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Integration of big-data ERP and business analytics (BA)

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ABSTRACT

Technology advancements in cloud computing, big data systems, No-SQL database, cognitive systems, deep learning, and other artificial intelligence techniques make the integration of traditional ERP transaction data and big data streaming from various social media platforms and Internet of Things (IOTs) into a unified analytics system not only feasible but also inevitable. Two steps are prominent for this integration. The first, coined as forming the big-data ERP, is the integration of traditional ERP transaction data and the big data and the second is to integrate the big-data ERP with business analytics (BA). As ERP implementers and BA users are facing various challenges, managers responsible for this big-data ERP-BA integration are also seriously challenged. To help them deal with these challenges, we develop the SIST model (including **S**trategic alignment, **I**ntellectual and **S**ocial capital integration, and **T**echnology integration) and propose that this integration is an evolving portfolio with various maturity levels for different business functions, likely leading to sustainable competitive advantages.

1. Introduction

On July 1, 2014, SAP, the world-renowned ERP vendor, released its own Certified Spark Distribution,[1] starting its journey of a brand new collaboration[2] with Databaricks[3] - the rising star behind the increasingly dominant distributed analytic platform Apache Spark. In three years, as the fruit of this collaboration, SAP announced its new product Vora in 2017.

"SAP Vora is an in-memory, distributed, query-processing engine … which extends the Apache Spark framework. … allows you to inexpensively process enterprise and Hadoop data for real-time business applications and analytics."[4]

This collaboration between SAP and Databricks exemplifies the integration of both the business transactional data generated by traditional ERP systems and the big data streaming from multiple social media platforms, mobile phones, and Internet of Things (IOTs) into a unified analytics system and represents a critical milestone in the evolution of ERP systems. We would coin a new term - the big-data ERP[5] - to represent the innovation of integrating the transaction data and the big data. Further, we would like to name

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[1] Apache Spark™ is a fast and general engine for large-scale data processing. https://spark.apache.org/, Accessed on June 21, 2017.
[2] https://databricks.com/blog/2014/07/01/integrating-spark-and-hana.html, accessed on June 20, 2017.
[3] Databaircks is a company, founded by the team who created Apache Spark and it provides a Unified Analytics Platform that accelerates innovation by unifying data science, engineering, and business. https://databricks.com/unified-analytics-platform, Accessed on June 21, 2017.
[4] White Paper, https://www.sap.com/documents/2017/05/82e66ce9-b97c-0010-82c7-eda71af511fa.html, Accessed on September 19, 2017
[5] In this paper, the big-data ERP broadly refers to systems responsible for managing daily operations and producing large amount of business transactional data, IOT (Internet of Things) data, social media data, etc. It represents a critical evolution from traditional ERP systems that process only transactional data.

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the integration between this big-data ERP and the business analytics (BA) as the big-data ERP-BA integration. The big-data ERP system is both the source of data for the BA system and the major consumer of the insights produced by the BA system. Managers as well as smart machines/devices apply those insights to make decisions and judgements such as optimizing inventories, assessing supplier risks, selecting efficient routing paths, evaluating marketing effectiveness, etc. As ERP implementers and business analytics users are facing various challenges (Gupta & George, 2016; Strong & Volkoff, 2010), managers responsible for this big-data ERP-BA integration are facing challenges in strategic alignment, inter-organizational collaboration, and technological integration.

On the one hand, the integration of transactional data from a traditional ERP system and the big data streaming from multiple sources is challenging in terms of distributed sensor management, data center management, use of the non-SQL database, configuration of the complex big-data ERP system, etc. On the other hand, a business analytics[6] (BA) system refers to the technologies that can be used to dig into the data supplied by the big-data ERP system to produce insights and help with the ERP supported operations management and strategic positioning for the ultimate value creation (Lavalle, Lesser, Shockley, Hopkins, & Kruschwitz, 2011).

To effectively manage this big-data ERP-BA integration, firms are facing the challenges of developing the strategic thinking, hiring and training highly qualified people, making them work together effectively, connecting the big-data ERP and BA systems, and maintaining a reliable and durable infrastructure. Users of the integrated big data ERP-BA system face the challenge of both exploiting existing processes and exploring untested fields. With data exploitation, the BA system can help identify opportunities for incremental improvements through adjusting parameters of and/or reconfiguring business processes embedded in the big-data ERP system. With data exploration, the BA system may be used to analyze the transactional and the social media/IOTs big data for strategic decision-making regarding product and manufacturing disruptive innovations (Fan & Gordon, 2014).

While the integration of the big-data ERP and BA technological systems itself is challenging, beyond it, through continuous interactions, social and intellectual exchanges are unavoidable between people from both the ERP and BA organizations. Subsequently, social/intellectual capitals are developed and nurtured, transforming the inter-organizational structures and processes for future exchanges that substantiate the big-data ERP-BA integration.[7] This aspect of ERP-BA integration sets up the environment for the effective collaboration among people across inter-organizational structures and processes. Moreover, since the big-data ERP and BA systems are critical for the long-term survival and prosperity of any sizable businesses in today's global competition, the strategic management of this ERP-BA integration is always valuable and highly preferable.

