Journal of the Association for Information Systems

Volume 21
Issue 5 *Special Section: Addressing Societal Challenges Through Analytics (pp. 1115-1190)*

Article 9

9-11-2020

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Journal of the Association for Information Systems (2020) **21**(5), 1115-1127
doi: 10.17705/1jais.00631

EDITORIAL

ISSN 1536-9323

Special Issue Editorial: Addressing Societal Challenges through Analytics: An ESG ICE Framework and Research Agenda

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Abstract

There is both a need and an opportunity to develop analytics-driven approaches to address many significant challenges facing society. Toward this end, this article presents an "ESG-ICE" framework that builds on environmental, social, and governance (ESG) perspectives by considering their interactions with desirable outcomes such as individual well-being, community welfare, and economic resilience (ICE). We then provide exemplars of research problems in energy, mobility, and health that can be positioned and understood through this lens so that they can be solved through analytics. Recognizing that addressing societal challenges through analytics presents unique methodological challenges, we highlight specific opportunities that emerge for the design of (1) new cyberphysical infrastructures, (2) smart markets and decision support systems, (3) hybrid predictive, prescriptive, and causal approaches, and (4) mechanisms that facilitate data sharing.

Keywords: Analytics, Societal Challenges, Sustainability, Well-Being, Resilience, ESG, Energy, Healthcare, Mobility

1 Introduction

We are living in a world in which technology and data are rapidly transforming organizations, industries, and societies. Information systems and data analytics have, over the last two decades, contributed to unprecedented advances in economic opportunities and productivity. We have seen companies such as Apple, Amazon, Alphabet, and Microsoft each reach trillion-dollar market capitalizations in part because of this wave of innovation enabled by data and technology. While the companies in this elite group have benefited from scale and platform economies to reach such valuations, hundreds of thousands of traditional businesses worldwide, including Coca Cola, Tesco and Unilever, have found innumerable opportunities to leverage the power of data to reinvent their businesses in ways that make them unrecognizable from the way they operated two decades ago. Product development, marketing, customer service, supply chains, internal operations, financial strategies, and human resources are all being reimagined through the use of data, analytics, and technology.

We are also living in a world in which businesses are examined through the lenses of corporate social responsibility and sustainability (Ketter, 2014). Social media amplifies these lenses, throwing a spotlight on firms' prosocial behaviors that lead to online and offline implications (Lee, Oh, & Kim, 2013; Pant & Pant, 2018). Furthermore, recent events such as the COVID-19 pandemic, numerous natural disasters worldwide, and socioeconomic inequities across groups are also shedding light on new problems that have remained somewhat hidden for many years. Yet, these are all areas where data, analytics, and technology can significantly contribute, in ways similar to what has been seen in the commercial world.

In the call for papers for this special issue we therefore particularly encouraged submissions that address challenging societal and economic problems through analytics and other IT-based solutions. One of the goals of this issue was to highlight technical solutions to address social issues. In response to the call for papers, we received 24 abstracts, leading to 22 invitations for paper submissions. After a careful review process, we selected two papers for inclusion in this special issue. We would like to thank the editorial board of this special issue for generously contributing their time and expertise to provide constructive feedback to the authors.

The first paper, titled "Who Is the Next 'Wolf of Wall Street'? Detection of Financial Intermediary Misconduct" by Jens Lausen, Benjamin Clapham, Michael Siering, and Peter Gomber focuses on detecting misconduct committed by financial advisors and brokers (Lausen et al., 2020). Such misconduct can diminish consumer trust in the financial system and lead to suboptimal social outcomes. Guided by information manipulation theory and warranting theory, the authors propose and evaluate a machine learning-based misconduct detection system. One of the interesting aspects of the paper is how it combines different data sources with self-disclosed and externally verified information to achieve superior predictive performance. The paper offers utility for both investors and regulators seeking to develop better governance and a more trusting and resilient financial environment.

The second paper, titled "Leveraging the Wisdom of Crowd to Address Societal Challenges: Revisiting the Knowledge Reuse Process for Innovation through Analytics" by Yue Han, Pinar Ozturk, and Jeffrey Nickerson studies the issue of harnessing the wisdom of the crowd to develop innovative solutions to complex environmental challenges such as climate change (Han, Ozturk, P., & Nickerson, 2020). The paper conducts an empirical study using data from Climate CoLab, an online collaborative community for problem solving. The focus is on remixes of prior proposals that lead to greater knowledge reuse (i.e., generativity). The study suggests strategies for improving the harnessing of collective intelligence in online communities involving thousands of participants.

