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Visualizing Business Intelligence Within Supply Chains: A Comparative Analysis Between USAF and Industry Leaders

December 2022

Capt Alexander R. Siangpipop, USAF

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Department of Defense Management

Naval Postgraduate School

Prepared for the Naval Postgraduate School, Monterey, CA 93943

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ABSTRACT

The purpose of this research is to provide the United States Air Force (USAF) with visualization of business intelligence within supply chain lessons learned and best practices. The comparative analysis was conducted between Air Force Installation Contracting Center's Business Intelligence Competency Cell and a Supply Chain Industry Leader, Flex Ltd. This research provides best practices for USAF in enhancing readiness through supporting supply chain resiliency modernization efforts as described in Executive Order 14017 and Department of Defense Action Plan (Securing Defense-Critical Supply Chains).

This research identified best practices to better understand, integrate, and create business intelligence (BI) visualizations within supply chains (SC). This research is comprised of literature review from various subjects including visualization theories, design considerations, SC visualization, and data-driven decision making. Methodologies included semi-structured/narrative interviews and thematic/comparative analysis. The prevailing theme of this research is increasing the speed of understanding; this is achieved through ensuring human centered design, simplicity, and consistency is considered and included in all aspects of visualization. With this research, I created a BI visualization framework model that will guide designers, stakeholders, and end-users in creating/designing BI visualizations that will augment their capabilities via increased speed of understanding.

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ABOUT THE AUTHOR

Captain Alexander R. Siangpipop is an Air Force Contracting Officer. He received his commission via the Air Force Reserve Officer Training Corps (AFROTC) at Rutgers University, New Brunswick, New Jersey in 2016. At Rutgers, Capt Siangpipop graduated with a Bachelor of Arts degree in Chinese (Mandarin), and a minor in Economics.

Capt Siangpipop's first tour was at Dover Air Force Base (AFB), Delaware, from 2016-2018. At Dover, he provided operational contracting support for the base that encompassed the 436th Airlift Wing, the 512th Airlift Wing, and the Air Force Mortuary Affairs Operations.

His second tour was at Defense Contract Management Agency (DCMA), International – Pacific Headquarters (HQ), Singapore, from 2018-2021. At DCMA Pacific, he was the executive officer to the DCMA Pacific HQ's Commander and an administrative contracting officer. Capt Siangpipop provided executive support and post-award systems contracting support for the United States Air Force, Navy, and Marine Corps withinin the Pacific area of responsibility (AOR) that includes:Australia, India, Japan, Malaysia, New Zealand, Singapore, South Korea, and Taiwan. He also served as the

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Of all the academic trials and tribulations I have encountered in my life, this has topped them all. There would be no way I would have completed this feat without support. I thank God for everything. I thank my mother and Father, for their hard work and sacrifice allowed me to be who I am today. I thank my advisor, professor, and mentor, Dr., Professor, Lieutenant Colonel, Daniel J. Finkenstadt, for his mentorship, wisdom, guidance, and encouragement. I thank you my friends for being grossly optimistic in my capabilities and for relentlessly believing in me. I also thank Captain + Stoker Café and Red-Bull© for supplying my daily dose of red-eyes and caffeine; and the Post No Bills team for supporting me through the many late nights working through this research.

For those that are still reading these acknowledgements, I share with you my two cents … Welcome Challenges, Continue to Persevere, and Always Remember Those that Contributed to Your Success – Sigi.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACCT	Accurate, Correct, Complete, Timely
AFBIT	Air Force Business Intelligence Tool
AFCOLS	Air Force Common Output Level Standards
AFICA	Air Force Installation Contracting Agency
AFICC	Air Force Installation Contracting Center
AFIMSC	Air Force Installation & Mission Support Center
AI	Artificial Intelligence
BI	Business Intelligence
BICC	Business Intelligence Competency Cell
BIV	Business Intelligence Visualization
CLIN	Contract Line Item Number
COR	Contracting Officer Representative
D2D	Data 2 Decisions Dashboard
DepSecDef	Deputy Secretary of Defense
DGI	Data Governance Institute
DoD	Department of Defense
EO	Executive Order
ERP	Enterprise Resource Planning
ETL	Extract, Transfer, Load
GAO	Government Accountability Agency
GDSD	Goals, Decisions, Signals, Data
GSA	General Services Administration
HCD	Human Centered Design
HR	Human Resources
IADQGA	The International Association for Data Quality, Governance, and Analytics
IT	Information Technology
KPI	Key Performance Indicator
KPMG	Klynveld Peat Marwick Goerdeler
MRP	Material Requirements Planning
MVP	Minimum Viable Product

OMB	Office of Management and Budget
POTUS	President of The United States
PMRT	Project Management Resource Tools
PWS	Performance Work Statements
SAF/AQC	Air Force Contracting
SAF/AQX	Air Force Acquisition Integration
SKU	Stock Keeping Units
SME	Subject Matter Expert
SOW	Statement of Work
UI	User Interface
USAF	United States Air Force
UX	User Experience
WW	Worldwide

I. INTRODUCTION

The world continues to face significant supply chain disruptions. From COVID-19 to recurring geopolitical issues (e.g., War in Ukraine, China and Taiwan tension, etc.) to natural disasters (e.g., earthquakes, hurricanes, flooding, feminine, etc.) and human-caused failures (e.g., Suez Canal blockage, labor issues, etc.), leaders around the world are facing increasing supply chain disruptions that threaten industry viability, profitability, and operations as well as national security. According to Handfield and Linton, 2017, p. 3, "these disruptions are no longer unique and rare; they are ubiquitous, and the time between disruptions seems to be shrinking. In fact, it is a rare day when no disruptions of any kind occur."

The increased frequency of these disruptions coupled with highly interconnected and dependent global consumer markets, adds urgency to the need for more visibility and insight into global supply chains. Increasing the effectiveness. efficiency, and resiliency of these systems is paramount for continued business and operational success (Handfield & Linton, 2017). The commercial sector has been the quickest to respond to this issue with increased investments into innovative business intelligence solutions designed to provide dynamic and timely insights into supply chains (McCrea, 2021; Handfield & Linton, 2022).

Unfortunately, the public sector, has been slower to respond and develop solutions to the issue.

Lagging slightly behind its commercial counterparts, the Department of Defense (DoD) has only recently acknowledged the need to seek solutions into its supply chain. In February of 2021, The President of The United States (POTUS) released an Executive Order (EO) 14017 detailing the need for a "resilient, diverse, and secure supply chains to ensure our economic prosperity and national security" (Biden, 2021). Moreover, in the EO, POTUS also acknowledged that the geopolitical issues, previously mentioned, have a negative effect on American supply chains. POTUS notes that a "[r]esilient American supply chains will revitalize and rebuild domestic manufacturing capacity, maintain

America's competitive edge in research and development, and create well-paying jobs" (Biden, 2021).

To achieve this, POTUS notes the need for close cooperation with allies and partners and further breaks down his vision for several government agencies, including the DoD. In February of 2022, the DoD responded to POTUS' EO with an action plan led by Dr. Kathleen Hicks, the Deputy Secretary of Defense. Dr. Hicks acknowledged the DoD's need for a more resilient supply chain and has called on all DoD Agencies to take action to increase the lethality and competitive advantage of our warfighters (DoD, 2022). Specifically, the action plan "details how the DoD—in coordination with other U.S. Government agencies, industry, and international partners—will address supply chain challenges that will improve America's overall national and economic security" (DoD, 2022, p. 6). Moreover, the DoD action plan calls on agencies to, "conduct data analysis: DoD will continue to build on previous efforts to expand its visibility into supply chains by collecting and organizing key data" (DoD, 2022, p. 3).

In response to the Deputy Secretary of Defense, Dr. Kathleen Hicks' action plan, I have identified business intelligence as a key proponent to building a more resilient supply chain. This research will show how pivotal visualization is to business intelligence within supply chains. In addition, it will provide best practices and lessons learned by analyzing industry and government leaders in business intelligence visualization.

A. PURPOSE

The purpose of this research is to provide U.S. Air Force (USAF) and Flex Ltd. (Flex) with a report of industry and government best practices. USAF and Flex were chosen because they are both leaders of their respective sectors in terms of visualization within business intelligence.

The best practices from this research will inform on how to best integrate business intelligence visualization into defense supply chains and identify key strategic decision-making factors. I will accomplish this by using semi-structured and narrative interviews, thematic and comparative analyses. This research will seek to understand: 1) how are firm/entity goals are created and if the firm/entity utilizes collaboration and teaming to

carry out business intelligence (BI) goals; 2) what decision factors are at play when the firm/entity decides what data is to be used and how it is collected; 3) how does the firm/entity understand and limit the data they focus on for decision-making; 4) how does the firm/entity decide which BI functions require visualizations and dashboards, as well as the design decisions to be made using visualization signals and interactivity; 5) and a review of the data that is presented by the created visualization, if after analysis the data fulfills the goals.

In addition to understanding how Flex Ltd. leaders make those key decisions for optimized strategic acquisitions, this research will analyze how those key decisions impact their ability to maintain and build upon their supply chain resiliency across the globe. Flex Ltd.'s supply chain consists of 1,000 customers, 16,000 direct suppliers, 18,000 indirect suppliers, $21+ billion in direct material spend, over 30 countries of operations, 25,000 purchase orders daily, and 1 million SKUs (Flex, 2015). Moreover, this research will seek to understand and analyze USAF's Air Force Installation Contracting Center (AFICC) Business Intelligence Competency Cell (BICC)'s BI tool suite – to include Air Force Business Intelligence Tool (AFBIT) for similarities and differences from Flex Ltd.'s supply chain management leaders.

B. ORGANIZATION OF REPORT

This report comprises five chapters. Chapter I (Introduction) introduces the topic of this thesis, the purpose of research, and an overview of Chapters II-V.

Chapter II reviews the background of the topic and literature related to a supply chain's business intelligence and current usages of visualization within the industry. Chapter II also reviews literature about goal formation; data collection/hygiene and cleanse; visualization and design decisions; and test and evaluation. Lastly, I present my proposed Business intelligence Visualization Framework with correlating findings from my literature review.

Chapter III discusses methodology used in this research, specifically how data was collected, understood, analyzed, and presented. I conducted semi-structured and narrative interviews with personnel from Flex Ltd. and USAF AFICC BICC. I then show

how I utilized thematic and comparative analysis to provide recommendations and best practices of both organizations.

In Chapter IV, I present my semi-structured and narrative interview findings conducted with Flex Ltd. and USAF AFICC BICC. I then provide my comparative analysis between the two organizations and provide recommendations to each of them. Afterwards, I explain the major changes to my proposed business intelligence visualization framework model and unveil the final iteration of my BIV framework model.

Lastly, Chapter V (Summary), is a summary of this research, limiting factors to this research, and recommendations for areas of further research.

II. BACKGROUND AND LITERATURE REVIEW

A. INTRODUCTION

In this chapter, I introduce who Flex Ltd. and USAF AFICC BICC are, their main focus, why they exist, and how business intelligence is an important factor of their organizations.

