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Michel Mitri
James Madison University, mitrimx@jmu.edu

Susan Palocsay
James Madison University

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Toward a Model Undergraduate Curriculum for the Emerging Business Intelligence and Analytics Discipline

Michel Mitri
Department of Computer Information Systems and Business Analytics, James Madison University
mitrimx@jmu.edu

Susan Palocsay
Department of Computer Information Systems and Business Analytics, James Madison University

Abstract:

Business intelligence (BI) combined with business analytics (BA) is an increasingly prominent strategic objective for many organizations. As a pedagogical subject, BI/BA is still in its infancy, and, in order for this to mature, we need to develop an undergraduate model BI/BA curriculum. BI/BA as an academic domain is emerging as a hybrid of disciplines, including information systems, statistics, management science, artificial intelligence, computer science, and business practice/theory. Based on IS 2010's model curriculum constructs (Topi et al., 2010), we explore two curricular options: a BI/BA concentration in a typical IS major and a comprehensive, integrated BI/BA undergraduate major. In support, we present evidence of industry need for BI/BA, review the current state of BI/BA education, and compare anticipated requirements for BI/BA curricula with the IS 2010 model curriculum. For this initial phase of curricular design, we postulate a preliminary set of knowledge areas relevant for BI/BA pedagogy in a multi-disciplinary framework. Then we discuss avenues for integrating these knowledge areas to develop professionally prepared BI/BA specializations at the undergraduate level. We also examine implications for both AACSB and ABET accreditation and describe the next phase of applying the IS 2010 concept structure to BI/BA curriculum development.

Keywords: Business Intelligence, Analytics, Model Curriculum, IS 2010, ABET, AACSB, Accreditation.

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1 Introduction

To construct a full-fledged curriculum for the business intelligence (BI)/business analytics (BA) discipline, we need to first concretely define BI. BI as a concept is still evolving, and definitions vary depending on perspective and context. Watson (2009, p. 487) has articulated one oft-cited definition: "business intelligence (BI) is a broad category of applications, technologies, and processes for gathering, storing, accessing, and analyzing data to help business users make better decisions". Gartner's (n.d.) IT glossary defines the term BI as "an umbrella term that includes the applications, infrastructure and tools, and best practices that enable access to and analysis of information to improve and optimize decisions and performance". Negash (2004, p. 179) describes BI as "systems (that) combine data gathering, data storage, and knowledge management with analytical tools to present complex internal and competitive information to planners and decision makers".

These definitions hearken to BI's genesis from previous work in decision support systems (DSS) (Watson, 2009) and artificial intelligence (Sharda, Delen, & Turban, 2015). They also focus on an audience of analysts, decision makers, and planners who need to sift through and make sense of large and complex data or tackle difficult reasoning tasks. In addition, the definitions emphasize the discipline's "broad" and "umbrella" nature. Rather than being a narrowly defined profession, BI evolves out of and draws from frameworks, architectures, systems, and techniques provided by a variety of sources.

Obviously, another key feature implied by the above definitions of BI is "business", which indicates that practitioners apply the technologies and computational techniques described above to real-world problems that corporations and their managers encounter. Therefore, a BI practitioner must also have some grounding in the business domain with an understanding of business processes and functions, organizational structures and communication flows, and the distinctions between operational, tactical, and strategic concerns. However, the technical and mathematical skills of BI practitioners could just as easily be applied to other, non-business, domains. The creators of the IS 2010 model curriculum were aware of this fact. One of the model curriculum's key elements, which the creators revised from IS 2002, emphasizes "reaching beyond the business school" (Topi et al., 2010, p. 370) to apply IS in areas such as biology, law, and healthcare. Likewise, the "intelligence" of BI can be applied to a range of domains.

All of the above suggests that any comprehensive academic program in BI/BA must involve a confluence of information technology, analytics, and business (or some other domain) knowledge. As such, in this paper, we examine options for integrating BI/BA skills and expertise into undergraduate business-oriented information systems (IS) curricula to build toward a model BI/BA curriculum. In Section 2, we review the history and recent advancements in BI/BA as a response to industry needs and provide motivation for new curricula. In Section 3, we describe trends in academic and professional programs aimed at meeting the high demand for BI/BA in the workforce. In Section 4, we appraise BI/BA content in the IS 2010 model curriculum and, in Section 5, present a multi-disciplinary framework for BI/BA curriculum development. In Section 6, using this framework in conjunction with concepts from the IS 2010 architecture, we outline two alternative curricula designs that form a basis for differing levels of BI/BA specialization at the undergraduate level. In Section 7, we address requirements for both AACSB and ABET accreditation. In Section 8 we describe next steps in the curriculum design process and, in Section 9, conclude the paper.

2 Overview of BI/BA Growth in Industry

Numerous industry reports chronicle the evolution of BI systems and their rising significance in the corporate world over the past decade. BI became the top-ranked technology among Chief Information Officers (CIOs) surveyed by Gartner in 2006 and gained initial recognition as a professional IT "career" with high compensation relative to other IT positions (Wu & Weitzman, 2006). At the same time, BI's traditional focus on addressing managerial reporting requests began to expand toward supporting performance management initiatives at the strategic level (Gartner, 2006). Since then, BI software platforms have matured by integrating core BI technologies such as reporting tools, online analytic processing (OLAP) cubes, and data mining engines with data warehouse servers. User interfaces typically include dashboards, spreadsheets, and ad hoc query facilities (Chaudhuri, Dayal, & Narasayya, 2011).

Advancements in BI have corresponded with increasing interest in BA as organizations look for ways to use enterprise and e-commerce data to enhance decision making and respond to competitive pressures. Books and media reports have documented contributions of analytics to improved business strategy and better financial results (e. g., Ayres, 2007; Baker, 2008; Davenport & Harris, 2007; Davenport, Harris, & Morison, 2010). More recently, the application of advanced analytics has been extended to incorporate "big data", which recognizes the enormous quantities of data being generated in an economy heavily based on digitized business activities. In addition to volume, big data is characterized by variety (diversity of data types) and velocity (real-time information) (Fingar, 2011). These data features are one of the trends that will require IT leaders to adopt new architectures for integrating BI and BA technology (Gartner, 2013a).