While the two accepted papers cover important societal challenges related to fraud, climate change, and innovation, we take this opportunity to propose a broader agenda for analytics research in the domain of sustainable and resilient systems.

2 Analytics for Sustainable and Resilient Systems

One framework that can be used to think about societal challenges involves three somewhat distinct perspectives: environmental, social, and governance (ESG). This three-factor ESG framework has become particularly salient in the area of sustainable investing (Widyawati, 2020). Organizations such as the CFA[1] institute provide guidance on ESG investing to finance professionals. Others, such as Morningstar,[2] provide ESG-based analytics such as carbon metrics to investors and asset managers. While sustainable investments have been a major driver for ESG popularity, the ESG framework is also an expansive and useful lens for viewing the sustainability and resilience of organizations and communities. The environmental factor of the framework focuses on the conservation and preservation of natural resources and thus addresses environmental issues such as climate change, pollution, green technologies, water accessibility, and deforestation, among others. The social factor focuses on human resources and relationships and includes issues related to human rights, diversity, social justice, privacy, gig workers, and algorithmic bias, among others. Finally, the governance factor focuses on laws, rules, and norms that underlie institutions and society and thus address governance issues such as lobbying, labor laws, CEO compensations, minimum wage, antitrust law, data protection regulations, markets, information and governance mechanisms, among others.

While the ESG framework itself suggests numerous opportunities for analytics, recognizing that societal well-being requires the well-being of people ("individual well-being"), communities ("community welfare"), and the economic system in which we all operate ("economic resilience") offers another dimension through which the opportunities for analytics can be viewed (Figure 2.1). This three-level interconnected hierarchy (ICE) provides a systematic framework to identify research opportunities and challenges for the use of analytics to address societal challenges.

Individual well-being includes both subjective and objective indicators of human welfare. While objective indicators of individual well-being rely on economic measures such as wages, employment, and wealth, subjective indicators are typically based on survey responses to well-being constructs. One of the most popular data sources on subjective well-being is the World Values Survey (Inglehart et al., 2000). Policy

[1] https://www.cfainstitute.org/en/research/esg-investing

[2] https://www.morningstar.com/products/direct/esg-data

makers and researchers, however, are increasingly realizing the need to further broaden the dimensions of individual well-being indicators. As such, multidisciplinary measurement approaches are beginning to emerge in what is commonly termed "happiness literature" (Blanchflower & Oswald, 2011). A key research interest in this domain is currently the exploration of the use of massive amounts of user-generated data available from mobile apps, social media, and the web that allow more frequent and real-time updates to individual indicators of well-being to be collected and analyzed.

While individual well-being would be expected to collectively contribute to community-level welfare indicators, the impact and effects of individual well-being within a community may involve inherently complex mechanisms. First, the definition of community in today's society should recognize community boundaries in terms of physical space as well as virtual space (public entities and corporations are also considered as communities in our definition). Individuals multiplex into multiple communities through their interactions and relations. Therefore, community welfare, while influenced by individual well-being, can in itself be a distinct indicator of the societal state. On the other hand, the nature of interactions within the community (physical or virtual) can impact perceptions of individual well-being. Therefore, individual memberships in communities, the depth and extent of participation, and the nature of relationships formed within communities interact to influence community welfare. The increasingly rich sources of data on individual participation and interactions in communities may prove beneficial in identifying and developing analytical solutions to address salient issues at the community level.

Regarding economy-level outcomes, risks to an economy arise because of the intrinsic features of a country and its vulnerability to external shocks (such as natural disasters and market failures) (Briguglio et al., 2009). Vulnerability may also arise due to policy decisions (e.g., environmental regulations) or dependence on particular intrinsic strengths (e.g., oil exports). Economic resilience is defined as the ability of a nation to cope with exogenous shocks through deliberate actions and policy mechanisms. In other words, economic resilience is achieved through the appropriate design of governance, markets, and policy tools that address intrinsic vulnerabilities.

