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Journal of Information Systems Applied Research

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Enterprise Architecture Transformation Process from a Federal Government Perspective

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ABSTRACT

The need for information technology organizations to transform enterprise architecture is driven by federal government mandates and information technology budget constraints. This qualitative case study aimed to identify factors that hinder federal government agencies from driving enterprise architecture transformation processes from a compliancy to a flexible process. Common themes in interviewee responses were identified, coded, and summarized. Critical recommendations for future best practices, including further research, were also presented.

Keywords: enterprise architecture (E.A.), qualitative study, the federal government, E.A. frameworks

1. INTRODUCTION

Federal government agencies use enterprise architecture (E.A.) to enable I.T. planning and I.T. decision-making. E.A. also guides federal government agencies on reducing wasteful I.T. spending, increasing shared I.T. services, closing performance gaps, and promoting engagement among government, industry, and citizens (Common Approach to Federal Enterprise Architecture, 2012). Federal government agencies need E.A. guidelines that leverage other federal, state, local, tribal, and international experiences and have to conform to technology-related policies and guidelines from the Office of Management, Budget, and Federal Enterprise Architecture before making any E.A. decisions (Common Approach to Federal Enterprise Architecture, 2012). In federal government agencies, E.A. plays a vital role and is a challenging task for enterprise architects, senior leadership, I.T. professionals, and the domain teams tasked with ensuring that the E.A. transformation process aligns with the I.T. business goals and objectives. Further, E.A. methodology debates have been targets for E.A. practitioners to argue over; rather than focusing upon their key stakeholders' needs, many have become enamored with completing a transformation process (Gotze, 2011).

There has been limited research on addressing how government agencies are using E.A. concepts to make I.T. decisions, explore the obstacles that interface with the E.A. transformation process and make the transformation process meaningful and measurable.

This study examined how federal government agencies transform from a compliance process to a practical implementation approach. The national government enterprise guides using E.A. to help federal government agencies to eliminate information technology duplication, increase shared services, and close

performance gaps (Common Approach to Federal Enterprise Architecture, 2012). The four researched questions are as follows: RQ1: What are the perceived obstacles that I.T. organizations encounter with driving the E.A. transformation process from a compliancy process to a more practical implementation process
RQ2: What are the perceived obstacles (i.e., mindsets, challenges, compliancy guidelines) I.T. organizations experience in executing an E.A. practical framework? RQ3: How can I.T. organizations make the transformation process meaningful and measurable? And RQ4: How is E.A. perceived to address the challenges on how to educate the mindsets of the stakeholders within the organization?

2. ENTERPRISE ARCHITECTURE & FRAMEWORKS PERSPECTIVE

E.A. is a discipline described as aspiring to improve enterprise coherence; however, E.A. is still an evolving discipline that is still relatively immature. The Chief Information Officer Council (2001) defined enterprise architecture as a strategic information asset, which describes the mission and I.T. best practices necessary to perform the mission. Additionally, the Chief Information Officer Council (2001) stated the transformation processes for implementing new technologies in response to the changing mission needs. Thus, organizations are confused about the meaning, purpose, scope, and role of the overall E.A. architecture function. Further, current literature on E.A. is not clear on whether the author refers to the knowledge base, the process and practice, or the stakeholders (Bean, 2011). Research has illustrated that 70 percent of senior management found it necessary and desirable to practice E.A. across the organization (Nassiff, 2012). Nassiff indicated through his research that there was a lack of comprehension of the meaning of E.A. in terms of its scope across the enterprise.
Conversely, E.A. provides a blueprint for the information technology organization's existing I.T. infrastructure, which consists of the as-is state and the vision of practical and modernized infrastructure and the to-be state (Perera, 2010). Furthermore, Spewak (1993) noted that E.A. promotes the organization's needs for an incorporated I.T. strategy, permitting the possible neighboring synergy across the extended enterprise (Spewak, 1993). Rabaey (2014) indicated that enterprise architecture is described as being the link between strategy and execution. E.A. provides the means for addressing the many facets of the enterprise's holistic approach to executing the overall strategy coherently in an efficient way.

A framework in enterprise architecture is described as the fundamental structuring mechanism that defines and separates concerns that may lead to a logical sequence of discovery and discourse on E.A. concepts. The most common frameworks the federal government uses are the Zachman framework, Federal Enterprise Architecture Framework (FEAF), and the United States
Department of Defense Architecture Framework (DoDAF). The Open Group Architecture Framework (TOGAF) and Enterprise Planning (EAP) are more methodology focused frameworks (Newman, 2014). The three structures that will be briefly addressed from a high-level approach are the Zachman framework, the United States Department of Defense Architecture Framework, and the United States Department of Defense Architecture Framework. Strategic planning plays a vital role in the synergy of an enterprise architecture framework. It is a reasonable step one; a strategic plan is also an essential best practice in the enterprise architecture frameworks process.

3. ENTERPRISE ARCHITECT'S ROLE IN THE ENTERPRISE ARCHITECTURE TRANSFORMATION PROCESS

An enterprise architect is a person who provides effective communication to the stakeholders about the enterprise architecture initiatives and forms active teams that develop and implement enterprise architecture content (Nakakawa et al., 2010). Enterprise architects, along with other stakeholders, are accountable for implementing the E.A. initiatives (Asfaw et al., 2009). Enterprise architects experience difficulty understanding and communicating with other stakeholders (senior leadership, I.T. professionals, and domain teams).

4. STRATEGIC ALIGNMENT MODEL PERSPECTIVE.

The strategic alignment model (SAM) is used to provide and conceptualize a visual of an organization's I.T. environment and business goals (Ullah & Lai, 2011). The strategic alignment model of Henderson and Venkatraman (1994) considers information technology (I.T.) alignment as occurring amongst the business strategy and business process, focusing on internal and external areas for both I.S. strategy and I.S. infrastructure and governance. Further, SAM can illustrate views across the domain and suggest that neither strategic nor functional integration provides the alignment of an organization's business objectives effectively (Henderson & Venkatraman, 1994).

5. METHODOLOGY

An exploratory case study design was used to allow the researcher to explore and identify the factors that hinder federal government agencies from driving the E.A. transformation process. The federal government encompasses over 300 organizational entities of differing size, scope, and complexity, including departments, administrations, bureaus, commissions, agencies, and boards (The Common Approach to Federal Enterprise Architecture, 2012). Additionally, the organizational entities employ approximately 2.6 million people (The Common Approach to Federal Enterprise Architecture, 2012). The participant recruitment focused on a population of senior managers, I.T. professionals, and enterprise architecture professionals within the LinkedIn community.

The point of data saturation was reached at 11 participants. The participants were full-time employees with at least two years or more experience. Triangulation of the data provided a means to ensure the validity and reliability of confirming the findings captured within the case study in a sound manner (Miles et al., 2014). Further, the triangulation of sources was used to examine the consistency of the different patterns and views of the findings retrieved from the interviews. Interviews were used to explain how agencies are dealing with the barriers of transforming E.A. from a compliance process to a practical implementation approach. Further, interviews were conducted via Skype or telephone. The participants were asked to answer questions that focused on the perceived obstacles that Information Technology organizations encounter with driving the E.A. transformation process from an E.A. compliance process, the obstacles Information Technology organizations experience in executing an E.A. practical framework, and how E.A. is perceived to address the challenges of how to educate the mindsets of the stakeholders within the organization.

The coding process was used to analyze and retrieve meaningful data (Miles, Huberman, & Saldana, 2014). The interview responses were analyzed using Microsoft Excel software to code the data collected from the interviews. The interview questions were evaluated by a panel of three I.T. professionals (known as field testers) that have experience with the E.A. transformation process. The three field testers that participated in the field test study knew E.A. and worked in E.A. and I.T. organizations.

The feedback received from the field test study provided recommendations on clarifying who the stakeholders were that are part of the E.A. process and provided suggestions on updating the interview questions, so the questions were more focused.

6. RESULTS

Demographic information collected from each participant included the participant's role, job title, years of experience, and geographic region. The years of experience of the participants ranged from 5 to 20+ years. The majority of the participants were located in the Washington DC geographical area. Two of the participants indicated they had performed in both the enterprise architect and management roles. The majority of participants, eight altogether (P1, P2, P3, P4, P5 P6, P8, & P9), indicated that they worked as I.T. specialists or I.T. managers.

Themes from the Analysis of Interview Data and Research Questions, RQ1

This question included topics relating to obstacles that affect the E.A. transformation process. Participants were asked four interview questions. The analysis revealed three main themes relating to the challenges that emerged in response to RQ1.

RQ1.Theme1: Definition of Requirements and Communications Objectives

Four of the 11 participants (P1, P2, P9, & P10) noted that understanding the requirements and having unclear requirements were obstacles. Six of the 11 participants (P1, P4, P7, P8, P9, & P11) believed that a communication process among users and stakeholders aids the E.A. transformation process.

RQ1. Theme 2: Gaining Buy-In

Five participants (P2, P4, P7, P9, & P11) had strong views about obtaining buy-in from management because users and stakeholders were obstacles that hindered the E.A. transformation process. P2 explained that it is essential to get user buy-in before the E.A. transformation process is implemented.

RQ1. Theme 3: Resistance to Change.
Three of the 11 participants (P4, P5, & P6) expressed views about why resistance to change impedes the E.A. transformation process. P4 stated that one of the main obstacles is "people's resistance to the change.

RQ2
This question included topics relating to obstacles**.** RQ2 revealed three main themes relating to the perceived barriers: (a) Planning the execution, (b) compliance guidelines, and (c) I.T. security challenges.

RQ2. Theme 1: Planning the Execution
Five of the 11 participants (P1, P2, P5, P10, & P11) believed planning plays a crucial role in executing an E.A. practical framework.

RQ2. Theme 2: Compliancy Guidelines
Three of the 11 participants (P3, P7, & P11) provided insight into the Office of Management and Budget (OMB) guidelines that I.T. organizations apply when implementing an E.A. framework.

RQ2. Theme 3: I.T. Security Challenges
Several common themes emerged among three of the 11 participants (P1, P8, & P11) concerning I.T. security challenges that I.T. organizations face when executing an E.A. practical framework.

RQ3
This question involved topics related to making the transformation process meaningful and measurable. Participants were asked four interview questions. The analysis revealed three main themes relating to making the transformation process significant and quantifiable.

RQ3. Theme 1: Focusing on the Target State
Two of the 11 participants (P7 & P11) provided helpful comments about making the E.A. transformation process meaningful and measurable. P7 stated that E.A. should be approached "from an end-to-end view of your operating environment." P11 suggested that I.T. organizations need to "keep the big picture" in mind when aligning the target state. The two participants both stated that the target state should be defined clearly. Further, the participants suggested the biggest challenge is prioritizing the target state of the E.A. transformation process.

RQ3. Theme 2: Budget and Cost-Benefit Analyses
Three of the 11 participants (P6, P8 & P10) provided views on how to budget, and cost-benefit analysis approaches should be considered when attempting to make the E.A. transformation process meaningful and measurable.

RQ3. Theme 3: Incorporating a Plan
Four participants (P4, P6, P8, & P11) provided sound suggestions as to why incorporating a plan is essential for making the E.A.'s process is meaningful and measurable.

RQ4
This question included topics related to addressing challenges concerning how to educate the stakeholders' mindsets within the organization. Participants were asked four interview questions. The analysis revealed three main themes for addressing the challenges shown in response to RQ4: (a) Face-to-face (F2F) meeting with stakeholders, (b) training the stakeholders, and (c) inviting stakeholders early in the process.

RQ4. Theme 1: F2F Meeting with Stakeholders
Four of the 11 participants (P1, P4, P5, & P9) expressed that formal communication approaches, such as F2F meetings and discussions, are ways to address the challenges within an I.T. organization.

RQ4. Theme 2: Training the Stakeholders
Training the organization's stakeholders was a common theme was among three (P2, P9, & P11) of the 11 participants. P2 explained that "various methods of training" that entailed "formal and informal classes, hands-on training, instructor-led training sessions, and online, self-service portals" about E.A. initiatives would serve to provide insight into and for users and stakeholders. P9 stated, "Mindset change starts with providing upfront training" at the beginning of a new process. P11 likewise suggested that the first task is to create awareness to provide training and show videos about the E.A. transformation process.

RQ4. Theme 3: Invite the Stakeholders Early

Inviting stakeholders early in the process was a unique theme communicated by two of the 11 participants (P5 & P6).

7. EVALUATION OF FINDINGS

Three findings related to the themes identified in response to RQ1 have empirical support in the literature reviewed.

Finding 1
The importance of balancing E.A. transformation process requirements within different levels within the organization and maintaining continuous communication with and among users and leadership was confirmed. Madison (2010) suggested that communication best practices are achieved best when the E.A. practice is centralized and the E.A. process formalized. The findings in this study supported Simon et al. 's (2013) perspective about why communication is the foundation for a common understanding of business and I.T. stakeholders. Besides, the findings in this study were consistent with Buckl et al. 's (2010) ideas about how proper management of E.A. fosters communication between stakeholders, such as enterprise architects, senior leadership, I.T. professionals, and domain teams, that are part of the E.A. transformation process and the E.A. review process.

Finding 2
Gaining buy-in from management, users, and leadership was a fundamental theme. Participants considered gaining buy-in from management as one of the most crucial elements for executing an E.A. transformation process. The finding is supported by Godoe and Johansen's (2012) perspective about why buy-in from users is necessary to initiate successful E.A. implementation and a more effective E.A. transformation process. In previous research, it has been suggested that gaining the feedback and input of users during the early stages of an E.A. transformation process is a critical component (Wax, 2011). Wax (2011) analyzed how user buy-in is increased when users take ownership roles in organizational changes. Increased user buy in allows for a decreased level of resistance during the change process, which increases the probability of successful implementation (Wax, 2011).

Finding 3
Resistance to change was another finding. Many participants communicated their views on how resistance to change hinders the E.A. transformation process. In general, the E.A. transformation process's implementation can result in users resisting the process due to uncertainties and fears of the unknown. The findings from this study confirm Hess's (2006) premise that resistance to change is a critical barrier that hinders the transformation of the E.A. in the federal government. Merely understanding that users' resistance to change is familiar will not provide management with any value if they fail to understand the methods and techniques used to minimize that resistance (Goodeve, 2009). Understanding why users resist change is necessary to understand ways to combat the act of resistance.

Three findings that contributed to answering RQ2 were found to have support in previous research.

They are finding 1
Planning the E.A. framework's execution plays a critical role in achieving an E.A. practical framework that was revealed in this study. Previous researchers have explained how the lack of proactive planning is one factor that hinders the execution of E.A. practical frameworks (Asfaw et al., 2009). The findings from this study also supported Meyers (2011) theory that planning E.A. objectives aids in the creation of an enterprise mission, vision, and strategic business plan. The planning process requires building relationships with crucial E.A. leadership to execute the E.A. framework process successfully. Besides, planning is a reasonable step that is a vital best practice in the E.A. frameworks process. Research by Rollings (2010) indicated that more effort needs to be invested in streamlining the connection between E.A. and organizations' strategic planning needs.

Finding 2
The compliance guidelines that I.T. organizations apply when trying to achieve an E.A. framework were also themes identified in this study. The analysis reveals that compliancy mandates do not provide practical guidance about E.A. transformation best practices.

The analysis disclosed that some participants felt frustrated with the compliance guidelines set by departments because the instructions can affect the workflow of the metric process; moreover, compliancy guidelines affect the CPIC process and can affect the amount of funding for I.T. and E.A. initiatives. Previous research indicated that the OMB mandates that federal agencies document and submit their E.A. initiatives to the OMB for review, along with any significant changes that may occur to the E.A. process (Grasso, 2011). The OMB also uses various studies to evaluate the adequacy and efficiency of each agency's E.A. compliance. For instance, Powner et al. 's (2014) examination indicated that PortfolioStat requires federal government agencies to conduct annual reviews of their I.T. portfolios (e.g., E.A.) as part of an effort to reduce commodity I.T. spending. Agencies are expected to demonstrate how their I.T. investments align with their missions and business objectives. Several federal government agencies have experienced limitations in implementing the PortfolioStat initiative, for example, the Chief Information Officers' authority constraints. This study's findings reveal that the best practices of meeting mandates and compliance guidelines are not followed when making I.T. decisions. The compliancy process does not provide practical guidance about E.A. transformation best practices.

Finding 3
Findings in this study reveal that I.T. security challenges exist for I.T. organizations when executing an E.A. practical framework. Participants emphasized their concerns about how I.T. security guidelines, such as Cybersecurity and firewall policies, can impede EA-related initiatives. Limited research exists on the I.T. security challenges organizations face with the implementation of EA-related initiatives. A great deal of research has been focused on how security is an integral part of the E.A. process and on how the synergy of security and E.A. working together save the organization money and time (Madewell, 2014; Minoli, 2008), but little research is focused on the challenges and I.T. security constraints that I.T. organizations face when implementing EA-related initiatives.