To help with managing this challenging big-data ERP-BA integration task, based on classic information systems management models and recent advancements in analytics, artificial intelligence, cloud computing research and practice, we develop a SIST model (including **S**trategic alignment, **I**ntellectual and **S**ocial capital integration, and **T**echnology integration) and propose that this big-data ERP-BA integration is an evolving portfolio with various maturity levels for different business functions. We conclude that this integration, as a moving target with path dependencies, is likely to sustain competitive advantages.

2. The big-data ERP-BA integration –SIST model

The SIST model in Fig. 1 illuminates the three layers for the big-data ERP-BA integration. The Strategic Alignment layer sets the value proposition and constructs the blueprints for the big-data ERP-BA integration. The second layer is the Intellectual and Social Capital Integration substantiating the ERP-BA integration in terms of integration of structures, processes, and people and acting as the environment within which both the alignment model formulation (at the first layer) and technology integration (at the third layer) occur. The Technology Integration layer is about the integration of the big-data ERP and BA technical systems to implement those blueprints constructed at the first layer for value realization.

2.1. The strategic alignment (SIST) for the big-data ERP-BA integration

The strategic alignment for the big-data ERP-BA integration is the conceptual strategic thinking about the value proposition and the construction of blueprints for the integration. Conceptually, both ERP and BA organizations can be value centers with external and internal orientations as depicted in Fig. 2 (adopted from Venkatraman, 1997). Firstly, ERP and BA organizations are profit centers as profits may come from providing consulting and other related services to external customers. A good example of this aspect of the alignment is the integration between Facebook's consumer-facing operational system at www.facebook.com and the business-facing analytics (BA) system at https://analytics.facebook.com. Behind the two systems, in Facebook, there is an end-user facing organization responsible for the frontend big-data ERP system's development, operations, and maintenance and there is also a business-customer facing organization responsible for providing social media analytics (Fan & Gordon, 2014). Facebook makes profits as it provides services of social media analytics to customers.

Secondly, as investment centers, both ERP and BA organizations can invest in each other or third parties for joint research and

[6] Wikipedia defines business analytics as making extensive use of "statistical analysis, including explanatory and predictive modeling, and fact-based management to drive decision making. … Analytics may be used as input for human decisions or may drive fully automated decisions." https://en.wikipedia.org/wiki/Business_analytics, Accessed on September 22, 2017. In our view, all data processing techniques, such as statistical analysis, machine learning, deep learning, reinforcement learning, other AI techniques, etc., should be included (Davenport, 2006; Silver et al., 2016; Silver et al., 2017).

[7] In the following, to make the writing more concise, the big-data ERP-BA integration is normally interchangeable with the ERP-BA integration. Otherwise, there will be specific explanations.

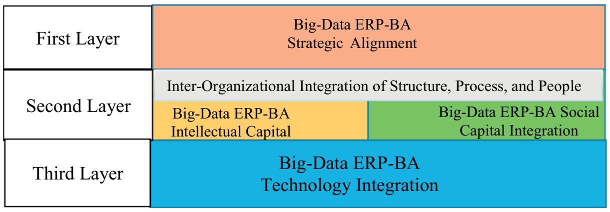

Fig. 1. SIST Model.

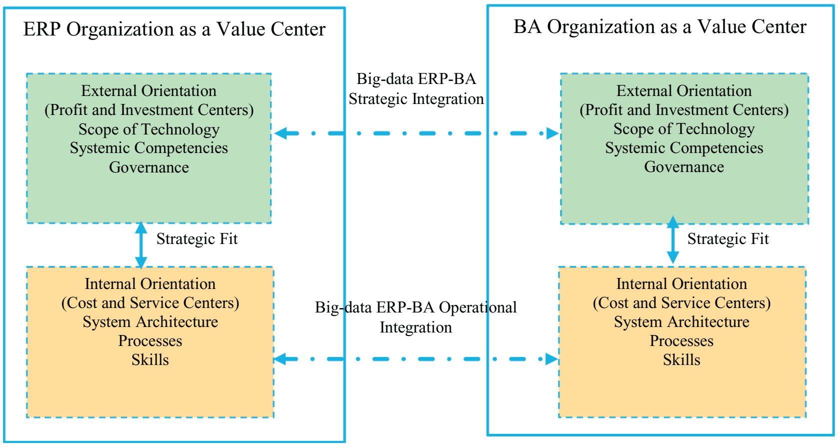

Fig. 2. Big-data ERP and BA Strategic Alignment.
Adapted from Venkatraman (1997) and Henderson and Venkatraman (1993).

technology development. The collaboration between SAP and Databricks demonstrates the mutual investments between a major ERP firm and an increasingly dominant big data analytics firm. The profit and investment centers are mostly externally oriented with the former facing the external service consumers and the latter targeting external technology providers. These two perspectives are related to strategic decisions on the scope of technologies, competencies, and governance[8] (Henderson & Venkatraman, 1993).