Before we discuss the vital role that analytics opportunities can play, it is worth considering how the ESG and ICE frameworks individually relate to each other. As Figure 2.1 shows, we know that environmental, social, and governance factors impact the well-being of individuals, communities, and entire economies. For instance, a lack of clean energy options, ineffective laws, and a social fabric that is resistant to change can all directly impact the lives of individuals, communities, and the sustainability of economies. Likewise, the well-being (or lack thereof) can influence what happens with respect to ESG factors. For instance, communities struggling with the impacts of pollution may find ways to build awareness and enact policies and procedures capable of altering this state.

In Figure 2.1 we use concentric circles to represent the ICE hierarchy since we view individual well-being as a part of community well-being, which in turn is a part of broader economic resilience. Rather than viewing the ESG components as orthogonal, we depict them here as overlapping to bring out the fact that, in practical use cases involving this framework, it is often common to think of these elements as combinations.

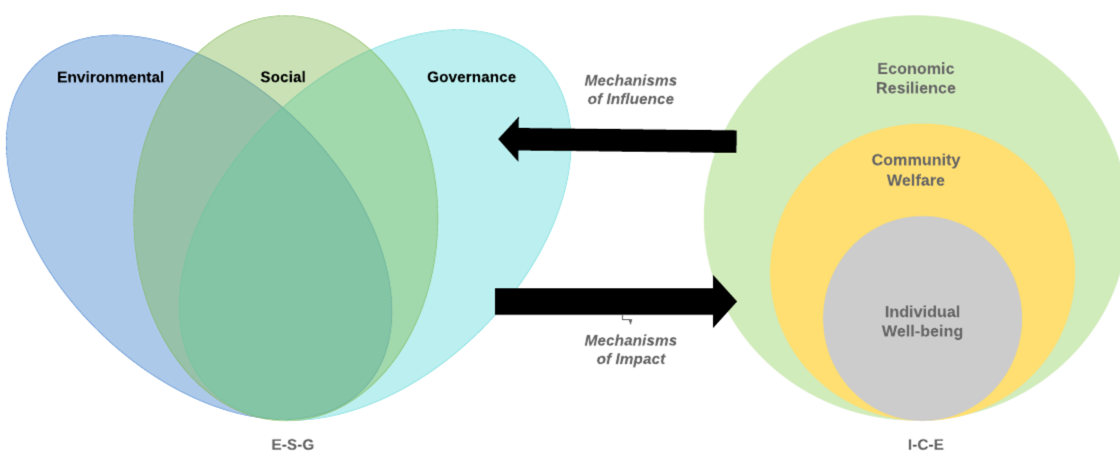

Figure 2.1. The ESG-ICE Framework

Table 2.1. Identification of Analytics Opportunities

	Individual well-being	Community welfare	Economic resilience
Environmental / **Social** / **Governance**	*How can analytics help improve the understanding of how environmental, social, and governance issues influence the well-being of individuals?*	*How can analytics help improve the understanding of how environmental, social and governance issues influence community welfare?*	*How can analytics help address intrinsic vulnerabilities in environmental, social, and governance issues to increase economic resilience?*

For instance, one may consider policies concerning social justice (SG) or the societal adoption of clean energy (ES) as use cases in order to develop solutions. Rather than depicting these elements as an overlapping Venn diagram, we use a similar representation that highlights the human and social perspectives that will likely be a component of any combination considered.

As outlined in Table 2.1, analytics can certainly help address some of the biggest challenges facing society at the individual, community, and economy levels. The emerging digital society enables expansive, near real-time data collection across these levels. Whereas data collection capabilities are rapidly improving, analytic tools and decisional support tools (predictive and prescriptive) are still in nascent stages of development. The IS community must rise to this challenge to develop novel solutions and insights through the innovative use of the vast troves of data that private and public entities are beginning to collect.

Analytics can improve the measurement of ESG factors, tease out their role in multidimensional societal welfare (ICE), and help in designing new systems that optimize across the ESG-ICE framework. Motivated by this, below we present specific examples in Tables 2.2 through 2.4. The purpose of these examples is to primarily illustrate the variety of questions that analytics can help answer in three application areas: energy, mobility, and health. These three application areas affect societal outcomes at all three levels. Moreover, these three areas also have witnessed a recent surge in data gathering abilities. As such, they serve as exemplars of how the ESG-ICE framework can drive critical questions that can be addressed through analytics research. While the examples are self-explanatory, we highlight a few examples across each domain below to specifically point out new analytics opportunities.