Big data and advanced analytics appear in Gartner's latest list of top 10 strategic technology trends. Gartner emphasizes the need for capabilities in both information management and predictive analysis (Gartner, 2013b). The McKinsey Global Institute (2013) has also emphasized big data and advanced analytics as among 10 IT-enabled business trends that provide additional opportunities for creating business value in the next decade. Using longitudinal surveys and interviews, Andriole (2012) describes heavy investment in BI/BA as one of seven future technology trends that will have a major impact on IT by 2015. We can find other evidence of big data's and advanced analytics' mounting importance in recent business publications aimed at executive managers (Barton & Court, 2012; Kiron, Ferguson, & Prentice, 2013; McAfee & Brynjolfsson, 2012; Rosenbush & Tottym, 2013).

One major obstacle for successfully adopt big data analytics, however, is the shortage of professionals with skills for implementing new BI/BA technologies (Evelson, 2013), for analyzing and modeling data in a business context, and for making managerial decisions (McKinsey Global Institute, 2011; Russom, 2011; Yeich, 2012). One of the major findings from the most recent BI Congress was that "demand for BI/BA students continues to outpace supply" (Wixom et al., 2014, p. 4). As a result, BI/BA projects are generating a profusion of IT job opportunities with substantial staff and managerial salaries (Henschen, 2014). These projects typically involve extensive face-to-face collaboration between business and IT. They will also require frequent updating and ongoing maintenance and, thus, are unlikely to be outsourced (McCarthy, 2011). Moreover, the future career outlook is bright because investment in BI/BA is expected to continue growing due to competitive pressures.

3 Academic and Professional Programs for BI

Beginning in 2009, researchers have conducted surveys associated with the BI Congress to establish a baseline for and monitor the status of BI/BA in undergraduate and graduate education (Wixom et al., 2011; Wixom et al., 2014; Wixom, Ariyachandra, & Mooney, 2013). Results have shown an upward trend in BI/BA content and classes but suggest that a significant gap continues to exist between employment needs and students' preparation to meet these needs. One of the major findings from the most recent BI Congress was that "demand for BI/BA students continues to outpace supply" (Wixom et al., 2014, p. 4). According to recruiters responding to surveys, they have hired for BI/BA primarily from two sources: IS programs (in business schools) and computer science. However, the recruiters also indicated that, while IS programs develop database, business, and communications skills, they were not delivering sufficient depth in quantitative analysis and specialized BI topics such as reporting and OLAP.

Sircar (2009) identifies several reasons for business schools lacking BI/BA in their curricula. He attributes it primarily to inadequate quantitative literacy among students combined with a resistance by schools to increasing mathematical requirements, but these requirements are necessary when introducing BI/BA programs. Sircar also cites the traditional silo orientation of academic disciplines that provide the major components of BI/BA as a factor. Addressing this silo tendency with an integrative, multidisciplinary approach would present a more coherent representation of BI/BA to both students and employers. With a business emphasis and DSS background, IS is particularly well positioned to take the lead in organizing educational programs for BI/BA (Wixom et al., 2011; Chen, Chiang, & Storey, 2012).

The initial academic response to industry demand for BI/BA has been aimed mainly at the graduate level. Master's degrees have been designed for both students with strong mathematical backgrounds and IT professionals seeking advanced technical and analytical skills (Chiang, Goes, & Stohr, 2012). For a managerial understanding of BI/BA applications and implementations, some MBA programs include BI/BA concentrations or specialties. There has been less progress in undergraduate curricula, although BI/BA appears to have recently gained more attention in some IS departments (Olsen & Dupin-Bryant, 2013; Wixom et al., 2014).

Sircar (2009) describes an early instance of an undergraduate minor in BA at Miami University as comprising courses in business statistics, IS management, regression and quantitative analysis, database systems, data mining, and knowledge management. This minor has since been refined with data mining, quantitative methods, and multidisciplinary tracks. St. Joseph's University and the University of Denver were also among the first institutions to initiate undergraduate business programs focused on BI/BA (Wixom et al., 2011). Both a major and a minor in BI are available from the Department of Decision & System Sciences at St. Joseph's, while the University of Denver's Business Information and Analytics Department has business majors and minors in both IT (with electives in BI and data warehousing) and statistics. Augusta State University and Georgia Southern University have bachelor degrees in IS with added BI/BA content. However, considerable variation in coverage of BI technologies and advanced BA topics and differences in IS core requirements exist. See Gorman and Klimberg (2014) for a more comprehensive survey of BA academic programs.

In parallel, some universities are beginning to offer data science programs that incorporate training for big data technologies. These programs are characterized by an interdisciplinary combination of mathematics, statistics, and computer science—data scientists are expected to have in-depth knowledge in at least one area and proficiency in the others. As a result, they generally hold graduate degrees with formal education in applying the scientific method for making hypotheses, designing and conducting experiments, and communicating results (Davenport & Patil, 2012).

Professional organizations have also become proactive in providing resources for continuing education in BI/BA. The Data Warehousing Institute (TDWI) hosts numerous conferences and seminars, publishes research papers and the *Business Intelligence Journal*, and has offered a BI certification program since 2004 (http://tdwi.org/). In this program, professionals specialize in one of four areas: BA, data analysis and design, data integration, and leadership and management. Leveraging its members' expertise in mathematical modeling and algorithms, the Institute for Operations Research and the Management Sciences (INFORMS) recently began sponsoring a certification in advanced analytics (Bennett & Levis, 2013). It also publishes the *Analytics* magazine and hosts an annual conference for practitioners (http://informs.org/). Other major sources include the research firm International Institute for Analytics (http://iianalytics.com/) and the Predictive Analytics World conferences (http://www.predictiveanalyticsworld.com/). BI/BA software vendors such as IBM, Microsoft, SAS, and Oracle are collaborating with these societies and offering a variety of educational resources and academic partnership programs (Watson, 2013).

4 BI/BA in the IS 2010 Model Curriculum

In this section, we explore the IS 2010 model curriculum with respect to BI/BA content. The model curriculum (Topi et al., 2010) specifies a set of topics and outcomes expected for IS graduates. It includes mention of BI/BA and proposes some electives devoted to these topics; it also includes basic BI/BA material in two core courses: the introductory course (IS 2010.1: Foundations of Information Systems) and the database management course (IS 2010.2: Data and Information Management). IS 2010.1 is intended for all business students, whereas IS 2010.2 is aimed specifically at IS majors and minors.