Thirdly, both ERP and BA organizations should provide the best possible services to each other at the lowest cost and play the roles of service and cost centers. Walmart's integration of its Hadoop[9] cluster system with its daily operational system (as a part of its big-data ERP system) demonstrates both the service and cost center roles played by its ERP and BA organizations.[10] Cost and service centers are internally oriented and relate to decisions on system architecture, processes, and people's skills[11] (Henderson & Venkatraman, 1993). Lastly, according to Venkatraman (1997), the big-data ERP-BA strategic alignment should be specified in terms of the horizontal strategic and operational integration across the two organizations and the vertical strategic fit between external and internal orientations within the two organizations respectively (as indicated in Fig. 2).

2.2. Dynamics of the Strategic Alignment

Dynamic changes in any of the four domains in Fig. 2 could trigger adaptive conceptual strategic thinking in other domains. For example, if the ERP organization decides to change its orientation on the scope of technology by moving its ERP system to the Amazon Web Service Cloud (i.e., an ERP external domain change), then this technology domain change may challenge the BA organization to redesign/reconfigure its architecture, processes, and skills. This redesign/reconfiguration could be conducted through either the demand-pull from the data analysis needs of the cloud based-ERP (i.e., Scenario 1 in Fig. 3) or the proactive supply-push

[8] In terms of technology scope, ERP systems may apply various technologies such as databases, programming, cloud computing services, etc. BA systems may apply techniques such as descriptive, prescriptive, predictive, adaptive, and various artificial intelligence methods. System competencies consist of flexibility, security, capacity, and robustness; governance mechanisms include such as joint ventures, joint research and development, and outsourcing agreements (Henderson & Venkatraman, 1993).

[9] "The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models. It is designed to scale up from single servers to thousands of machines, each offering local computation and storage." http://hadoop.apache.org/. Accessed on October 21, 2017.

[10] https://mapr.com/blog/walmart-harvesting-value-big-data-hadoop-nosql/. Accessed on November 17, 2017.

[11] System architecture consists of a portfolio of applications, hardware, networks, and data architecture; processes are procedures regarding system development, maintenance, monitoring, and control; skills refer to knowledge of people required to effectively manage and operate ERP and BA systems (Henderson & Venkatraman, 1993).