Next, I review the necessity of data in relation to supply chain visualization and visualization in general to include the necessary prerequisite actions to take in ensuring accurate, correct, complete, and timely (ACCT) data as guided by the Data Governance Institute and influenced by the GAO. GAO has frequently stated that Government acquisition systems have consistently suffered from inaccurate, incorrect, incomplete and late data entry and have as a result they conducted study GAO 14–707 stating, "having complete, timely, and accurate information on contractor performance allows officials responsible for awarding new federal contracts to make informed decisions" (GAO, 2014).

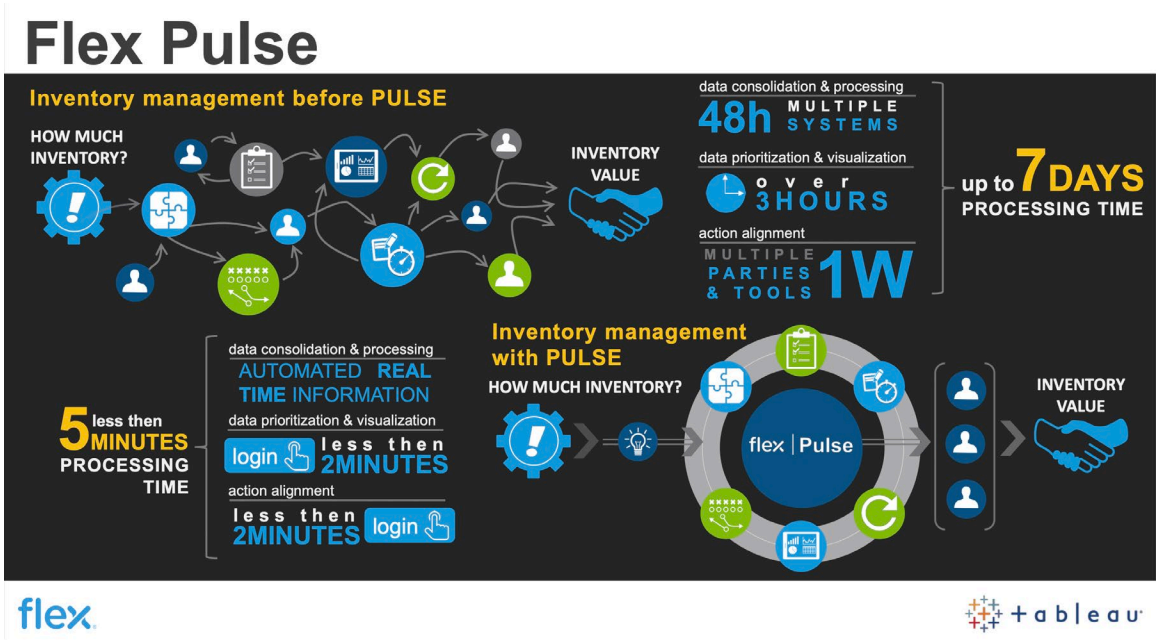
Afterwards, I will investigate literature that primarily focuses on supply chains, data-driven decision making and what visualization/signal cues inform those decisions, supply chain visualization (SCV), visualization theory, user experience (UX) design theory and a few commonly used data visualizations to include what level of data-literacy is recommended in relation to types of audiences, common usages and ideal usages, and a general guide.

B. FLEX LTD.

Flex Ltd., originally Flextronics, was founded in 1969 in Silicon Valley, California (Flex Ltd., n.d.a) as a contract manufacturing company. The company produced circuit boards for other organizations in Silicon Valley (Flex Ltd., n.d.a). By automating the manufacturing process, Flextronics produced circuit boards much faster that proved to be more reliable and more cost efficient (Flex Ltd., 2019). By 1980, "The company expanded its services to include the purchase of materials and parts for manufacturing, as well as using computer-aided design to create and optimize the circuit board for each product" (Flex Ltd., 2019).

By 1994, "Flextronics was named in the top three in IndustryWeek's '100 Best Managed Companies' list" (Flex Ltd., 2019). Flex noted the source of their tremendous growth was attributed to the introduction of "vertical integration to optimize the supply chain, and aggressive global expansion by creating industrial parks where suppliers could re-locate to be close to where the products were manufactured" (Flex Ltd., 2019).

Flextronics evolved from a "contract manufacturing to a Sketch-to-Scale® provider" (Flex Ltd., 2019). With expanded scalable growth through the acquisition of a competitor in 2007 and the unveiling of Flex Pulse in 2015 (Figure 2), Flextronics established 'Flex' as their master brand (Flex Ltd., 2019). Flex's operations include "approximately 160,000 employees, 45 million square feet of manufacturing and services space that span over 30 countries" (Flex Ltd., 2019). Flex was able to reduce inventory management processing time from seven (7) days to five (5) minutes, as shown in Figure 1 (Wrenn, n.d.).



Flex Pulse aggregates and interprets live streaming data from multiple sources… The resulting intelligence highlights global variables that may impact or disrupt supply chains, facilitating contingency planning and crisis preparedness and response (Flex Ltd., 2015).

Figure 1. Flex Pulse Inventory Management Before/After Pulse. Source: Wrenn (n.d.).

In a newsletter the Flextronics CEO explained the need for a business intelligence solution, i.e., Flex Pulse:

We live in a rapidly changing world, full of disruptive events, technologies and business models. Today's executives and innovators need to run their businesses intelligently to win, and one of the biggest challenges they face is the management of highly complex, globally distributed supply chains. Flex Pulse provides us with extraordinary real time insight into our supply chain, which allows us to reduce risk and improve the efficiency of any supply chain. (Flex Ltd., 2015)

Figure 2. Flex Pulse at A Glance. Source: Wrenn (n.d.).

C. USAF AFICC BICC

United States Air Force – Air Force Installation Contracting Center, originally Air Force Installation Contracting Agency (AFICA), was stood up in 1 Oct, 2013 (Ripple, 2016). AFICC is a "worldwide-postured organization… providing responsive and mission-enabling enterprise acquisition solutions for efficient and effective mission and installation operations across the Air Force" (AFIMSC, n.d.). AFICC is comprised of eight enterprise sourcing units that are specifically tied to each category of USAF's category management program (AFIMSC, n.d.). AFICC currently supports over 3,000 USAF contracting professionals and has upwards of 750 employees (AFIMSC, n.d.). Over the past five fiscal years, AFICC has committed, obligated, and executed $58 billion providing acquisition support for the warfighter. As noted on their website:

> [AFICC] provides business advice and specialized contract support to Air Force major commands, contracting authority to operational contracting squadrons, and enterprise, regional, and local sourcing solutions to affect rate, process and demand, maximizing the use of Air Force installation spend. (AFIMSC, n.d.)

The Business Intelligence Competency Cell (BICC) was established in Oct 2013 (Ripple, 2016) as a means to effectively implement USAF's category management goals. Category management is a "federally mandated initiative directed by the Office of Management and Budget [OMB]" (Ripple, 2017). In addition to identifying and implementing enterprise solutions to meet the category management goals, BICC is also the leading edge in providing contracting professionals with the state-of-the-art acquisitions research and data to ensure "smart, defendable, and cost-effective decisions" are made when augmenting organic capabilities with outsourced commodities and services for USAF (Ripple, 2017).

As a result, BICC created their first analytics tool with the goal to accurately track cost-savings called Air Force Business Intelligence Tool (AFBIT). AFBIT "allows users to retrieve spend information and details about any commodity or service the Air Force purchases" (Ripple, 2017). In Figure 3, I show a screenshot of AFBIT Lite. AFBIT Lite is an open-source version that is accessible to the public, however, if users have a common access card, they are able to access the full version of AFBIT. Akin to Flex, USAF AFICC BICC quickly identified the tremendous amount of time saved with a business intelligence solution like AFBIT. The BICC Chief at the time, Air Force Major John Sharkey stated:

> What used to take days, weeks, even months to obtain now only takes a matter of seconds with AFBIT. Again, we're aiming to equip the workforce with all the business and market intelligence it takes to make the smartest buy… the right thing, at the right time, for the right price to get the biggest bang for the taxpayer's buck. (Ripple, 2017)

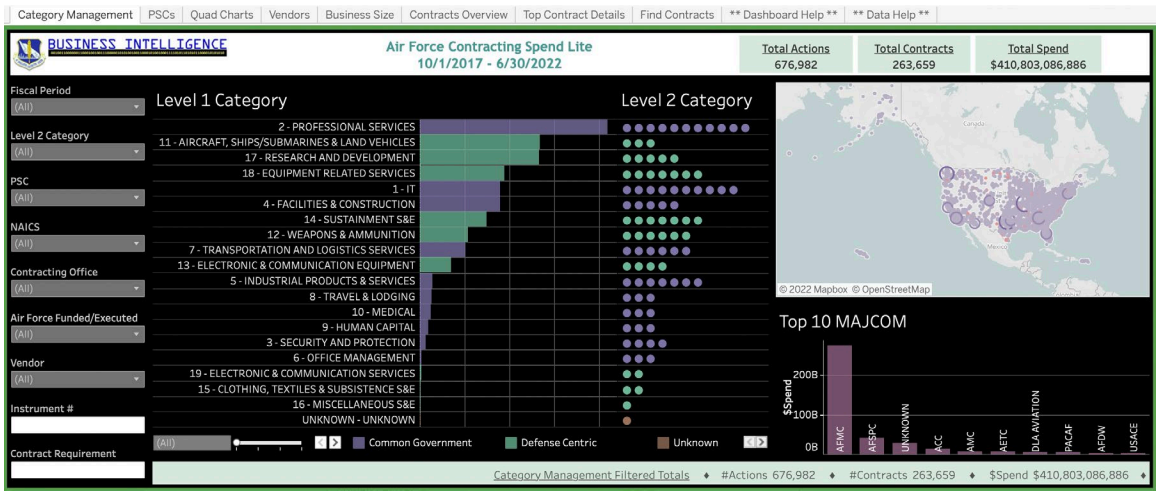


Figure 3. Air Force Business Intelligence Tool Lite Main Dashboard. Source: AFICC BICC (2022).

With an original cost-savings goal of $1 billion over five years, set by the 2013 AFICA Commander, Brigadier General Cameron Holt (Ripple, 2016), through BICC's AFBIT the AFICA was able to achieve this $1 billion in cost-savings in only two years (Warns, 2018).

Today BICC's mission still retains its original intent, Air Force Major Peter Herrmann (current BICC Chief) states the mission of BICC is to "[p]rovide actionable business intelligence to the Air Force through data collection, integration, and deployment of tools and methodologies that enable data driven decisions in managing cost and increasing mission effectiveness." BICC currently operates under a four-step business intelligence cycle (collection, integration, analysis, presentation) to achieve their goals.

D. IMPORTANCE OF DATA AND ACCURATE, CORRECT, COMPLETE, TIMELY DATA

Business intelligence within supply chains have always been heavily reliant on data and without accurate, correct, complete, and timely (ACCT) data – supply chains begin to experience disruptions (Ali et al., 2022; Basole et al., 2016; Shao et al., 2022). According to Handfield and Linton, "data is foundational to everything we [supply chain professionals] do… data is a natural resource – those who capture data and learn how to exploit it will be those who succeed in the new economy" (Handfield & Linton, 2017, p. xiv). In the early days of the supply chain field, data was less abundant, analysis was slow, and

interconnectivity was limited; this is understood today given the type of tools professionals had access to – fax machines, telephones, and eventually refrigerator-sized computers. With the invention of the internet and adoption of modern computing technologies, the supply chain field has evolved immensely. Yesterday's problem no longer exists today – supply chain professionals have access to a slew of tools at their fingertips to include video conferences, e-mail, and cloud-based supply chain software.