Table 2.2 presents examples of analytics opportunities in the E-ICE dimensions that focus on environmental issues. In the area of energy, for instance, understanding how individuals adopt different sustainable sources of energy is important (Steg, Perlaviciute, & van der Werff, 2015). There are opportunities to do this by bringing together data on the actual energy consumption patterns of individuals, their exposure to awareness messages and pricing campaigns, and the behavior of their social network. These data sources can be leveraged to understand the drivers of user decisions to adopt sustainable sources of energy, given their availability. This understanding, along with an understanding of the role that individual heterogeneity and covariates play, can assist in the design of effective policies to improve environmental outcomes.

Table 2.3 presents examples of analytics opportunities in the S-ICE dimensions that focus on the social angle. In the mobility infrastructure domain for example, determining the economic impact of an equitable mobility/transportation infrastructure is important as societies grapple with justifying the potentially high costs of smart mobility infrastructure. In particular, designing a mobility infrastructure that is *equitable* can provide all individuals in the population with transportation opportunities that can directly impact the level of economic opportunities available to them. Understanding exactly how this might impact the economy can help policy makers justify the investments necessary to create such equitable systems. Data and forward-looking simulations can provide some answers by bringing together information about where individuals live and where economic opportunities exist, and combining these data with simulations can assist in the evaluation of different scenarios. Such simulations are also exceedingly helpful for evaluating the impacts of public health measures during pandemics (Arora, Raghu, & Vinze, 2010).

Furthermore, analytics research can enhance policy solutions for determining "true-cost pricing" in the mobility sector (see Table 2.3 under Mobility and Community Welfare). IS scholars could work on developing an argument for why and how mobility prices can best solve mobility-related problems that are caused by external effects (parking pressure, congestion, emissions). With mobility pricing, policy makers can provide a framework that encourages sustainable urban transport solutions and evidence-based transport policies, ultimately providing greater equity across demographics and regions.

Table 2.2. Environmental Examples

Domains	**Individual well-being**	**Community welfare**	**Economic resilience**
Energy	*Bringing together disparate sources of data to examine conditions that influence individual decisions to adopt sustainable energy solutions*	*Identifying and measuring community impacts of new technologies deemed environmentally beneficial (e.g. e-scooters)*	*Explaining mechanisms that drive carbon tax / renewable energy policies to impact energy production diversity*
Mobility	*Modeling the effects of inefficient urban (e.g., congestion) mobility on individuals' choice patterns, life satisfaction and health*	*Assessing efficiencies in allocation of urban spaces (e.g., residential area, parks, roads) with geographic information systems*	*Optimizing energy mix and consumption in (commercial, private, and public) transportation systems*
Health	*Predicting individual health impacts of pollution*	*Assessing impact of urban spaces on healthy behaviors among community members*	*Using real-time economic indicators to assess and mitigate the adverse economic impacts of quarantines during a pandemic*

Table 2.3. Social Examples

Domains	**Individual well-being**	**Community welfare**	**Economic resilience**
Energy	*Understanding how peer influence in social networks affects individual decisions to adopt sustainable energy mechanisms*	*Determining fairness of energy infrastructure across areas with socioeconomic disparity.*	*Estimating variance in energy consumption due to shifts and trends in urbanization across the country*
Mobility	*Designing smart-city transportation infrastructures that offer equitable opportunities for individuals from different backgrounds and groups*	*Designing sustainable mobility mechanisms to enable the implementation of "true-cost pricing" (i.e., internalize external effects such as congestion and emissions).*	*Examining the association between equitable mobility in urban areas and income mobility of residents*
Health	*Detecting and removing algorithmic bias in health management*	*Applying network analytics to monitor pandemic spreads*	*Uncovering fraud in real-time markets and procurement systems (e.g., mask procurement during COVID)*

Table 2.4 presents examples of analytics opportunities in the G-ICE dimensions that focus on the governance angle. An example of this in the area of health, for instance, is the examination of how price transparency and recommender systems can affect overall healthcare costs through modifications to prescribing behavior (Bouayad, Padmanabhan, & Chari, in press). Based on findings from analytics-driven research, it may be possible to enact policies that can then move the needle in a significant manner. In this case, requiring real-time price transparency within electronic health record systems and in hospitals would be a policy directive emanating from such findings.