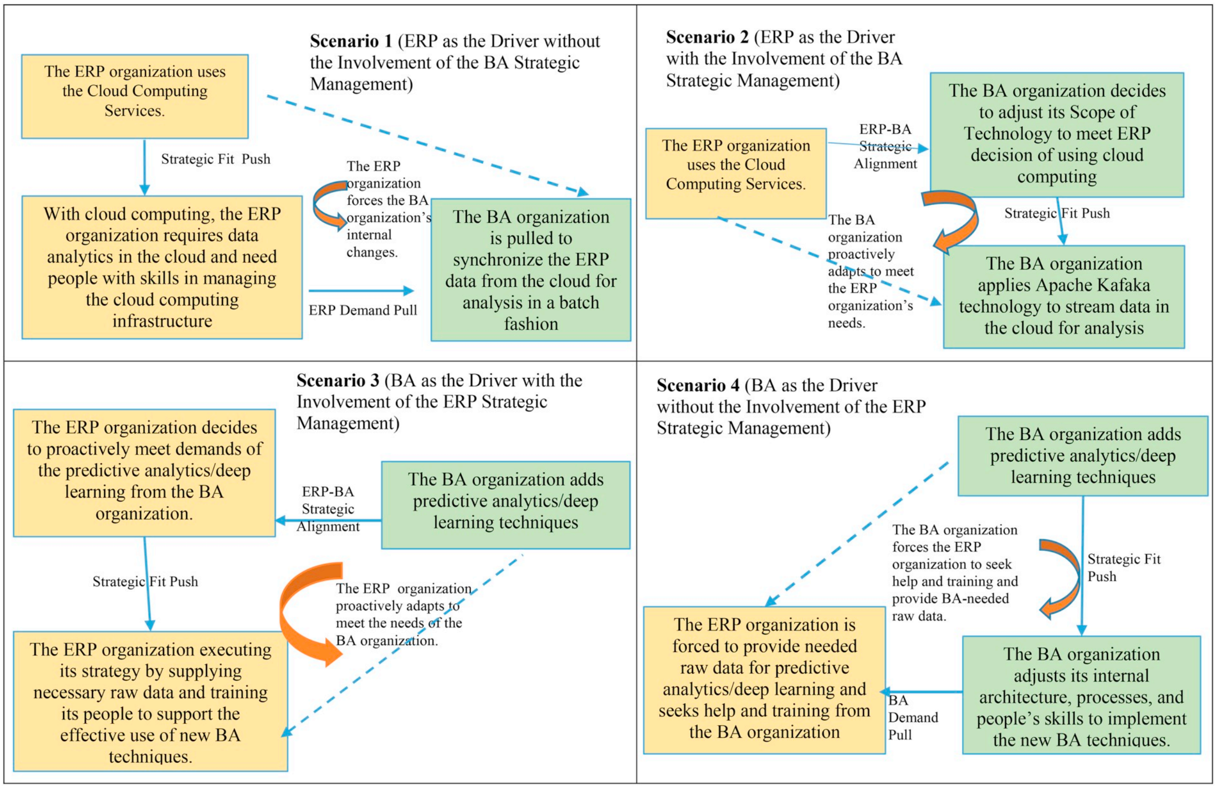

Fig. 3. Sample scenarios of the strategic alignment dynamics.

from the BA's external orientation adjustment of its own technology scope (i.e., Scenario 2 in Fig. 3). More specifically, with an operational big-data ERP system (such as an ecommerce web store integrated with multiple social media platforms) running in the Amazon Cloud, the ERP organization will certainly expect the BA organization to be able to take the analysis into the cloud. To accommodate this ERP technology change, the BA organization may adjust passively following the ERP demand-pull to synchronize the ERP data from the cloud in a batch fashion as in Scenario 1. Alternatively, it may adapt proactively with the BA's external technology position adjustment by applying the Kafka[12] technology in the cloud to stream the ERP data in a real time fashion as indicated in Scenario 2.

Similarly, the BA organization's external position adjustment can also be the driver for the alignment dynamics as illustrated in Scenarios 3 and 4 in Fig. 3. For example, as a response to the BA's external technology scope change of adding predictive analytics or deep learning methods, the ERP organization may decide to proactively supply additional types of data with a higher volume and frequency and train their people to support the effective use of predictive analytics/deep learning techniques in operations as illustrated in Scenario 3. Alternatively, the ERP organization may adjust passively with the demand-pull of the BA organization forcing the ERP organizational changes as illustrated in Scenario 4. More specifically, for Scenario 3, the ERP organization may adjust its governance by setting up a partnership with an external BA training agency to educate the ERP users on the effective use of predictive analytics and deep learning techniques. For Scenario 4, with the lack of guidance from the ERP organization's strategic management, the ERP users may become aware of challenges related to predictive analytics and deep learning during daily operations and then, they may seek training from the BA personnel directly at the grassroots level.

With a high level of strategic alignment between ERP and BA organizations/systems at the conceptual level, the big-data ERP-BA integration is likely to be successful, leading to super business performance. However, it is important to distinguish scenarios in which either ERP or BA strategic management is missing from those in which both BA and ERP strategic management are involved. Scenarios 1 and 4, without going through either BA or ERP strategic management, have the advantage of timely response to evolving ERP or BA operational needs at the grassroots level. They are efficient in facilitating continuous adaptation to incremental innovations of ERP/BA systems and organizations. In contrast, Scenarios 2 and 3, with the strategic management from both the ERP and BA organizations, have the advantages of top management support, company resource commitment, and appropriate rewarding/

[12] "Kafka™ is used for building real-time data pipelines and streaming apps. It is horizontally scalable, fault-tolerant, wicked fast, and runs in production in thousands of companies". "It lets you publish and subscribe to streams of records. In this respect it is similar to a message queue or enterprise messaging system. It lets you store streams of records in a fault-tolerant way. It lets you process streams of records as they occur." From https://kafka.apache.org/, accessed on Jan 25 2017.

motivating mechanisms to nurture the big-data ERP-BA integration. They are likely to be effective in managing discontinuous innovations in ERP/BA systems and organizations.

2.3. The Environment of the Big-data ERP-BA Integration

The strategic positioning and blueprints developed in the ERP-BA alignment model (Fig. 2) at the first layer of the SIST model are implemented in the social and intellectual environment within and across both ERP and BA organizations (Reich & Benbasat, 1996). If the big-data ERP-BA integration is treated as the ERP organization outsourcing the data analysis task and the BA organization producing the needed insights, then both the social capital integration and the intellectual capital integration among people from both the BA and ERP organizations are required (Shi, 2010). Together, they affect the inter-organizational processes and structres of knowledge transferring and sharing across the two organizations. Existing empirical studies on antecedents of knowledge transfer from ERP consultants to clients reveal that both the intellectual capital (such as absorptive capacity and shared understanding) and the social capital (such as arduous relationships) all significantly affect knowledge transfer effectiveness (Ko, Kirsch, & King, 2005). The next four sections will elaborate on how the integration of social and intellectual capital, through supporting the integration of structures, processes, and people, affects the big-data ERP-BA integration.