A study conducted by Cortada presents an example of the transformation during the time of the third industrial revolution (Cortada, 2006; Klaus Schwab 2016), he observed that an automotive manufacturer in the 1960s would work in a vacuum to identify the type and the quantity of tires to order from a supplier via reviewing their production schedule on their computer. Fifteen years later, that same manufacturer was able to share that data with the supplier and allow and open channel of communication for a quicker and more accurate ordering process.

By the 1990s, manufacturers and suppliers would have capabilities to swiftly communicate back and forth with open flow of data to which Cortada observed suppliers even participating in the design of manufacturer parts. "Across most industries, managers embraced speed, shed cost, and reduced their workforces as they increasingly relied on computing" (Cortada, 2006, p.761).

Nevertheless, yesterday's problems (lack of data) has not disappeared but rather transmogrified to a new problem – 'too much data' to a fault in which ACCT data is difficult to achieve, yet pivotal to successful supply chains and subsequent visualizations (Basole et al., 2016; Handfield & Linton 2017; Kalaiarasan et al., 2022; Zhu & Chen, 2006).

"Today the sheer volume and complexity of the data can often become too overwhelming, making the value of the data and the competitive advantages it can create lost in the noise" (Basole et al., 2016, p. 288). This issue continues to persist in post-pandemic 2022 as presented by Finkenstadt et al. and Whitler:

> Too much data and not enough direction to leverage it. These issues don't just crop up during global contingencies like a pandemic, they exist in most public and private organizations, especially in our age of what Spivey coined as 'Data Saturation' and Debra Bass has named "InfoObesity." (Finkenstadt et al., 2022; Whitler, 2018)

The nascent fourth industrial revolution blurs the line of a new industrial revolution and the prolongation of the third revolution. However, the few things that differentiate the two classifications are: velocity, scope, and system impact (Klaus Schwab, 2016). Handfield and Linton (2017) describe the fourth industrial revolution to be, "characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres" (p. 21). Today, the speed by which data travels across the world is near instantaneously, connects over seven billion people across the world – especially via mobile devices (Handfield & Linton, 2017, Klaus Schawb, 2016). The speed of data transfer also brings a new frontier of challenge to the realm of supply chain. This new frontier will multiply as technology matures through innovation and time in various fields (Handfield & Linton, 2017; Klaus Schwab, 2016). For example, the internet, machine learning, artificial intelligence, and quantum computing (Handfield & Linton, 2017; Klaus Schwab, 2016). As a result, the new frontier of challenge will be the aforementioned overabundance of data.

These prerequisites are a product of the new frontier of challenge for supply chain visualization – the challenges of navigating the overabundance of data requires data to be accurate, correct, complete, and timely (ACCT). The process of acquiring and maintaining ACCT data requires proper data governance or "the exercise of authority and control (planning, monitoring, and enforcement) over the management of data assets" (Handfield & Linton, 2022, p. 140). They argued further that ACCT data via data governance is monumental to the success and downfall of supply chains and is apparent in both industry and academia. A Deloitte Survey found that nearly 50% of supply chain professionals "believe that data quality was the biggest barrier to digital technology" (Handfield & Linton, 2017, p. 8)

We also see this same trend in academia via a North Carolina State University study which found "in almost two-thirds of organizations, poor data quality is the primary cause of less-than-optimal supply chain decisions, and that only 20 percent of organizations are addressing the issue through an improvement program." (Handfield & Linton, 2022, p.137). The Data Governance Institute provides a great framework to ensure data is ACCT and recommends that users consider it prior to beginning data visualization (Figure 4).

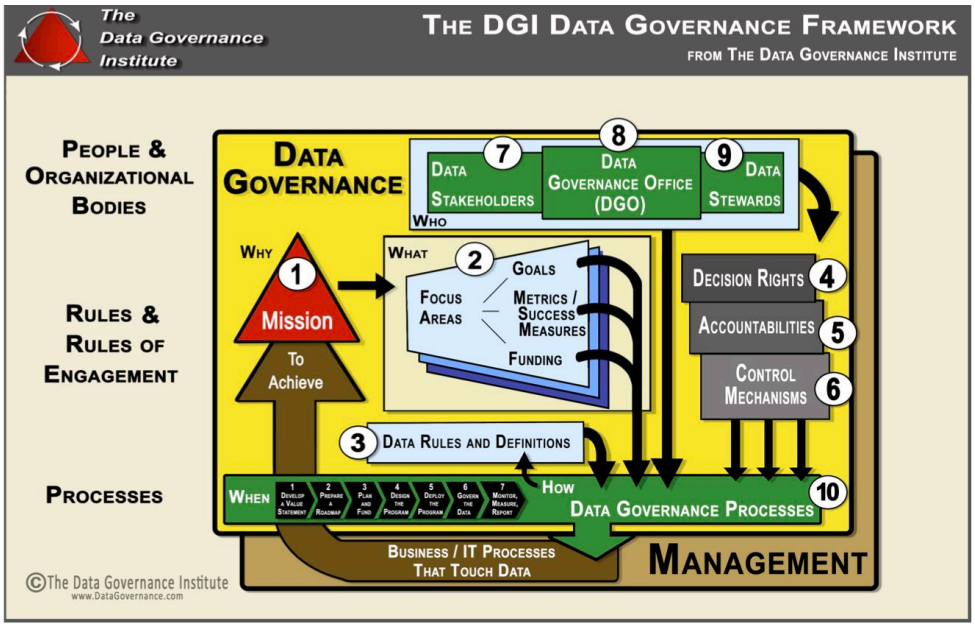


Figure 4. The DGI Data Governance Framework. Source: DGI (n.d.).

E. THE NEED FOR VISUALIZATION

Benjamin Franklin's aphorism, *time is money* is a short and concise statement of scientific principle that stands true in many aspects of life, especially in the realm of supply chain. According to Handfield and Linton (2017):

> In the new global era, speed and velocity are more important than everything else! Speed drives business value and inventory turns, reduces working capital, produces cash (monetizes) assets, and makes customers happy, which in turn further drives top line revenue. (p. 12

In Handfield and Linton's book Flow (2022), they discuss how important the speed of understanding through explaining the faster you can complete tasks within supply chain, the faster you can acquire data-points. Those data-points will validate how ACCT the data is through failure or success (Handfield & Linton, 2022). Therefore, if time is money, and velocity is a necessity in supply chain, then the faster data is interpreted, digested, and understood by professionals, the faster the feedback loop can be enabled.

Data visualization typically has two forms of usages, both present data in a form that can be observed in both a visual and verbal way; Basole et al., Dewan, Rayner et al., and Zhu and Chen argue that there are more advantageous when used together as opposed to independently (i.e., only reading, or only pictures). The forms of usage both transform data

into a visualization to identify hidden patterns, signals, and cues within the data, however the first purpose if forecasting actionable insights and the second purpose being to validating statements.

In relation to receiving data, there are generally only two ways humans receive data visually. Those two ways are either through reading words or observing visualizations. Visualization as referenced by Oh et al., 2015, is "a process that transforms data, information and knowledge into a form that relies on the human visual system to perceive its embedded information" (p. 1033). In research conducted by Rayner et al., 2010, readers classified as fast readers, averaged 330 words read per minute. Readers classified as slow readers, averaged 200 words read per minute. However, visualizations prove to allow users to extract data much faster than reading. On the account of research conducted by Dewan (2015):

> Pictures are not only more effortless to recognize and process than words, but also easier to recall. When words enter long-term memory, they do so with a single code. Pictures, on the other hand, contain two codes: one visual and the other verbal, each stored in different places in the brain (Paivio). The dual-coding nature of images allows for two independent ways of accessing visual memories, increasing the odds of remembering at least one of them. (p. 2)

The assertion that visualization is superior to reading is supported by Rayner et al., 2010. They state that visual systems receive large amounts of visual information at higher bandwidths that processes parallel when at the preconscious level (Rayner et al., 2010). Zhu and Chen support this claim stating that the human eye is able to process several visual cues quickly at the same time (Zhu & Chen, 2006). They provided the example stating that, "the human eye can detect a single dark pixel in a 500 x 500 array of white pixels in less than a second. The display can be replaced every second by another, enabling a search of 15 million pixels in a minute" (Zhu & Chen, 2006, p. 139) (see Figure 5).

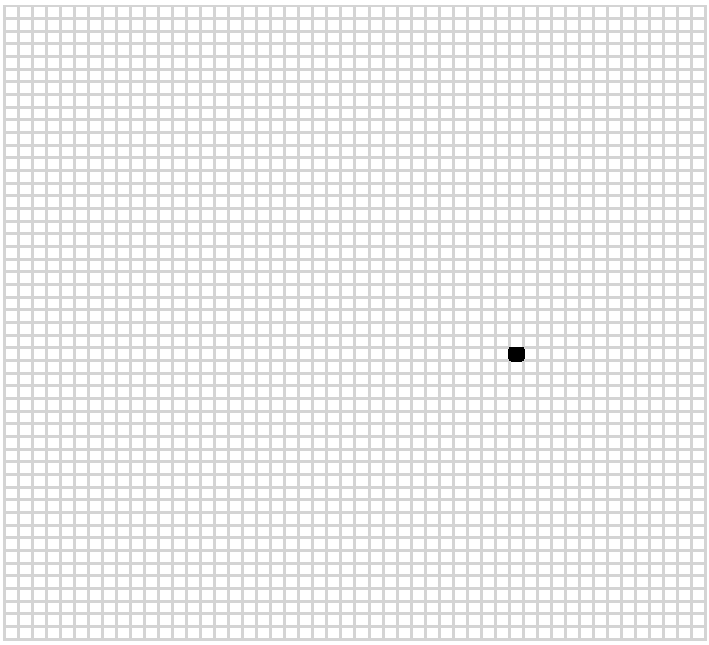


Figure 5. Example 50 x 50 Array of White Pixels Plus One Black Pixel

For a comparison exercise, I created a scaled down array of 50 x 50 white pixels with one black pixel embedded in the visualization, with just a glance – you are able to identify where the black pixel is within milliseconds. As opposed to if I were to describe where the black pixel is with a text description such as:

There is an array of 50 x 50 white pixels. The black pixel is roughly three inches to the left from the right and slightly lower than halfway down from top to bottom. With the text description, if a reader read at the average speed of 200 words per minute and visualized it in their mind – mathematically that would equate to 3.33 words per second. Given the 33 words used in the text description above, that would amount to roughly 10 seconds give or take. Just by this simple comparison exercise, we can see that data can be extracted with visualizations using the human eye, nearly 10 times faster and thereby increasing the speed of understanding.

However, it is not the case nor recommended to only utilize one or the other – it does not have to be a binary decision. In most cases it is better to utilize visuals with text descriptions to improve the efficiency and utility of the visualization. This statement is supported through research done by Dewan (2015), "if we really want others to remember something, we should use words and pictures together. Because we store visual and verbal memories separately, we have the best recall when we are able to access one or the other"

(p. 2) Moreover, Dewan's research supports the notion that it is counterintuitive to only use one or the other because of the way the human mind receives, comprehends, and processes information, "in the unconscious mind, the verbal and the visual are also inextricably linked… If we have different ways of communicating, it makes little sense to rely on only one" (p. 2).

