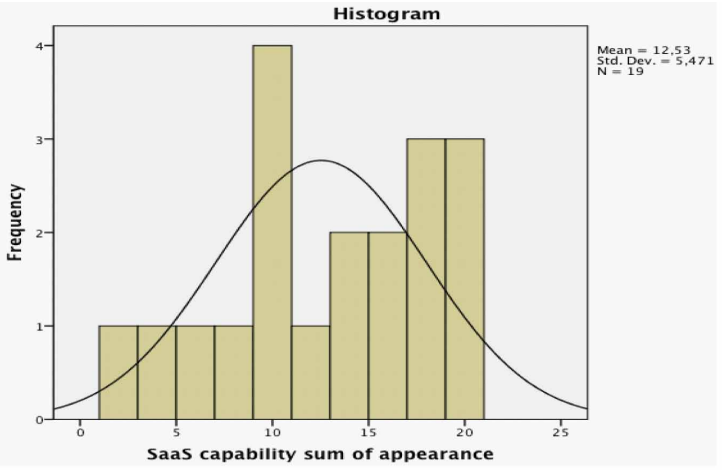


*Figure 4. BI Product review outcome test of normality*

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| BI capability sum of appearance | ,131 | 27 | ,200* | ,947 | 27 | ,184 |

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

*Figure 5. Cloud computing product review outcome test of normality*

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SaaS capability sum of appearance | ,109 | 19 | ,200* | ,952 | 19 | ,430 |

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

*Table 5. Mapping capability results to maturity levels*

| Value | Level |
|---|---|
| $x_i \geq (\mu+1.5s)$ | Level-1 |
| $(\mu+0.5s) > x_i < (\mu+1.5s)$ | Level-2 & level-3 |
| $(\mu+0.5s) \leq x_i \geq (\mu-1.5s)$ | Level-4 & level-5 |
| $(\mu-0.5s) < x_i > (\mu-1.5s)$ | Level-6 & level-7 |
| $x_i \leq (\mu-1.5s)$ | Level-8 |

from Table 3 and Table 4 with the corresponding level from Table 5.

Figure 6 illustrates the idea of a normal distribution (curve) and the use of standard deviation (horizontal axis) to segment results (vertical lines and percentages). Due to this normal distribution and the use of a standard deviation, most capabilities have a value near to the mean (indicated with green, yellow and orange) and only a small percentage are higher or lower than $\mu \pm 1.5*s$ (indicated with purple and blue respectively). Due to the latter, the mapping of the near-to-average values are mapped into two levels of maturity and the highest and lowest value into one.