2.3.1. Intellectual capital integration (SIST)

Intellectual capital refers to the "knowledge and knowing capability of a social collectivity, such as an organization, intellectual community, or professional practice" (Nahapiet & Ghoshal, 1998). The intellectual capital integration between ERP and BA organizations is about the shared knowledge and partner-specific knowing capacities among people in those organizations. Since the BA generated insights are to make ERP operations more efficient, adaptive, and even cognitive, as an analogy, we may treat the ERP organization as the traditional IT function (by providing data and consuming BA insights) and the BA organization as the business function (by consuming the ERP data and generating analytic insights). With this analogy in mind, as the intellectual environment within which ERP and BA organizations collaborate with each other, shared knowledge should significantly influence their joint performance (Nelson & Cooprider, 1996; Reich & Benbasat, 2000). Second, with a high level of partner-specific knowing capacity (i.e., a high level of intellectual capital integration), both ERP and BA organizations can better study each other's demand and supply to make full use of their resources and capacities. More specifically, the demand is about the raw data demand from the BA organization/system and the analytic insights demand from the ERP organization/system and the supply is about the analytics insights produced by the BA organization/system and the raw data provision from the ERP system/organization.

2.3.2. Caveats of under- and over- integration of intellectual capital

While an under-integration of intellectual capital between ERP and BA organizations renders the ERP-BA communications less efficient or even not effective at all, an over-integration may fully occupy brainpowers of people in both ERP and BA organizations with existing technologies and associated issues. Subsequently, this over-integration may leave a limited amount of knowing capacities for people to explore disruptive innovations. Analysis of a variety of industries clearly demonstrates the risk of ignoring disruptive innovations (Tushman & Anderson, 1986). In essence, neither under- nor over- integration of the intellectual capital is appropriate for the optimal big-data ERP-BA integration.

2.3.3. Social capital integration (SIST)

Three aspects of social capital (Nahapiet & Ghoshal, 1998) across ERP and BA organizations contribute to the big-data ERP-BA integration. The structural aspect of the social capital mainly refers to the centrality of members of ERP and BA organizations, the density of their ties, and other structural characteristics. The social network structures, to a large degree, reflect inter-organizational informal and formal structures as they set up the context in which people from both ERP and BA organizations socialize and work with each other.[13] This aspect of social capital facilitates access to knowledge and knowing capacities (Nahapiet & Ghoshal, 1998). Consequently, with an appropriate social network across ERP and BA organizations, it is likely that the ERP organization could have a better understanding of all the needed raw data and analytic options from the BA organization and conversely, the BA organization could have a better understanding of the demand for contextualized analytic insights and the available raw data from the ERP system/organization.

The cognitive aspect of the social capital refers to shared languages and narratives among people in ERP and BA organizations. They are vehicles of communications and are the foundation for an innovative big-data ERP-BA integration as they support the building of communities of practices for working, learning, and innovating (Brown & Duguid, 1991). For example, as a variety of new BA methods (e.g., deep learning and machine learning) are available, it is important for people in the ERP organization to have a full understanding of those methods before efficient communications may occur. In this case, the community of learning across ERP and BA organizations could be very helpful in educating members of the ERP organization about those analytic methods and informing the BA organization about various types of available ERP data and expected analytic insights. Further, as community members are situated in the very detailed inter-organizational contexts (Brown & Duguid, 1991), successful contextualized stories spreading

[13] A study of the social network established through 1 million emails during a two-month period in the HP Lab reveals both the formal and the informal communities (Tyler, Wilkinson, & Huberman, 2003). These communities form the structures through which people in the HP lab produce various information and knowledge flows.

among the joint ERP-BA community can motivate and facilitate both organizations to forge a customized and reliable integration, likely leading to the path-dependent and customized big-data ERP-BA integration.

The relational aspect of the social capital refers to mutual trust, identification, and obligation, and the shared norms between ERP and BA organizations. The level of mutual trust represents the degree to which people of the ERP (BA) organization willingly take risky actions in accommodating the needs of people in the BA (ERP) organization with the expectation of long-term oriented benefits. With the level of mutual trust surpassing a certain minimum required level, many monitoring processes and mechanisms are not required anymore, implying a closer and more streamlined integration across ERP-BA organizational boundaries. Second, mutual identification means that people of both organizations treat themselves as a part of a bigger entity with common visions and goals, likely leading to more collaborative efforts. Moreover, mutual obligation, as a control mechanism originated from either psychological and/or business contract (Koh, Ang, & Straub, 2004), enforces collaborative efforts from both ERP and BA organizations. Lastly, as both organizations adhere to the shared norms such as openness, collaboration, etc., conflicts may be avoided and the resolution of disagreement may be expedited. In essence, the integration of the three aspects of the social capital across ERP and BA organizational boundaries triggers collaborative efforts through supporting appropriate inter-organizational structures and processes across ERP and BA organizations.