Finding 1
Participants offered practical advice about how organizations can implement E.A. initiatives from a target state perspective to ensure E.A. transformation processes more meaningful and measurable. The approach to delivering enterprise initiatives requires broader thinking and maintaining a streamlined focus on the current state and future state outcomes. Previous researchers have indicated that E.A. has the means to guide enterprise initiatives toward enterprises' transformation (Krishnamurthy, 2014), and E.A. provides a blueprint for the as-is state and the vision of practical and modernized infrastructure and the to-be state (Pereira, 2010). Schekkerman and Hendricks (2002) and Op't Land et al. (2008) discussed how governance ensures conformity to the E.A. transformation process when defining the current state's goals and the desired state of the E.A. process. The governance approach provides a way to efficiently and adequately govern the E.A. transformation process (Gotze, 2011). Previous research cited by Sidorova and Kappelman (2011) found that stakeholders consider E.A. an aspect of the status quo. Some leadership subscribes to the view that E.A. is a set of mandates, standards, or blueprints for the enterprise's future. In contrast, other directions include both the current state and desired state and the transformation plan between those present and future states.

Finding 2
Conducting budget and cost-benefit analyses was revealed as an approach that needs to be incorporated and managed correctly in the E.A. implementation process. This finding supports that of Wagter et al. (2014), which is that maintaining the E.A. governance process with cost-benefit analyses would ensure that the contribution of E.A. is known continuously. The finding also coincides with the study by Grasso (2011), who indicated that management efforts should be focused on unnecessary cost avoidance; for example, enterprise software-license agreements consolidation efforts assisted the Department of the Interior with saving approximately $80 million. Further, the Department of Health and Human Services achieved budget and avoided costs by leveraging E.A. governance best practices in improving its telecommunications infrastructure (Grasso, 2011).

Finding 3
Incorporating a plan was revealed is an approach that would include roadmap objectives to assist with making the E.A. transformation more efficient and making E.A. transformation decisions. This finding confirmed Niemi and Pekkola (2013) view that having an initial plan in place before any acquisition and E.A. initiative decisions are made is critical. Incorporating a plan can help make architectural decisions when guiding I.T. initiatives to comply with the overall E.A. process. Outcomes from this study concerning incorporating a project plan that included

information about the target architecture, priorities, and roadmap objectives (i.e., investments) were consistent with Khadem's (2007) theory that combining and engaging I.T. units, such as plans and investments, are needed to support the overall functionality and purpose of the organization.

Three findings that contributed to answering RQ4 were found to have support in previous research.

Finding 1
F2F meetings with stakeholders (i.e., leadership) can assist with addressing the E.A. transformation process challenges was a finding that was revealed in this study. Davis et al. (1989) developed an abstract style for providing insight into individual behaviors when addressing I.T. implementation challenges by meeting with I.T. user groups. The finding supports Davis et al. (1989). They indicated that the problems presented by user behavior could be addressed with meetings with users to gain clarity on users' attitudes and subjective norms as well as gain insight into the perceived usefulness and ease of use.

Finding 2
Training stakeholders about E.A. objectives (i.e., the E.A. transformation process) creates awareness and understanding about E.A. objectives and aids in addressing E.A. transformation challenges. This finding concurs with research conducted by Lapalme and de Guerre (2014). They suggested that ongoing training and development are proactive ways to tackle the complexities of turbulent E.A. environments and are necessary for organizational sustainability and adaptation. Besides, the findings are supported with literature that indicated the implementation of E.A. transformation processes face challenges because of the lack of knowledge and understanding of how to execute the enterprise transformation process in a practical way (Asfaw et al., 2009).

Nassiff (2012) indicated through his research that a lack of comprehension of the meaning of E.A. in terms of its scope across enterprises exists. Niemann (2006) explained that knowledge offers a competitive advantage for enterprises in today's ever-changing market environment. Further, the power of knowledge not only originates from competitors, future trends, and technologies, but also derived from the internal makeup and processes of an enterprise (Buckl et al., 2010). Locke et al. (2010) indicated that building an understanding of the E.A. transformation process from a humanistic viewpoint is vital for learning about the transformation process.

Finding 3
The findings revealed that inviting the stakeholders (i.e., management) to participate early in the process would assist with gaining support and providing direction before the execution of E.A. initiatives. Based on previous related research, this approach's success would depend on the ability to transform the beliefs of management about control and design opportunities that inspire a productive dialogue amongst managers and users (Lapalme & de Guerre, 2014). According to Op't Land et al. (2008) and Wagter (2009), E.A. offers a means for stakeholders to obtain insight about the organizational structure and make decisions early on the direction of the E.A. transformation process. As a result, the E.A. can provide a means to guide the E.A. transformation process and enable senior management to govern the enterprise coherently (Wagter et al., 2014).

An essential proactive approach would be to discuss E.A.'s goals and objectives with the stakeholders (i.e., management) before introducing and describing how to measure payback (Rico, 2006). Further, Rico (2006) indicated that understanding the goals and objectives of E.A. is a necessary approach for the stakeholders (i.e., management) to measure return on investment, apply E.A. successfully, and receive benefits of the E.A. process. Several recommendations for the E.A. transformation process were identified based on this qualitative case study.

Practical recommendation 1
I.T. organizations must use different communication approaches within I.T. and business organizations. Communication will assist with clarifying confusion about constructs about the management of E.A. as well as achieve a common understanding of the overall E.A. initiatives (Simon et al., 2013). Communication should be simple, fluid, and ongoing with leadership and users of the I.T. organization and the business organization. The interface will provide a foundation for common understanding for both business and I.T. stakeholders (Simon et al., 2013). Based on the research findings, communication should not be

a one-time approach; discussion should be ongoing.

Practical recommendation 2
The proposal is that more research is conducted about the usefulness of obtaining support from stakeholders before implementing the E.A. transformation process. Support from the stakeholders (e.g., users and leadership) at all levels of the E.A. transformation process should be obtained. Obtaining assistance from users is necessary to initiate a successful I.T. implementation process (Godoe & Johansen, 2012). The findings revealed that gaining buy-in from stakeholders is essential in the E.A. transformation process's practical execution. Obtaining support from stakeholders will minimize the challenges of executing the E.A. transformation process and assist with influencing the stakeholders' views.

Practical recommendation 3
The proposal is to incorporate a plan during all stages of the E.A. transformation process. Based on the findings, including a project is a means for tracking the current state's components and the target state of the E.A. transformation process. The research results of this study highlighted that a plan (i.e., E.A. plan) is necessary for making the E.A. transformation process more efficient. Research participants agreed that putting together an action plan, a project plan, and a deployment plan and creating a timeline for the E.A. plan should be presented to the stakeholders before the I.T. infrastructure changes occur. Doing so may ensure that the E.A. transformation process is executed in a more agile fashion. Strategically, incorporating a plan plays a vital role in the synergy of the E.A. transformation process stages. Further, a program may aid in creating an enterprise mission, vision, and strategic business plan. Previous research suggested that building relationships with crucial E.A. stakeholders may be required if the E.A. transformation process is to be executed successfully (Meyers, 2011).

8. CONCLUSIONS

This qualitative case study focused on the challenges facing the execution of an E.A. transformation process within the federal government. This topic has not been researched qualitatively. The study's goal was to fill the gap in scholarly research about the barriers that affect the transformation process and focus on how to apply strategic approaches for driving the E.A. transformation process toward a practical approach. In general, E.A. is an emerging discipline, and like other maturing business processes and technical concepts, E.A. provides a foundation for both organizational transformation and I.T. management. The effective use of E.A. is a recognized hallmark of successful public and private organizations (U.S. GAO, 2010).

The study confirmed that several of the E.A. transformation process challenges were congruent with findings from previous studies and uncovered additional findings that could drive future research and theory building.
This qualitative study's results make a significant contribution to the E.A. transformation process area of research by further refining the E.A. transformation process phenomenon. The insightful information and understanding gained from participants in this study highlighted factors that hinder federal government agencies from driving the E.A. transformation process from a compliance process to a more efficient implementation process that is flexible enough to accommodate the change.

The study has contributed to the scholarly research by further refining the E.A. transformation process phenomenon within the federal government and identified obstacles that interfere with the E.A. transformation process. The latter entails understanding how to make the transformation process meaningful and measurable while addressing the challenges that the federal government faces on how to influence the views of the stakeholders.

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Job and Career Satisfaction of Software Engineers

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Abstract

The purpose of this study is to evaluate how several factors including gender, years coding, education level, compensation, hours worked, work setting, and confidence level in manager affect job and career satisfaction for software engineers. The data was analyzed from a 2019 done by Stack Overflow, an online community for developers to learn, share programming knowledge. Surveys from over 65,000 software engineers were analyzed. Based on the survey results, women have the highest job satisfaction. The younger a person coding the higher the job satisfaction. Women and men have equally high job satisfaction. Respondents who identified as other gender are significantly less satisfied then men or women. Education level does not significantly influence career or job satisfaction. Job satisfaction is influenced by the confidence level an employee has in their manager. Although those employees that had no managers scored high in job satisfaction, those who were very confident in their manager scored a higher level of job satisfaction.

Keywords: job satisfaction, software engineers, information technology, gender

1. INTRODUCTION

Organizational behaviorists and organizational psychologists have long studied the subject of employees' job satisfaction. The literature includes several facets of what variables make up job satisfaction. According to Lumley, Coetzee, Tladinyane & Ferreira (2011), job satisfaction can be defined as "an individual's total feeling about their job and the attitudes they have towards various aspects or facets of their job, as well as an attitude and perception that could consequently influence the degree of fit between the individual and the organization" (pg. 101). Career satisfaction represents "an overall summary of how a person feels about a lifetime_of work … and all the diverse activities and experiences that comprise a career."

(Lounsbury, Moffitt, Gibson, Drost, & Stevens, 2007). Employee satisfaction is "determined by subjective perceptions related to the treatment received by the organization, for instance, policies of rewards, hiring and firing policies, performance and retribution." (Crespi-Vallbona & Mascarilla-Miro, 2018, pg. 36). Sempane, Rieger & Roodt (2002), assert that job satisfaction is made up of many variables such as "structure, size, pay, working conditions and leadership", all representatives of organizational climate (pg. 23). Some of these variables may also include the "importance of job position, teamwork atmosphere, leadership, recognition and compensation, physical labor conditions and personal labor conditions as key aspects of employees' well-being." (Crespi-Vallbona & Mascarilla-Miro, pg. 37). In a study done by LeRouge, Wiley, & Maertz (2013), the authors included job security, the work itself, one's supervisor, compensation, work/life balance, and advancement/opportunities as important facets of job satisfaction.

Lumley, et. al (2011) used Spector's (1994) Job Satisfaction Survey to analyze nine facets of job satisfaction (Table 1).

Facet	Description
Pay	Satisfaction with pay and pay raises
Promotion	Satisfaction with promotion opportunities
Supervision	Satisfaction with person's immediate supervision
Fringe benefits	Satisfaction with monetary and non-monetary fringe benefits
Contingent rewards	Satisfaction with appreciation, recognition and rewards for good work
Operating procedures	Satisfaction with operating policies and procedures
Co-workers	Satisfaction with co-workers
Nature of work	Satisfaction with type of work done
Communication	Satisfaction with communication within the organisation

Table 1: Nine Facets—Spector's Job Satisfaction Survey (1994)

Much of the literature has focused on the satisfaction of Information Technology (IT) professionals, with little emphasis on the software engineer, specifically. This study analyzes the career and job satisfaction of software engineers, with specific attention to gender, age, education, experience, leadership and compensation.

2. LITERATURE REVIEW

Education Level

Numerous researchers have examined the effect of education level on job satisfaction (González, Sánchez & López-Guzmán, 2016; Ross & Reskin, 1992; Yeo, Sasaki, Serenko, Sato & Yu, 2018). Ross and Reskin (1992) surveyed 557 Illinois workers and found that well-educated respondents were more likely to work in an area that provides more control, but the total effect of education on job satisfaction was nil. Yeo, et al (2018) examined job satisfaction among IT workers in Taiwan, Japan and China. They also determined that the level of education had no effect on job satisfaction (Yeo, et al, 2018). Similarly, Gonzalez et al (2016), looked at the hospitality industry and found that education level does not influence job satisfaction.

Opposingly, Pew Research Center (2016) found that there was a difference in job satisfaction based upon education level. They found that highly educated workers among the most satisfied with their jobs.

Gender

Does the job satisfaction of men and women who work in technology differ? In a study on gender inequality and job satisfaction of working professionals in 32 European countries, including IT and non-IT workers, Perugini & Vladisavljevic (2019), found that despite being paid less than men and facing worse working conditions, lower promotion opportunities and workplace discrimination, women typically report higher levels of job satisfaction.

Ghazzawi (2010) surveyed 132 IT professionals, 99 men and 33 women in various Southern California organizations using the Minnesota Satisfaction Questionnaire (MSQ) which is made up of a 5-point Likert scale, to ascertain general job satisfaction. The study examined the effects of gender on job satisfaction and concluded that gender does not play a role in job satisfaction among IT professionals in the United States.

The author also found that, regardless of gender, major sources of job satisfaction of IT professionals were, 1) the ability to keep busy all the time (male 82% vs. female 85%); 2) the ability to do things that don't go against one's conscience (male 80% vs. female 94%); 3) the steady employment (male 78% vs. female 85%); 4) the chance to work independently (male 76% vs. fe1nale 85%); co-worker's comradery (76% male vs. 82% female); 5) the chance to try one's own methods of doing the job (72% male vs. 88% female) (pg. 24).

Major sources of job dissatisfaction experienced by both male and female IT professionals were, "1) the chances for advancement (male 35% vs. female 48%); 2) the way company policies are put in to practice (male 36% female 45%); 3) pay and the amount of work (male 46% vs. female 55%) and 5) the chance to delegate to people (male 49% female 55%)" (Ghazzawi, 2010). Although these factors are their lowest job satisfaction, "28% of male and 27% of female respondents indicated that they were not satisfied regarding their chances for advancement on the job." (pg. 24)

Sharma (2017) studied 220 IT professionals across three IT companies in India. The findings revealed that, "organizational cultural values such as fairness, growth opportunities and reputation of organization have a positive effect on the job satisfaction, whereas organizational traits like aggressiveness have a negative influence on job satisfaction." (pg. 35) Both men and women felt organizational fairness to be an equally important and equally strong foundation to their job satisfaction. Female IT professionals found that attention to details is a factor, influencing job satisfaction of female employees more than their male equivalents.

Naidoo (2018) surveyed 158 South African IT professionals to ascertain their pay level and its relationship to job satisfaction. The findings of the study revealed that, "irrespective of gender or ethnicity, IT employees in South Africa who are generally less satisfied with the salary they are receiving, have a low degree of commitment to their organizations, and are only moderately satisfied with their jobs." (pg. 17)

Priya & Mahadevan (2013) conducted a study with 151 female information technology (IT) and 70 information technology enabled services (ITES) employees from India. The respondents were between the ages of 23 to 45 years, with an average age of 34 years. They found no significant difference in job satisfaction among junior, middle and senior levels of women executives in the sector.

3. METHODOLOGY

Data from a survey hosted by Stack Overflow, an online developer's community, was used for this research. The use of Stack Overflow is well established as a source for peer-reviewed journals including Barua, Thomas, and Hassan (2014), Asaduzzaman, Mashiyat, Roy, and Schneider (2013), and Treude and Robillard (2016). The Stack Overflow dataset consisted of dozens of demographic, descriptive, and opinion questions about the state of programming today. Over 90,000 responses were gathered from code developers from all over the world (Appendix 1). The data was filtered to respondents who indicated they were software developers by profession. This resulted in a dataset of over 65,000 responses. The results of this study reflect an analysis of a subset of these questions that may be relevant to software engineers' job and career satisfaction. Two questions were used as measures of satisfaction.

(1) How satisfied are you with your current job? (If you work multiple jobs, answer for the one you spend the most hours on.)
(2) Overall, how satisfied are you with your career thus far?

The responses were on a 5-point Likert scale from very dissatisfied to very satisfied. These two variables were used as dependent variables. The independent variables tested were those that may influence job and career satisfaction. They included gender, age, year started coding, years coding, education level, total compensation level, hours worked, work setting, confidence level in manager.

4. RESULTS

Gender and Age

The average age of respondents was 31 and predominantly male. The distribution of the respondents' ages and job satisfaction is shown in Figure 1. A regression analysis was performed on age and job satisfaction. It was found that age is not a significant variable for career satisfaction but was significant for job satisfaction at $p < .02$. In other words, younger individuals have higher current job satisfaction, but older individuals are just as satisfied with their careers as younger individuals. These findings may be the result of other variables such as years coding which we explore later.