In this section I reviewed that time is money, with more velocity we can save time and money through identifying ACCT data through failing or succeeding faster (Handfield & Linton, 2022), the way we can increase velocity is through utilizing visualizations in presenting data because visualizations are more than 10 times faster than utilizing only text. However, through the review of both now we understand the importance and necessity of tangential usage of visualizations with texts when presenting data (Dewan, 2015; Rayner et al., 2010; Zhu & Chen, 2006). In the next section I will review what visualization theory is and how it contributes to visualizing business intelligence within supply chains.

F. VISUALIZATION THEORY

In modern times, information and data availability is no longer the problem, rather extracting useful and ACCT data from all the available data is the key challenge to business intelligence within supply chains (Zhu & Chen, 2006). We can extract useful and ACCT data efficiently by increasing the rate in which we can complete one cycle of a feedback loop (i.e., increasing the speed of understanding). According to Handfield and Linton (2017), more iterations of the feedback loop generates more data, and more data helps formulate useful data that is pivotal to supply chains. Therefore, to increase the speed at which we can iterate the feedback loop, we should utilize the fastest way to extract data. Section C denotes that data is extracted the fastest when utilizing our eyes to the maximum potential via representing data using visuals and text. Although creating visualizations may seem straight forward, the science behind it provides insights to the specificity required when designing and creating an ideal visualization. This ensures the visualizations allow the user to extract useful ACCT data from a dataset quickly and effortlessly. In the next section I discuss the pros and cons of Figure 6's visualization decisions.

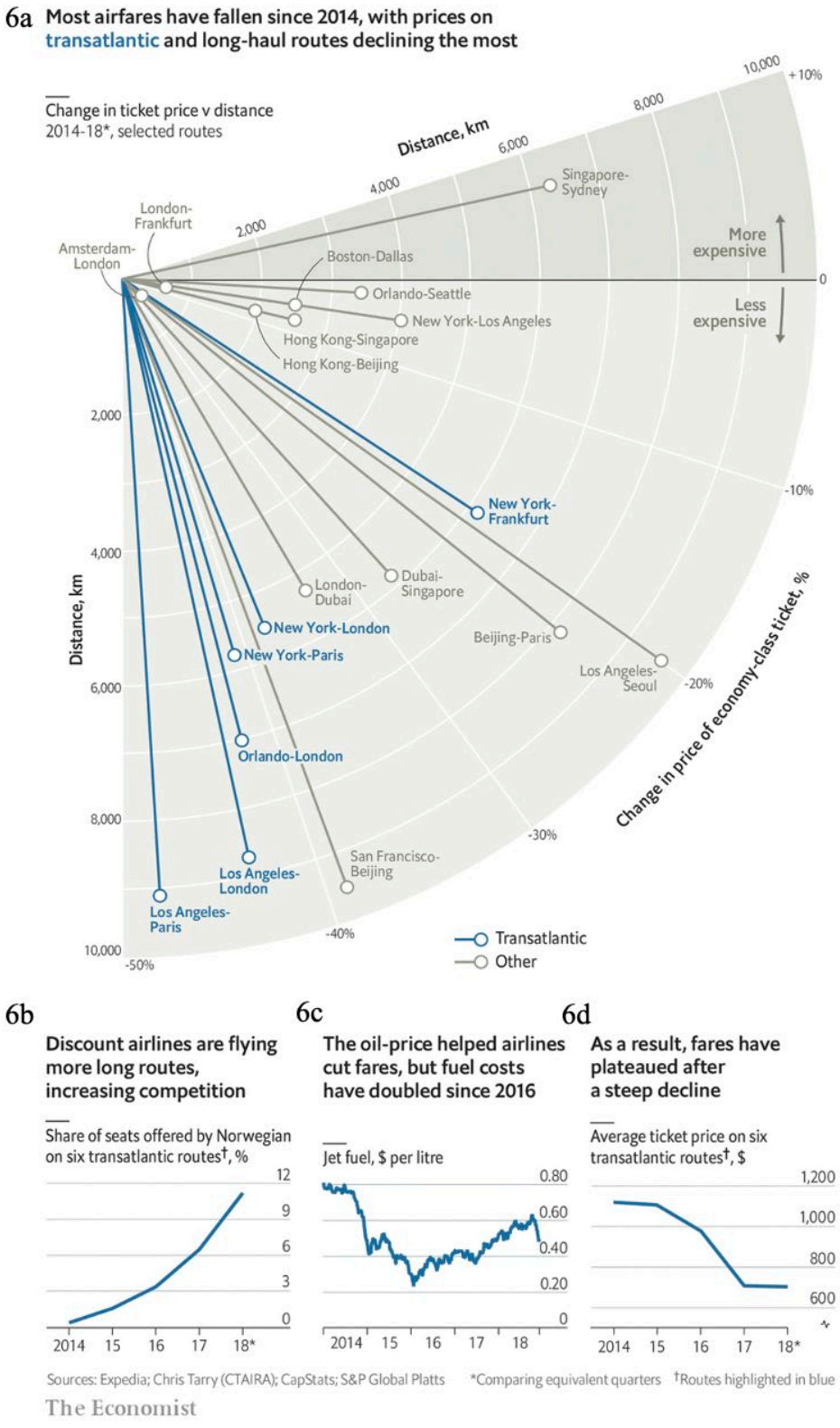


Figure 6. Why Ticket Prices on Long-Haul Flights Have Plummeted. Adapted from The Economist (2018).

At first glance, Figure 6 looks informative, however not much data can be extracted from these visuals without spending several minutes of investigation, which ends up being useless non-ACCT data. As a whole, the visualization (Figure 6) has some positive features, however, individually we can identify some poor features as well. When we look at Figure 6a's "change in ticket price v distance" and 6d "average price on six trans-Atlantic routes," they leave much to be desired. Figure 6b's "share of seats offered by Norwegian on six transatlantic routes' and 6c. 'jet fuel, $ per litre," represent generally good visualizations.

I have identified that simplicity and speed as repeated key themes within visualization theory and design literature review (Basole et al., 2016; Handfield & Linton, 2017 & 2022; Norman, 2013; and Zhu & Chen, 2006). From the perspective of simplicity and speed, Figure 6a represents a poor visualization because it is too complex and difficult to read. Figure 6a is supposed to represent change in ticket price versus distance at a glance, yet the overlap of lines, busy design, faint texts and descriptions, and awkward alignment that makes you tilt your head to read – misses the mark. Zhu and Chen state in their research that color and luminance can interfere with each other as both utilize the same portion of our visual receptive channels in the brain, therefore when it comes to legibility of color and luminance, they need to be clearly contrasted.

Figure 6d is an average visualization, however this one suffers from poor descriptions – at first glance, it is difficult to identify the purpose of the visual, which six routes they refer to, vagueness of x and y axis descriptions, and poor scaling of the x and y axis (specifically because the scaling exaggerates the steepness of the drop). Visualizations should avoid unnecessary complication and should seek to make data extraction as simple as possible, or elementary (Clark & McGill, 1984).

Figure 6b and 6c are not perfect but they do not suffer from most of the troubles that the other two diagrams faced. However, Figure 6b-6d all suffer from poor design of the title, instead of bolding the title, The Economist decided to bold the description which can be confusing when trying to identify what data the visualization is supposed to represent. Nevertheless, the aforementioned examples only scratch the surface of visualization theory, in the section below I will further provide research on what the

theory states and how we can apply this to present useful and ACCT data through visualizations.

1. Visualization Theory

The general intent of utilizing visualizations is to efficiently extract useful and ACCT data from a dataset quickly and effortlessly (Basole et al., 2016; Norman, 2013; Unzueta, 2022; Zhu & Chen, 2006). However, for visualizations to be useful the first notion to consider is to collect ACCT data. According to Basole et al., data collection is of the utmost importance. In order to create visualizations that are useful and effective, data collection need not only be ACCT, but a sufficient amount of relevant data must also be collected. The more high-quality data there is, the more effective and useful a visualization will be (Basole et al., 2016).

The second notion refers to the graphical perception theory in which Cleveland and McGill argue that, "[t]he subject of graphical methods for data analysis and data presentation needs a scientific foundation… Our approach is based on graphical perception – the visual decoding of information encoded on graphs" (p. 531). Cleveland and McGill state that, "graphs should employ elementary tasks as high in the ordering as possible" (p. 532). When they mention elementary tasks, they are referencing those tasks required to extract qualitative data from graphical representations, i.e., visualizations (Cleveland & McGill, 1984). It is of utmost importance to ensure data is ACCT because once data is presented in graphical/visual form, the data appears strong and valid at first glance. When that strong effect is perceived by a person, it has the same effect on others as well (Cleveland & McGill, 1984).

Cleveland and McGill further explain the connection of first glance and elementary tasks, that is, a graphical representation should allow the observer to effortlessly extract data (first glance) and extract the immediate interaction between the individual representations of data (elementary tasks); i.e., if one slice of a pie chart is larger than the other, the effortless perception is that the data represents the bigger pie slice represents data that is more, greater, or larger than the other.

Cleveland and McGill then show graphical representation as an ontological visualization and references Julesz's theory of textons. The theory of textons argue that visualization is ontological and presents pre-attentive vision – vision that observes and extracts interaction effortlessly and instantaneously without having to focus on local data, i.e., extracting data at a glance, effortlessly yet quickly (Cleveland & McGill, 1984).

Researchers have argued for information visualization theory while practical users have sought to explain visualization ontologically (Card et al., 1999; Munzer, 2015b; Liu & Stako, n.d.; and Zhu & Chen, 2006). From the work of Zhu and Chen we find that visualization is application focused and can typically be categorized into three varieties: scientific visualization, software visualization, and information visualization. Zhu and Chen argue that these categories should not be considered mutually exclusive. On the surface level they may differ, however, they all operate under a similar underlying technique. Zhu and Chen provide an example for this, "for instance, scientific visualization often involves visualizing the multidimensional attribute space of a physical object; this overlaps with information visualization, which delivers patterns embedded in large-scale information collections" (Zhu & Chen, 2006, p. 144).

Zhu and Chen describe scientific visualizations as a tool that increases efficiency among scientists and engineers, with the distinguishing factor of being solely based on physical objects (e.g., natural subjects such as earth, human body, molecules, DNA etc.) (Zhu & Chen 2006). Software and information visualization represent abstract data digitally (e.g., on a computer screen), unlike scientific visualization. Naturally, software visualization has a sole focus on representing software data visually, helping software programmers manage complex data (e.g., managing the 50 million lines of code in Windows 10); whereas information visualization help people "identify patterns, correlations, or clusters" and "focuses on graphical representation to reveal patterns" (Zhu & Chen, 2006, p. 145).

For my research I will focus on information visualization as it is the most relevant in terms of business intelligence within supply chains. Information visualization has a range of definitions; however, there are two that are widely accepted definitions. The first is, "the use of computer-supported interactive visual representations of abstract data to

amplify cognition" (Oh et al., 2015, 1033). Faiola et al. (2015), argues that the intent and purpose is not focused on visualizations as pictures themselves, however it is for insight or "rapid information assimilation or monitoring large amounts of data" (p. 439).