2.3.4. Caveats of under- and over- integration of social capital

While being aware of the benefits of social capital integration, managers should recognize that an over-integration of social capital for ERP and BA organizations may damage the effectiveness of the big-data ERP-BA integration (Adler & Kwon, 2002). Highly integrated social networks may produce a large amount of redundant information that may very well reduce the BA/ERP organization's cost effectiveness (Burt, 2009). Moreover, while the social capital based influence, power, and control may help with fast decision-making for firms to take advantage of nearly elusive ERP-BA integration opportunities, it may also block much needed in-depth debates, preventing firms from embracing disruptive innovations in ERP and/or BA technologies and organizations. Lastly, while dense social capital supports cohesiveness, enabling coordinated actions and facilitating exchanges of sticky tacit domain knowledge, it may also produce social closure and stifle inflow of innovative ideas from parties external to both ERP and BA organizations (Coleman, 1988). Consequently, only an appropriate (neither over- nor under-) social capital integration will positively affect the conceptualization of the strategic ERP-BA alignment at the first layer and its implementation at the third layer in the SIST model.

3. Technology integration for the big-data ERP-BA integration (SIST)

Technology integration (TI) between the big-data ERP and BA systems is the material foundation for the successful implementation of the strategic alignment conceptualized at the first layer of the SIST model. TI is advanced through both the continuous and exploitative ERP/BA technological refinements during the equilibrium period of an industry and the disruptive and explorative ERP/BA technological innovations during the revolutionary period of the industry (Gersick, 1991). We propose that there are three TI levels. For the first level of the technological integration between the big-data ERP system and the BA system, it is the No Electronic integration (TI-1). ERP and BA systems have their own databases. System maintainers/operators use disks or other manual processes to transmit the transactional and social media/IOTs data from the big-data ERP system to the BA system in a batch fashion. Data analysts process data infrequently and feed descriptive results (such as means and averages of sales) and prescriptive/predictive analytic insights (such as optimized production schedules and market trends) back to the big-data ERP system for its efficient operations.

For the second TI level, it is the Simple Electronic integration (TI-2). It is different from the first level in terms of the data sharing mechanism. The big-data ERP and the BA systems have their own databases and use web services, data streaming, or other in-memory technologies to communicate with each other electronically. The big-data ERP system feeds transactional, IOT, and social media data to the BA system in real time or in a batch fashion. Similar to the TI-1 level, the BA system produces descriptive results and prescriptive/predictive analytic insights for the big-data ERP system to make effective decisions at the business processes level. The SAP Vora, with Apache Spark as its integrated analytics engine, is a typical example of this level of technology integration. Further, cloud computing vendors, such as Amazon Web Services[14] with services such as S3 (simple storage services), EC2 (elastic computing), VPC (virtual private cloud), Kinesis analytics, AMR (Amazon map-reduce services), etc., provide all the necessary infrastructure elements for building a reliable service-oriented architecture (SOA) to integrate the operational big-data ERP and the analytics-oriented systems for their customers.

The third TI level is the Cognitive Electronic integration (TI-3). The key difference from the TI-2 level is that heavy artificial intelligence (AI) techniques (such as machine learning, deep learning, reinforcement learning, etc.) are applied in the BA system. The big-data ERP and BA systems together form an integrated intelligent system with cognitive capabilities. Good examples of this level of technology integration are such as Alibaba's heavy use of AI techniques in processing multiple petabytes of operational data on the day of 2016/2017 Double 11 Festival[15] and WellPoint's application of the IBM Watson Cognitive system to streamline its process of pre-approving treatment requests.[16]

[14] Please check https://aws.amazon.com/for details of the services from Amazon Web Services.

[15] https://www.technologyreview.com/s/602850/big-data-game-changer-alibabas-double-11-event-raises-the-bar-for-online-sales/, Accessed on September 23, 2017. https://www.chinainternetwatch.com/22791/double-11-2017/, Accessed on March 31, 2018.

[16] http://knowledgeproviders.com/uploads/media/IBMWatsonCaseStudy-WellPoint_Health_care.pdf, Accessed on January 5, 2017.

4. A maturity model of the big-data ERP-BA integration

To help managers evaluate the maturity level of of their big-data ERP-BA integration, based on the above proposed SIST model and the tradition in IS-Business strategic alignment research (Sabherwal & Chan, 2001), a maturity model (in Table 1), including defenders, analyzers, and prospectors, is developed from the perspective of an ERP organization using a BA organization's services.