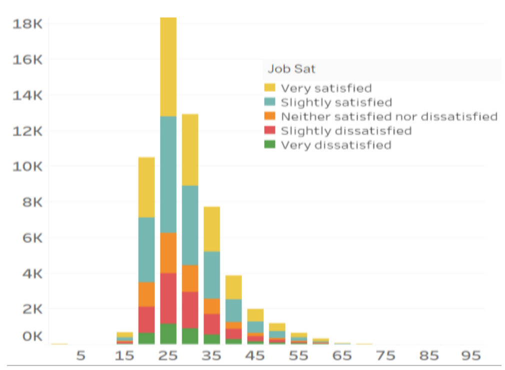


Figure 1. Age and Job Satisfaction

The distribution of gender with average age and years coding are given in Table 2. It was found that women have the highest average level of job satisfaction, approaching only slightly satisfied (4 on a scale of 1 to 5). Next satisfied are men followed by other. All are significantly different at p < .01 (Table 3)

Gender	Count	Avg Age	Avg Years Coding	Avg Age Started Coding
Male	56,959	31	13	15
Female	4,208	30	10	17
Other	2567	30	12	14

Table 2. Gender with Average Age, Years Coding, and Avg Age Started Coding

	N	Average Job Satisfaction
Male	56,959	3.69
Female	4,208	3.78
Other	2,567	3.60
Overall	*63,734*	*3.69*

Table 3. Job Satisfaction by Gender

With just career satisfaction as the dependent variable the results were somewhat different. Women and men had equally higher career satisfaction but only approaching 4.0 slightly satisfied (Table 4). An ANOVA showed a significant difference by gender but a post hoc analysis showed no significant difference between males and females. It is interesting that career satisfaction is higher than job satisfaction and that the difference between males and females no longer exists when career satisfaction rather than job satisfaction is examined. Other genders are significantly less satisfied in their career than males or females at p < .01.

	N	Average Career Satisfaction
Male	58,145	3.96
Female	4,333	3.99
Other	2,806	3.78
Overall	*65,284*	*3.95*

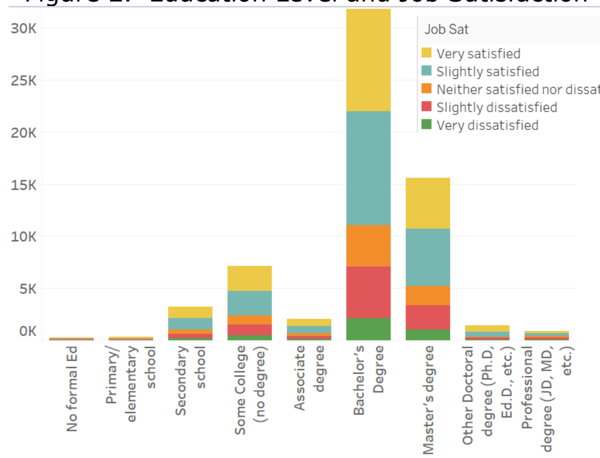
Table 4. Career Satisfaction by Gender

These findings of job and career satisfaction by females either equaling or exceeding males is an important finding. The scarcity of female computing majors in universities today does not map to this positive job and career satisfaction by females.

Education Level

Most of the respondents had bachelor's degrees. The education level along with job satisfaction is shown in Figure 2.

Figure 2. Education Level and Job Satisfaction



Education level does not significantly affect job satisfaction, which has a non-significant p value of .214. These results further support the finding of other researchers (González, Sánchez & López-Guzmán, 2016; Ross & Reskin, 1992; Yeo, Sasaki, Serenko, Sato & Yu, 2018). However, education level is an influencing variable for career satisfaction. For software developers the greater the education level the lower the career satisfaction. (Table 5). These results suggest that career expectations are not being met for college graduates but that they are satisfied in their current jobs.

Educational Level	*Avg. Job. Sat*	*Avg. Career Sat*
No formal Ed.	3.43	3.60
Primary School	3.62	3.75
Secondary School	3.77	4.00
Some College	3.72	3.98
Assoc. Degree	3.73	4.02
Bachelor's Degree	3.67	3.97
Master's Degree	3.70	3.92
Other Doctoral (PhD, Ed,.D)	3.93	4.08
Professional Degree (JD, MD)	3.42	3.70
	3.69	***3.95***

Table 5. Educational Level with Job and Career Satisfaction

Experience Coding

Two relevant variables in the survey were, the age that the respondent first started coding and the total number of years that the respondent had been coding. In other words, the data indicated how old the respondents were when they started programming and how many years they have been practicing. The number of years coding and the age that an individual starts coding influences job satisfaction. The earlier age an individual starts coding and the longer respondents had coded lead to higher levels of job satisfaction and career satisfaction (Tables 6 and 7). Both factors were statistically significant with a p<.01. The impact of both of these variables on career and job satisfaction were very similar as both had nearly identical standardized coefficients.

Age Started Coding	Job Satisfaction	Career Satisfaction
0 -5	3.57	3.8
6 -10	3.78	4.04
11 -15	3.74	4.00
16 – 20	3.62	3.89
21 – 25	3.58	3.91
26 - 30	3.77	4.08
31 - 35	3.84	4.06
36 – 40	3.85	4.05
41 – 45	3.43	4.52
46 -50	3.5	3.54
+50	4	3

Table 6. Age start Coding with Job and Career Satisfaction

Years Coding	Job Satisfaction	Career Satisfaction
0 -5	3.68	3.67
6 -10	3.66	3.66
11 -15	3.67	3.67
16 – 20	3.70	3.70
21 – 25	3.73	3.73
26 - 30	3.75	3.75
31 - 35	3.78	3.78
36 – 40	3.80	3.80
41 – 45	3.88	3.87
46 -50	4.05	4.05
+50	4.22	4.22

Table 7. Years Coding with Job and Career Satisfaction

These findings suggest that perhaps the earlier we expose children or young adults to programming, the more satisfied they may be with their computing job and career. Also, there is not a fatigue factor in programming. This is an extremely important finding. That is, the more you code, the more you like your job and career. Coders seem not to "burn out" as perhaps many in other careers do.

Regression output shown in table 6 and 7 confirms these speculations. The younger one started to write code (lower age), the higher the job satisfaction. The more years coding, the higher job satisfaction. Both are significant at p < .01.

Confidence Level in Manager
Job satisfaction is influenced by confidence level in one's manager, as shown in table 8. The higher the confidence level in a manager, the higher the job satisfaction. However, job satisfaction for those having no manager is high as well. Only Very confident in manager is higher than No manager. All are significantly different from one another at p < .05.

	N	*Average*
No Response	10060	3.77
No manager	1623	3.82
Not at all confident	8196	2.74
Somewhat confident	22274	3.57
Very confident	21699	4.13
Total	***63852***	***3.69***

Table 8. Confidence Level of Manager with Job Satisfaction

Compensation
Compensation and the number of hours per week worked are factors for a job and career selection. This study looked at Converted Compensation (to USD) and number of hours worked per week to determine if either of these variables significantly impacted job or career satisfaction. As shown in tables 9 and 10 for both job and career satisfaction, compensation does make a significant positive difference but the number of hours worked per week is not significant. Compensation is significant at p< .01.

	Unstandard. Coeff	Std. Coeff	Sig.
(Constant)	3.673		.000
Conv. Comp	1.970E-7	.045	.000
Weekly Hrs	.000	.003	.462

Table 9. Weekly Hours Worked and Compensation on Job Satisfaction

	Unstandard. Coeff	Std. Coeff	Sig.
(Constant)	3.673		.000
Conv. Comp	2.563E-7	.063	.000
Weekly Hrs	.000	.005	.291

Table 10. Weekly Hours Worked and Compensation on Career Satisfaction

Country
The final variable examined was country of residence to see if there was an international difference in job or career satisfaction. Table 11 through 14 show career and job satisfaction by the top 10 Countries and Bottom 10 with over 100 respondents.

For the most part Western countries show high career and job satisfaction than eastern or Communist nations. For example, Kowal & Roztocki (2015) conducted a study of 391 IT professionals working in various companies in Poland. They found that many Polish IT professionals "feel that their compensation level and promotion opportunities are inadequate for the competency they possess." They concluded that this might be explained by "the existing compensation structures in many Polish companies." (pg. 1008)

Perugini & Vladisavljevic (2019) found in a study of job satisfaction over 32 European countries that women in Europe "have on average higher levels of job satisfaction than men." (p. 138) However, employment in "typically male occupations also decreases female job satisfaction…". (p. 139)

Further research would be needed to determine if this is due to general work conditions in the countries or the nature of the software work performed within these countries.

Country	N	Mean
Norway	419	4.23
United States	16,028	4.22
Estonia	154	4.19
Canada	2481	4.13
Sweden	959	4.12
Lithuania	183	4.11
Netherlands	1,356	4.09
Finland	413	4.08
United Kingdom	4,432	4.07
New Zealand	391	4.06

Table 11. Career Satisfaction by Country Top 10 with over 100 respondents

Country	N	Mean
Japan	308	3.60
Nepal	143	3.59
Turkey	654	3.57
Malaysia	194	3.56
Italy	1086	3.55
Iran	558	3.53
Indonesia	305	3.44
Viet Nam	137	3.39
Taiwan	126	3.32
China	437	3.17

Table 12. Career Satisfaction by Country with over 100 respondents Career Satisfaction Bottom 10

Country	N	Mean
Norway	417	4.07
Estonia	153	3.94
Sweden	944	3.93
Finland	401	3.92
Netherlands	1337	3.91
USA	15,679	3.90
Canada	2,427	3.89
Denmark	440	3.85
Australia	1,402	3.82
Slovakia	165	3.79

Table 13. Job Satisfaction by Country Top 10 with over 100 respondents

Country	Count	Mean
Mexico	474	3.39
Indonesia	300	3.39
Malaysia	191	3.37
Bangladesh	374	3.34
Viet Nam	131	3.31
Turkey	635	3.29
Iran	534	3.27
Nepal	135	3.23
Taiwan	120	3.16
China	411	2.99

Table 14. Job Satisfaction by Country Bottom 10 with over 100 respondents

5. CONCLUSIONS

Scholars have been studying job satisfaction for a long time, as far back as 1935 when Robert Hoppock published his seminal book, *Job Satisfaction*. Over time, scholars have studied a wide variety of variables that constitute employee satisfaction.

This study examined job and career satisfaction of software engineers using a Stack Overflow dataset of over 65,000 respondents from around the world on the state of programming careers today. Job satisfaction variables that were analyzed included; education level, gender, age, number of years of experience, confidence in one's manager, compensation and country of origin.

We found that job and career satisfaction by females either equaled or exceeded males' satisfaction. The authors noted that career satisfaction is higher than job satisfaction and that the difference between males and females no longer exists when career satisfaction rather than job satisfaction is examined. These conclusions are supported by Ghazzawi (2010), Sharma (2017) and Naidoo (2018). Perugini & Vladisavljevic (2019), found that despite being paid less than men and facing worse working conditions, lower promotion opportunities and workplace discrimination, women typically report higher levels of job satisfaction.

Software engineers are the most satisfied with their jobs if they started coding between 30-40. Satisfaction begins to drop off at age 40-50. But career satisfaction is influenced positively by age started coding throughout the age brackets. A possible explanation is that older individuals have had a long successful career but at an advance age may be less satisfied in their jobs because of advances by younger individuals and/or resistance to changes in programming languages and practices

Our analysis determined that education level does not significantly affect job satisfaction. These results further support the findings of other researchers (González, Sánchez & López-Guzmán, 2016; Ross & Reskin, 1992; Yeo, Sasaki, Serenko, Sato & Yu, 2018). However, education level is an influencing variable for career satisfaction. For software developers the greater the education level the lower the career satisfaction. These results suggest that while career expectations are likely not being met for college graduates, they are satisfied in their current jobs.

This study also found that the earlier an individual started to write code, coupled with length of time (experience) one had coding, the higher levels of job satisfaction and career satisfaction one had. These findings suggest that perhaps the earlier we expose children or young adults to programming, the more likely they will be satisfied with their computing job and career. We also found that the frequency with which an individual wrote code, the more they enjoyed their job and career.

Job satisfaction is influenced by confidence level in one's manager. Lumley, et al (2011) assert that "employee satisfaction increases when the immediate supervisor is understanding, friendly, offers praise for good performance, listens to employees' opinions and shows personal interest in them." (p. 103) Our results found that the higher the confidence level in a manager, the higher the job satisfaction. Interestingly, we also found that job satisfaction for those having no manager at all is also high.

Our analysis concluded that compensation does make a significant positive difference in employee satisfaction but the number of hours worked per week is not significant. According to Kowal & Roztocki (2015), "many IT professionals feel that their compensation level and promotion opportunities are inadequate for the competency they possess." (pg. 1008) Naidoo (2018) found that "IT employees in South Africa who are generally less satisfied with the salary they are receiving" are only moderately satisfied with their jobs (p. 17). Lumley, et al (2011) concluded that "managers need to review existing pay practices so as to offer fair pay…". (p. 115)

We concluded that, in general, Western countries show high career and job satisfaction as compared to Eastern or Communist nations. Kowal & Roztocki (2015) found that many Polish IT professionals "feel that their compensation level and promotion opportunities are inadequate for the competency they possess." (pg. 1008) Perugini & Vladisavljevic (2019) found that women in Europe "have on average higher levels of job satisfaction than men." (p. 138) However, employment in "typically male occupations also decreases female job satisfaction…". (p. 139) Further research would be needed to determine what variables are causing the disparity between the countries who have a high level of satisfaction among their software engineers and those who have a low level of satisfaction.

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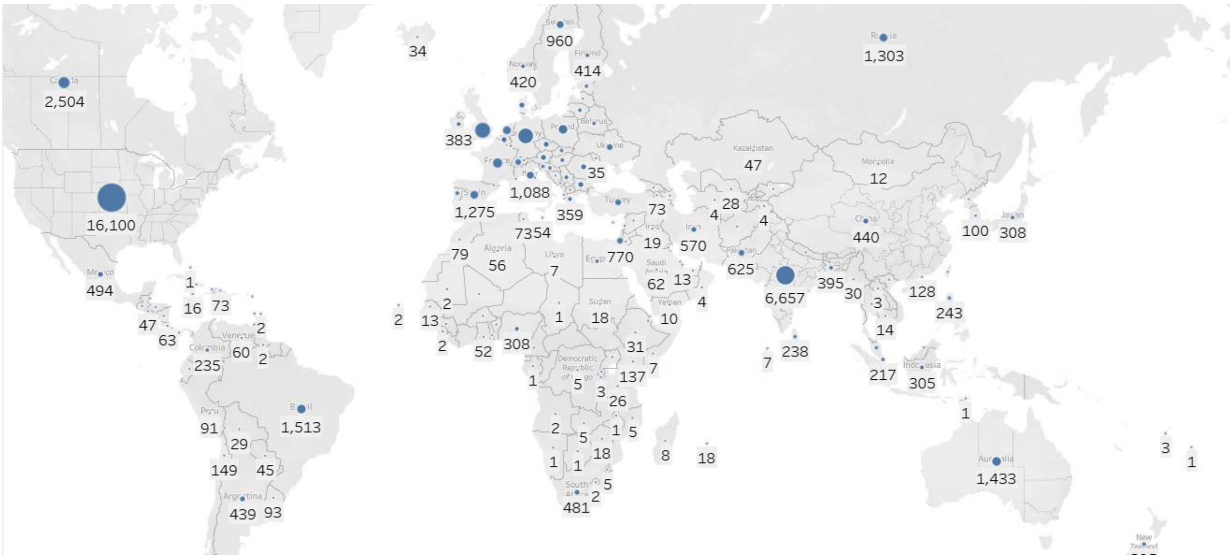
Appendices and Annexures



Appendix 1. Distribution of Respondents

Does the Executive Perception of the Value of Information Technology (IT) Influence the IT Strategy? A Case Study

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Abstract

Information Technology (IT) constitutes a significant part of a firm's investment. IT leaders struggle to communicate IT's value to stakeholders. Often, they focus on technology and operational performance metrics that bore business leaders and fail to convey IT's value to the business (Nagel & Ganl, 2020). Perception plays a vital role in an individual's decisions making process. It is essential to understand executives' perceived "value of IT" in the firm and examine whether executives' perceptions of the "value of IT" influence the development of the firm's IT strategy. This study explores this relationship using a qualitative case study as a methodology. The results suggest that the perception of the "value of IT" influences IT strategy development in organizations. It is crucial to be able to communicate this value at multiple levels. Decision-makers in organizations perceive the "value of IT" differently based on their roles and experiences. Implications are drawn, and future research directions are proposed.

Keywords: IT Strategy, Business Value of IT, qualitative study, case study, governance

1. INTRODUCTION

Around 63% of Information technology (IT) executives struggle to communicate IT's value (Nagel & Ganl, 2020). IT constitutes a significant part of a firm's investment. Worldwide spending on IT is expected to grow across major sectors of the economy and reach $3.4 trillion by the end of the year 2020 (Gartner, 2020). IT spending forecasts indicate that IT is recognized as a critical resource that creates sustainable business value. However, this assumption has not always been shared by business leaders or executives. The IT leadership of organizations criticizes that business stakeholders perceive IT more as a cost center than the cost of doing business (CIO.com, 2013). This criticism could be partly because many business executives distrust IT and consider investing in IT as irresponsible spending (Flood, 2013). IT Leaders often focus on technology and operational performance metrics that bore business leaders and fail to convey IT's value to the business. Business executives in organizations perceive that investment in IT does not provide expected returns.