BI topics in the foundations course are broken into four main categories: (1) organizational decision making, functions, and levels; (2) information and knowledge discovery; (3) application systems; and (4) information visualization. As one may expect, the foundation course focuses on using BI for managerial decision making, which is expressed in the course's tenth learning objective: "Understand how various types of information systems provide the information needed to gain business intelligence to support the decision making for the different levels and functions of the organization" (Topi et al., 2010, p. 391).

By contrast, the data management course dives deeper into technical and implementation-related topics and has three BI-related objectives numbered 19, 20, and 21 (Topi et al., 2010, p. 394):

- Understand the difference between online transaction processing (OLTP) and OLAP and the relationship between these concepts and business intelligence, data warehousing, and data mining.
- Create a simple data warehouse ("data mart").
- Understand how structured, semi-structured, and unstructured data are all essential elements of enterprise information and knowledge management. In this context, the students will learn the principles of enterprise search.

For the data management course, the major BI/BA-related topic areas are: (1) online analytic processing, (2) data warehousing, (3) data mining, and (4) enterprise search. Although the document does not define the term “enterprise search”, the fact that it is described with respect to unstructured data implies a relationship to emerging trends in big data and associated database technologies such as NoSQL (not only SQL) (Sharda et al., 2015). Interestingly, in the discussion points of the database management course, BI topics largely supplant database administration concerns compared to the IS 2002 Model Curriculum: “The focus on the physical data model and the DBA-level work on database implementation has been reduced for improved understanding of the role of databases in the enterprise application context and various business intelligence topics, including enterprise search” (Topi et al., 2010, p. 395).

The idea of knowledge management systems (KMS), which use contemporary information technologies to capture and disseminate organizational information (Sharda et al., 2015), also appears in both the IS 2010 foundations and data management courses. In addition, an elective in “Innovation and New Technologies” includes KMS coverage. This course also contains other BI-related topics, such as search and taxonomic classifications. A separate data mining elective is recommended for 13 of the 17 proposed IS 2010 career tracks, but the document does not describe the details of this course. On the quantitative side, the “Business Process Management” elective covers process modeling, statistical analysis, simulation, and performance measurement. However, the IS 2010 authors acknowledge that information systems as a discipline requires less mathematical depth than other computing disciplines (Topi et al., 2010, p. 380).

The IS 2010 model curriculum places little emphasis on practical hands-on experience in OLAP and data mining in the core. For example, the learning objectives for the data management class discuss “understanding” but not practicing or applying OLAP and data mining techniques. In fact, technical content in IS 2010 core are diminished compared to previous editions (i.e., IS ’97 (Gorgone et al., 2003) and IS 2002 (Davis, Gorgone, Couger, Feinstein, & Longenecker, 1997)). For the first time, software application development has been taken out of the core curriculum and is relegated to an elective. This puts IS 2010 at odds with ABET IS requirements for which programming competence is an important criterion (Saulnier & White, 2012). In general, ABET-qualifying IS programs must adhere to stricter technical standards than the minimum requirements as laid out by IS 2010.

One reason for the sacrifice in technical content is the importance that IS 2010 places on domain knowledge. One of the changes from IS 2002 is the emphasis on the applicability of IS curricula to a variety of domains such as government and healthcare, which opposes the assumption that IS is strictly a business discipline. This shift has implications for BI/BA. In principle, the “intelligence” of BI/BA can be (and has been) used in other domains such as geographic information systems, life sciences, health, and security (Chen et al., 2012). Although we concentrate primarily on business as the domain in crafting a BI/BA curriculum in this paper, generalization to additional application areas is possible.

5 A Multidisciplinary Framework for BI/BA

The rapid evolution of BI and BA has led to differences in descriptions across and in industry and academia. As a formal context for curricular design, we adopt a modified version of the multi-modal representation of BI from Klimberg and Miori (2010) (preceded by Sircar (2009)) in Figure 1. This framework is based on a broad view of BI (as Section 1 and Sharda et al. (2015) outline) defined as “the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions” (Davenport & Harris, 2007, p. 7). BA models and methods subsequently fall into three major categories: descriptive (what has happened in the past), predictive (what is likely to happen in the future), and prescriptive (what is the best course of action) (Lustig, Dietrich, Johnson, & Dziekan, 2010).

BI/BA is, therefore, primarily characterized from the perspectives of three distinct disciplines: IS/IT, statistics, and operations research/management science (OR/MS). These perspectives correspond to the three circles in the diagram shown in Figure 1 and are referred to as business information intelligence (BII), business statistical intelligence (BSI), and business modeling intelligence (BMI). Thus, BA encompasses statistical (BSI) and other mathematical modeling approaches (BMI) while BI/BA combines major elements of IS (BII) with BA.

This framework provides a solid foundation for designing, developing, and implementing BI/BA programs. By distinguishing BII from BSI and BMI, it acknowledges the individual disciplines that are primary sources of BI/BA-related knowledge and skills and, by inference, their traditionally separate academic offerings. At the same time, it identifies the existence of overlapping techniques and technologies.

Klimberg and Miori (2010) have labeled the intersection in their Venn diagram as “modeling”, while Sircar (2009) have denoted it as “business analytics”. Instead, we place “managerial decision making” at the juncture. The most important aspect of the representation in Figure 1 is that it highlights the critical requirement for integrating BII, BSI, and BMI to establish comprehensive BI/BA curricula in support of business decisions. Gartner (2013c) has predicted that increasing the effectiveness of BI/BA will result in the dominance of user-driven data discovery and improve the quality of strategic and tactical management decisions.

As a guide for curriculum design, we consider each of the circles in Figure 1 to be a cluster of “knowledge areas” in the context of the knowledge area-knowledge unit-topic hierarchy used in IS 2010’s architecture (Topi et al., 2010). The hierarchy serves to organize knowledge content as a precursor to assigning topics to courses and specifying course learning objectives. To initiate this organizing process, we briefly outline the contents of BII, BSI, and BMI knowledge areas below.