As highlighted above, the ESG-ICE framework presents numerous opportunities to ask specific high-impact questions that analytics can help address. Although we presented a few examples from the tables in the discussion above, we note that these were mainly used for motivation. We hope that the ESG-ICE framework will encourage readers to both generate new questions using this framework and specifically explore the role of analytics in those cases.

Table 2.4. Governance Examples

Domains	Individual well-being	Community welfare	Economic resilience
Energy	*Determining the impact of energy policies on individual decisions to adopt different sources of energy*	*Applying smart contracts and blockchain for distributed control in transactive systems*	*Understanding the impact of energy availability and pricing on economic opportunities and growth*
Mobility	*Assessing user acceptance of self-driving public transportation systems*	*Designing communication and coordination protocols among autonomous vehicles to create safe, smooth, and conflict-free systems*	*Design of efficient real-time markets to allocate scarce resources such as road space during heavily congested times*
Health	*Understanding how mandated information sharing in health exchanges improves individual health outcomes*	*Studying how price-transparency rules reduce healthcare costs for society as a whole.*	*Designing new telehealth markets matching individuals and providers in a manner that optimizes access, outcomes, and costs*

Certainly, the use of analytics in many of these examples is not straightforward and may require innovations that are more fundamental. These are indeed great opportunities for contributing to important societal challenges methodologically as well as practically. The next section takes this perspective and outlines a few major research challenges in the use of analytics to address some of the societal challenges described here.

3 Research Challenges

The growing cyberphysical infrastructure and adoption of smart markets produce and make available large-scale data related to the environment, society, government, and their interactions. This has unleashed methodological and design opportunities as well as challenges in analytics. Hence, we begin our discussion on research challenges by considering the role of cyberphysical infrastructure and smart markets before delving into broader methodological and data integration issues.

3.1 Design of New Cyberphysical Infrastructures

Cyberphysical infrastructures merge the physical space with computing networks to bring more visibility, control, and interoperability among devices, systems, and humans. Major critical infrastructures such as power grids, aviation, railroads, and water systems have embedded cyberphysical systems capabilities to varying degrees. The growing scale, diversity of devices and networks, and the massive amounts of data they can generate pose both challenges and new research opportunities (Ransbotham et al., 2016). The devices used in cyberphysical systems include internet-of-things (IoT) devices (effectively, any appliance or device that can connect to a network), transducers, actuators, sensors, and industrial control systems. As systems mature, analytics capabilities might range from algorithms being embedded in the device itself to complete cloud management.

The potential environmental benefits of cyberphysical systems at the community and individual levels are enormous. As mentioned in Table 2.2, estimating urban mobility or the effects of pollution on individual well-being could greatly benefit from data generated, for example, from public transportation records, traffic camera systems, and air quality sensors. Impacts of energy source diversity and consumption patterns (Table 2.3) could be better measured through real-time data feeds from smart meters at endpoints and monitoring sensors at generation and distribution facilities. Temperature and air quality sensors, motion detectors, and a variety of other sensor devices could help make buildings and facilities highly energy efficient. Many local, state, and national governments offer tax incentives to commercial and residential property owners to reduce energy consumption costs. To effectively tune these devices for optimal consumption, algorithmic developments currently represent an area of high research activity (Ketter et al., 2018). While it is easier to assume that organizations will be the primary consumers of analytic techniques for energy efficiency, individuals may also have the opportunity to adopt such measures. For instance, consumer device manufacturers could install algorithmically driven control systems in residential homes. This would be much similar to the robot advisers used for retail financial investments. While the use of health monitoring devices is also rapidly growing, there are enormous benefits to sharing anonymized sensor data from health monitoring devices to monitor individual and community health status and to develop new scientific evidence on healthy behaviors (Table 2.2).

At the policy level, governments need to balance the security risks against the benefits of cyberphysical infrastructures. More pertinently for IS researchers, the area of cyberphysical systems invokes a number of important research questions related to privacy and security issues. IS researchers could contribute to the development of intelligent systems for modeling threats, discovery of vulnerabilities, and development of mitigation mechanisms. Darknet research in information systems (Benjamin, Valacich, & Chen, 2019) has begun to examine these issues only recently. The paradigm change in the era of IoT, cloud, and edge devices calls for new models and analyses of security measures since where and how data are stored, accessed, and analyzed is highly contextual and open to design choices. Eventually, as IoT devices are used to make real-time decisions (e.g., self-driving cars), policy and governance frameworks for legal recourse related to algorithm malfunction, vulnerabilities, and service level guarantees will need to be created.