Business leaders’ views differ on the “value of IT” and “goals of IT” in the organization. These differences are significant as it influences the scale and direction of IT investment decisions and the extent to which IT investment impacts firm performance (Kiessel, 2012). Business leaders & executives’ perception plays a crucial role in assessing the impacts of IT on their business. The unstructured nature of the understanding of the relationship of the value of IT and its implications of business makes the executive perceptions of these constructs even more critical. Executives' positive perception of IT builds confidence and encourages leaders to focus on IT not only as operational but also as a strategic tool (Porter, 1996). A study about executives’ perception of IT value and its impact on IT strategy is warranted.

Kohli and Grover (2008) argue that IT investments are not monolithic, and IT creates a plethora of information that needs to be harnessed to create or enhance value. The value of IT, when intentionally linked to the business model of the organization, enables a firm to do its business better (McKeen & Smith, 2012). IT in organizations has evolved to the point where its goal is not only to enable the company but also to improve and to transform the organization’s capabilities (McDonald, 2007). Leadership in organizations acknowledges that IT is critical to an organization’s success, and it directly impacts the mechanisms through which businesses create and capture value to earn a profit (Drnevich & Croson, 2013). Researchers and business managers consider IT investment as an enabler for improved organizational efficiency and competitiveness (Kohli & Devaraj, 2003). The considerable investment in IT demands that IT and business executives work together and layout strategy to achieve the organizational objectives and transform IT from a cost center into a strategic partner to gain competitive advantage. There is no clarity if IT's value in business is providing the competitive advantage the organizations seek from information technology mechanisms. The goal of this research study is to understand the executives’ perception of the “value of IT” and their perceived value of IT on the IT strategy of the firm. The specific research questions posed in this study are:

RQ1. What are executives’ perceptions of the value of IT in a firm?

RQ2. Does the executives’ perception of the value of IT influence the IT strategy of a firm?

The next section presents a literature review section followed by the case study.

2. LITERATURE REVIEW

It is challenging to identify robust methods to measure the value created by IT in a firm. The business value of IT research focuses on the relationship between information technology investment and firm performance (Melville et al., 2004). Gerow et. al. (2014) define firm performance in terms of three over-arching types: financial performance, productivity, and customer benefit. Financial performance is the firm’s ability to gain competitive advantage and, therefore, higher profits or stock value. Productivity is the measure of the contribution of various inputs to total outputs. Customer benefit is the full benefit that a given purchase confers to consumers. Resource-based theory (RBT) has been frequently used by information system researchers to examine and understand the relationship between information technology investment and firm performance (Bharadwaj, 2000; Chae et al., 2013; Melville et al., 2004; Shaw et al., 2013; Wade & Hulland, 2004).

Contingency theory postulates that alignment between the patterns of relevant contextual, structural, and strategic factors leads to superior firm performance (Oh & Pinsonneault, 2007). Several studies show that the strategic alignment of IT affects firm performance, and IT alignment is positively associated with perceived organization performance (Kearns & Lederer, 2001; Sabherwal & Kirs, 1994).
Masli et al. (2011) synthesize the empirical archival research investigating the link information technology investment and business value. Investment in IT has been positively associated with earning volatility, market valuation and short-and long term abnormal returns, contribution to productivity and consumer value and subsequent firm performance and shareholder return (Henderson, Kobelsky, Richardson, & Smith, 2010; Hitt & Brynjolfsson, 1996; Kobelsky et al., 2008). To examine the business value of IT in a firm, many researchers propose to measure IT capability rather than IT investment (Bharadwaj, 2000; Mithas, Ramasubbu, & Sambamurthy, 2011; Rai et al., 2012).

Santhanam and Hartono (2003) suggest that firms with superior IT capability reveal superior current and sustained firm performance when compared to average industry performance. IT investment has served to increase firm productivity and consumer value. Investments in

IT are creating significant intangible benefits to the firm (Bharadwaj et al., 1999).

Kohli & Grover (2008) say, "IT with its complementary resources can create value at a functional level or firm level. We can understand how to create differential value by extending our knowledge of complementary and mediating factors in the value creation process. Thus using this method, we get a better understanding of how IT investments interact with mediating factors (e.g., organizational changes, complementary resources, alignment, capabilities) to create the value of different types (productivity, processes, profit) and levels (individual, firm)". IT enhances the firm's current capabilities and enables flexibility to focus on rapidly changing opportunities or to losing initiatives while preserving essential asset value. Thus, investment in IT and complementary organizational capabilities considerably refine the set of business-level strategic alternative and value-creation opportunities that organizations may pursue (Drnevich & Croson, 2013).

Kraemer et al. (1999) found that management practices play an essential role in creating IT business value and in turning strategic intent for IT into position payoff for the business. IT positively impacts firm performance at multiple points along the value chain(Tallon et al., 2000). IT creates a lot of information that needs to be harnessed to create or enhance value. The reporting structure of the chief information officer (CIO) in an organization reflects the visibility that IT gets in the boardroom (McKeen & Smith, 2012). When Chief Information Officer (CIO) reports to the Chief Executive Officer (CEO) and is a part of senior management, the IT division can form valuable partnerships and involve them in technical planning and execution.

IT governance structure in an organization focuses on setting up the control structure to manage risks and returns by reducing transaction costs and incentivizing new value co-creation (Grover & Kohli, 2012). Cramm (2010) argues that IT is instrumental in lowering day-to-day operational costs and mitigating operational business risks. IT value is achieved through exploitation of resources by performing daily business activities more efficiently (Lin & Shao, 2000; Newell et al., 2003; Xue et al., 2012)

The researcher takes the firm performance into account when investigating organizational phenomena such as firms structure, strategy, and planning (Dess & Robinson, 1984). There are three perspectives frequently used to conceptualize firm performance in the research literature (Ford & Schellenberg, 1982): goal approach, system resource approach, and process approach. The goal approach provides a framework to assess the firm performance based upon explicit or identifiable goals which the firm aims to pursue. The system resource approach emphasizes the relationship between the firm and its internal and external environment. The process approach assesses firm performance in terms of the behavior of firm participants (Tallon, 2007). This study adopts the process approach to determine the value of IT in a firm. In the process approach, firm performance is assessed in terms of the behavior of firm participants.

3. CASE STUDY

The research methodology employed for this research paper is a single case study. The case study research method is best suited for providing an in-depth understating of a case or cases (Creswell, 2012). A case could be an organization, group, individual, social, political, and related phenomena. Mid-Atlantic Financial Institution (MAFI), a pseudonym, was given to the research site for the context of this research study. Also, MAFI is being referred to as "the firm" in this paper. MAFI is a co-operative financial institution. The customers are required to have a membership in the firm. The customers share ownership of the firm, along with other member financial firms. MAFI's mission is to provide low-cost liquidity to its customers and enhance the quality of the communities it serves. An independent Board of Directors and executive committee govern the firm. The executive committee consists of President, CEO, COO, Chief Strategy Officer (CSO), CFO, Chief Risk Officer (CRO), and General Counsel (GC). The CIO leads the information technology department and reports to the COO of the firm. There are seven committees: Executive Committee, Audit Committee, Finance Committee, Risk Committee, Human Resource Committee, Product and Service Committee, and Governance and Public Policy Committee. These seven committees report to the Board of Directors and are formed by members of the senior management team of the firm. Each committee is led by one of the executive committee members.

4. RESULTS & DISCUSSION

RQ 1. What are executives' perceptions of the value of IT in a firm?

Value is the worth or desirability of a thing and is assessed subjectively. An individual IT value perspective is a composite of several factors such as preconceived ideas about IT as a whole that influences value expectation, the role that the individual plays in an organization, the individual's value system, and the IT culture of the organization (Cronk & Fitzgerald, 1999). IT value is a multilayered business construct that must be effectively managed at several levels if the technology is to achieve the benefits expected. Strategic positioning, increased productivity, improved decision making, cost-saving, and improved service are some of the examples of how value could be defined (Smith et al., 2007, p. 2). Data suggest that IT value is perceived to be high in MAFI. As one of the senior executives described the value of IT as:

> The value of IT is immense. Without IT, we would not have the financial industry anymore. We will not be competitive with other firms. More and more, our clients rely on technology to transact business. A company being good in IT is probably imperative to growth prospects.

Three emergent factors influence an individual's perception of the value of IT:
(1) nature of the current job role, (2) organizational position, and (3) past work experience. The executives' perceived value of IT at MAFI could be understood better by exploring executive's perception of investment in information technology (IT), perception of IT governance, perception of services delivered to customers via the online channel, perception of IT infrastructure, and perception of IT infrastructure flexibility.

IT Investment
There are different levels of understanding that managers have regarding the complexity of the IT expenditure. As IT evolves within a company from operational to informational, the assignment of a dollar amount to the value of the benefits derived becomes more difficult (Matlin, 1979). To understand the perception of IT investment of the executives at MAFI, following probing question was asked:

> In your experience from the last 3-5 years, did this organization make adequate investment in information technology?

The majority of the participants (IT/ non-IT/ senior management/ mid-level management/managers) agree that IT investments are critical to the organization's success. There have been significant and thoughtful investments in IT projects over the last five years in the organization. One executive shared his view on IT investment as: "I think we made an adequate investment. I think a steady pace of IT investment in terms of dollars has been very good with well-defined processes. The investments in IT were regulatory-driven and on core systems of the bank. However, few participants feel that resource constraints at MAFI are causing inadequate investment in IT. One of the business executives shared his disappointment in the IT investment scenario: "I would grade average 'C' as of IT investment goes. We don't allocate any type of capital expenditure for any large project."

Business and IT alignment is an essential driving force to achieve business value through investment in IT. IT governance enables business/IT alignment, which allows business value from IT investments (Van Grembergen & De Haes, 2009, p. 6). The next section presents the executives' perception of IT governance at MAFI.

IT Governance
"IT governance is the responsibility of executives and the board of directors and consists of the leadership, organizational structures, and processes that ensure that the enterprise's IT sustains and extends the organization's strategy and objectives" (Van Grembergen & De Haes, 2009, p. 3). At MAFI, the IT governance committee is responsible for IT project prioritization and budget allocation, business/IT strategic alignment, assessment of services provided by IT and review and development of policy and procedures around IT. One of the senior executives described the IT governance committee as:
IT is one of the many components that gets reported to the board of directors. Critical system availabilities and security matrix are reported and communicate effectively on a need to know basis. Another business executive said that "There are lots of crucial discussions occur at IT governance steering committee. There is a proper step to provide approval. Committee members are allowed to have a conflicting opinion. It improves the governance of IT".

At MAFI, there is a methodological approach in place to assess IT. External auditors assess IT periodically, whereas the internal audit and compliance team performs penetration testing regularly.

The purpose of IT governance is to control the process of formulating and implementing IT strategy and ensuring that it assists business in achieving its objective (Van Grembergen & De Haes, 2009). The alignment between business and IT strategy increases profitability and generates a sustainable competitive advantage. Failure to align results in wasted resources in IT initiatives has adverse organizational outcomes (Gerow et al., 2014).

Service Delivery Channel

The customer perspective of a balanced scorecard framework delineates how the firm's value proposition (products, services, brand, relationship with the customer) delivers customer value (Masli et al., 2011).To understand the executive perception of online services enabled by IT, following probing question was asked:

Does our customer value services that are delivered through an online channel?

As one of the senior executives said, "Absolutely, our customers value services that are delivered through an online channel. The bulk of our everyday routine transactions are done through the online channel. The customers highly value the online channel based on our end users' customer survey". One of the business executives described the importance of online services as "we have very high usages of the services that are available online. At times when the online channel is not available, it is a major problem, and the customers are not happy about it". At MAFI, the products and services provided via the online channel are perceived as valuable to its customers. The next section presents the perception of IT flexibility at MAFI.

IT Infrastructure Flexibility

IT infrastructure flexibility is defined as "the ability to easily and readily diffuse or support a wide variety of hardware, software, communication technologies, data, core applications, skills and competencies, commitments and values within the technical, physical base and the human component of the existing IT infrastructure" (Byrd & Turner, 2000). IT infrastructure flexibility is an organizational core competency that is necessary for an organization to respond to opportunities as they arise, whether these are client relationships or new products or new service release in rapidly-changing, competitive, business environments (Chung et al., 2003). Two themes have emerged about the perception of IT infrastructure flexibility at MAFI: 1) acknowledgment of the importance of IT flexibility, 2) lack of IT flexibility in vendor products, and resources (people and cost).

Figure 1 shows that the factors leading to the perceived value of IT are: IT investment, IT governance, online services, IT infrastructure flexibility, and management support. Further analysis of the data suggests that the individual perception of IT is influenced by the participant's nature of the job, past work experiences, and their current organizational role. These perceptions of IT lead to three prominent themes about the value of IT:

- Efficiency and Productivity
- Manage risks
- Product and service delivery channel

Appendix Figure 1

Efficiency and Productivity

Traditionally IT has been instrumental in reducing ongoing "lights-on" costs and mitigating operational business risks (Cramm, 2010). The firm invests in IT to improve efficiency and enhance the productivity of its existing business operations by reducing inventory, substituting labor, or eliminating waste. IT value is achieved through the exploitation of performing existing activities more efficiently (Lin & Shao, 2000; Newell et al., 2003; Xue et al., 2012). One of the senior executives at MAFI said that "IT is dynamic in the financial world. We have to look for ways to substitute technology to improve our productivity. I see IT [as a means] to streamline processes, make the system better, re-engineering old ways of doing things, and increase productivity and efficiency". Another executive said that "Value of IT is very strong here. The firm is interested in investing in IT for efficiency purposes". The business manager shared a similar sentiment, "To me, IT value is in support of advancing business efficiency."

Product and Service Delivery Channel

The financial industry emphasizes seamless multi-channel integration to serve its clients better and improve customer relationships. Financial institutions usually encourage their customers to adopt low-cost channels over high-cost channels for business transactions (Kanchan, 2012). The use of an online channel for product and service delivery is encouraged at MAFI. One of the business managers commented, "In today's world, a business would have been in trouble without IT. I think IT brings a lot of value. We provide online service to our customers. Online services help our customers to do their business quicker, cheaper and efficiently"

Managing Risks

Risk is a multilayered concept that implies the possibility of loss or exposure to loss or even a hazard, uncertainty, or opportunity (McKeen & Smith, 2012). Risks can be classified into known knowns, known unknowns, and unknown unknowns (Wu, Chen, & Olson, 2014). The IT-based risk to the firm includes anything that affects its: brand, reputation, financial value, competitiveness, and customer experience (Aula, 2010; McKeen & Smith, 2012; Taleb, Goldstein, & Spitznagel, 2009). At MAFI, managing risk is part of the business strategy and is a key priority for senior management. IT is instrumental in managing risk at MAFI. A broad range of external and internal IT-based risk can affect the firm. IT-based external risks can come from: (1) third parties such as software vendor, service providers, customers or partners, (2) natural or human-induced disasters, hazards, epidemic, pandemics, etc. and (3) failure to comply with regulations with industry-specific laws, policy or procedures. IT-based internal risk can come from (1) inadequate IT governance, (2) ineffective internal controls to prevent or mitigate risk incidents, (3) poorly designed business processes, and interruption in IT-supported business operations (McKeen & Smith, 2012, p. 266).

RQ 2 . Does the executive's perception of the value of IT influence the IT strategy of a firm?

A conceptual mapping of emergent themes of the perceived value of IT and the current IT strategy of the firm is presented in table 1.0. The table maps the current IT strategy objectives at MAFI to the perceived value of IT and helps to understand the influence of perception of IT on IT strategy. The mapping considers the primary and secondary impact of the perceived value of IT on a specific IT strategy objective.

Appendix Table 1

The primary influence in this context means the particular value of IT has a higher scope or broader impact on the linked IT strategy objective compared to other values of IT. The secondary influence in this context means the particular value of IT has an indirect effect or narrow scope on the linked IT strategy objective. For example, in table 1.0, the IT strategy objective "Implementation of easy-to-use tools for tracking interactions with customers" does get influenced by multiple values of IT in a primary (P) manner. This relationship implies its scope as a broadly defined and secondary (S) manner indicating its narrow scope. The IT strategy objective "Create a balanced approach regarding risks, costs, and benefits in managing risks" shows the only primary influence of the value of IT as "Managing risks." The next section provides the descriptive analysis of the influence of the perceived value of IT as "Managing risks" on current IT strategy objectives, the influence of the perceived value of IT as "Efficiency & Productivity" on current IT strategy objectives and the influence of the perceived value of IT as "Products & Services delivery channel" on current IT strategy objectives.