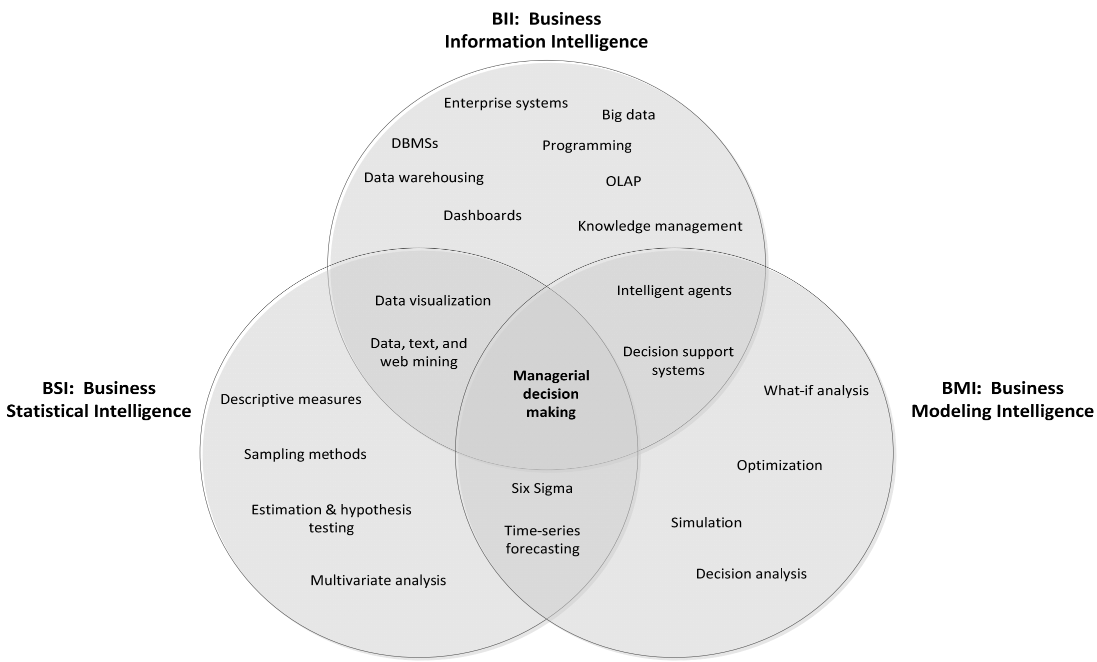

Figure 1. Business Intelligence/Business Analytics Framework (Adapted from Klimberg & Miori, 2010)

5.1 Business Information Intelligence (BII) Knowledge Areas

Much of the BII cluster focuses on database-related technologies and their extensions. The relational database architecture (Codd, 1970) has been the industry standard for storing and manipulating business data since the 1980s. It offers many advantages over traditional file processing, including maximized data integrity, simple data structure design, and guaranteed atomicity of transaction results. In short, relational databases are well suited for storing and retrieving data on a continuous basis and recording business transactions in high-volume, high-update settings. Although a great deal of business data is stored in relational databases, additional data resides in file structures of other sorts, from Virtual Storage Access Method (VSAM) to Extensible Markup Language (XML), Excel, and unformatted text files. All of these disparate data sources generate the inputs for BII’s decision support technologies.

Two prominent threads of BII are data warehousing (Inmon, 2005) and online analytical processing (OLAP) (Hoffer, Ramesh, & Topi, 2011; Sharda et al., 2015). Data warehousing involves extracting data from multiple data sources (e. g., relational databases, text files, spreadsheets, XML sources) and integrating them into a common location and interface for decision support purposes. In contrast to traditional relational databases, data warehouses are not concerned with handling business transaction processing’s high-volume input/out activities. Data warehouses are not used to manage a business’s day-to-day operations. Rather, they are intended as a repository of enterprise-wide data in a subject-oriented, time-variant, and integrated format that supports decision making and knowledge discovery for managers and analysts (Sharda et al., 2015).

The data warehousing approach migrates business data from a relational (transactional) structure toward a multi-dimensional (decision-support) structure. While it sacrifices the transaction processing capabilities of relational databases, it results in a much better framework for supporting complex ad hoc data querying with optimal system performance. The shift in data structure culminates in the development of OLAP cubes (Codd, Codd, & Salley, 1993), which are multi-dimensional and hierarchical structures that enable analysts and decision makers to view information at various levels of aggregation, "slice-and-dice" along different dimensions, "drill-down" and "roll-up" on dimensions to see data at high-level or more detailed levels, and produce visualizations in a way that quickly answer users' complex queries of the "big picture" in a company's data.

In this sense, BII is primarily concerned with the descriptive task of reporting what is going on, whereas BSI and BMI place more emphasis on predicting the future and prescribing an optimal course of action. However, there are some BII influences with predictive and prescriptive elements. For example, KMS (Alavi & Leidner, 2001) often include rules-of-thumb for best practices in a particular domain and, thereby, facilitate prescriptive tasks. Similarly, automated decision systems analysts (Sharda et al., 2015) use rule-based systems for deciding on best courses of action for given circumstances. As opposed to the optimization techniques described below in BMI prescriptive techniques, these rule-based approaches borrow on the idea of "satisficing" (Simon, 1956) and build on the knowledge representation frameworks from earlier AI research in expert systems (Hayes-Roth, Waterman, & Lenat, 1983).

5.2 Business Statistical Intelligence (BSI) Knowledge Areas

Statistics has long been considered essential for business curricula, most likely due to its affiliation with economics (Becker, 1987; Tabatabai & Gamble, 1997). It comprises methodologies that span across both descriptive and predictive analytics. BSI requires a grounding in the basic areas of descriptive statistics, sampling methods, and estimation and hypothesis testing. Descriptive statistics classifies data by type and summarizes current and past data with appropriate charts, tables, numerical measures, and frequency distributions. Methods of collecting sample data facilitate analyses by providing subsets of data from populations and generating sampling distributions.

Point and interval estimates are developed from these distributions to make inferential statements about populations of interest. Hypotheses about population characteristics can then be tested to answer managerial questions (Keller, 2012). To make comparisons between populations, one can apply advanced methods from multivariate statistics, such as analysis of variance and chi-square tests. And multivariate procedures in regression analysis are commonly used to construct statistical models of the relationships between variables for both explanatory and predictive purposes.