*Figure 6. Normal curve with standard deviation percentages*

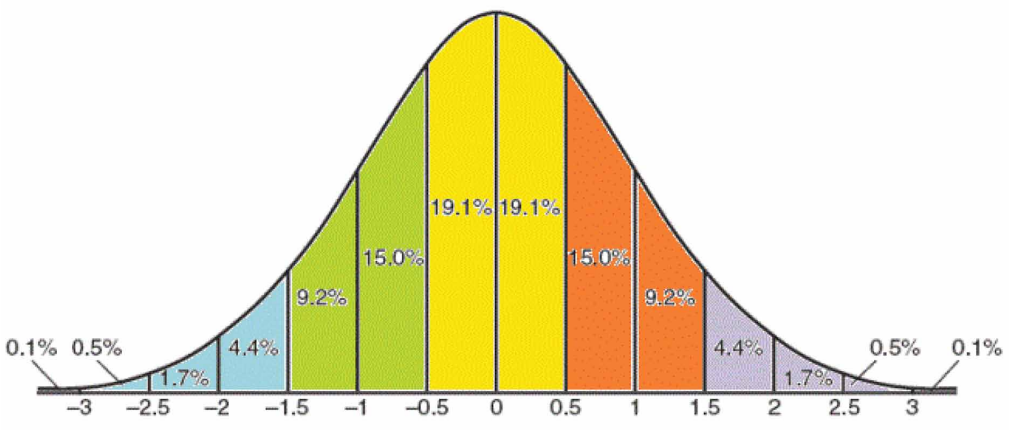

*Table 6. The BIaaS capability maturity matrix*

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| **Design** | | | | | | | | | |
| Data Storage | | A | | | B | | C | | |
| Accessibility | | A | B | | C | | | | D |
| **Data** | | | | | | | | | |
| Data gathering | | A | | | | | | B | C |
| Data management | | A | B | C | D | | E | | F |
| Data processing | | | | | A | | B | C | D |
| Data analysis | | A | B | C | D | E | F | | |
| **Usage** | | | | | | | | | |
| Application logic | | A | B | | C | | | | D |
| Usability | | | | | A | B | C | | |
| Consumerization | | A | B | C | D | E | F | | |
| **Support** | | | | | | | | | |
| Alerting | | | | | | | A | | B |
| Service | | A | B | C | D | | | | E |

## 3.5. Contents of the BIaaS CMM

Using the mapping from Table 5, the results from the product review (Table 3 and Table 4) and the BIaaS capability model, a BIaaS capability maturity matrix is developed which is shown in Table 6. The BIaaS capability maturity matrix consists of BIaaS focus areas, each with their own number of maturity levels. The focus areas are represented in the left-most column and the specific maturity levels are represented by the characters A-F in a maturity range from 1 to 8 (see top-most row). The characters A-F correspond to capabilities from that focus area. The levels of maturity per focus area indicate a best practice order in which the capabilities are implemented from left to right.

The BIaaS capability maturity matrix is the foundation of the BIaaS capability maturity model (CMM). The BIaaS CMM is a physical assessment tool which uses the maturity matrix in a working model in Microsoft Excel (Boer & Spruit, 2014). The model uses an assessment sheet as input in the form of yes/no answers to questions regarding specific capability functionality. The input is calculated by the calculation sheet and provides output in the BIaaS CMM sheet. The BIaaS CMM sheet is the calculated feedback for the assessment providing overall maturity, problem areas and ordered maturity per focus area.

### 3.5.1. Assessment Sheet

The BIaaS CMM is used to assess existing BI, SaaS or BIaaS solutions to provide a strategy for an evolutionary path to BIaaS solution maturity through an incremental development roadmap. This is done by providing the current state of solution maturity but also provide specific problem areas for product improvement. The assessment starts by providing yes/no answers to questions provided in the first sheet of the BIaaS CMM, the *assessment sheet*.

The assessment is preferably carried out by the software product manager or the project leader for the development team, because they can answer the questions best about the different focus areas and implemented capabilities. All the questions are answered with *yes* or *no* by

selecting the correct answer from the drop-down menu to the right of each question. The answer column (the right-most column) will change color from orange to white when an answer is provided. When all questions are answered, hence all boxes in the answer column are white, the assessment is done and the results can be analyzed in the CMM sheet.

### 3.5.2. Calculation Sheet

The calculation sheet is a hidden sheet where all calculations for the BIaaS CMM outcome are performed. The calculation sheet consists of three types, the *problem areas, CMM ordered* and *overall maturity.*

The *problem area* part is sub-categorized into three categories each representing all the focus areas in the first column with their associated capabilities in the corresponding row. The capabilities in each row are ordered according to their importance (level-1 to level-8) from left to right. The *first* (left-most) category of the problem areas checks if a capability is implemented. The outcome is a boolean value True or False, where True means the capability is implemented and False otherwise (not implemented or not answered). The *second* category checks wether the questions that correspond to the capability is answered (regardless of the answer) or not and returns True or False respectively. The *third* and last category of the problem area is the merger of the other two calculating for each capability whether it is *implemented* (answer to question is "yes"), *missing* (answer is "no") or *unknown* (not answered yet).