The IT strategy objective, "Identify emerging security risks and develop a plan to mitigate the risks," adds value to business by ensuring that there is an ongoing awareness of emerging security risks. This objective ensures that policies, procedures, and tools are in place to mitigate security risks. The IT strategy objective "Provide reasonable protection against the most likely cyber threats while maintaining business operation" adds value to business by providing required technical capabilities to safeguard IT assets and IT infrastructure. The IT strategy objective "Modernize the technology platform" adds value to business by addressing future technology needs for the company. The IT strategy objectives "Develop and implement enterprise data backup and recovery solution consistent with emergent technologies," " Develop and maintain secure, reliable, scalable and flexible IT infrastructure," "Provide flexibility to run production systems from multiple sites" and "Develop comprehensive remote computing solution for business recovery" are focused on advancing IT infrastructure. These IT strategic objectives add value to business by ensuring business system/applications & data integrity, accuracy, security, and quality to sustain and to provide effective, efficient, and uninterrupted service by reducing the operational risk in any given scenario such as system failure and natural disaster or human-induced disaster. The IT strategy objective "Develop and implement policy and procedure around vendor management to ensure uninterrupted business" adds value to business by providing a framework. This framework enables the firm to develop, manage, and control vendor contracts, relationships, and performance for the efficient delivery of contracted products and services while reducing operational risks caused by a third-party vendor. The IT strategy objective "Create a balanced approach regarding risks, costs and benefits in managing risks" adds value to business by developing a framework to introduce new technology delivery capabilities while understanding the conservative nature of the firm and its risk appetite.

5. CONCLUSION AND IMPLICATIONS

The conceptual mapping of the value of IT and IT strategy objectives reflects the executive's perception of the influence of the value of IT in determining the strategic objectives of information technology IT in a firm. There is no standard model to measure IT value. Some organizations define IT value by rate-of-return measurement, such as return on investment, while other organizations perceive IT value resulting from having the standard processes across the organization. Another way of measuring the value of IT is by using a set of standard matrices such as key performance indicators, system availability, or service level agreement. Melville et al. (2004) argue that the dimension and the extent of IT value depend on a variety of factors, including the type of IT, management practices, and organization structure. Groups and individuals perceive the value of IT to an organization differently. Value varies depending on where one looks for it (McKeen & Smith, 2012, p. 3). Three influential factors emerged, informing the individuals' perception of the value of IT :

- nature of job
- past work experience
- organizational position

The value of IT is usually classified into two broad categories: tangible value and intangible value. Tangible value generally gets measured in financial post hoc metrics or even ex-ante market value (Kohli & Grover, 2008; Matlin, 1979). Intangible value reflects a broader range of value base upon observation of practice. Businesses and customers are the final judges of value creation. Characteristics such as flexibility, agility, and customer services could be the criteria for assessing the intangible value of IT (Kohli & Grover, 2008). At MAFI, the value of IT is perceived as:

- Value of IT on the defensive side of the business model

  On the defensive side, IT adds value to the business through enterprise risks management, operational risks management, market analysis, financial model simulations, assessment, and scenario forecasting, accounting, and regulatory and compliance type activities. One of the executives said, "I don't think what we are doing offensively, we would be able to do business without IT." Another business executive shared a similar view as, "In the absence of IT, we would not be able to leverage and take a particular risk to help provide the financial return to our customers."

The emerged perceived value of IT themes "Managing risks" and "efficiency and productivity" fall under the defensive side of the business model.

- Value of IT on the offensive side of the business model

  On the offensive side, IT adds value by providing products and services to customers. One of the executives said that "Our customers love our online business application portal. The bulk of everyday routine transactions are done via the online portal". The emerged perceived value of the IT theme "Products and services delivery channel" falls under the offensive side of the business model.

IT value is recognized in uplifting business productivity and increasing efficiency. The value of IT is known for providing technology channels to deliver products and services to customers, partners, and vendors. IT contributes to the effective management of business risk by understanding threats and vulnerabilities and identifying ways to mitigate the risks. IT value is recognized in managing business risk. At MAFI, C-level executives, mid-level management, and managers perceived the value of IT in:

- managing risks
- increasing efficiency & productivity
- products & services delivery channel

The current IT strategy reflects these IT values. Table 1 demonstrates that each IT strategy objective is influenced by one or more of the above-mentioned values of IT. The IT strategy objective "Provide flexible system to implement new product" is influenced by the primarily perceived value of IT "efficiency & productivity." The IT strategy objective "Provide easy access to products and services" is influenced by the primary perceived value of IT "Products and Services delivery channel" and secondary perceived value of IT "efficiency & productivity." Based on the findings, it can be concluded that the perceived value of IT does influence the IT strategy of the firm. A relationship can be inferred based on the data (see Figure 2).

Appendix Figure 2

In an organization, the perceived value of IT does influence the development of the IT strategy of the organization. In this case, IT leaders can play an essential role in representing IT among business executives while developing a business-focused IT strategy aligned with the overall organization's goal, mission, and business strategy. Effective strategy decisions are best made with input from both business and IT executives.

In this single interpretive case study research, there are two major areas of criticism: generalizability and researcher bias. Yin (2003) argues that "in interpretive field research, many of the results do not hold in other organizations. It is not the intention of this research to do so. The findings are not generalizable in a statistical sense but are generalizable to the theory". As per Yin (2003), theories used in other studies can be used as a template to compare the results.

There could be a criticism that the researcher, as the research instrument, allows several confounding variables to creep in, which biases the results. Klein and Myers (1999) said that "by consciously stating the historical and intellectual basis of this research and involving what the interviewees said in critical reflections, we refrain from falling prey to bias and show how the various interpretations emerged in this research." For the data collection phase, it was ensured that only individuals with substantial experience in decision making with some form of business domain expertise are interviewed. Even though the interviewees appeared knowledgeable, it is possible that their understating about the value of IT is not an accurate representation of the actual state of affairs.There are several streams of work that can arise from this research. More investigation is required to assess a similar organization for the cross-case analysis. For the cross-case analysis, quantitative data would be collected, and multivariate analytical techniques would be utilized to analyze the data. Further investigation to establish relationships between IT strategy and the value of IT is required. Statistical tests could be performed for each of the paths presented in conceptual mapping between the value of IT and IT strategy objectives rather than basing the relationships merely on arguments.

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Appendices and Annexures

Table 1: Conceptual mapping of emergent themes of perceived values of IT and IT Strategy of MAFI

IT Strategy Objectives	Perceived value of IT		
	Managing risks	Efficiency & Productivity	Product & Services delivery channel
Provide easy access to products and services		S	P
Provide flexible system to implement new product		P	
Automation of manual and paper-intensive process	S	P	
Modernize the technology platform	P	S	S
Implementation of easy-to-use tools for tracking interactions with customer		S	P
Improve measurement and accounting capabilities by upgrading current financial systems	P	S	
Create a balanced approach regarding risks, costs, and benefits in managing risk	P		
Provide reasonable protection against the most likely threats while maintaining continues business	P		
Develop and implement enterprise data backup and recovery solution, consistent with emergent technologies	P		
Provide flexibility to run production systems from multiple sites	P	S	
Develop a comprehensive remote computing solution for business recovery	P	S	
Ensure business continuity plans for managing vendor risks	P		
Identify emerging security risks and develop a plan to mitigate the risks	P		
Develop and maintain the secure, scalable, flexible and reliable technical infrastructure	P	S	S
Develop capabilities for quality IT services including targeted service level agreement and repeatable provisioning processes		P	
Develop a policy to evaluate and use emergent technologies such as cloud		P	S
Implement selected key enterprise architecture processes	S	P	
Explore and implement adaptable and flexible system development framework to reduce development cost and improve time to market delivery		P	
Ensure required resources are assigned to enhance operational excellence		P	
Create capabilities to enable a seamless flow of data through an information supply chain		S	P

Figure 1.0: Perceived value of IT at MAFI

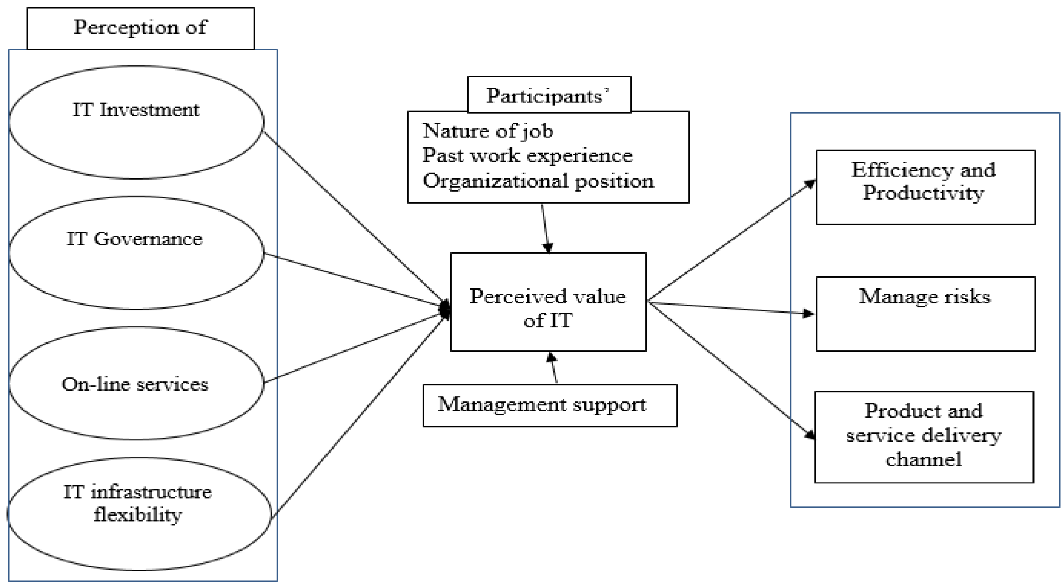
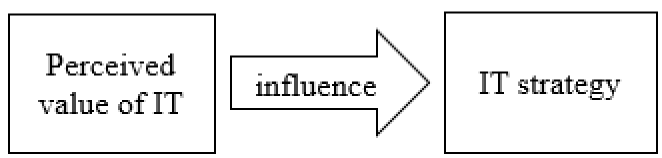


Figure 2.0: Perceived value of IT and IT Strategy



The Internet of Things: Application of Content Analysis to Assess a Contemporary Area of Academic Research

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Abstract

The rate at which new technologies and technological innovations are being introduced and widely disseminated is increasing at an exponential rate. Consequently, technology concepts and topics tend to evolve significantly over time. Therefore, it is important to review, analyze and assess the current state of technology concepts and topics reported in the research literature. The concept coined as the Internet of Things (IoT) in 1999 initially referred to the use of radio frequency identification to send product data over the Internet. Over the next two decades the description of IoT has evolved and greatly expanded. This research project collects, synthesizes, and analyses both the research methodologies and content (e.g., topics, focus, categories) of the academic literature focused on IoT, and then discusses an agenda for future research efforts and opportunities. We conducted a structured literature search and analyzed 214 articles published over the past twenty years (1999-2018) in forty-three top Information Systems (IS) journals listed in the Australian Deans' Business Council's (ABDC) 2019 journal quality list review. We found (1) an increasing level of academic research activity during this 20-year period; (2) a biased distribution of IoT articles focused on exploratory methodologies; (3) several research methods that were underrepresented or completely absent from the pool of research articles; and, (4) identified several topics that need further exploration. The compilation of the methodologies used and IoT topics being studied can serve to motivate researchers to strengthen current research and explore new areas of this research.

Keywords: Internet of Things, Literature Review, Content Analysis

1. INTRODUCTION

The Internet of Things (IoT) can be described as a collection of autonomous devices, sensors, data analytics, artificial intelligence, and communications technologies that will evolve the Internet from an information system (IS) dependent upon humans to assist in the collection, analysis, and storage of data to a system of systems with a marriage of virtual and physical subsystems collectively working, learning, repairing, and improving the IoT's ability to collect data and make the data-driven decisions necessary to improve, learn, and adapt to new environments. The widely varied application of IoT includes continuous improvement of supply chains (Papert and Pflaum, 2017), cities (Hashem, Chang, Anuar, Adewole, Yaqoob, Gani, Ahmed, & Chiroma, 2016), homes (Talbot, Temple, Carbino, & Betances, 2018), autonomous cars (Derikx, de Reuver, & Kroesen, 2016), wearable devices (Liu, Liu, Wan, Kong, & Ning, 2016), and even toys (Brito, Dias, & Oliveira, 2018). There are no uniformly adopted protocols or standards on how the IoT will be built, and therefore the following issues must be addressed: (a) implementing technologies; (b) coordinating secure communication across an unprecedented number of devices in real time; and, (c) protecting the confidentiality, integrity, and availability of data collected via the IoT. The ability to acquire such large quantities of quality data about individual users, hardware, applications, metadata, and the environment through the IoT is a new phenomenon.

With implications as varied as these, a periodic review of the literature can be helpful to assess current research and plan for future research projects to investigate the results of these applications of the IoT to how we live and work. To this end, this paper is designed to be what Palvia, Kakhki, Ghoshal, Uppala, and Wang (2015) would categorize as a literature analysis because this paper critiques, analyzes, and extends existing literature and attempts to build new groundwork. A literature review which analyses the current literature is important to progress the field of IS (Webster & Watson, 2002). A systematic literature review subsequent analysis is difficult for a variety of reasons (vom Brocke, Simons, Riemer, Niehaves, Plattfaut, & Cleven, 2015). First, IS research is a diverse discipline with a variety of reference disciplines and research themes (Benbasat & Weber, 1996). Second, IS research results are created and published at an increasingly higher rate with a more frequent use of multiple authors across a wide variety of knowledge domains (Peffers & Hui, 2003). Third, literature searches can produce unknown results, are notoriously difficulty to plan, are dependent on wildly different research database results, and for these reasons terminating a literature review successfully can be difficult. Finally, while literature reviews are quite common in IS research, no common standards exist for conducting literature reviews (and subsequent analyses), and the nature of methodologies used in cross-disciplinary research studies in IS inhibits the creation and adoption of such strategies (vom Brocke et al., 2015).

Building on the analysis of 127 IoT articles by Whitmore, Agarwal, and Xu (2015) and a co-citation analysis of 68 articles conducted by Ng, Wu, Yung, Ip, & Cheung (2018), this paper attempts to answer the research question: What is the current state of IoT research in the top academic information systems journals? The following sections of the paper will examine the current literature to determine what is known about the concept of the IoT. The remainder of this paper is organized as follows: a description of the methodology for the analysis of the IoT research is presented. This is followed by the results. Finally, the research is summarized with a discussion of the limitations of this project and suggestions for future research.

2. METHODOLOGY

The approach to the analysis of the IoT research is to capture the trends pertaining to (1) the number and distribution of IoT articles published in the leading journals, (2) methodologies employed in IoT research, and (3) the research topics being published in this research. During the analysis of this literature, we attempted to identify gaps and needs in the research and therefore enumerate and discuss a research agenda which allows for the progression of research (Webster & Watson, 2002). In short, we hope to paint a representative landscape of the current IoT literature base in order to influence the direction of future research efforts in this important area of study.

In order to examine the current state of research on IoT, the authors conducted a literature review and analysis in three phases. Phase 1 accumulated a representative pool of articles. Phase 2 classified the articles by research method. Phase 3 classified the research by research topic. Each of the three phases is discussed in the following paragraphs.

Phase 1: Accumulation of Article Pool
We used the Web of Science (WoS) citation database to search for research articles with a focus on IoT. The search parameters were constrained based on (a) a list of top ranked journals, (b) a specific time range, and (c) key search terms. First, the researchers chose to use the Australian Business Dean's Council (ABDC, 2018) ranking of journals because the ABDC is a newer ranking and to avoid the "ethnocentric American perspective" that Palivia et al. (2015) warned was prevalent in many IS journal rankings. Then, we filtered the ranking of journals to include only information systems journals (Code 0806) and collected the list of A* and A journals (see Table 1 in Appendix A). The journals Communications of the ACM and MISQ Executive were dropped from the search parameters due to their practitioner focus.

Kevin Ashton (2009) is credited with for coining the phrase "Internet of Things" during a presentation at Proctor & Gamble in 1999 which described his work as Executive Director of the Auto-ID Center at the Massachusetts Institute of Technology (MIT). The IoT is evolving into a system of systems using such varied technologies as cloud computing, radio frequency identification (RFID), wireless sensor networks (WSN), big data analytics, and an everchanging mix of architectures, protocols, hardware, and applications. Many of these technologies that enable the IoT did not exist prior to the widespread adoption and dissemination of the public Internet and the Worldwide Web (WWW). Therefore, the search parameters were further constrained based on the historical timeframe in which technologies capable of facilitating the development of IoT were first introduced. Therefore, the search parameters for the WoS search was constrained to the time period of January of 1999 through December of 2018.

The final constraint was based on the key search term "Internet of Things." In the WoS search engine scanned for the term 'Internet of Things' and close variations of this term found in the title, abstract, and keywords of articles published in the ABDC information systems' list of A* and A journals between January of 1999 and December of 2018. Once non-research articles (book reviews, editorials, commentary, etc.) were removed, 214 articles remained in the final composite article data pool for analysis. All 214 article files were collected in Adobe Acrobat form and loaded into NVivo 11 to run a word frequency query of the content without numbers and extemporaneous words (i.e. a, and, the, etc.). Figure 1 shows the word cloud that resulted from this query.