Defenders focus on efficiency and exploitation and they are successful mostly in mature industries during the equilibrium period of an industry's life cycle. Dominant product designs and production processes have been very well established. The big-data ERP system is the key for smooth operations and the BA system is to provide insights to fine-tune product designs and process controls. For defenders, the big-data ERP-BA integration can be established with TI-1 (No Electronic integration) or TI-2 (Simple Electronic integration) to share both operational and big data for descriptive, prescriptive, and predictive analysis. With partnerships with suppliers, distributors, service providers, and internal loyal workers, defenders benefit from the dense integration of social and intellectual capital supporting the integration of inter-organizational structure, processes, and people for efficient communications, problem solving, and continuous improvement. For defenders, their big-data ERP positioning is mostly the driver for the big-data ERP-BA integration (i.e., scenarios 1 and 2 for the strategic alignment layer in the SIST model). Defenders are at the first maturity level of the integration and they focus on the current as their industries are deemed to be at the equilibrium period of their life cycles.

Analyzers are those companies with a balanced view of efficiency vs. effectiveness, exploitation vs. exploration, and continuity vs. disruption. They anticipate that disruptive product and process innovations may occur in the near future and these innovations may very well shake their industries out of the equilibrium state and push their industries into the revolutionary period during which dominant product/process designs are likely to collapse and multiple emerging designs may compete for new dominant positions. Analyzers understand that the big-data ERP system helps them with smooth operations and the integrated BA system help them with fine-tuning business processes for continuous improvement. At the same time, to meet challenges of disruptive innovations when the revolutionary period is coming, they also proactively embrace various emerging BA techniques such as deep learning, reinforcement learning, and other AI techniques to extract deep analytic insights and make adaptive adjustments in all areas.

For this level of maturity, TI-2 (Simple Electronic integration) level integration is preferred. For analyzers, while their ERP and BA organizations have unique intellectual capitals, an appropriate level of intellectual capital integration is needed for both organizations to smoothen communications and facilitate innovations. In addition, the social capital integration (including the structural, cognitive, and relational integration) between ERP and BA organizations should not reach the upper limit where intellectual capital development may be throttled. For analyzers, both the ERP and BA external positioning can drive organizational changes as conceptualized in the strategic alignment layer in the SIST model (i.e., a portfolio of the 4 scenarios in the SIST model may be applied). Analyzers are at the second maturity level of the big-data ERP-BA integration as they are spreading their energy and investments to both the current and the future.

Prospectors are those companies that already feel the initial heartbeats of revolutions in their respective industries. They heavily depend on a powerful BA system to provide real time in-depth data analysis. They are willing to invest into and experiment with emerging BA techniques that have the potential of transforming their industrial structures and redefining the evolutionary path of the society. Rather than just recommending adaptive adjustments of a variety of operational parameters, the BA system/organization may be required to provide the cognitive type of analysis, using artificial intelligence (AI) techniques to simulate human brain capabilities. AIEQ, announced in October 2017 as the world's first artificial intelligence (AI) based ETF (exchange-traded fund), applies the cognitive and big data processing abilities of IBM Watson to analyze a variety of information and make investment decisions.[17] The technology underlying the fund helps solve the information explosion challenge for portfolio managers, equity analysts, quantitative investors and index builders. Clearly, the company behind this ETF is a prospector.

For prospectors, the TI-3 (Cognitive Electronic integration) is required. Social and intellectual capital integration between ERP and BA organizations can be at the same level as those for analyzers. In most cases, the BA's external positioning is the driver for organizational changes and dynamics (i.e., scenarios 3 and 4 for the strategic alignment layer in the SIST model). Prospectors are at the highest maturity level of the big-data ERP-BA integration and focus on those technologies that simulate human brains.

5. Integration of the big-data ERP and BA: A portfolio perspective

Top management should be aware that the big-data ERP-BA integration could be very well un-balanced for different business functions. While a firm may be a defender with the big-data ERP-BA integration for production management, it may very well be a prospector for customer relationship management and an analyzer for supply chain management. While BA can be applied equally well to all functional ERP data for a few very innovative companies with abundant resources, for most companies, due to path dependencies, limited resources, industry-specific characteristics, and different views on the data-driven decision-making culture, the big-data ERP-BA integration is most likely a portfolio with varied maturity levels for different functions. In the following, we elaborate the portfolio perspective using a fictional company (♣) with the defender level of maturity for production management and the

[17] http://www.businesswire.com/news/home/20171018005986/en/AI-Powered-Equity-ETF-AIEQ-Launches-NYSE, and https://www.bloomberg.com/news/articles/2017-10-17/ibm-s-watson-is-key-to-new-artificial-intelligence-powered-etf, Accessed on October 30, 2017. In this case, the daily trading system, combined with social media platforms and other related operational systems, forms the big-data ERP system and the AI algorithms used are the foundation of the business analytics system. Information (related to 6000 U.S.-listed equities) such as company management documents, regulatory filings, quarterly results releases, news articles, and social media posts are analyzed.

Table 1
Maturity Model of the Big-data ERP-BA Integration.