Visualization is useful for exploring data to identify errors, derive and select variables, uncover important patterns and trends, and report on analyses (Shmueli, Patel, & Bruce, 2010). Techniques in this knowledge area extend basic statistical charts to present multi-dimensional data and address data with specialized structures (e. g., networks, geographical information systems) (Camm et al., 2015). BSI overlaps with BII, particularly in how they implement dashboards to display metrics for current business operating conditions.

Data mining encompasses quantitative techniques that help one to extract useful information from large data sets to identify potentially important patterns and business opportunities. By applying these techniques to structured data, one can build predictive models for classification, prediction, and association problems in all functional areas of business. New technologies that incorporate natural language processing have extended data mining to analysis of data from textual and Web sources (Sharda et al., 2015). With origins in both traditional statistics and artificial intelligence, this area is recognized as being one of the primary intersection points between BSI and BII.

In business settings, forecasting variables' future values is a necessary step in planning. There are a host of different quantitative techniques available for forecasting using historical time-series data. Smoothing methods are appropriate for predictions based on stationary time series. When trend and/or seasonal components are present in the data, one can apply other methods including regression analysis. In addition, forecasts are often required as input to the mathematical models in BMI.

Control charts and process capability indices are commonly used statistical tools to monitor and evaluate causes of variability in process characteristics (Keller, 2012). Their adoption in quality management, as well as that of other statistical methods, led to the development of Six Sigma—a formal, systematic approach for improving process performance. BMI provides advanced analytical and simulation techniques for modeling and design of business processes in Six Sigma.

5.3 Business Modeling Intelligence (BMI) Knowledge Areas

OR/MS is the source of mathematical models for advanced predictive and prescriptive analytics (Lustig et al., 2010). Many of these models were originally applied in production operations management before spreading to the other functional areas of business. With the introduction of spreadsheet-based modeling, OR/MS become more practical and relevant for business students (Palocsay & Markham, 2014).

A pervasive theme throughout OR/MS is the what-if analysis, which addresses the need to consider how uncertainty about model inputs will affect predicted results. Basic tools for conducting what-if analyses include data tables and scenarios, while additional methodologies for parametric sensitivity analysis have been developed for specific types of models such as linear programs.

One of the fundamental modeling approaches in prescriptive analytics is optimization (Evans, 2013). Optimization models are used to select the best decision options for minimizing or maximizing a performance metric in the presence of specified requirements and limitations. Typical applications of optimization are developing production/inventory schedules, choosing investment portfolios, allocating advertising budgets among different media, and planning shipping routes (Camm et al., 2015).

Monte Carlo simulation models based on probability distributions for uncertain quantities have proven useful for risk analysis in competitive business environments. Alternative modes of simulation can represent a system's evolution over time for business process management. Model output comprises forecasted values from a large number of randomly generated what-if scenarios. Statistically analyzing simulation results provides a summary of these forecasts and facilitates probabilistic descriptions.

Decision analysis also incorporates uncertainty via probability assessments (Camm et al., 2015). The most common type of model in this area is the decision tree, which is used to graphically depict a sequence of decision alternatives dependent on chance events. One can then determine the optimal strategy by using expected value computations. One can state outcomes in either monetary amounts or utilities that measure relative value. Decision analysis also provides alternative methods for decision problems that involve more than one criteria or objective (Ragsdale, 2015).

Prescriptive analytics often requires hybrid modeling approaches that combine prescriptive optimization, simulation, or decision analysis techniques (e.g., using chance constraints in an optimization model, optimizing a simulation model's input parameters, or simulating uncertain events in a decision tree) (Ragsdale, 2015), and OR/MS models are frequently embedded in computer-based decision support systems to make analysis capabilities more accessible to managers, which puts them in the realm of BII (Sharda et al., 2015). Another connection between BII and BMI is in developing and applying evolutionary algorithms and agent-based simulations (Macal & North, 2013).

6 Curricula Options for BI/BA in Undergraduate IS

In this section, we discuss two alternative strategies for structuring undergraduate BI/BA programs. The first and more modest approach involves incorporating a BI/BA career track into existing IS degrees. The section entitled "Overall Degree Structures and Coverage of Foundational and Domain-specific Skills and Knowledge" in IS 2010 (Topi et al., 2010) compares three typical IS curriculum configurations: (1) AACSB-accredited North American schools with eight-12 business courses (considered domain heavy in business), (2) non-business North American schools with a domain core of only five courses (domain light), and (3) typical European business schools with 10 business courses (domain heavy). The IS 2010 authors also recognize the difference in depth and type of IS coverage for these three configurations. The domain-heavy curricula contain eight-10 core and elective IS courses, whereas domain-light curricula involve 15 core and elective IS courses.

The second, more ambitious approach encompasses creating a distinct new undergraduate major in BI/BA. Depending on the proportion of business core courses, this major could be either business domain-heavy or domain-light in the context of IS 2010. With respect to AACSB, a BI/BA program does not have to be a conventional "business major". AACSB standards allow "extensions of traditional business subjects, including interdisciplinary courses, majors, concentrations, and areas of emphasis" (Association to Advance Collegiate Schools of Business International, 2013, p. 11), although they still fall under accreditation review. An example in our school is the quantitative finance major. It is a bachelor of science degree that only includes a small subset of the business core courses required in bachelor of business administration majors such as accounting and marketing. Thus, the breadth of typical business core coverage is replaced by greater depth in finance, economics, and higher-level mathematics. We discuss a similar domain-light structure for BI/BA specialization in Section 6.2.

6.1 BI/BA Career Track in IS

The IS 2010 model curriculum divides courses into two categories: core (required) courses and electives. It uses seventeen career tracks as examples to illustrate how elective courses can contribute to one or more career tracks (Topi et al., 2010). However, the IS 2010 model curriculum does not explicitly designate a BI/BA career track, most likely because its importance was not yet fully recognized at the time IS 2010 was developed. The most relevant elective course that the curriculum identifies, data mining/BI, is linked with career tracks for business analyst, database administrator, database analyst, and IT architect. It also indicates a knowledge management course as another elective needed for business analyst. Adding a separate career track in BI/BA would incorporate a BI/BA specialization into the overall IS curriculum, which is consistent with the curriculum's design (Bell, Mills, & Fadel, 2013).