Figure 1. Word Cloud from NVivo 11

Phase 2: Classification by Research Methodology
Once the researchers identified the articles for the final data pool, each article was examined and categorized according to its research methodology. Due to the subjective nature of research methodology classification, content analysis methods were used for the categorization process. Figure 2 illustrates steps in the content analysis process adapted from Neuendorf (2017) and successfully employed by several similar research studies (Corley, Jourdan, & Ingram, 2013; Corley, Jourdan, & Rainer, 2011; Cumbie, Jourdan, Peachey, Dugo, & Craighead, 2005; Jourdan, Rainer, & Marshall, 2008). The fourteen research methodologies were adopted from Palvia, Kakhki, Ghoshal, Uppala, and Wang (2015), who extended the research methodologies initially described by Palvia, P., Mao, E., Salam, A.F., and Soliman (2003) and later updated by Palvia, Leary, Mao, Midha, Pinjani, and Salam (2004).

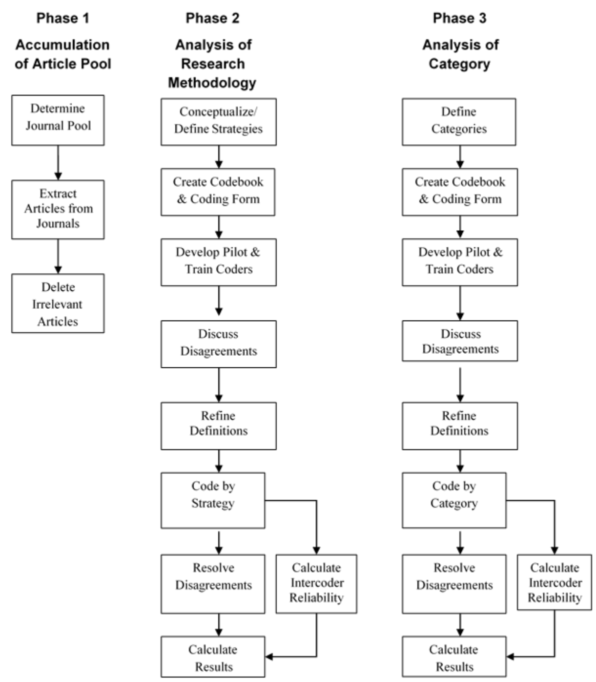

Figure 2. Overview of Literature Analysis Process

Second, to guard against the threats to reliability (Neuendorf, 2017), we performed a pilot test on articles not included in the final data pool for this study. Researchers independently categorized the articles in the pilot test based on the best fit among the fourteen research methodologies. After all articles in the pilot test were categorized, the researchers compared their analyses. In instances where the independent categorizations did not match, the researchers re-evaluated the article collaboratively by reviewing the research methodology definitions, discussing the disagreement thoroughly, and collaboratively assigning the article to a single methodology. This process allowed the researchers to develop a collaborative interpretation of the research methodology definitions. Simply stated, this pilot test served as a training session for accurately categorizing the articles for this study.

Each research methodology is defined by a specific design approach and each is also associated with certain tradeoffs that researchers must make when designing a study. These tradeoffs are inherent flaws that limit the conclusions that can be drawn from a particular research methodology. These tradeoffs refer to three aspects of a study that can vary depending on the research strategy employed. These variable aspects include: generalizability from the sample to the target population (external validity); precision in measurement and control of behavioral variables (internal and construct validity); and the issue of realism of context (Scandura & Williams, 2000).

Two coders independently reviewed and classified each article according to research methodology. The coders categorized only a few articles at a time to minimize coder fatigue and thus protect intercoder reliability (Neuendorf, 2017). Upon completion of the classification process, we tabulated agreements and disagreements. Then, intercoder reliability (κ = .82) using Cohen's Kappa (Cohen, 1960) and Krippendorf's Alpha (Krippendorf, 2013) for each methodology (α = .82) was calculated. Neuendorf (2017) suggests that a Cohen's kappa greater than .800 is considered acceptable. Krippendorf (2013) stated that researchers could use reliability scores greater than .800. Therefore, the calculations for intercoder reliability were well within the acceptable ranges. We calculated the reliability measures prior to discussing disagreements as mandated by Weber (1990). If the original reviewers did not agree on how a particular article was coded, a third reviewer arbitrated the discussion of how the disputed article was to be coded. This process resolved the disputes in all cases.

Phase 3: Categorization by IoT Research Topic

Typically, the process of categorizing research articles by a specific research topic involves an iterative cycle of brainstorming and discussion sessions among the researchers. This iterative process helps to identify common themes within the data pool of articles. Through the collaborative discussions during this process researchers can synthesize a hierarchical structure within the literature of overarching research topics and more granular level subtopics. The final outcome is a better understanding of the current state of a particular stream of research. This iterative process was modified for this specific study on the topic of IoT.

To guard against the threats to reliability (Neuendorf, 2017), we once again performed a pilot test on articles not included in the final data pool for this study. Following the adoption of the six research topic categories, this second pilot study was used as a training session for categorizing articles by research topic. Researchers independently categorized the articles in the pilot test based on the best fit among the six research topics. After all articles in the pilot test were categorized, the researchers compared their analyses. In instances where the independent categorizations did not match the researchers re-evaluated the article collaboratively by reviewing the research category definitions, discussing the disagreement thoroughly, and collaboratively assigning the article to a single category. This process allowed the researchers to develop a collaborative interpretation of the research topic definitions.

Once we established the topic definitions, we independently placed each article in one IoT category. As before, we categorized only a few articles at a time to minimize coder fatigue and thus protect intercoder reliability (Neuendorf, 2017). Upon completion of the classification process, we tabulated agreements and disagreements. Then, intercoder reliability (κ = .84) using Cohen's Kappa (Cohen, 1960) and Krippendorf's Alpha (Krippendorf, 2013) for each topic (α = .84) was calculated. Again, the two calculations were well within the acceptable ranges (Neuendorf, 2017; Krippendorf, 2013). We again calculated the reliability measures prior to discussing disagreements as mandated by Weber (1990). If the original reviewers did not agree on how a particular article was coded, a third reviewer arbitrated the discussion of how the disputed article was to be coded. This process also resolved the disputes in all cases.

3. RESULTS

In order to identify gaps and needs in the research (Webster & Watson, 2002), we hope to paint a representative landscape of the current IoT literature base in order to influence the direction of future research efforts in this important area of study. In order to examine the current state of this research, the authors conducted a literature review and analysis in three phases. Phase 1 accumulated a representative pool of IoT articles, and the articles were then analyzed with respect to year of publication, journal, and author. Phase 2 contains a short discussion of the research methodologies set forth by Palvia et al. (2004) and the results of the classification of the articles by those methodologies. Phase 3 involved the creation and use of six IoT research topics, a short discussion of each topic, and the results of the classification of each article within the research topics. These results are discussed in the following paragraphs.

Results of Phase 1

Using the described search criteria within the selected journals, we collected a total of 214 articles (For the complete list of articles in our sample, see Appendix D). In phase 1, we further analyzed the articles' year of publication, journal, and author. Figure 3 shows the number of articles per year in our sample. There is a dramatically increasing trend over the last five years in the sample. The vast majority (80%) of the articles in the last twenty years have been published in the years 2014 through 2018. With issues related to the Internet of Things becoming ever more important to researchers and practitioners, this comes as no surprise.

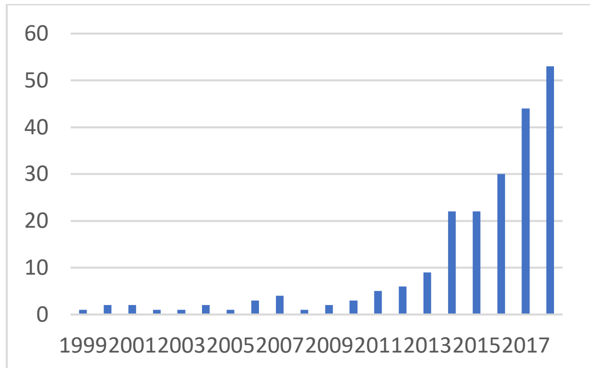

Figure 3. Number of IoT Articles per Year

In addition to number of IoT articles being published per year, we analyzed the productivity of authors who published in this research sample by assigning scores based upon each author's share of each article. Because most articles in our sample were projects with multiple authors, we decided that each co-author would be given an equal share of the credit. For example, an author who published an article alone was assigned a score of 1.0, two authors earned a score of .500 each, and so on. The scores for each author were totaled, the authors were sorted from highest to lowest scores, and the results of the top 49 authors are displayed in Table 2. Authorship order was not calculated into this formula. This system rewards both quantity of research and ownership of research. While the author ranked first (L. D. Xu) had the highest score by sharing in eleven different articles, our second ranked author (N. Kshetri) had two sole-author articles, and the third ranked author (A. J. Jara) had six multi-author articles in this sample. When two or more authors received the same score, their corresponding ranking was a tie. For example, 28-way tie existed for position seven, a 3-way tie for position nine, and a 67-way tie for the rank of twenty.

#	Author	Score
1	**Xu, L. D.**	**2.06**
2	**Kshetri, N.**	**2.00**
3	**Jara, A. J.**	**1.49**
4	**Sun, Y. C.**	**1.33**
5	**Chang, V.**	**1.21**
6	**Sood, S. K.**	**1.08**
7	Adewale, O. S.	1.00
8	Beltran, M.	1.00
9	Best, K.	1.00
10	Bornman, E.	1.00
11	Bruce, H.	1.00
12	Bygstad, B.	1.00
13	Caelli, W. J.	1.00
14	Chmielewski, J.	1.00
15	Das, S.	1.00
16	Eachempati, P.	1.00
17	Frost, C.	1.00
18	Furnell, S.	1.00
19	Hale, T. M.	1.00
20	Hawryszkiewycz, I. T.	1.00
21	Jennex, M. E.	1.00
22	Khazanchi, D.	1.00
23	Kim, B. W.	1.00
24	Krawczyk, B.	1.00
25	Kuhn, E.	1.00
26	Lee, C. S.	1.00
27	Palmer, C. C.	1.00
28	Papsdorf, C.	1.00
29	Prasopoulou, E.	1.00
30	Shepherd, S. J.	1.00
31	Shin, D. H.	1.00
32	Veith, R. H.	1.00
33	Weber, T. A.	1.00
34	Zhu, D. J.	1.00
35	**He, W.**	**0.84**
36	**Barrett, M.**	**0.83**
37	**Skarmeta, A. F.**	**0.83**
38	**Zamora, M. A.**	**0.83**
39	**Sheng, Z. Q.**	**0.82**
40	**Zheng, L. R.**	**0.79**
41	**Manaa, M.**	**0.75**
42	**Bi, Z. M.**	**0.73**
43	**Chen, X.**	**0.67**
44	**Wang, J. P.**	**0.66**
45	**Zhou, Z. B.**	**0.62**
46	**Zhang, J. S.**	**0.58**
47	**Chen, Q.**	**0.55**
48	**Pang Z. B.**	**0.52**
	*** Bold = Multiple Articles**	

Table 2. Authors Ranked by Score

Results of Phase 2
The results of the categorization of the 214 articles in the sample published over the twenty-year period from January of 1999 to December of 2018 categorized with respect to the fourteen research methodologies described by Palvia et al. (2004) are summarized in Table 3 [See Appendix B]. Of the 214 articles, 71 articles (33.2%) were classified as Frameworks and Conceptual Model making it the most prevalent research methodology. This was followed by Mathematical Modelling with 43 articles (or 20.1%), Laboratory Experiment with 21 articles (9.8%), and Speculation/Commentary with 15 articles (7.0%). Case Study and Secondary Data tied at 13 articles each (6.1%). These six research methodologies composed 82.3% of the articles in the sample. No articles were classified as a Literature Reviews or Content Analysis. So, the remaining six research methodologies represented the remaining 17.7% of the sample with respect to research methodology.

Further analysis showing the research methodologies illustrates that Case Study, Interview, Field Experiment, and Field Study are poorly represented methodologies in this research sample. These four methodologies have a high degree of realism because the data is collected from individuals or organizations, and the low percentages of these research methodologies indicate the beginnings of a body of research (Scandura & Williams, 2000). Further categorization and analysis of the articles with respect to IoT topic categories was conducted in the third phase of this research project.

Results of Phase 3
Table 4 shows the number of articles per IoT research topic category. These six categories provided a topic area classification for all the 214 articles in our research sample. Of the 214 articles, 43.0% were classified as 'Architecture' making it the most prevalent IoT topic category. This category was followed by 'Applications' (21.5%), 'Privacy and Security' (20.1%), and 'Users" (8.9%). These four IoT topics accounted for 93.5% of the articles in the sample. The topics "Business Models' (3.7%) and 'Research' (2.8%) accounted for a very small percentage of the research. The high percentage of articles focused on the building phases of IoT (Architecture) indicates the IoT is still in the designing and build phase, and we could be years away from what the completely autonomous IoT world envisioned by futurists. The evidence that IoT technologies are being deployed in a variety of industries is indicated by the Application category which describes how these technologies are being used now by organizations in a variety of industries.

Research Topics	Key Concepts	IoT Articles	%
Applications	Using IoT in real-world implementations	46	21.5%
Architecture	How IoT is built and manages itself, hardware, organization of hardware, sensor networks, algorithms	92	43.0%
Business Models	Business methods using IoT technologies	8	3.7%
Privacy and Security	Privacy issues, security of IoT networks, secure communications among IoT devices	43	20.1%
Research	Research on information systems as a discipline	6	2.8%
Users	Issues related to users (examples: digital divide, intention to use, usage behavior, etc.)	19	8.9%
	Total:	**214**	**100.0%**

Table 4. Topics in IoT Research

By plotting IoT research topics against research methodologies (Table 5 – See Appendix C), many of the gaps in IoT research are exposed. The gaps are at the intersection of less used methodologies and less studied domains in IoT. In our minds, these gaps exist for two reasons. First, some of these research methodologies are not as prevalent in IS research, and some top IS journals do not accept papers that use unusual research methodologies. So, researchers avoid unorthodox methodologies. The reason that some of these IoT topics have not been studied is they represent a relatively new phenomena, the research has not caught up with the business reality, and it is difficult to find organizations who have data on their new IoT deployment even if those organizations were open to being studied. The great news for researchers interested in IoT is that this domain should provide research opportunities for years to come.

4. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The current analysis of the IoT literature is not without limitations and should be offset with future efforts. Future literature collections could expand article searches to search a broader range of research outlets (including B journals from the ABDC list) and include other IoT related search terms. Our literature analysis is meant to serve as a representative sample of articles and not a comprehensive and exhaustive analysis of the entire population of articles published on the topic of 'Internet of Things'. Future studies could explore the various architectural components used in these systems of systems and investigate how organizations are applying the IoT technologies and measure the results from an organizational perspective. As more firms deploy these technologies, new business models will emerge and will need description and measurement. As privacy and security threats emerge and countermeasures are developed, these too will need to be explored in the IS research. This IoT will operate on a global scale and will likely disrupt information ownership, economic systems, political power, and how humans exist in ways that can only be imagined in the same way our society knew the implications of the Internet as it was being implemented a generation ago.

Clearly, future studies should consider the identified gaps and consider developing future research projects using a variety of research methodologies across the six IoT research topics. Future efforts could consider applying methodologies across the six IoT topics and vice versa because this research domain is still in a very exploratory stage. This research sample analyzed showed much of the research the new technologies and issues in the IoT research without attempting to explain the fundamental issues of IS research. This is to be expected in the exploratory stages of research in a subject area. This absence of coordinated theory development causes the research in IoT to appear haphazard and unfocused as a knowledge stream and not speaking to any individual research project. The good news is that many of the topics and methodologies in this research are open for future development. We hope that this literature analysis has laid the foundation for such efforts that will enhance the IS body of knowledge and theoretical progression relative to the IoT.

5. CONCLUSIONS

This research study collects, synthesizes, and analyses both the research methodologies and content (e.g., topics, focus, categories) of 214 articles published over the past twenty years (1999-2018) in forty-three top Information Systems (IS) journals as ranked by the Australian Deans' Business Council. Over the twenty-year period from 1999 to 2018 we found a significant increase in the number of IoT articles published each year beginning in 2014 with a biased distribution of IoT articles focused on exploratory methodologies. Specifically, 33.2% of the IoT research articles in our sample were categorized as Frameworks and Conceptual Model making it the most prevalent research methodology. This was followed by Mathematical Modelling at 20.1%, Laboratory Experiment at 9.8%, Speculation/Commentary at 7.0%, and both Case Study and Secondary Data tied with 6.1%. These six research methodologies composed 82.3% of the articles in the sample.

We also found several research methods that were either underrepresented or absent from the pool of research. First, we would like to highlight the fact that no articles were categorized as a Literature Reviews or Content Analysis. Therefore, our research current study represents a significant contribution to the field of IoT research. The remaining six research methodologies combined (literature analysis, survey, field study, field experiment, qualitative research, and interview) represented the remaining 17.7% of the sample with respect to research methodology. This biased towards exploratory research methods typically occurs when researchers are investigating a new phenomenon.