The level of maturity	Focus	Attitudes towards the role of ERP and BA systems/organizations	Drivers for the Big-data ERP-BA integration	Technology integration	Social and intellectual capital integration
Defender	Efficiency and exploitation	The big-data ERP system is both the key for smooth operations and the driver for continuous incremental improvements. The BA system is to provide analytic insights to fine-tune product designs and process controls.	The big-data ERP positioning is mostly the driver for the big-data ERP-BA integration (i.e., scenarios 1 and 2 for the strategic alignment layer in the SIST model).	TI-1 (No Electronic integration) or TI-2 (Simple Electronic integration)	Dense social and intellectual integration. Over-integration is highly possible.
Analyzer	A balanced view of efficiency vs. effectiveness, exploitation vs. exploration, and continuity vs. disruption	The big-data ERP system helps analyzers with smooth operations and the descriptive/ prescriptive data analytics of the BA system helps them with fine-tuning business processes for continuous improvement. At the same time, to meet challenges of disruptive innovations when the revolutionary period is coming, they also proactively embrace various BA techniques such as predictive analysis and deep learning and other AI techniques to extract deep insights to make adaptive adjustments in all areas.	Both the ERP and BA external positioning can drive organizational changes as conceptualized in the strategic alignment layer in the SIST model. Analyzers are at the second maturity level of the big-data ERP-BA integration as they are spreading their energy and investments to both the current and the future. A portfolio of the 4 scenarios in the SIST model may be applied.	TI-2 (Simple Electronic integration)	The social capital integration should not reach the upper limit where intellectual capital development may be throttled.
Prospector	The exploration of technologies that simulate human brains.	Prospectors heavily depend on a powerful BA system to provide real time in-depth data analysis and are willing to invest into and experiment with new BA techniques that have the potential of transforming their industrial structures and redefining the evolutionary path of the society. Besides recommending adaptive adjustments of operational parameters, the BA system/organization may be required to apply artificial intelligence (AI) techniques to simulate human brain capabilities and provide cognitive type of analytic insights.	The BA's external positioning is the driver for most organizational changes and dynamics (i.e., scenarios 3 and 4 for the strategic alignment layer in the SIST model).	TI-3 (Cognitive Electronic integration)	Same as the integration for the analyzer

prospector level of maturity for marketing and customer relationship management.

The defender level of the big-data ERP-BA integration with production management means that the ♣ firm tends to apply various BA methods to process traditional ERP transactional data and IOTs data in order to reduce product defects through refining manufacturing processes. It is for efficiency enhancement and cost reduction through single-loop learning and the firm assumes that the equilibrium period for production management is still far from ending in its industry.

The prospector level of the big-data ERP-BA integration in the marketing and customer relationship management function implies that the company (♣) is proactive in applying all existing and newly emerging BA methods to analyze the raw data from the big-data ERP system and produce analytic insights into potential improvements in customer service, new product design, promotion, and marketing. These methods include AI techniques such as machine learning and deep learning. The raw data from the big-data ERP may include streamed product reviews (in the form of text, image, audio, and video) and customer interactions (in the format of email, phone, and on-line chatting records) through various social media platforms. The company's purpose in marketing and customer relationship management is for more flexibility and deeper exploration to prepare itself for disruptive innovations. The ♣ firm believes that the revolution in these functions is happening here and right now. Taking together the defending perspective in production management and the prospecting perspective in marketing and customer relationship management, the ♣ firm is competing on a portfolio of the big-data ERP-BA integration.

6. Sustainable competitive advantages

As competitors, product and process technologies, and markets are changing dynamically, it is inevitable that the portfolio of the big-data ERP-BA integration should evolve over time and it is likely that this evolving portfolio will help with sustaining competitive advantages. As Porter (2001) indicated, "when a company's activities fit together as a self-reinforcing system, any competitor wishing to imitate a strategy must replicate the whole system rather than copy just one or two discrete product features or ways of performing particular activities." Because the operation-focused and data-oriented big-data ERP system and the learning-focused and innovation-oriented BA system are complementary to each other, an evolving portfolio of their integration, as a self-reinforcing mechanism and a moving target, is hard to be imitated and consequently, it is likely to sustain competitive advantages.

7. Conclusion

The SAP's collaboration with Databricks not only helps with developing the Vora system to integrate both the business transactional data and the big data into a unified distributed analytics platform, but also demonstrates an increasing demand for the big-data ERP-BA integration, signifying a new era for both the evolving ERP and BA systems/organizations. The SIST model, developed in this paper, explicates this integration with three layers. These are the strategic alignment layer (focusing on the value proposition and the construction of integration blueprints), the social and intellectual capital integration layer (supporting and substantiating the integration of inter-organizational structures, processes, and people), and the technology integration layer (focusing on the implementation of the blueprints and value realization). Based on the SIST model, three maturity levels of the big-data ERP-BA integration, including defenders, analyzers, and prospectors, are proposed to help with developing an evolving portfolio for the integration. Lastly, as a moving target with path dependencies, this evolving integration portfolio is likely to sustain competitive advantages. It is our hope that this paper prepares managers for the new era of the big-data ERP-BA integration.

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