The second definition identified by Zhu and Chen, (2006) states, "a process that transforms data, information and knowledge into a form that relies on the human visual system to perceive its embedded information" (p. 1033). Although both definitions differ slightly, they both identify information visualization as the process of taking data and transforming it into a visual form that increases cognition quickly and effortlessly through the use of relying on human visual capabilities. I rely on this combined definition in this research.

2. Data Literacy within Visualization

An important factor to keep in mind when creating visualizations is the level of data and technological literacy of the recipient. In many cases, data literacy and visualization are commonly complimentary terms as identified by the DoD AI Education Strategy mentioned in Jacobson's data literacy research (Jacobson, 2021). Although all visualizations should always be kept as simple as possible with minimal visual clutter, the type of visualization (i.e., a pie chart, bar chart, tree map, heat map, etc.) used should be in keeping with your audience's level of data and technology literacy. Some people may find interpreting different visuals and extracting useful data to be quite intuitive, however that is hardly the norm (Handfield & Linton, 2022). Although there are several definitions of data literacy, for the purposes of this research I found Jacobson's 2021 research as the most relevant. Jacobson provided a data literacy definition adapted from the International Association for Data Quality, Governance and Analytics (IADQGA):

> the ability to read, understand, create and communicate data as information. It also means the ability to create and interpret graphical representation of the data, draw conclusions from the data and recognize when data is being used in misleading or inappropriate ways. (Jacobson, 2021, p. 2)

Knowing your audience is important to communicating data quickly, at a glance. The audience can be categorized into four groups, data believers, data users, data scientists, and data leaders (Data Literacy - KPMG Global, 2021) see Figure 7. The four

groups of data literacy roles differ based on their roles within their workplace, but moreover, they create differences in the need, usage, and exposure to data. For example, the level of data literacy for an aviation maintenance worker (data user) may be very tactical i.e., understanding how many rivets are required per section by aircraft, or how many hours are required per type of maintenance, repair, overhaul or upgrade. Whereas a vice-president (data believer) has more of a strategic level of data literacy, they take data derived from data users and make decisions based on data analysis (Data Literacy - KPMG Global, 2021).

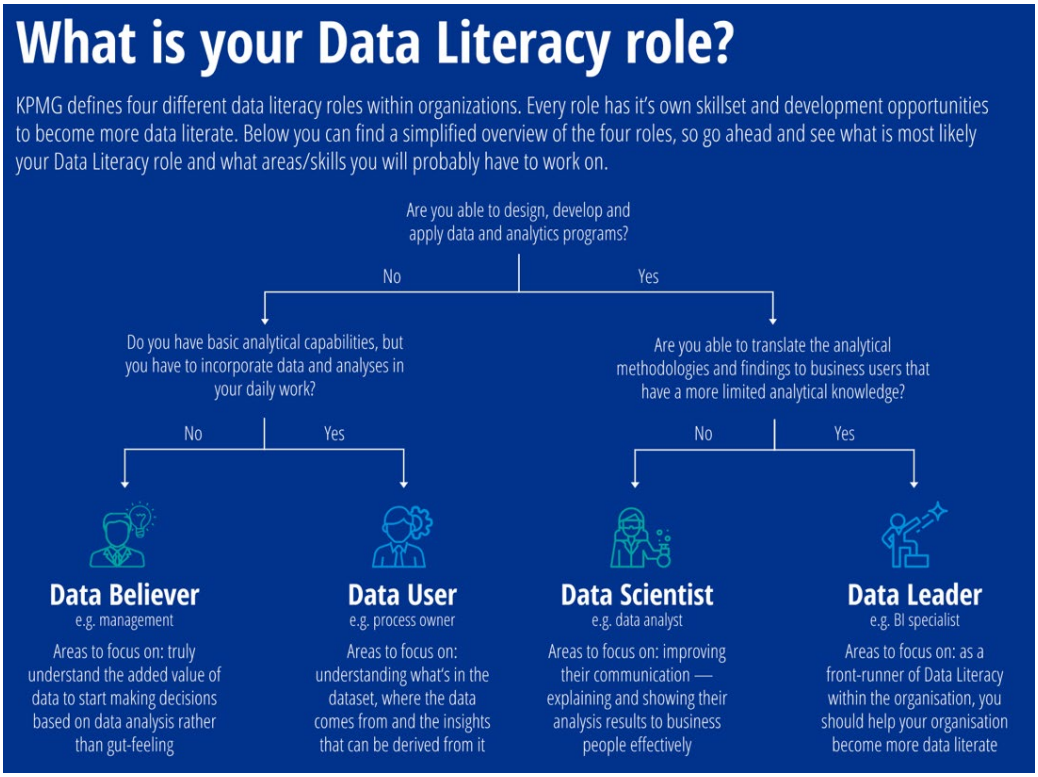


Figure 7. KPMG – What Is Your Data Literacy Role?
Source: KPMG (2021).

Not only is it important to understand the different roles of data literacy, but it is also important to know what level your audience's data literacy is. Jacobson notes that the average Domestic U.S. data literacy level is a majority 'average', with equal distribution of 35% of the population being above and below 'average', and 12.5% having no data literacy (see Figure 8).

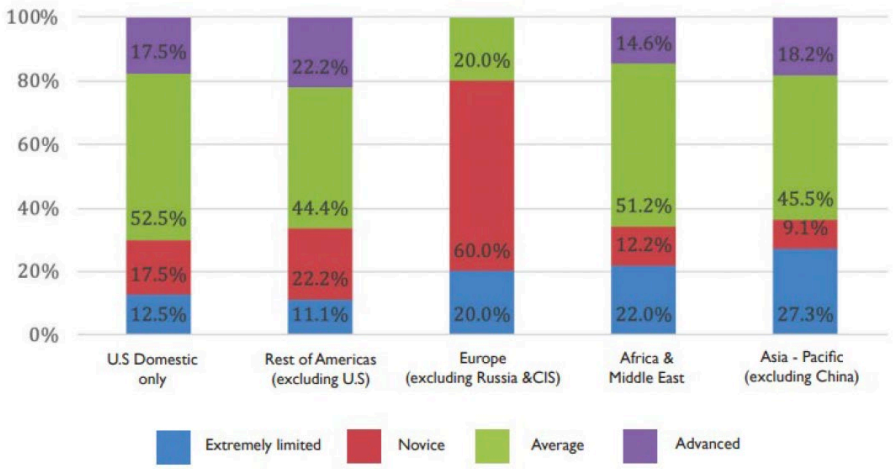


Figure 8. Data Literacy Across the World. Visualization Adapted from Jacobson (2021) and Handfield et al. (2020) (data source).

Although these statistics are derived based on a self-evaluation, it does not discount the fact that most of domestic U.S., Europe, Africa, Middle East, and Asia-Pacific audience identifies themselves as having average knowledge of data literacy, therefore visualizations should seek to simplify data representations to be as easily understood as possible. Although, if an audience has a higher or lower average level of data literacy, that must be taken into account to utilize more complex or simpler visualizations.

G. DESIGN, UX/UI, VISUALIZATION SIGNALS AND INTERACTIVITY

Simplicity is a key ingredient in data visualization among other aspects, but just as there are differences in data literacy across continents and across data literacy categories; there are differences in the term ‘simplicity’ for humans. For example, the human design between western visualizations will often follow the general way people read text, i.e., from left to right, and top to bottom; in these cases, data that is more important is generally positioned from left to right. Whereas in far east countries (albeit not as apparent today as most reading styles have adopted the western ways), the general way people read text was from top to bottom and right to left (Bergen & Chan Lau, 2012; Sun et al., 1985) (see Figure 9).

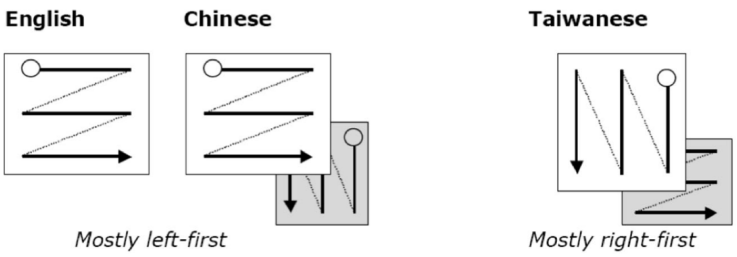


FIGURE 1 | Writing directions of English, Mainland Chinese, and Taiwanese. English is written exclusively from left to right, while Chinese in Mainland China is written primarily from left to right, with some texts still written top to bottom. In Taiwan, at the time when we collected data, in 2004, characters were predominantly written top to bottom, but there were at the time some left to right texts, and there are even more at present.

Figure 9. Reading and Writing Direction, English (West) vs Chinese (Far East). Source: Bergen and Chan Lau (2012).

In this section I will investigate design challenge, fundamental design principles, modern User Experience/User Interface (UX/UI) design best practices to include design features for optimal visualizations for business intelligence within supply chains – understanding of visual signals and features of interactive controls.

1. Design Challenge

According to Norman, 2013 (p. 239), "because the fundamental principles of designing for people are the same across all domains… the design principles are the same." Norman argues the first step to designing a good product is to understand your clients, or in other words identifying the goal. Not only does the goal need to be identified, but a harmonious team and team of teams must be established to ensure there is a cooperative and consummate atmosphere to ensure smooth functioning design process (Norman, 2013, p. 240).

The other component to this is that clients may not always be the end-users. Consider the example, "in businesses, purchasing departments make decisions for large companies, and owners or managers, for small companies. In all these cases, the purchaser is probably interested primarily in price… almost certainly not in usability" (Norman, 2013, p. 241); while one may argue with Norman's understanding of a purchaser, the importance of understanding what the true goal is prior to compiling a

dataset and proceeding to creating a visualization still holds – otherwise the visualization may be for naught.

The last challenge to design is standardization. Norman describes standardization as the concept of being able to replicate a process regardless of type, size, or shape, "with standardization, once you have learned to drive one car, you feel justifiably confident that you can drive any car, anyplace in the world" (Norman, 2013, p. 248). He adds that "standardization provides a major breakthrough in usability" (p. 248). It can be said that standardization is just as important as simplicity when creating data visualizations especially when it comes to creating dashboards (a dashboard being a collection of visualizations for a similar or same goal) (Norman, 2013, p. 248).

Consider being in a company in which they utilize 10 different dashboards, if the visualizations are not standardized it would create a massive learning curve going from one visualization to another. It would be most beneficial to ensure that after training/ learning the features of one visualization, that it be transferred to all the others the same way. Not only does it delete the learning curve for understanding this visuals format, but it increases efficiency as well. For example, imagine three different visualizations being a manual motorcycle, a manual car, and an automatic car… unless you have prior knowledge with utilizing all three types of transmissions and vehicles, there would be a necessity for training in order to learn how to operate each one individually even though all three vehicles serve the same purpose of transportation.

Norman argues the difficulty without standards is that humans are naturally habitually programmed, that is we expect processes to be repeatable for a single underlying goal – i.e., telling time. He points out if an analog clock was reversed and traveled in a counterclockwise position – it would be difficult to determine the time because the general understood logic behind clocks is that they travel clockwise, thus the very definition of clockwise (Norman, 2013, p. 250).