The *CMM ordered* part of the calculation sheet contains the BIaaS focus areas and corresponding capabilities as shown in the maturity matrix and are also divided into three sub-categories. The *first* table checks if the capabilities are implemented, making use of the first table from the problem area part. If the capability is implemented the value is set to zero (0), otherwise to one (1). The sum of each column is provided at the top of the column of each solution unit. The empty fields from the maturity matrix are set to zero by default (no value). The *second* table does not contain the focus areas, only the solution units and calculates the maturity per unit. The maturity per unit is calculated first looking at the levels individually (starting at level one, the column with the "1" in the header). For each level of the unit the corresponding sum from the first table is checked. If the sum is not zero (hence, there are unimplemented capabilities at this level), the maturity of that level is equal to the previous level (note that the left-most level is zero to start with). However, if the sum is zero (all capabilities of this level are implemented) than the maturity at this level becomes equal to the corresponding maturity level (equal to the header of the level), but only if the previous level is also equal to the previous header (the previous capabilities are also implemented). In other words, the maturity of a solution unit at a particular level is calculated by checking if all capabilities at that level are implemented and also all previous capabilities from the lower levels are implemented. There is a special case in this calculation, when there are no capabilities at a particular level in a solution unit. In that case, the previous maturity is taken and is only updated when the next level is fully implemented or the units at that same level are all fully implemented. The *third* table is the integration of the third from the problem area part and the characters from the maturity matrix from Table 6. This table provides for each field of the maturity matrix if it is implemented, missing or unknown with the corresponding capability character.

The *third* part contains the BIaaS maturity calculation of the assessed solution. It contains the maximum maturity level for each solution unit calculated on each row in the second table of the *ordered CMM.* The overall solution maturity is calculated by taking the minimum of the maturity levels of each solution unit.

### 3.5.3. CMM Sheet

The last sheet in the BIaaS CMM provides all the information about the assessment in one overview, as shown in Table 6. The *Problem area*

part provide information about which capabilities from each focus area are implemented. The *Ordered CMM* provides the implemented and missing capabilities per maturity level, which can be used as roadmap for maturity improvement. The *Solution maturity* provides the solution maturity per unit and the overall maturity.

### 3.6. BIaaS Assessment using the BIaaS CMM

A BIaaS assessment using the BIaaS CMM requires explicit knowledge about the technological design, data management, the usage and the supporting model of the solution. Therefore, the BIaaS assessment is preferably performed by a BIaaS vendor's software product manager or the project leader of the development team. The assessment starts with the assessment sheet which contains forty-seven questions (Boer & Spruit, 2014). All questions need to be answered with "yes" or "no" using the drop-down functionality available at the end of each question. When all questions are answered (there are no orange fields left in the answer column), the outcome is provided in the CMM sheet. This sheet provides the overall *maturity* level of the BIaaS solution, which is composed from the maturity levels of the solution units which are also provided. The *problem areas* pinpoint those capabilities that are missing from the assessed solution, and thus need attention from the developer of the solution. The *CMM ordered* part of the CMM sheet can be used as a roadmap for solution improvement by providing an implementation order for each capability. The improvement path starts at the left-most maturity column by implementing each capability from that column working to the right, level by level.

Using the BIaaS CMM as an assessment tool which provides a roadmap for BIaaS solution improvement answers the main research question "*How can BIaaS capabilities be used to create a product portfolio roadmap for BIaaS solution vendors?*". The BIaaS CMM is developed using the capability model which contains all BIaaS key capabilities, and the BIaaS CMM can be used to create a roadmap for solution improvement to be used by BIaaS solution vendors.

## 4. DISCUSSION AND CONCLUSION

### 4.1. Discussion

This research's major contributions and deliverables are the BIaaS capability model, which conceptually models BIaaS, and the BIaaS capability maturity model, which introduces a assessment model for BIaaS solutions and aims to be used as a roadmap for BIaaS solution vendors. There are however some limitations to the introduced models.

The BIaaS capability model is constructed using a literature review and extracts the key capabilities from existing literature. Although this method, where literature is used to position concepts, is often used in scientific research, it has its limitations. Particular the information technology branch has quickly changing capabilities and introduces newly development technologies relatively often. Therefore the constructed model should be updated every five to ten years, to exclude absolute capabilities and to introduce new key capabilities (if available).