IS research has seldom focused on the implications of where analytics systems are implemented. In cyberphysical systems, decisions on where analytics systems are implemented can have major implications for privacy, security, policies, and efficiencies. For instance, facial recognition systems adoption and implementation in public places have major societal ramifications. Trust in facial recognition and similar biometric systems depend on whether and how data are stored, shared, and utilized. To build trust and to provide more control to individuals regarding data use, technical solutions as well as policy and regulatory frameworks are needed. The European Union's General Data Protection Regulation (GDPR) is one prominent example of major shifts that are occurring in society in response to data ubiquity.

Within the norms of established privacy and security mechanisms, sharing anonymized data from cyberphysical systems can greatly improve the ability of IS researchers to build new analytic methods and study how individuals and communities interact in cyber- and physical spaces. Creating innovative data-sharing norms for cyberphysical infrastructures can release enormous amounts of data for research use. Already, many countries make environment-related data publicly available. Sources of power generation and consumption are also often available to researchers. Many organizations have released vast amounts of data related to telecommunications, energy, weather, transportation, social networks, and events.[3] If more such anonymized data from IoT devices and cyberphysical systems were released for research purposes, it would open up exciting new avenues of research for IS scholars.

3.2 Smart Markets and Decision-Support Systems

An important element of a smart energy, mobility, or healthcare ecosystem is the efficient matching of resources with demand toward a certain objective. Real-time matching of tasks and offers is complex and requires high-performance automated mechanisms (Collins, Ketter, , & Gini, 2009, 2010). The study of matching and coordination with the intent of allocating scarce resources is a cross-disciplinary field that has been investigated in computer science, information systems, organization theory, operations research, economics, linguistics, and psychology (Malone & Crowston, 1994). In most cases, an efficient allocation is desired by individuals who value a resource the most and thus wish to acquire this specific resource. We distinguish between centralized and decentralized coordination approaches. At the two extremes are central coordination and cooperative control. Market- or auction-based mechanisms are typically seen as hybrids, as they incorporate central elements (e.g., auctioneer and systems operator) combined with decentralized elements (individuals submitting asks and bids based on their preferences).

IS scholars have developed a rich portfolio of deep contributions in this field. Auctions and other smart market-based coordination approaches (Bichler et al., 2010) have been investigated in depth both from a mathematical and a behavioral point of view in application domains such as server capacity allocation (Bapna, Goes, & Gupta, 2005), iterative combinatorial auctions (Adomavicius & Gupta, 2005), as well as auctions specialized in electric mobility allocation and charging (Abdelwahed et al., forthcoming; Kahlen, Ketter, & van Dalen, 2018; Valogianni et al., 2020), or shared mobility (Yu, Lam, & Lu, 2018). However, when designing smart market mechanisms (Bichler, Gupta, & Ketter, 2010), e.g., for a smart mobility ecosystem, where vehicles are connected, autonomous, shared, and electric, one can appreciate that the complexity increases. These problems have many dimensions that pose constraints and influence stakeholder objectives differently, making their management in a smart ecosystem far from trivial. Because of the complexities of the required coordination in a system with many agents, analytical solutions may often not be feasible. Testing and benchmarking different design concepts in large-scale

[3] See examples here—http://theodi.fbk.eu/openbigdata/; https://en.wikipedia.org/wiki/Open_energy_system_databases

(agent-based) simulations may be fruitful to achieve a consensus on the preferred mechanism design. Multi-agent transport simulation (MATsim) (Axhausen & ETH Zürich, 2016), focusing on smart transportation, and power trading agent competition[4] (Power TAC) (Ketter, Collins, & Reddy, 2013, Ketter et al., 2016b) focusing on sustainable smart energy markets are examples of platforms that could be leveraged for tackling wicked problems using the competitive benchmarking of design approaches to address societal challenges (Ketter et al., 2016a). Building on this body of knowledge, IS scholars are uniquely positioned to push and lead, in an iterative fashion, the design of efficient matching instruments and mechanisms. The IS community has expertise both in terms of the tools required to address these challenges effectively and the understanding of the complexity posed by interdependencies between physical and digital layers in dynamic environments.