2. Fundamental Design Principles

Norman provides a few key challenges with design; however, he also provides seven fundamental design principles to ensure it overcomes these challenges. (See Figure

10 and Table 1). The root of the seven design fundamentals root from seven insights, one at each stage, that shape the fundamentals.

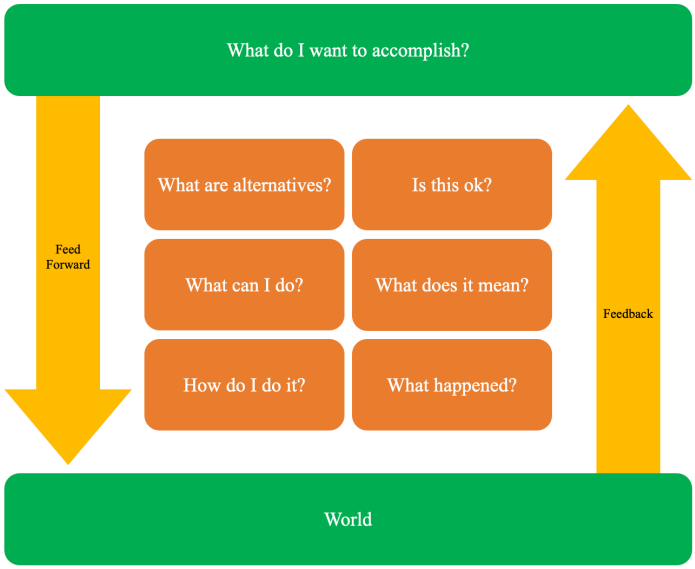


Figure 7. **The Seven Stages of Action as Design Aids.** Each of the seven stages indicates a place where the person using the system has a question. The seven questions pose seven design themes. How should the design convey the information required to answer the user's question? Through appropriate constraint an mappings, signifiers and conceptual models, feedback and visibility. The information that helps answer information that helps answer questions of execution (doing) is *feedforward.* The information that aids in understanding what has happened is *feedback.*

Figure 10. The Seven Stages of Action as Design Aids. Adapted from Norman (2013).

Table 1. Norman's Seven Fundamental Design Principles and Insights. Source: Norman (2013, pp. 71 and 72).

Norman's Seven Fundamental Design Principles and Insights	
"What do I want to accomplish?"	"Discoverability"
"What are the alternative action sequences?"	"Feedback"
"What action can I do now?"	"Conceptual Model"
"How do I do it?"	"Affordances"
"What happened?"	"Signifiers"
"What does it mean?"	"Mappings"
"Is this okay? Have I accomplished my goal?"	"Constraints"

The first insight of discoverability is quite straightforward, Norman asks us to identify what the current status is and its limitations. In feedback, he brings the attention to the idea of data collection, is there enough ACCT data and is there an existing process that produces results that a new status is easy to determine. The conceptual model insight

is akin to a minimal viable product, or a good model of the system that allows for a feeling of control.

The importance of this insight creates additional feedback for the first two principles – discoverability and feedback. According to Norman, "affordances determine what actions are possible. Signifiers communicate where the action should take place. We need both" (Norman, 2013, p. 14). Therefore, the idea behind affordances should also include signifiers by ideating different potential courses of action to take along with including a targeted signifier and so naturally principles four and five are intertwined and work together.

When Norman discusses mapping, the underlying insight is simplicity and standardization – when both are achieved the ease of understanding i.e., data extraction, becomes simplified as well. Lastly, once complete, take a look at the product you have designed and examine it. Sometimes there are too many features that may clutter the design, consider constraints that focus the user to ensure your intent of the design is met.

3. User Experience and User Interface Design

User Experience (UX) and User Interface (UI) have subtle nuanced differences; however, designers typically see the principles in the same light (Hartson & Pyla, 2019). User Interface came before User Experience and was initially analog in nature (Hartson & Pyla, 2019). However, today User Interface is the underlying software behind User Experience. Hartson and Pyla explain that UX design is more than the design of interaction. They further the notion through their definition of UX as, "User experience is the totality of the effects felt by the user before, during, and after interaction with a product or system in an ecology" (Hartson & Pyla, 2019, p. 5).

The aforementioned seven fundamental principles of design and insight also apply to user experience. User experience is important and critical to design, albeit subjective, however it determines whether or not the user finds the interactions with the design positive or negative – whether easy or complicated to use, and whether they intend to use it again in the future (Norman, 2013, p. 10). When discussing UX, the concept of a human-centered design (HCD) is important, obviously because a business intelligence

visualization for supply chain is for humans. Human-centered design describes, “an approach that puts human needs, capabilities, and behavior first, then designs to accommodate those needs, capabilities and ways of behaving” (Norman, 2013, p. 8). In other words, “the process that ensures that the designs match the needs of the people for whom they are intended” (Norman, 2013, p. 8).

Norman argues that the first step to a good design is to ensure the HCD is kept on the forefront of the mind and to ensure communication is open between the designer and the client/end-user. HCD principle ensures that the need of the client/end-user is identified before problem solving occurs. In fact, Norman warns against specifying the problem early on but rather to delay as long as possible to ensure multiple iterations of the feedback loop is achieved to acquire ACCT data.

The idea of ensuring multiple iterations of the feedback loop is iterative design vs waterfall design (or linear). In the past, a waterfall design was considered necessary to acquire user feedback. Although it works, the fallacy is in that it increases the time between feedback loops as this type of design requires the product to be complete before it is released. The opposite of iterative design is true, releasing a product in iterations, communicating with users for feedback, then going back to the design and improving upon it with given feedback. This is done iteratively until the design is complete. Hartson and Pyla (2019) provide a few great examples of where UX went wrong and became enormously costly:

> Bad UI/UX design costs an enormous amount of money and more importantly, lives. Distractions due to bad UX designs for operating cars can lead to traffic accidents, injuries, and even death. The same caution applies to UX design for operating aircraft and ships at sea. For example, the crash of EgyptAir Flight 990 in 1999 (Section 32.6.3.3) was determined to be caused by poor usability in the design of cockpit controls. And the collision of the USS McCain is said to be the result of bad UX design of the navigation console. (Hartson and Pyla, 2019)

To overcome this, Hartson and Pyla, 2019 categorized UX into four categories which can be seen as principles of UX design (see Figure 11).

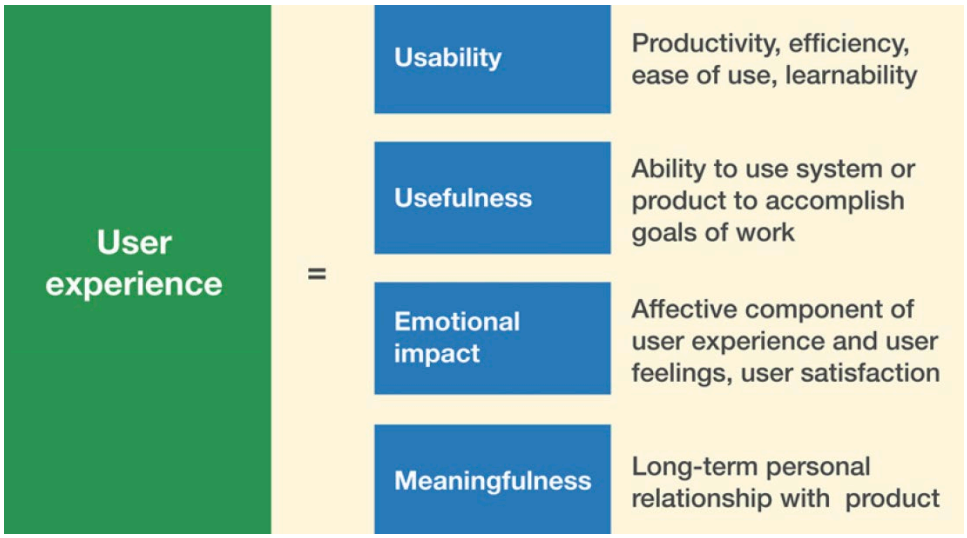


Figure 11. The Components of UX. Source: Hartson and Pyla (2019, p. 9).

In comparison to Norman's seven design principles and insights, all four categories fall under principles one through five (discoverability, feedback, conceptual model, affordances, and signifiers). This is intuitive, given the understanding of UX, a visualization can only succeed if the client/end-user's needs are met.

4. Visual Signals and Interactivity

Visual signals, visual cues, and visualization interactivity reside at the tactical level of design. Visual signals and cues are the specifics to which a visualization is designed, i.e., how it looks, color choice, luminance, detail, size, shape, proximity, etc. There are complimentary cues and uncomplimentary cues. I.e., there are cues that work well together and those that clash and should not be used together. Zhu and Chen argue that visual cues like color and proximity are processed in different visual channels in humans and are considered independent. Therefore, the two types of visual cues allow utilization of independent observation channels to depict different data points (Zhu & Chen, 2006). However, other cues such as color and luminance clash because they utilize the same visual channels and therefore should be reconsidered when using together to ensure the intended projected data is not lost (Zhu & Chen, 2006).

Visualization interactivity can be categorized into two groups: static (i.e., a single non-manipulatable visual, e.g., infographics, analog charts – pie charts, line graphs, bar charts, scatterplot graphs, etc.) or interactive (i.e., generally more modern visualizations

like tableau and excel, the data within the visualization is interactive/can be modified, e.g., data within the visualization can be filtered, sorted, searched, etc.) (Basole et al., 2016). Basole et al., further detail interactivity, from research gathered from prior works, into three subsets, data viewing specification, manipulation, and analysis process and provenance. Specification entails filter, sort, and derive; manipulation entails select, navigate, coordinate, and organize; analysis process and provenance entails record, annotate, share, and guide (Basole et al., 2013) (see Table 2).

Table 2. Basole et al.'s Three Data Visualization Interactivity Categories. Source: Basole et al. (2016, pp. 298 and 299).

Basole et al.'s Three (3) Data Visualization Interactivity Categories	
"Data Viewing Specification"	"Filter"
	"Sort"
	"Derive"
"Data Manipulation"	"Select"
	"Navigate"
	"Coordinate"
	"Organize"
"Analysis Process and Provenance"	"Record"
	"Annotate"
	"Share"
	"Guide"

In modern times, visualizations are typically interactive and, in some cases, compiled into a dashboard (an interactive compilation of individual visualizations) for increased efficiencies. The efficiencies are enjoyed through a single point of contact through compilation. This is because the visualization only need be created once and modified slightly for a multitude of specialties across business intelligence within supply chain (e.g., inventory, human resources, manufacturing, purchasing, etc.). By compiling big data into a single visualization or dashboard, we achieve standardization and simplicity.

With standardization, users need not learn another interactive visualization, UX, or UI. However, this presents the problem of too much data at one time as well as irrelevant data. To this point, Basole et al., argue the necessity for data interactive data in terms of specification, manipulation, and analysis. Basole et al., further argue that some interactive functions like filtering can be agreed upon as a necessity for all interactive visualizations. "Filtering is an essential control in visual analytic tools. Analysts frequently want to visualize only a subset of the data based on a set of dimensions or criteria, for example, to examine different levels of parameters" (Basole et al., 2016, p. 295).