The BIaaS CMM has been developed using the newly introduced CApability Maturity Positioning (CAMP) method and is dependent on the products currently available on the market. CAMP positions capabilities from a capability model by examining the current top most solutions on the market. Therefore the BIaaS capability maturity model is dependent on the solutions available on the market at the time of the performed CAMP (i.e. snapshot). The outcome of an assessment using the BIaaS CMM is therefore always bound to a particular period in time. To keep the BIaaS CMM up-to-date, preferably the CAMP method should be performed every two years, as this is the average cycle for major IT vendors for releasing new versions of their solutions.

Different methods are used to develop the BIaaS CMM. First the BIaaS capability model is introduced by using a structured literature

review introduced by Webster and Watson (2002) and expert input. The BIaaS capability model is used for the development of the BIaaS capability maturity model, which is constructed by the CAMP method including a product review and statistical analysis. Although strictly following the methods used for the construction of the model from which we may conclude that valid research was performed, the model has not been evaluated in the field yet. To strengthen the model, evaluations should be performed to correct possible unforeseen flaws in either the model or the development process.

## 4.2. Conclusion

This research's first aim is to conceptually model the integration of two research domains, business intelligence and cloud computing, into the concept *business intelligence as a service* (BIaaS), to extend research on BIaaS and to aid BIaaS solution vendors in the development (or improvement) of new BIaaS solutions. This aim has been met by answering the first research question: "*What are business intelligence as a service capabilities and how do they differ from conventional business intelligence capabilities?*". As mentioned earlier, BI and cloud computing are two research domains that already exist for some time. This research extracted the main capabilities from BI and cloud computing research by conducting a literature review. The literature review shed light on the available capabilities in each domain, and an analysis of the review extracted key BI and cloud computing capabilities. Strongly coherent groups of key capabilities are formed using literature and expert group sessions which form the BIaaS focus areas. The key capabilities, grouped into focus areas, result into the business intelligence as a service capability model. The BIaaS capability model, together with the explanations of the capabilities, conceptually models the novel concept of business intelligence as a service and answers the first research question.

For a BIaaS solution vendor to successful develop BIaaS solutions, there are a number of aspects which needs to be considered, including which capabilities should be implemented and in which order. The second aim of this research is to use business intelligence as a service capabilities for the creation of a roadmap for BIaaS solution development. This aim is met by answering the second research question: "*How can business intelligence as a service capabilities be used to create a product portfolio roadmap for business intelligence as a service solution vendors?*" This research introduces the CApability Maturity Positioning (CAMP) method, which calculates the position of capabilities in the current commercial market. Analysis provides an ordered value for each capability in their focus area, resulting in a BIaaS maturity matrix. The BIaaS maturity matrix is input for the developed BIaaS capability maturity model which can be used as an assessment tool for BIaaS solutions. The second research question is answered by the development of the BIaaS capability maturity model (CMM). The BIaaS CMM and the knowledge provided by the BIaaS capability model and additional background knowledge will assist BIaaS solution vendors in the development of BIaaS solutions. An assessment using the BIaaS CMM provides an ordered development process, depicts problem areas for solution improvement, and calculates a level of maturity for solution positioning. The BIaaS CMM assists BIaaS solution vendors by creating a roadmap for their development process.

## 4.3. Future Research

The biggest limitation of this research in its current incarnation is a missing evaluation in the field of the BIaaS CMM. An interesting follow-up study could therefore evaluate the model through case studies where BIaaS (or maybe BI) solutions are assessed. The use of experts can be of importance for the case studies, whereas the experts can compare the assessment output with their own expected outcome. Analysis of the similarities and differences can provide possible improvements for the model or the methods used to develop the model.

Another recommendation for further research is to use the capability maturity positioning (CAMP) method on available open source products. Such a comparison might provide a better understanding between open source and commercial products. Moreover the comparison of the resulting maturity matrix can be compared with the suggested maturity matrix in this research, where analysis can perhaps strengthen the current model or provide suggestions for improvement.

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