Consider, for instance, a mobility example (economic resilience in Table 2.4). In order to operationalize an IS-enabled digital mobility platform ecosystem as we envision it, various additional questions require scientific exploration. What seems to be missing from the current literature is a consideration of multiple resource requirements for mobility task fulfillment. To complete a mobility task, if negative externalities such as congestion are to be avoided, not only must a distributed mobile resource be allocated but also the required infrastructure. IS scholars should work on developing novel platform ecosystem models that improve upon existing coordination mechanisms in mobility platforms such as Uber, Lyft, or moovel. Thus far, it is unclear which level(s) of centralization should be employed for effective coordination of the different resources and infrastructures. The lack of clarity prompts another research challenge related to the scope of the platform ecosystem. Whether single- or multiple-coordination mechanisms (i.e., single- or multiple-platform ecosystems) should be employed to facilitate the resource and infrastructure allocation in multiple locations for mobility task fulfillment remains to be explored. Is a single all-encompassing mobility platform ecosystem preferred or should multiple interlinking platforms focusing on different task sectors, resources, or geographies coexist? If multiple mechanisms and platforms are favored, how would the interaction of mechanisms be facilitated? The scope for IS smart mechanism design research is abundant.

In a real-time data-driven world in which a large volume of operational decisions must be made, decision support tools such as recommender agents become necessary enablers of demand response (Adomavicius, Gupta, & Zhdanov, 2009). An additional promising avenue of applying analytics to mobility is individual decision support (individual well-being in Table 2.2). While not deeply researched in mobility, demand response is a common notion in the domain of electricity systems, where it has received considerable attention in IS research (Gottwalt et al., 2011; Peters et al., 2013; Watson, Boudreau, & Chen, 2010). For example, Valogianni and Ketter (2016) propose a decision support system for consumers combined with a central demand response module that develops effective pricing strategies for different user groups. In the mobility domain, Cramton, Geddes, and Ockenfels (2018) propose a DSS aimed at enabling user response to real-time road prices based on current and forecasting market regimes (Ketter et al., 2009, 2012). Dynamic and precise forecasts in the energy and mobility area are of utmost importance in the future landscape to react to changing market regimes accordingly. The methodology behind these approaches provides a basis for further IS research.

3.3 Causal, Predictive, and Prescriptive Approaches

Many of the research problems listed in the tables in Section 2 can be seen methodologically as causal, predictive, prescriptive, or some combination of these. For example, a causal problem such as "understanding how peer influence in social networks affects individual decisions to adopt sustainable energy mechanisms," would require an identification strategy capable of teasing out the average treatment effect from many different confounders. A predictive problem such as, "predicting individual health impacts of pollution" would potentially require a machine learning model that can integrate various data sources and leverage hundreds of variables to accurately predict the individual-level outcome. The prescriptive problem of "designing new telehealth markets matching individuals and providers in a manner that optimizes access, outcomes, and costs," would involve searching for optimal solutions with multiple objectives and constraints.

These three types of problems bring with them specific challenges and policy implications. Often, researchers seeped into one of these methodologies (i.e., causal, predictive, or prescriptive) do not fully recognize the challenges and implications of other methodologies (Kleinberg et al., 2015). However, in recent years, a growing body of work is combining these methodologies to take advantage of their complementarities. A straightforward combination of causal and predictive analytics is a two-stage model (Ghose, Ipeirotis, & Li., 2012). In the first stage, a predictive model is used to measure a variable such as sentiment in online reviews of e-scooters. A second stage econometric model is used to tease out the causal

[4] http://www.powertac.org

effect of the measured variable on an outcome of interest, such as sales of e-scooters. Motivated by the increasing use of such two-stage models, a body of work is now considering ways to correct the measurement errors that are inherent in the output of a predictive model to create better estimates in the second stage (Yang et al., 2018; Qiao & Huang, in press).