H. PROPOSED BUSINESS INTELLIGENCE VISUALIZATION FRAMEWORK

I have been unable to find a framework that informs/guides business intelligence visualization creation and design. Therefore, I have utilized a comprehensive literature review to establish a framework of my own and will utilize it as part of my methods for comparing the relative strengths and weaknesses of business intelligence data visualization between the USAF and Flex, a leading supply chain management corporation that has been recognized for cutting-edge data visualization practices. There are frameworks/models and literature I derive this proposed framework from including DGI's Data Governance Framework; Finkenstadt et al.'s Goals, Decisions, Signals, Data Model (GDSD); Norman's Seven Stages of Action as Design Aids; Basole et al.; Handfield & Linton; Hartson & Pyla; and Zhu & Chen (figure 12).

Existing Framework, Models, & Literature that Inform on Business Intelligence Visualization					
Literature	**Goals**	**Data Collection**	**Data Hygiene & Cleanse**	**Visualization & Design Decisions**	**Data Analysis**
Finkenstadt et al.'s GDSD Model	■	■			■
Handfield & Linton	■		■		■
Norman's Seven Stages of Action as Design Aids	■			■	
DGI's Data Governance Framework		■	■		
Basole et al.		■	■	■	■
Zhu & Chen				■	
Hartson & Pyla				■	

Attributes	**Gaps**

Figure 12. Existing Framework, Modes, and Literature that Inform on Business Intelligence Visualization

The Data Governance Institute's Data Governance Framework provides great insight into how a creator can ensure that data collected can be useful data in terms of ACCT, how to properly maintain and govern said data. However, DGI's data governance framework ends there and does not inform a creator on how to create and design a visualization.

Finkenstadt et al.'s Goals, Decisions, Signals, Data model presents great guidance into data driven decision making in which I utilize for my first through third step of 'goals, data collection, and data hygiene and cleanse'. Before creating a visualization, it is imperative that creators and their teams look into identifying what they are trying to accomplish (which is in line with Finkenstadt et al.'s first step), "what will you need better intelligence on for making decisions" in terms of creating a team and allocating resources (Finkenstadt et al.'s second step). In addition, specifically what are end-users/ stakeholders targeting in their goals (Finkenstadt et al.'s third step) – "ask yourself what

would serve as a signal for decision-making" (Finkenstadt et al., 2022). Finkenstadt et al. provide the examples of signals as:

> [d]o you need to know things like delivery delays, vendor vetting results, supply chain disruptions anticipated from weather or other disasters, market impacts from global policies, contract performance and delivery term issues etc. (Finkenstadt et al. 2022)

I attribute their signals to goals rather than visualization and design decisions because they inform and guide a visualization designer on what data they should be seeking to collect. Whereas within my proposed BI visualization framework, the visualization and design decisions phase informs a designer on considerations to best represent the data with the set of tools they have.

In terms of data collection, hygiene, and cleanse, I utilized Finkenstadt et al.'s model's fourth step – "ask yourself what data would lead to informative signals that can lead to intelligent decision-making within your focal value chain" (Finkenstadt et al., 2022). The difference between my proposed framework and Finkenstadt et al.'s GDSD model is that their model is focused on data-driven decision making, while my proposed framework is focused on how to properly utilize/create visualizations for business intelligence for supply chains. In other words, my proposed framework utilizes all steps of Finkenstadt et al.'s GDSD model but adds additional steps that are focused on visualization.

Norman's Seven Stages of Action as Design Aids framework was specifically created as a guide to understand the considerations for designing everyday things. Nevertheless, his framework transcends past a guidance for the design of everyday things and can be utilized for visualizations as well. I find that his framework can be applied to most things in business intelligence, especially his identification of goals as the first step, then the six questions in which he presents as a confirmation to ensure creators are on vectored correctly. Lastly, I adopt the constant feedback loop he has embedded in his framework to show that design cannot be completed in a vacuum. Where this differs from my proposed framework is that Norman's framework solely focused on design and does not inform on many of the business intelligence focused prerequisites, such as Finkenstadt et al.'s GDSD model for data-drive decision making.

In reviewing The Living Supply Chain and Flow, Handfield and Linton provide a case study of designing a business intelligence and supply chain system, but does not, in itself, offer a framework. Handfield and Linton focus on velocity and speed of feedback loop iterations. Drawing from Handfield and Linton's themes in The Living Supply Chain, Finkenstadt et al.'s GDSD, and Norman's Seven Stages of Action as Design Aids, I have also included the continuous feedback loop into my proposed framework. Maximum communication at every step with the customer/client/end-user should be paramount and consistent, in order for this proposed framework to reach maximum efficiency.

With that in mind, it is also important to note that this proposed framework is not linear nor static. At every phase of the proposed framework, each iteration should align with the goal. The reason every iteration should be communicated to the customer/client/end-user is to ensure that the visualization stays aligned with the goal or inform the customer/client/end-user of anything they have not previously identified but consider useful for the final product.

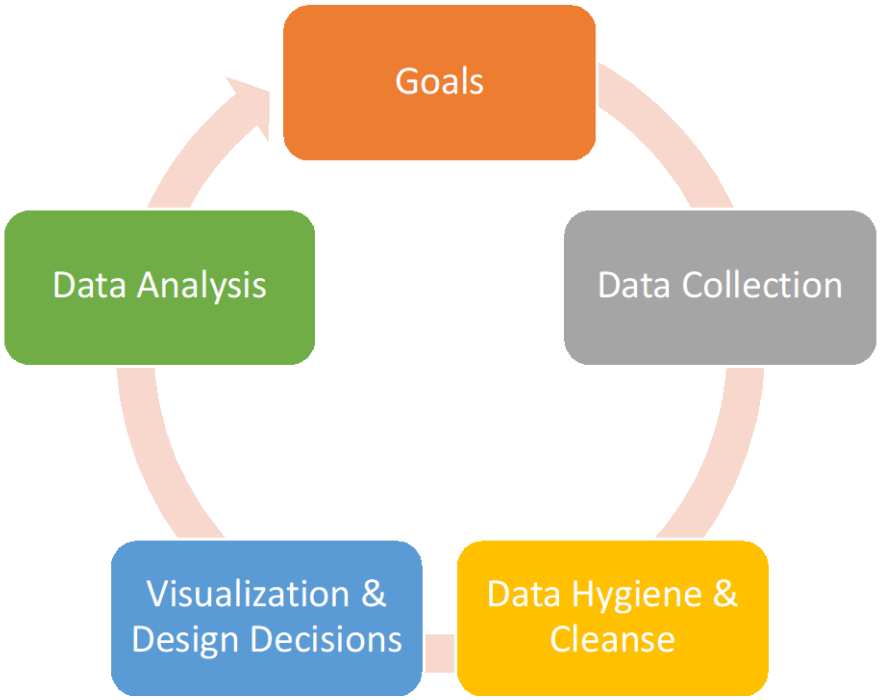


Figure 13. Proposed BI Visualization (BIV) Framework

1. Goals

Before any type of visualization can begin, a visualization creator/designer must consider what issue or problem is in question, what data/information needs analysis, or what data/information needs to be portrayed and why; in other words, what is the goal that is sought to be accomplished and will visualization be useful (Finkenstadt et al., 2022; Norman, 2013).

A simple test to see if a visualization can be useful is utilizing Munzer's research. She argues, "visualizations are suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods" (Munzer, 2015b). Next, ensure that a fully automatic solution does not exist, otherwise data visualization is useless (Munzer, 2015b). This phase is incredibly important because it will be what drives and guides the visualization design and creation for business intelligence. My proposed framework relies on creators and designers to embrace the iterative process, while progression from one phase to the next phase of the proposed framework – open communication with stakeholders is crucial. Consider Finkenstadt et al.'s GDSD model as a guide to ensure goals are clearly identified, defined, and understood among all stakeholders as well as a common understanding of what the end product should look like (Finkenstadt et al., 2022). As each iteration of the visualization is created, refer back to this phase and make any changes/modifications to the goals as required.

2. Data Collection

Once the goal has been identified, a creator must identify the type and amount of data required in order to create the visualization. Business intelligence within supply chains have always been heavily reliant on data (Ali et al., 2022; Basole et al., 2016; Shao et al., 2022). In our day and age, there is no longer a problem of lack of data rather the problem today is too much data, or data saturation/InfoObesity (Finkenstadt et al., 2022; Whitler, 2018).

Finkenstadt et al. inquires, "ask yourself what data would lead to informative signals that can lead to intelligent decision-making within your focal value chain." In data

collection, it is important to understand that the data collected should have the goal in mind… do not collect data because it is available, collect and utilize the data it if it will be supportive in achieving the goal. However, the caveat to this is understanding that data collection is not a singular action. Most times it may be necessary to identify secondary data requirements. In these scenarios creators must use data not originally collected or designed for the primary question, but may assist in making inferences regarding the underlying effects. In this phase of the proposed framework, it is also important to keep in mind the data literacy level of the audience for which the visualization is created for and their data literacy roles. This is to ensure the visualization is designed with HCD in mind and can be used effectively, effortlessly, and quickly (Jacobson, 2021; KPMG, 2021).

3. Data Hygiene and Cleanse

ACCT data is a prerequisite prior to moving to phase 4 (Handfield & Linton, 2017). This can be achieved through utilizing DGI's data governance framework. Ideally, during the data collection phase, the data collected is already rich and useful, thus making this phase much easier; in which case, the only thing to do would be to standardize the data and prepare it for phase 4 (Basole et al., 2016).

If the review of the data collected proves to be other than relevant, useful, and ACCT, the creator must cleanse, modify, and standardize this data and prepare it for utilization. In this phase, recall what the goal is and compare it to the data collected. Does the collected data support the visualization that is being created to achieve the goal? The placement of data within the framework differs from Finkenstadt et al.'s GDSD model because their model has a goal of being the guide to navigating through a data saturated world to make informed data-driven decisions, however, my framework has a goal of being the guide to navigate the unstructured process of creating visualizations for business intelligence organizations especially within supply chains.

4. Visualization and Design Decisions

Refer to the goal again, what is the purpose of creating this visualization? What is the best way for designing this visualization, will it be scientific-based, software-based,

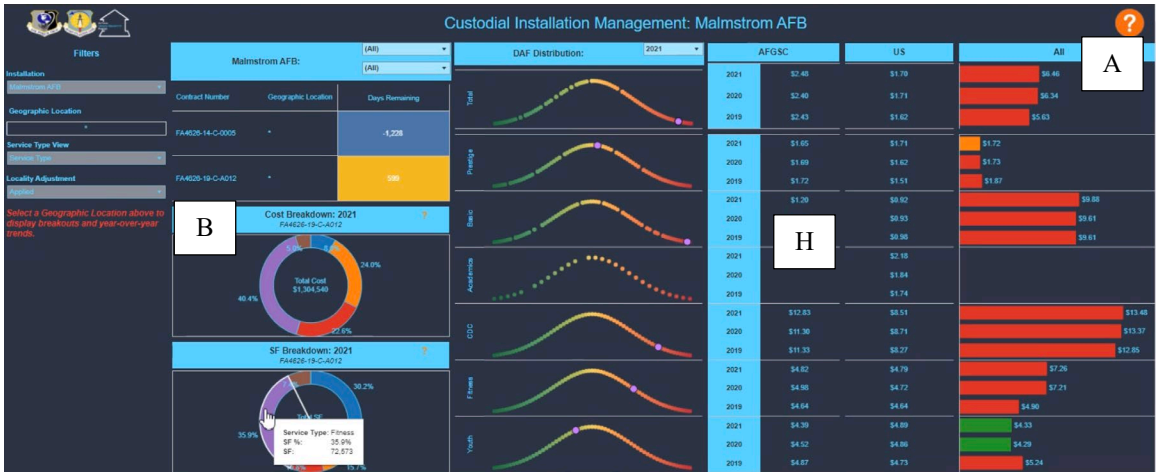
or information-based? (Zhu & Chen, 2006). As the purpose of this proposed framework is to guide creators in the realm of business intelligence, the route I inform on is information-based visualizations.