IS 2010 already covers some of the BII knowledge areas in Figure 1 that correspond to core IS topics, but it lacks required programming content. In addition to programming, a robust BI/BA career track should include advanced data management (data warehousing, advanced querying and information retrieval, and OLAP), dashboards, knowledge management, data visualization, and big data topics. Although it does not describe the data mining/BI elective(Topi et al., 2010), we can reasonably assume that it would address most of these topics and provide some coverage of basic data mining techniques (from BSI) and intelligent agents and DSS (from BMI).

However, other knowledge areas of BSI and BMI are largely missing. Thus, a robust BI/BA career track will need considerably more analytics than is currently available in the curriculum. As we discuss in Section 3, both Sircar (2009) and Wixom et al. (2011) have previously noted this deficiency. Fortunately, many business schools already require substantial course work with a strong quantitative emphasis in their core undergraduate curricula (Palocsay & Markham, 2014), which provides a foundation for supporting a BI/BA career track with additional coverage of BSI and BMI.

As an initial solution at our institution, we have encouraged IS students that demonstrate solid statistical and quantitative abilities to augment their academic program with a newly created minor in business analytics. This minor adds only six credits to their course load since requirements for the minor include two courses from the business core and another portion counts as elective credits towards the IS major. Our Executive Advisory Board has expressed strong interest in recruiting from this subset of IS graduates. Departments that include IS with other business disciplines such as operations, accounting, or management could take a similar approach to encompass BI/BA applications by cross listing courses in forensic accounting (Smith, 2012), human resource analytics (Bassi, 2011), and supply chain management (Sahay & Ranjan, 2008).

6.2 New BI/BA Degree Program

A second and considerably bolder curriculum option is to develop a standalone BI/BA degree program predominantly based on the framework for BI/BA in Figure 1. We envision this major as an instantiation of the IS body of knowledge, which has four categories of high-level knowledge areas: general computing, IS specific, foundational (including general education), and domain specific. By varying the portion of a typical 40-course (120-credit) degree allocated to each category, this option introduces the possibility of building a BI/BA program with either a "domain-heavy" or a "domain-light" degree structure as IS 2010 discusses (Topi et al., 2010).

The domain-heavy structure is largely governed by AACSB requirements and involves as many as 12 business (domain) courses with only eight IS-specific courses. To incorporate a BI/BA specialization, more advanced data management, decision-support, and analytics skills would be needed, which would result in a likely overload of at least two to three courses. In contrast, IS 2010's "domain-light" degree reduces domain courses to as few as five, which makes room for up to 15 IS courses. The obvious advantage of this approach is that a domain-light BI/BA program would also allow greater technical depth in BII, BMI, and BSI areas but at the expense of domain (business) coverage, which has implications for AACSB accreditation (see Section 7).

Another consideration in designing a standalone BI/BA major is possibly reducing and/or removing IS core content that is not central to the BI/BA discipline. For example, IS 2010 includes required coverage of IT infrastructure (telecommunications/networking), IS strategy and acquisition, and enterprise architectures. Much of this subject matter is arguably less relevant for BII, which is mainly concerned with data management, data analysis and interpretation, reporting, prediction, knowledge discovery, and decision support. Separating BI/BA from IS curricula presents a potential conflict with IS 2010 and accreditation issues (particularly with ABET).

7 Accreditation Considerations

Many IS programs are housed in business schools where they fall subject to AACSB standards (Association to Advance Collegiate Schools of Business International, 2013). In addition, these and other non-business IS programs increasingly consider the benefits and costs of seeking ABET accreditation (ABET, 2014). In this section, we examine how accreditation standards related to curriculum content may affect the prospects of a BI/BA-specialized curriculum.

Neither AACSB nor ABET is strictly prescriptive in terms of required course content. Both are fairly specific about expected student learning outcomes but flexible in terms of how these outcomes can be satisfied. This gives plenty of leeway for institutions to innovate and craft their business and IS programs to best suit their own mission and objectives while also ensuring quality standards. Indeed, key components of both ABET's and AACSB's philosophies emphasize the importance of innovation in curriculum design. We contend that a new BI/BA curriculum is by definition "innovative" in this context, that the time is ripe for developing a model for such a curriculum, and that this can be done consistently in the spirit of AACSB and ABET missions and curricular standards.

7.1 AACSB Accreditation

AACSB-accredited institutions generally offer a bachelor's degree that includes a common core of classes taken by all business students (regardless of their specific major), forming an application domain for IS 2010. A typical core curriculum is comprised of introductory courses in accounting, finance, management, marketing, IS, business law, economics, operations, and statistical/quantitative methods. AACSB 2013 standards do not specify a minimum number of credit hours for the business core, but IS 2010 estimates it to be 20 percent of a typical 40-course degree (Topi et al., 2010, p. 386). It assigns another 20 percent to IS courses and 50 percent to general education. The model curriculum leaves the remaining 10 percent open for business electives, which could be used for BI/BA courses. However, if either IS or the business core exceeds these allocations by a total of more than 10 percent, it will eliminate this flexibility. Thus, a domain-heavy BI/BA program that adheres to IS 2010 should meet AACSB standards but may require more than a standard number of credit hours.

However, with respect to AACSB, a BI/BA program does not necessarily need to be a "business major" in the same sense as traditional business subjects such as finance or management. AACSB also evaluates some bachelor's degrees that may be housed in the college of business but do not require students to take the entire business core. The determination of which degrees fall under AACSB review depends on their relationship to traditional business disciplines, amount of college resources used, and whether or not they are marketed in conjunction with the university's business college. We anticipate that a BI/BA major based on an IS 2010 domain-light structure would be eligible for AACSB accreditation in this category, albeit with less certainty than the domain-heavy major.

While AACSB does not give strict prescriptions on course content, the 2013 AACSB curriculum standards acknowledge the importance of data analysis as a key component of a modern business curriculum, and their wording reflects an understanding of current and emerging industry practices. One of the general business and management knowledge areas that accredited bachelor's degree programs are expected to address is:

> *Information technology and statistics/quantitative methods impacts on business practices to include data creation, data sharing, data analytics, data mining, data reporting, and storage between and across organizations including related ethical issues. (*Association to Advance Collegiate Schools of Business International, *2013, p. 32)*

This is a distinct change of verbiage from the 2003 standards that make no mention of “data analytics” or “data mining”. Clearly, we are seeing an evolution in AACSB’s criteria, influenced no doubt by the emergence and importance of “big data” over the past decade. We believe that this is further evidence of the timeliness of a new BI/BA model curriculum and that AACSB should agreeably receive such a model.