As the scale of data available for research (such as through cyber-physical infrastructure) has dramatically increased, researchers are now identifying the potential for leveraging machine learning methods (typically utilized in predictive problems) in identifying heterogeneous treatment effects (HTEs). These HTEs allow for more nuanced policy implications for various subgroups of the population. For example, it could be helpful to identify which subgroups of people (without an a priori grouping) are most susceptible to peer influence in adopting sustainable energy solutions. A prime example of this type of hybrid methodology is causal trees that use a popular CART algorithm from predictive modeling to identify subgroups of the population with different treatment effects (Athey & Imbens, 2016). Limitations of traditional predictive analytics are also leading researchers to seek casual frameworks for machine learning (Pearl, 2019). Furthermore, as data sources vary in quality and biases, there is also an effort to combine causal information from such disparate sources using a nonparametric approach (Bareinboim & Pearl, 2016).

While the use of techniques from prescriptive analytics (i.e., optimization) is widespread in predictive analytics (i.e., machine learning), there is also an increasing body of work that utilizes machine learning for optimization (Bengio, Lodi, & Prouvost, in press). These and other efforts to combine traditionally distinct methodologies of causal, predictive, and prescriptive analytics are creating opportunities for new insights and designs driven by data.

3.4 Data-Integration, Sharing, Quality, and Security Issues

Consider the example of using analytics to measure and monitor the spreading of a pandemic (a community-level example in Table 2.3). The data that are necessary to do this well are fragmented. Physician offices or clinics where individuals with symptoms are seen have detailed information about patients and their symptoms. In cases in which individuals test “positive,” some of this information is reported to state-level databases. Wireless providers and platform owners such as Verizon, Google, and Apple have information about user mobility and proximity to other users. Hospitals have information on those admitted, and often these represent the more serious cases rather than early infections. Information about contact networks—those individuals with whom infected individuals regularly communicate—is stored in different places, often in nonstandard formats.

Integrating all of these data into a system that monitors pandemics has several challenges. First, how can these different entities share information that is useful enough (i.e., often at the individual level) while ensuring adequate privacy protections? Second, what incentives or policy initiatives would enable such information sharing? Third, what mechanisms could help to ensure that the quality of the shared data is consistent across the entities?

Some of these issues can be addressed using new protocols for data sharing. In the context of the COVID-19 pandemic, Moorthy et al. (2020) describe how a rapid protocol for labeling research articles ensured that research articles related to COVID-19 would be instantly available and open to the community—an effort that facilitates the rapid discovery and dissemination of important scientific insights. There are also efforts at developing federated data architectures capable of enabling privacy-preserving data sharing. Lu et al. (2020) present a blockchain-based federated data solution to the problem of building better systems in an IoT world, where distributed parties can share data with applications in a manner that protects privacy and prevents data leakage. Also, moving beyond the traditional public-private partnership model, there are now efforts at developing “data collaboratives” that can bring together even purely private companies into a data-sharing initiative for the public good.[5] As we, as a community, imagine and design forward-looking analytics-driven solutions for addressing societal challenges, we must make sure this is done in a secure manner. Rather than viewing security as an afterthought, designing these systems for secure use will be critical and will also represent significant research opportunities.

These are still early days yet, and we envision many opportunities for IS researchers to develop new mechanisms that can enable important data sharing between entities for social good, while addressing quality, privacy, and security issues.

4 Conclusions

The last two decades have seen analytics go mainstream across a range of industries. IS researchers have played an important role in facilitating this by developing a wide range of models and methodologies,

[5] https://datacollaboratives.org/

and presenting many innovative possibilities for how data and analytics might provide insights. While businesses and problems they face will continue to offer researchers new opportunities for research ideas, there is an equally powerful portfolio of opportunities for analytics to address the critical challenges facing society today. In this article and in this special issue we have presented some ideas that can help our research community navigate this space.

In particular, the ESG-ICE framework presented here offers a novel perspective that can be used to identify powerful research ideas. While the framework is domain independent, bringing specific domains (e.g., health, energy) into the process of inquiry can help identify specific research questions in important areas. This article presents several examples of these in the context of three current important application domains today: energy, mobility infrastructure, and health.

However, important challenges remain—all of which represent potentially high-impact research opportunities for IS researchers. In particular, (1) the design of new cyberphysical infrastructures, (2) smart markets and decision support systems, (3) new predictive, prescriptive, and causal approaches, and (4) mechanisms that facilitate data sharing. These areas offer tremendous opportunities for the IS community to make important contributions that can ensure that analytics is as much a success in the context of societal problems as it has been for the business community.

Acknowledgments

We thank the many AEs and reviewers who assisted in the review process for this special issue.

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