We identified several topics that need further exploration. More specifically, of the 214 articles, 43.0% were classified as 'Architecture' making it the most prevalent IoT topic category. This category was followed by 'Applications' at 21.5%, 'Privacy and Security' at 20.1%, and 'Users" at 8.9%. These four IoT topics accounted for 93.5% of the articles in the sample. The topics "Business Models' (3.7%) and 'Research' (2.8%) accounted for a very small percentage of the research. The high percentage of articles focused on the building phases of IoT (Architecture) indicates the IoT is still in the designing and build phase, and we could be years away from what the completely autonomous IoT world envisioned by futurists. The compilation of the methodologies used and IoT topics being studied can serve to motivate researchers to strengthen current research and explore new areas of this research.

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Editor's Note:

This paper was selected for inclusion in the journal as the CONISAR 2020 Best Paper The acceptance rate is typically 2% for this category of paper based on blind reviews from six or more peers including three or more former best papers authors who did not submit a paper in 2020.

Appendix A – Table 1

Rating	Journal	Abbreviation	Count	%
A*	ACM Transactions on Computer-Human Interaction	ACMTCHI	8	3.7%
A*	Decision Support Systems	DSS	8	3.7%
A*	European Journal of Information Systems	EJIS	3	1.4%
A*	Information & Management	I&M	3	1.4%
A*	Information and Organization	I&O	1	0.5%
A*	Information Systems Journal	ISJ	0	0.0%
A*	Information Systems Research	ISR	2	0.9%
A*	Journal of Information Technology	JIT	2	0.9%
A*	Journal of Management Information Systems	JMIS	1	0.5%
A*	Journal of Strategic Information Systems	JSIS	0	0.0%
A*	Journal of the Association for Information Systems	JAIS	2	0.9%
A*	MIS Quarterly	MISQ	1	0.5%
A	Applied Ontology	AO	2	0.9%
A	Australasian Journal of Information Systems	AJIS	1	0.5%
A	Behavior & Information Technology	B&IT	4	1.9%
A	British Journal of Educational Technology	BJET	1	0.5%
A	Business & Information Systems Engineering	B&ISE	1	0.5%
A	Communications of the ACM #	CACM	0	0.0%
A	Communications of the Association for Information Systems	CAIS	2	0.9%
A	Computers & Security	CS	26	12.1%
A	Data & Knowledge Engineering	D&KE	6	2.8%
A	Data Base for Advances in Information Systems	DBAIS	2	0.9%
A	Electronic Commerce Research	ECR	2	0.9%
A	Electronic Markets	EM	3	1.4%
A	Enterprise Information Systems	EIS	17	7.9%
A	IBM Systems Journal	IBMSJ	1	0.5%
A	Information and Software Technology	I&ST	1	0.5%
A	Information Communication & Society	IC&S	4	1.9%
A	Information Systems Frontiers	ISF	22	10.3%
A	Information Technology & People	IT&P	1	0.5%
A	International Journal of Cooperative Information Systems	IJCIS	1	0.5%
A	International Journal of Information Management	IJIM	9	4.2%
A	International Journal of Medical Informatics	IJMI	2	0.9%
A	Internet Research-Electronic Networking Applications and Policy	IRENA&P	2	0.9%
A	Journal of Computer Information Systems	JCIS	2	0.9%
A	Journal of Global Information Management	JGIM	3	1.4%
A	Journal of Knowledge Management	JKM	1	0.5%
A	Journal of Organizational Computing and Electronic Commerce	JOC&EC	4	1.9%

A	Journal of the American Medical Informatics Association	JAMIA	2	0.9%
A	Journal of the American Society for Information Science and Technology	JASIS&T	2	0.9%
A	Journal of the Association for Information Science and Technology	JAIS&T	1	0.5%
A	Knowledge-Based Systems	KBS	6	2.8%
A	MIS Quarterly Executive #	MISQE	0	0.0%
A	Personal and Ubiquitous Computing	P&UC	48	22.4%
A	The Information Society	IS	4	1.9%
		Total:	**214**	**100.0 %**

Table 1. A* and A Journals from ABDC and Number of Articles

Appendix B – Table 3

Methodology	Definition	IoT Articles	%
Speculation/Commentary	Research that derives from thinly supported arguments or opinions with little or no empirical evidence.	15	7.0%
Frameworks and Conceptual Model	Research that intends to develop a framework or a conceptual model.	71	33.2%
Literature Review	Research that is based mainly on the review of existing literature.	0	0.0%
Literature Analysis	Research that critiques, analyzes, and extends existing literature and attempts to build new groundwork, e.g., it includes meta-analysis.	4	1.9%
Case Study	Study of a single phenomenon (e.g., an application, a technology, a decision) in an organization over a logical time frame.	13	6.1%
Survey	Research that uses predefined and structured questionnaires to capture data from individuals. Normally, the questionnaires are mailed (now, fax and electronic means are also used).	12	5.6%
Field Study	Study of single or multiple and related processes/ phenomena in single or multiple organizations.	2	0.9%
Field Experiment	Research in organizational setting that manipulates and controls the various experimental variables and subjects.	5	2.3%
Laboratory Experiment	Research in a simulated laboratory environment that manipulates and controls the various experimental variables and subjects.	21	9.8%
Mathematical Modelling	An analytical (e.g., formulaic, econometric or optimization model) or a descriptive (e.g., simulation) model is developed for the phenomenon under study.	43	20.1%
Qualitative Research	Qualitative research methods are designed to help understand people and the social and cultural contexts within which they live. These methods include ethnography, action research, case research, interpretive studies, and examination of documents and texts.	7	3.3%
Interview	Research in which information is obtained by asking respondents questions directly. The questions may be loosely defined, and the responses may be open-ended.	8	3.7%
Secondary Data	A study that utilizes existing organizational and business data, e.g., financial and accounting reports, archival data, published statistics, etc.	13	6.1%
Content Analysis	A method of analysis in which text (notes) are systematically examined by identifying and grouping themes and coding, classifying and developing categories.	0	0.0%
	Total:	**214**	**100.0%**

Table 3. Methodologies in IoT Research (from Palvia et al., 2004)

Appendix C – Table 5

Methodology	IoT Topics 1	2	3	4	5	6	Total	%
Speculation/Commentary	3	4		5	2	1	**15**	**7.0%**
Frameworks and Conceptual Model	14	37	5	15			**71**	**33.2%**
Literature Review							**0**	**0.0%**
Literature Analysis		1	1		2		**4**	**1.9%**
Case Study	10	2			1		**13**	**6.1%**
Survey	1	3	1	1		6	**12**	**5.6%**
Field Study	2						**2**	**0.9%**
Field Experiment	3	2					**5**	**2.3%**
Laboratory Experiment	1	11		8		1	**21**	**9.8%**
Mathematical Modelling	8	23	1	10		1	**43**	**20.1%**
Qualitative Research	1	3		1	1	1	**7**	**3.3%**
Interview		1		1		6	**8**	**3.7%**
Secondary Data	3	5		2		3	**13**	**6.1%**
Content Analysis							**0**	**0.0%**
Total	**46**	**92**	**8**	**43**	**6**	**19**	**214**	**100.0%**
Percentage	**21.5%**	**43.0%**	**3.7%**	**20.1%**	**2.8%**	**8.9%**	**100.0%**	

1=Applications
2=Architecture
3=Business Models
4=Privacy and Security
5=Research
6=Users

Table 5. Research Methodologies vs. Topics in IoT Research

Appendix D – Data Sample (214 IoT Articles)

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Exploring Sentiment Towards Contact Tracing

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Abstract

In the midst of COVID-19, contract tracing systems are an important tool for governments around the world to control and track the spread of the disease. However, contract tracing requires pubic acceptance and cooperation to be effective. This study provides an overview of contact tracing, including a review of literature and potential privacy concerns that have been identified. In order to measure public sentiment towards contact tracing, over 50,000 Twitter posts (tweets) across a three-month time frame in April, May, and June of 2020 were gathered. Using established sentiment analysis models (Bing, AFinn, and NRC), it was found that sentiment towards the term "contact tracing" became more negative across the time frame and that words associated with the emotion categories of "Anticipation", "Fear", and "Trust" were most prevalent. We also found that retweeted posts have an important impact on the results and that anecdotal examination of specific tweets shows polarizing views on the subject. This study has limitations due to the potential biases of Twitter posts and the potential inaccuracies of sentiment analysis models. Future research could expand on contract tracing research by studying the topic empirically or by examining case studies on specific systems.

Keywords: Contact Tracing, Sentiment Analysis, Privacy, COVID-19, Twitter.

1. INTRODUCTION

Epidemic diseases such as COVID-19, SARS-CoV2 and Ebola have spread worldwide over the past decade. In addition to the various measures (social distancing, wearing masks, shelter in place, vaccine development) to control the growing global health threat from COVID-19, large-scale testing plus *contact tracing* for those who test positive is beginning to be used by public health organizations. Tracking people who may have come in contact with an infected individual can limit the spread of a virus and help to understand how the virus is spreading. With contact tracing, an infected individual is required to share all of his or her travel details with the health care authorities to reliably track and quarantine people who could contract an illness due to one's own physical connection with the infected person (World Health Organization, 2014).

As a contact tracing system requires participation and cooperation to be successful, it is important to understand the sentiment that prospective users feel towards these systems. This study provides a background and literature review of contact tracing systems and the privacy concerns that may arise. Sentiment towards the term "contact tracing" was examined by using extracted Twitter posts across the timeframe of April, May, and June 2020. This time frame was when contact tracing became widely known in the United States and Europe. The sentiment analysis includes three widely used models: Afinn Model (Nielsen, 2011), Bing Model (Bing, Chan, Ou, 2014), and NRC Model (Kiritchenko, Zhu, Cherry and Mohammad, 2014). These were used to analyze the positive or negative sentiment of the words used and the relative percentage of words used in eight different emotional categories.

2. BACKGROUND AND LITERATURE REVIEW

Contact Tracing and Virus tracking

COVID-19 is infecting millions of people and the spread is mainly through person-to-person contact. A group of scientists (Ferretti, Wymant, Kendall, Zhao, Nurtay, Abeler-Domer, Parker, Bonsall, and Fraser, 2020) examined some key parameters involved with the epidemic spread of the COVID virus in order to estimate the contribution of different transmission routes. They found that it predominately spread through personal contact. This being the case, contact tracing would be a way to follow the spread of this and any future virus since it would build a database of proximity contacts. This database could be used to immediately notify people of positive cases with whom they might have come in contact. Thus, helping to control and maybe stop an epidemic. The general notion is that by targeting health sanctions to only those at risk, epidemics could be contained without the need for massive quarantines that can be harmful to the overall social and business environment. The World Health Director-General said at the WHO meeting in March, 2020 (World Health Organization, 2020), "You cannot fight a fire blindfolded. And we cannot stop this pandemic if we don't know who is infected."

Until a vaccine becomes available, the only way to prevent the spread of the disease is to control the spread. Strict social distancing measures are necessary, but difficult to enforce for extended periods of time. The only way to return to a normal life is to keep the spread under control and with active tracing this can happen. The World Health Organization recommends a combination of rapid diagnosis along with immediate isolation and then rigorous contact tracing. A well-designed contact tracing database is needed (World Health Organization, 2020).

This database can be built by digital means such as with the use of smartphone apps and manually with person-to-person contact tracing and reporting. Contact tracing has a history of being a central public health response to infectious disease outbreaks especially in the early stages when specific treatments are limited or unknown (Keeling, Hollingworth and Read, 2020). The manual tracing previously being used for epidemics is slow and difficult to manage a global pandemic such as CoVID-19 so computer applications will be needed to automate a more successful viral tracing and alert system.

With contact tracing, regardless of process, comes the required collection of privacy-intrusive information such as GPS locations, the logging of privacy-sensitive data on a third-party server, or required additional infrastructures such as Wi-Fi Apps with known locations (Hekmati, Ramachandran and Krishnamachari, 2020). Since the contact tracing process involves gathering private and sensitive data, individuals might push back on sharing that data which would hamper the tracing process and therefore expose more people to the virus.

In order to avoid push back from individuals, ethical measures need to be considered with this personal tracing. Researchers from the University of Southern California (Hekmati et al., 2020) examined a number of mobile applications, with wireless technologies and GPS locators but these involve unreliable self-reporting or relying on external trackers which make privacy-savvy people nervous and usually less cooperative. Besides individuals being hesitant to share personal data, there are also laws that can stop or slow down tracing collection. During an outbreak of measles on three international flights to Germany in 2017 (Thole, Kalhoefer, der Heiden, Nordmann, Daniels-Haardt and Jurke, 2019) contact tracing was substantially delayed due to an interpretation of Germany's data protection act. The Public Health Authority had to wait a week to notify Health officials in various international countries who then could notify the passengers of the Measles exposure, which meant that measles had spread among those whom passengers contacted.

Knowing that only a vaccine or contact tracing can control this pandemic technology, governments across the world along with health authorities are working together to find solutions to stop this COVID-19 pandemic. Technology developers are crafting technical tools to help with tracing. Google and Apple have a joint effort to enable the use of Bluetooth technology to help governments and health agencies reduce the spread of the virus, with user privacy and security central to the design (Sainz, 2020).

Privacy Concerns

Maintaining a sense of user privacy is an essential requirement for people involved with contact tracing. A study by Taewoon Nam (2019) discussed how expansion of government surveillance capacities through information and communication technologies (ICT) has grown over the past two decades because of 9/11 and the passage of anti-terrorism laws and with the upsurge of ICTs and the consequential increase of the capability to conduct monitoring. Americans, in particular, are now more aware of government surveillance after the revelations from Edward Snowden, a contractor for the National Security Agency (NSA). Mass media have been reporting on state surveillance since Snowden's exposure of PRISM in June 2013 (Preibusch, 2015). PRISM is a tool used by the US National Security Agency (NSA) to collect private electronic data belonging to users of major internet services like Gmail, Facebook, Outlook, and others. It's the latest evolution of the US government's post-9/11 electronic surveillance efforts, which began under President Bush with the Patriot Act, and expanded to include the Foreign Intelligence Surveillance Act (FISA) enacted in 2006 and 2007.

When it comes to who people trust, Sabin of *Morning Consult* (April 27, 2020) reported results from a survey of 2,200 U.S. adults and found the majority of people trust researchers (55%) and agencies (54%) more with building an effective COVID-19 tracking app than tech companies (41%). In addition, the survey reported that 59% of the public is also at least somewhat uncomfortable with having tech companies share their location with the government to map a viral outbreak.

Government officials in Washington, D. C. have started acting to build privacy safeguards for the new tracking technologies. Sen. Ed Markey (D-Massachusetts) laid out guidelines for establishing a national contact-tracing system, which would call for transparency about what information is collected, voluntary participation and thorough data security processes. Sen. Josh Hawley (R-Missouri) requested Apple Chief Executive Tim Cook and Google Chief Executive Sundar Pichai to take personal responsibility for protecting the data collected by their contact-tracing system. (Sabin, 2020).

Apple and Google (April, 2020) created a collaboration to create a protocol to maintain privacy in contact tracing. The protocol includes the following:

- The Exposure Notification Bluetooth Specification does not use location for proximity detection. It strictly uses Bluetooth beaconing to detect proximity.
- A user's Rolling Proximity Identifier changes on average every 15 minutes, and needs the Temporary Exposure Key to be correlated to a contact. This behavior reduces the risk of privacy loss from broadcasting the identifiers.
- Proximity identifiers obtained from other devices are processed exclusively on device.
- Users decide whether to contribute to exposure notification.
- If diagnosed with COVID-19, users must provide their consent to share Diagnosis Keys with the server.
- Users have transparency into their participation in exposure notification.

Interest in Contact Tracing

As the COVID-19 virus began to spread rapidly in parts of the United States, there were several terms that became a regular part of the public's vocabulary. As shown in Figure 1, interest in "contact tracing" as a Google search term became increasingly popular during the month of May 2020. While a portion of the search interest could derive from job searches related to the term, as shown in Figure 2, interest in the term itself exceeds that of "contact tracing jobs".

Figure 1: Google Search Interest in Contact Tracing

Another way to demonstrate the increased interest in contact tracing is to compare it with another, unrelated search term that was also part of the COVID-19 vocabulary. Figure 3 shows that searches for "herd immunity" were initially higher than those of "contact tracing" but that interest in contact tracing rose comparatively during the month of May. These charts show that the term was just recently become popular which demonstrates the importance of the topic but also serves as a caveat that understanding of the impact of the term may not be well established.

Figure 2: Google Search Interest in Contact Tracing vs Contact Tracing Jobs

Figure 3: Google Search Interest in Contact Tracing vs Herd Immunity

3. METHODOLOGY AND RESEARCH QUESTIONS

Sentiment analysis refers to the use of natural language processing, text analysis, computational linguistics, and biometrics to systematically identify, extract, quantify, and study affective states and subjective information. Over the past two decades, various models have been developed and tested to systematically evaluate words to quantify the extent to which a string of text is positive or negative and to quantify the emotions that are expressed in the text. Sentiment analyses have been widely applied to customer reviews, qualitative survey responses, social media, and healthcare materials for applications that range from marketing to customer service to clinical medicine and other fields of study. For example, one such study demonstrated how the analysis of Twitter sentiment was closely correlated to a Gallup poll of public opinion (O'Connor, Balasubramanyan, Routledge, 2010). Another study showed how the moods depicted in tweets can predict stock market trends (Bollen, Mao, and Zeng, 2011).