7.2 ABET IS Accreditation

ABET’s IS standards are a subset of the general computing criteria established by the Computing Accreditation Commission (CAC). The CAC is responsible for accrediting three types of computing programs: computer science (CS), information technology (IT), and information systems (IS). Many CAC standards apply across all three programs; others are specific to one of these three subdomains. Our concern here is the implication of ABET’s criteria for a standalone BI/BA major in an accredited IS program.

General CAC standards require a range of knowledge and skills related to the technical aspects of designing and implementing computer-based systems and communication and teamwork skills, global and ethical issues, and continuing professional development. For IS programs, there is an additional student outcome criterion for “An understanding of and an ability to support the use, delivery, and management of information systems within an Information Systems environment” (ABET, 2014, p. 6). In reviewing the general standards, we found that many of them are consistent with the technical and quantitative requirements embedded in the BII, BSI, and BMI knowledge areas that we describe in Section 5 and that the remainder will not pose any difficulties for a BI major. The IS-specific outcome requirement may or may not be problematic depending on interpretation and the extent of IS 2010 core content retained.

ABET also requires that students in IS programs complete course work in (ABET, 2014, p. 8):

- Information systems: one year that must include:
  - Coverage of the fundamentals of application development, data management, networking and data communications, security of information systems, systems analysis and design and the role of Information Systems in organizations.
  - Advanced course work that builds on the fundamental course work to provide depth.
- Information systems environment: one-half year of course work that must include varied topics that provide background in an environment in which the information systems will be applied professionally.
- Quantitative analysis or methods including statistics.

The curriculum content in these requirements is more technical than that of the IS 2010 core. In particular, IS 2010 has no required programming core, a fact that has sparked debate in the IS community (Saulnier & White, 2012). We view the “information systems environment” as equivalent to the domain component of IS 2010, which we also espouse in both the domain-heavy and -light versions of a BI/BA major. And the quantitative requirements for BSI and BMI in a BI curriculum significantly exceed the threshold for ABET-accredited IS programs.

The potential stumbling block seems to be with the emphasis on “networking and data communications” and perhaps “the role of information systems in organizations”. Reducing or removing either of these topics could prevent even a high-quality BI/BA curriculum from meeting ABET IS accreditation requirements.

Thus, while the IS component of BI (referred to as BII) and the IS discipline as a whole considerably overlap, they also have significant differences. We speculate that some topics such a networking and data communication may not be as relevant for BI as for IS and that quantitative skills will necessarily have greater importance for BI. Eventually, these points might suggest the need for a fourth ABET-accredited computing discipline to accommodate BI/BA, similar to the development of IT standards (Gowan & Reichgelt, 2010).

8 Use of IS 2010 Architecture for Building Model BI/BA Curricula

In this paper, we lay the groundwork for the next phase of designing undergraduate model curricula for BI/BA. To move forward in this endeavor, we plan to use the same process advocated by the authors of IS 2010 (Topi et al., 2010).

8.1 Overview

Topi et al. (2010) conceptually base IS 2010's methodology on an "optimal curriculum architecture" (Figure 2) that provides linkages to development of other computing curricula. This architecture is characterized by an arrangement of multiple elements: course, coverage entity, learning objective, and a knowledge area-knowledge unit-topic hierarchy. Therefore, knowledge content is organized into knowledge areas that comprise knowledge units that encompass topics that may, in turn, have associations with other topics. And, as Figure 2 illustrates, each coverage entity corresponds to attaining a learning objective for a specific topic at a particular cognitive level. Thus, a key principle of this architecture is the mapping of learning objectives to knowledge content via coverage entities; a course is then simply a composition of many coverage entities.

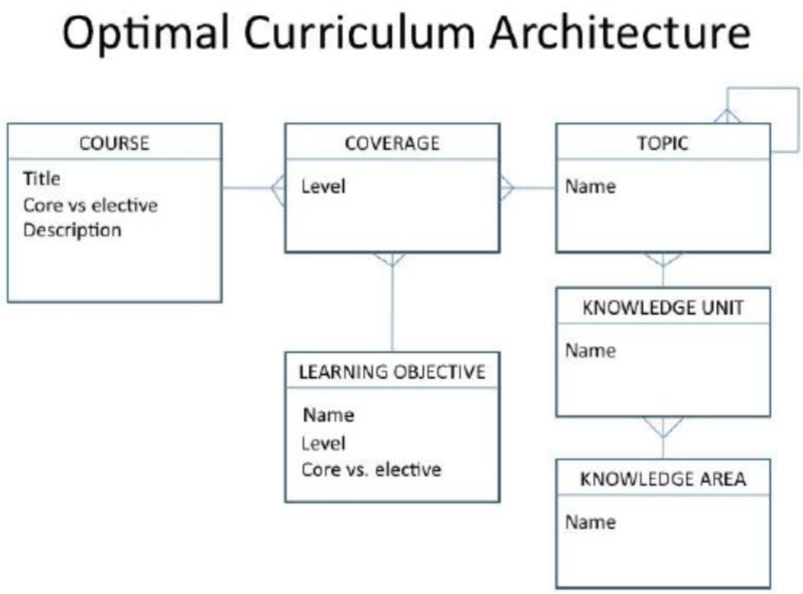

Figure 2. Optimal Curriculum Architecture for IS 2010 (Topi et al., 2010, p. 382)

In principal, topics and learning objectives are linked via coverage entities. Therefore, in this framework, learning objectives and topics (and their combinations as coverage units) are independent of courses. Therefore, various coverage entities can be distributed among multiple courses in a flexible manner to suit the needs of a particular program at a particular time. ABET's curriculum structure adds nuance to the notion of "learning objective" by further two types of learning objectives: "student outcomes" and "program educational objectives". Student outcomes indicate knowledge and skills that should be acquired by time of graduation, whereas educational objectives state expectations for graduates three to five years out in terms of meeting industry needs (ABET, 2014).

By following IS 2010's approach for constructing BI/BA model curricula, we can apply the same set of design primitives:

1 Create a detailed hierarchy of knowledge areas/knowledge units/topics for BII, BSI, and BMI.

2 Define BII, BSI, and BMI learning objectives that are not already included in IS 2010. For ABET, also describe what students will accomplish after they have been professionally employed for some period of time.

3 Conceive of best mixes of coverage associations for BII, BSI, and BMI to develop courses for implementing a model BI/BA curriculum.

Topi et al.'s (2010) adoption of a structural architecture for IS 2010 represents one of their most significant achievements in revising IS 2002. It introduces a formal educational methodology that supports curriculum design while maintaining the flexibility to create degrees and define a variety of career tracks for professional roles in IS. Carlsson, Hedman, and Steen (2010) show an example application of some of its elements in their proposal for an undergraduate curriculum in business IS design. Building up courses for BI/BA curricula from mapping knowledge areas and units into topics, coverages, and learning objectives will allows curriculum designers to systematically articulate both content and skills. It will also help educators select strategies for teaching, measure learner performance, and assess program achievements.

8.2 Examples

While it is beyond our scope here to fully implement the methodology we describe above, consider "data warehousing" as an example knowledge area. Possible knowledge units in this area could include:

- Data warehouse characteristics (subject oriented, nonvolatile, time variant, integrated)
- Data structures in DWs (dimension and fact tables, star and snowflake schemas, conformed dimensions and factless fact tables)
- Data warehouse architectures (enterprise data warehouses versus data marts, independent versus dependent data marts, bus, hub-and-scope, federated)
- Data integration approaches (extract/transfer/load (ETL), enterprise information integration (EII), enterprise application integration (EAI))

Learning objectives indicate the expected cognitive level. For instance, a rudimentary awareness or understanding objective could require students to distinguish between dependent and independent data mart architectures. An advanced objective (i.e., synthesis) might involve use of a tool such as Microsoft SQL Server Integration Services to implement an ETL data integration process. Thus, we define two possible "coverage entities": one applies "understanding" to "DW architectures" and the other applies "synthesis" to "data integration".

As a second example, consider text analytics as a knowledge area. For this, we could include knowledge units such as natural language processing (NLP), lexical dictionaries, information retrieval, and sentiment analysis. Each of these units would be further decomposed into topics. For example, natural language processing would include concepts and techniques for sentence detection, parts of speech (POS) tagging, word-sense disambiguation, chunking and parsing, and recognition of named entities (people, places, events, organizations).

Each of these knowledge units and topics could be associated with different learning objectives to form coverage entities. For an introductory BI course, a typical coverage entity could involve "conceptual understanding" (a learning objective) of the definition of "POS tagging" (knowledge topic). At an intermediate level, students could apply sentiment analysis tools to analyze text documents such as customer reviews, Facebook posts, and/or tweets. This coverage unit associates "application" (a learning objective) to "sentiment analysis" (knowledge topic). At an even more advanced technical level, students could use Java APIs (e.g., Apache openNLP and Lucene) to develop applications. Such coverage units combine "design and implementation" (learning objective) with "NLP" and "information retrieval" (knowledge units or topics). As a result, knowledge areas/units/topics will be repeated throughout the curriculum, albeit at different levels and with different learning objectives, which helps to integrate a curriculum and gives it cohesion throughout the student's coursework over time.

9 Summary

In this paper, we present a needs assessment and rationale for launching BI/BA curricula development from both academic and industry perspectives. We formally characterize BI/BA as a blend of BII, BSI, and BMI knowledge areas that highlights the increasing convergence of advanced data management and analytics in industry. As investments in big data technology continue to grow, finding employees with the specialized skills needed to implement and effectively generate benefits from it (alongside existing enterprise systems) is a major organizational challenge (Franks, 2012). The need to collect, store, integrate, and analyze unstructured and real-time event data, in addition to data from transactional processing, will continue to accelerate with growth in use of cloud computing and mobile platforms.

Established IS programs already provide a strong mix of business and technical abilities and, thus, are in an ideal position to capitalize on this opportunity and create a leadership role for the IS profession.

Organizational IS has experienced significant changes at a rapid pace over the past two decades. Two notable examples are the implementation of enterprise resource planning (ERP) systems and the rise of e-commerce. Both have required modifications to IS education to expose students to new concepts and develop their technical skills with new technologies (Alter, Markus, Scott, & Vessey, 2001; Bradford, Vijayaraman, & Chandra, 2003; Boyle, 2007; Moshkovich & Olson, 2006). In a similar manner, we anticipate that the current demand for BI/BA expertise will generate discussion in the IS academic community about how to address trends in big data analytics.

To stimulate future BI/BA curricula development efforts at the undergraduate level, we outline two distinct strategies: a BI/BA career track and a degree in BI/BA. Integrating a BI/BA concentration in an IS 2010 program provides a practical way to quickly leverage existing resources and adapt to emerging trends. Movements in this direction have begun to surface at various institutions. Nevertheless, they could benefit from deliberating on knowledge units and topics for the knowledge areas in the multidisciplinary BI/BA framework presented here. Taking into account practical issues associated with credit-hour limits and accreditation, we plan to elaborate further on this foundation in an upcoming paper to define a comprehensive BI/BA program with course descriptions and detailed learning objectives.

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About the Authors

Michel Mitri is Professor of Computer Information Systems in the College of Business at James Madison University. His primary teaching focus is on software development, business intelligence, database design, and web/mobile application development. His research interests include business intelligence, decision support systems, artificial intelligence, text analytics, and educational impact and applications of information systems. He has published in journals such as *Journal of Computer Information Systems, Journal of Information Systems Education, Communications of the ACM, Computers and Education,* and *AI Magazine*.

Susan Palocsay is Professor of Business Analytics in the College of Business at James Madison University where she has taught courses in management science, statistics, data mining, business process management, simulation, and decision analysis. Her research interests include nonlinear optimization, neural networks, ranking methods, lean/Six Sigma applications, and pedagogical approaches to teaching quantitative analysis using spreadsheet-based tools. She has published in journals such as *Operations Research*, *European Journal of Operational Research, Journal of Global Optimization*, *INFORMS Transactions on Education,* and *Decision Sciences Journal of Innovative Education.*