In this study, three different models of analyzing sentiment were utilized. The AFinn lexicon is a list of English terms rated for valence with an integer between -5 (negative) and +5 (positive). The model was developed by Finn Årup Nielsen between 2009 and 2011 (Nielsen, 2011). The Bing index (Liu, Hu and Cheng, 2005) is a binary model that assigns words as positive or negative. Applied to Twitter entries, each word in a tweet string is tabulated to determine the net positive or negative score. The NRC lexicon (Kiritchenko, et. al, 2014) is an effort coordinated by the National Research Council of Canada. Its model categorizes English words in alignment with eight emotions: anger, anticipation, disgust, fear, joy, sadness, surprise, and trust. When applied to Twitter entries, each tweet's word count for each emotion is tabulated. The emotions are then compared to a total to determine the relative percentage of each emotion that is found in the set of extracted tweets.

To search and extract the keywords "contract tracing" into a dataset, first, a development account on Twitter that provides access to an open API was requested. This development account on Twitter provided access to an open API. Next, an R script that installs an open source application (R-Tweet) was used with its corresponding library to extract all tweets associated with the search term. The code also saved the search results in a csv format that could then be opened in Excel or read by a programming language to score the tweets in accordance with the sentiment models. The resulting csv file contained all of the tweets, along with the user name and various other attributes, including the number of times that the tweet had been retweeted. Next, a macro enabled Excel file with embedded VBA code was used. This computed the results for the set of tweets in accordance with the three sentiment analysis models presented earlier in this paper (AFinn, Bing, and NRC).

Sentiment analyses can be flawed, especially when small sample sizes are used. The models are not able to capture the context or nuances of the words used and thus can misclassify a particular tweet. However, in large data sets, these individual errors in classification are offset by the greater number of classifications that accurately represent the emotions or positivity/negativity of the tweets. For each of the three dates in the April to June 2020 time frame, a minimum of 12,000 tweets that contained the term "contact tracing" were extracted.

Clearly, an analysis using Twitter data does not necessarily represent a universal perspective on a topic. There is an inherent non-response bias and likely polarizing views expressed, especially on a topic such as contract tracing that can have political or privacy implications. There is also a limitaton by the language, as only English tweets were extracted. The United States has the most Twitter users with over 64 million accounts as of April 2020 (Statista, 2020). However, this is followed by Japan with over 46 million accounts and by other countries whose perspectives are not captured in this analysis. To further complicate the analysis, it is very common for users (or even automated bots) to retweet particular messages. Because these retweets can have a significant impact on the overall results of a sentiment analysis, it is important to examine these effects. At the same time, the retweets are an important source of data on a topic, so one cannot simply delete the duplicate tweets and ignore the impact on the sentiment surrounding contact tracing. In this study, the results of the sentiment analysis is shared along with raw data (that includes retweets) as well as an analysis of unique tweets with all duplicates removed. In order to examine retweets more closely, the text of the most commonly retweeted entries is published in this study. Lastly, in order to illustrate perspectives on contact tracing, anecdotal examples that depict differing views as reflected in the results is included.

Research Questions
As a result of the preceding discussion, this study examines the following research questions:

1. What is the average sentiment score for tweets that contain "contact tracing" (including all retweets), using the AFinn and Bing models during the months of April, May, and June of 2020? How have the positive or negative scores changed during the time frame?
2. What are the average percent of each emotion score for "contact tracing" tweets using the NRC model during the months of April, May, and June of 2020? How have the scores for each emotion changed during the time frame?
3. How do the preceding scores for each model differ if only unique tweets are examined?
4. What are the most frequent retweets for the each of the three data sets and how do they impact the sentiment scores?
5. What are representative tweets that depict positive or negative perspectives and particular emotions on contact tracing?

4. FINDINGS

Research Question 1: Positive and Negative sentiment towards "contact tracing" tweets using AFinn and Bing models (including retweets)
As shown in Figure 4, the average AFinn score for tweets (including retweets) that contained the term "contact tracing" were initially positive in April of 2020 with an average of .28. The average AFinn score became negative in May with average of -.10 and fell much further in June with an average of -.54. The Bing scores followed a similar pattern, although with higher averages across the time span (with averages of .76, .22, and -.29 for April, May, and June respectively).

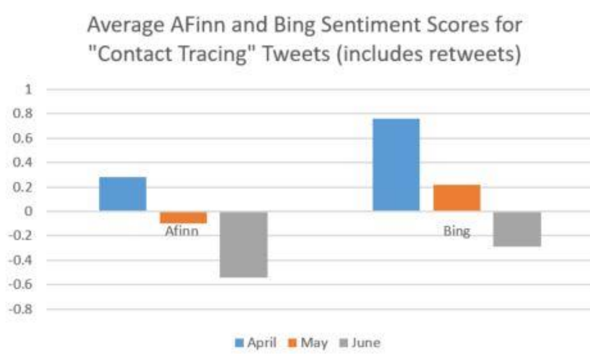

Figure 4: AFinn and Bing Sentiment Analysis for Contact Tracing April, May, June 2020

Research Question 2: Emotional words used in "contact tracing" tweets using NRC sentiment model (including retweets).
As shown in Figure 5, words classified in the "Anticipation", "Fear", and "Trust" categories were most prevalent in the April dataset with 21%, 19% and 22% of the share of the words that were able to be categorized. In May, there was an increase in "Disgust" from 5% to 9% and "Surprise" from 4% to 9% along with modest declines in "Anticipation" to 17% and "Fear" to 14%. In June, there was a sharp rise in the "Anticipation" category to 32% and "Anger" to 15% (from 9% and 10% in April and May). Much of these differences can be explained by

the metrics from the mostly commonly retweeted items in the June dataset.

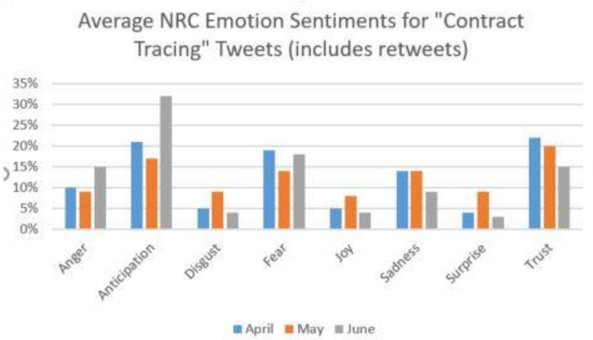

Figure 5: NRC Sentiment Analysis Emotions for Contact Tracing April, May, June 2020

Research Question 3: Differences in results from AFinn, Bing, NRC sentiment scores when only unique tweets are used.

For the same data sets, but retweets removed, as shown in Figure 6, one can see a similar pattern of declining sentiment in the AFinn and Bing scores but with much less volatility in ranges. The AFinn averages fell from .15 to .06 to -.06 across the time frame while the Bing averages fell from .26 to .22 to .13. As a result, once can conclude that the sentiment towards contact tracing became more negative as the popularity of the term became more widespread. However, the magnitude of the decline is impacted by retweets. In the examination of the NRC emotions, comparing the results shown in Figure 5 with those of Figure 7, one can see that the percentages of words classified in each emotional category are much more consistent across the time frame when the dataset includes only unique tweets. As a result, the emotion scores, particularly from June, are impacted to a great extent by the words used in retweets.

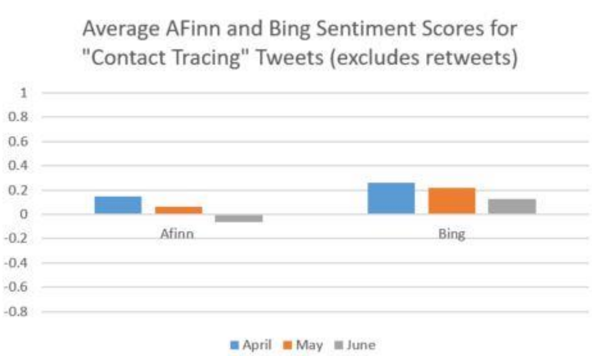

Figure 6: AFinn and Bing Sentiment Analysis for Contact Tracing April, May, June 2020 (excludes retweets)

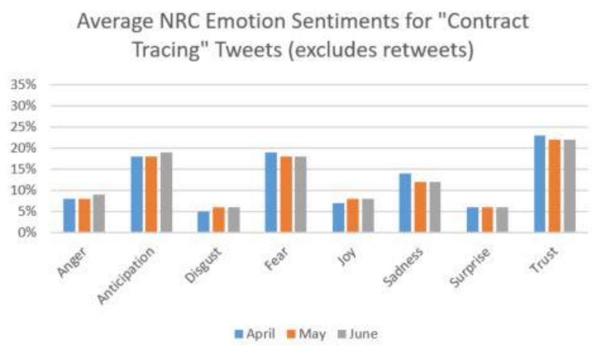

Figure 7: NRC Sentiment Analysis Emotions for Contact Tracing April, May, June 2020 (excludes retweets)

Research Question 4: Most frequent retweets for the each of the three data sets and impact on sentiment score.

In the April dataset, the following entry appeared 1404 times, representing approximately 8% of the tweets: "*Democrats are fighting for our $30 billion plan for a comprehensive national testing strategy. A major new investment that includes bolstering the supply and manufacturing chain, significantly expanding free testing for all, and expanding reporting and contact tracing."* This tweet has a positive AFinn score of 1.5 and Bing score of 2. Interestingly its words are only classified as a 1 in the "Anger" category and a 1 in the "Anticipation" category.

In the May dataset, the following entry appeared 850 times, representing approximately 7% of the tweets*: "Doctors don't think it's safe for schools to re-open. Countries with lower death tolls than ours don't think it's safe for schools to re-open. We don't even have our testing and contact-tracing system set up yet. Why are the govt pushing for something they haven't prepared for?"*. Despite the pessimistic tone to this tweet, the word classifications for AFinn and Bing are actually positive with values of .25 and 2 respectively. The tweet includes words for each of the NRC emotion categories, with 4 words in the "Trust" category, two in the "Anger", "Sadness", and "Joy" categories (one in the other four categories).

In the June dataset, there were two tweets that had a major impact on the sentiment results. The following entry appeared 3154 times, accounting for 26% of the tweets: "*We are paying 45 million pound to Serco for contact tracing. Serco's 18000 call handlers contacted only 10,000 contacts in two weeks. Meanwhile local public health teams contacted 77600 contacts ie almost eight times more according to*

DHSC Test and Track data.". This tweet was actually neutral in the AFinn and Bing scores so it did not affect the overall average decline in those averages for June. However, the quote does have scores of 2 for "Anticipation" and 1 for "Anger" which would explain much of the increases in those averages for month. June also had a tweet that appeared 1843 times, accounting for over 15% of the entries. This tweet: *"Contact tracing: FAIL. Herd immunity: FAIL. PPE: FAIL. Testing: FAIL.Lockdown: FAIL. Care homes: FAIL. Contact tracing, again: FAIL. This government has presided over a serious of failures so catastrophic that it should trigger an overhaul of how things are run in this country*" results in scores of -3 for AFinn and -2 for Bing for each entry, which would have a significant impact on the overall decline in those averages in June. The quote also has an emotion score of 1 in the "Fear" category.

These frequently retweeted quotes should not be ignored (since they would appear in the Twitter feeds and may represent legitimate perspectives on contact tracing), however, the conclusions should be tempered by understanding the potential disparate impact they may have on the overall findings.

Research Question 5: Tweets that depict positive or negative perspectives and particular emotions on contact tracing.

Within the framework of the sentiment analysis models, it is useful to examine polarizing views on contact tracing by examining anecdotal tweets from the data. These quotes show reactions that represent varying levels of support for and against contact tracing systems.

The following quotes represent positive scores from the AFinn and Bing models:

- *"In the absence of a prove. antiviral therapy and a viable vaccine, extensive contact tracing and testing is our best defense. the epidemiologist in me is delighted. HOWEVER COMMA...."* (+3 AFinn)
- *"Japan's official contact-tracing app is out for iOS now. I wonder how much traction this will gain. Hopefully enough to be effective."* (+5 Bing)

The following quotes represent negative scores from the AFinn and Bing models:

- *"Wait the government has f***ed off contact tracing?! At what point can you take a Government to court for negligence and manslaughter?"* (-4 AFinn)
- *"Seriously, why does LEFT seem excited/almost giddy about: -Declarations of Systemic Racism, Police brutality, broken justice system -Spending into bankruptcy -Contact Tracing ?? We HAD a beautiful country of strength & independence. FREEDOM TO THINK/TO BE IS SLOWLY DYING IN CANADA"* (-2 Bing)

The following quotes represent specific word classifications from the NRC emotions model:

- *"They promised a 'World Beating Track and Trace System' on 1st June - more lies from this dishonest and incompetent Government that have had fatal results. UK abandons contact-tracing app for Apple and Google model"* (+4 "Anger")
- *"HUGE win! Government to ditch "world-beating", GCHQ-backed, data-centralising contact tracing app that we warned was a failure from the start - & replace it with a decentralised app. How much precious time was wasted How much public money was wasted"* (+6 "Anticipation")
- *"#DP3T entered as a candidate to so-called PEPP-PT in good faith, but it is now clear that powerful actors pushing centralised databases of Bluetooth contact tracing do not, and will not, act in good faith. PEPP-PT is a Trojan horse."* (+ 5 for "Joy")
  - Note: this is an example of a spurious classification. The entry also has a +6 score for the Bing model.
- *"A lawsuit in federal court is challenging #Texas #ContactTracing efforts. A constitutional law professor said lawsuit is unlikely to succeed, but it remains to be seen whether campaigns against contact tracing will undermine the state's public health"* (+4 "Fear")
- *"If you are diagnosed with COVID-19, expect a call from a County public health specialist. They are not law enforcement agents and will not ask about immigration status. It will appear on your phone as L.A. Public Health please answer. Contact tracing helps us save lives."* (+5 "Trust")
- *"The cost of these failures. Contact tracing: FAILURE LEADING TO DEATHS Herd immunity: FAILURE LEADING TO DEATHS PPE: FAILURE LEADING TO DEATHS Testing: FAILURE LEADING TO DEATHS Lockdown: FAILURE LEADING TO DEATHS Care homes: FAILURE*

LEADING TO DEATHS Truly shocking !"
(+6 for "Disgust", "Fear", "Sadness")

5. CONCLUSIONS

Contact tracing systems (as well as the concept of "contact tracing") are in their infancy. This study's efforts, to gather and analyze qualitative perspectives on contact tracing should not be viewed as conclusive. Rather, it is informative and interesting to capture and document these sentiments during a time of great change in our world. Based on the perceptions of news reports, it appears that contact tracing is of growing interest as a way to track and prevent disease outbreaks. The rising interest in the term is supported by Google metrics regarding searches of the term. One could speculate that due to the nature of contact tracing, perceptions of the term may change once the public becomes more aware of the potential privacy implications and restrictions placed on the freedoms of individuals identified in these systems.

The use of Twitter as a data source and sentiment analysis models to classify tweets may not be universally accepted as a rigorous scientific approach to academic research. However, this style of research has become increasingly common in both practice and academic studies across a wide spectrum of fields. In this study, it was found that sentiment towards contact tracing tweets have become less positive as depicted in trending results from June vs those from April and May of 2020. Also, emotional word classifications of "Anticipation", "Fear", and "Trust" are most prevalent across the three month time frame.

Clearly there are inherent limitations to using Twitter as a data source since there is a certain motive for sharing a perspective on Twitter and its user base may not represent the same demographics as the public at large. It is noted that specific tweets that have been retweeted many times can influence the sentiment analyses. Moreover, the classification of certain tweets using the sentiment models may not match a common sense perspective of an individual reading the same tweet. Contact tracing is a very diverse and quickly changing subject. In the US, the systems are mostly operated at the state level. Similarly, across the world, there are different systems, technologies, and laws that are rapidly changing that may influence sentiment towards contact tracing. The acquisition of tweets that are only in English is a further limitation of this study. Future research could use this study's results as a foundation for empirical studies that explore perspectives in a more controlled setting. Research using case studies of contact tracing implementations along various stages of maturity to reveal best practices and implementation success factors is recommended.

Lastly, as a topic that has political implications, sentiment regarding a topic like contact tracing, is subject to change as news or opinions on the topic becomes widespread. Conversely, interest in the topic could wane if treatments or vaccines for COVID-19 are developed making contact tracing systems a less pressing priority for governments across the world. However, these systems will become more prevalent as the impact of pandemic diseases are realized. This study makes an important contribution by documenting the perceptions of contact tracing during a notable time period where interest in the term was emerging.

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