At this point, it is also important to reconnect again with whom this visualization is built for (customer/client/yourself) and who the end-user will be (Norman, 2013); the purpose is to ensure the direction of the visualization is meeting its goal. Moreover, recall that the purpose of user experience/interface (UX/UI) which is to put human needs, capabilities, and behavior first i.e., human centered design. This requires receiving feedback from customer/client through communicating the proposed UX/UI (Hartson & Pyla, 2019; Norman, 2013). Consider Table 3 for common uses and targets of visualizations within information visualization and Figure 15 for types of visual encodings (Metwalli, 2021; Munzer, 2015b).

I have also included Figure 14 (Big 3 Dashboard – Custodial Installation Management Example) as an example of how AFICC BICC utilizes these common visualizations. Within Figure 14, it shows an overview of custodial installation management at Malmstrom Air Force Base, Montana. The screenshot shows a cost breakdown, cost distribution in regard to different areas of spend, and spend over time. A Key point to note is from Unzueta's research in which he argues that no more than two visual encodings (embedded data extracted via vision) should be used within the same visualization as more visual encodings will clutter the visualization and create confusion/ extend data extraction time.

Table 3. Common Visualizations and Usage.
Adapted from Metwalli (2021) and Munzer (2015b).

Common Visualizations and Usage		
A	**Bar Charts**	**Compare parts of a larger set of data, showing change over time, focusing on certain categories**
B	**Pie Charts**	Compare and show proportions/percentage relative to the entire dataset
		When data is nominal and not ordinal
C	**Line Charts**	**To visualize trends and changes over time instead of exact values**
		When data is continuous
D	**Scatterplot**	To show correlation and clustering within large datasets
		When data order is not essential
E	**Area Charts**	**To show part-to-whole relations/portray volume of data in addition to its relation to time**
F	**Combo Charts**	To compare values with different measurements and show values that are different in range
G	**Boxplot**	**To identify the distribution of static data aggregation and range**
H	**Tables**	To categorize dataset in order to query - identify, compare, or summarize data



This figure utilizes letters that correspond to Table 3 to show real-world usage.

Figure 14. Big 3 Dashboard – Custodial Installation Management Example.
Adapted from AFICC BICC.

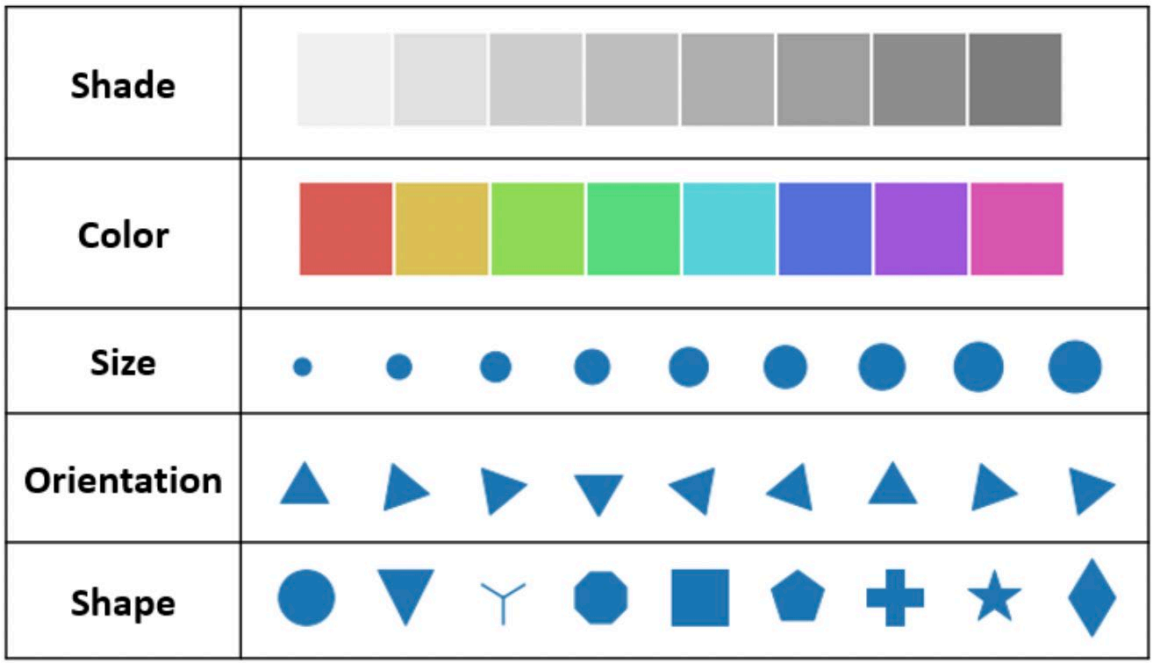


Figure 15. Retinal Encodings. Source: Unzueta (2022).

5. Data Analysis

Before the visualization can be considered complete, recall the goal and the customer/client/end-user once again – what was the purpose of creating the visualization; consider if the visualization requires interactivity. Unless the visualization is for presentation purposes only, more often than not, visualization interactivity is essential in any visual analytic tool (data viewing specifications, manipulation, and analysis process and provenance) (Basole et al., 2016) – this allows users to visualize the entire dataset, focus on subsets, categories, dimensions, or criteria etc. (Basole et al., 2016).

At this point, the creator would have completed one cycle of this proposed framework. However, I argue that it is not the end; data visualizations are not static because global events are not static. Data today may be useful for now and may be obsolete in a year, or even a second. As goals shift and change, so should these visualizations that support in achieving the goal. Finkenstadt et al. argue that continuous feedback is not only the key to ensure data remains relevant and useful for its purpose (ACCT), but it may also impact near and peer goals within the organization. I enforce this continuous feedback by creating my proposed framework in the form of a loop. Once one cycle is complete, we must ask ourselves if the goal is being met. If so, delay the

restart however keep communication channels open. If not, execute the proposed framework again.

I. SUMMARY

In this chapter, I discussed the importance of data as well as the importance of accurate, correct, complete, and timely (ACCT) data as it is the precursor to begin any type of visualization. I also showed the need for visualization as it allows for the maximum data extraction by human visual system. Next, I discussed visualization theory, what it is, and how data literacy is relevant in visualization. Then I presented design challenges and insights of visualization and correlating remedies, user experience (UX), user interface (UI) of design, and the four categories of UX. Finally, I reviewed visual signals, cues, and the need for visualization interactivity in the forms of specification, manipulation, and analysis.

The literature review guided my thematic analysis in order to find, categorize, and bin qualitative data identify factors and themes for my proposed BI Visualization framework. The literature review provided support that goals are essential in any visualization. It also showed that data collection can be simplified with more high-quality data. Moreover, this literature review shows that data cleansing is imperative to ensure information going in is standardized to produce a good visualization.

In this Chapter I also presented what common visualizations are and how they are used based on research, this also proved that visualizations benefit from allowing user interactivity. Moreover, the literature review allows the proposed framework to guide the methodology used to identify if real world application supports research claims. In the next Chapter, I will discuss the methodologies used for data collection and data analysis.

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III. METHODOLOGY

A. INTRODUCTION

This section of my research provides an overview of how information was gathered through semi-structured and narrative interviews with subject matter experts and end-users, and thematic analyses of Flex Ltd. (an industry leader in visualizing business intelligence within supply chain) and United States Air Force – Air Force Installation Contracting Center's Business Intelligence Competency Cell (USAF AFICC-BICC).

Using the findings of the interviews, I utilized a thematic analysis approach to analyze the responses against my literature review with qualitative data. My literature review presented six common themes that align with how to effectively utilize visualizations within business intelligence for procurement and supply chains. Those six themes were establishing goals, creating teams for collaboration, decision factors, data hygiene and cleansing practices, visualization/dashboard characteristics and decisions, and visualization cues and data analysis (Table 4).

Table 4. Theme Examples.

Themes	Example	Reference
Establishing Goals	"The design and development of interactive visualizations begins with a careful understanding of user requirements and task contexts. This step is often conducted through a multiphase design requirement analysis, consisting of field studies, interviews, and online surveys, with prototypical users."	Basole et al., 2016
Creating Teams for Collaboration	"The exceptions govern. They bring the right team of people from silos together to solve a problem. So what an enterprise needs is a mechanism that pulls exceptions and puts together in real time, a cross-functional team that operates across the end-to-end supply chain... "	Handfield & Linton, 2017, pg. 42
Decision Factors	"Ask yourself what critical decisions you will face in managing this value chain. What will you need better intelligence on for making decisions?"	Finkenstadt et al., 2022
Data Hygiene and Cleansing Practices	"Accurate, timely, reliable, and standardized data is essential for taking actions based on information. The adage "garbage in, garbage out" is citing in multiple organization interviews, yet managers are often unsure what steps are needed to improve data quality."	Handfield & Linton, 2022, pg. 137
Visualization/Dashboard Characteristics and Decisions	"...to develop these dashboards, individual users must visualize the desired outcome and critical leverage points in value chain processes that determine criticality or shifts in flows."	Handfield & Linton, 2022, pg. 142
Visualization Cues and Data Analysis	"Visual cues such as color and proximity are independent of each other because they are processed in different visual channels. As such, they can be employed independently to convey different attributes… Other visual cues such as color and luminance can interfere with each other because their visual channels overlap."	Zhu & Chen, 2006

Adapted from Basole et al. (2016); Finkenstadt et al. (2022); Handfield and Linton, (2017, p. 42); Handfield and Linton (2022, pp. 137, 142); Zhu Chen (2006).

For the first approach, I formulated the questions, for the semi-structured interviews for the subject matter experts, keeping in mind my proposed Business Intelligence Visualization Framework. The questions are focused on investigating the industry and government best practices, similarities, and differences. Aside from semi-structured interviews with Flex Ltd. and USAF AFICC BICC SMES, I also conducted narrative interviews with each organization to gather qualitative end-user experience information on their respective visualizations/dashboards.

Next, I compared and contrasted Flex's best practices against BICC's policies and best practices based on my aforementioned BIV Framework and literature review. These two approaches do not seek to conduct a comparative analysis of all business intelligence between the two organizations. Rather the analysis seeks to specifically investigate the

visualization of the business intelligence of procurement and supply chains by the way of information visualization. Through these three methods, I was able to objectively identify where gaps are, provide consolidated best practices, and similarities and differences of both organizations for each organization to consider.

B. DATA COLLECTION – INTERVIEW STRUCTURE AND DESIGN

I collected qualitative data through the use of a combination of key elements derived from the literature review to create interview questions for the semi-structured interviews. Harrell and Bradley's 2009 research on Data Collection Methods provided a range of interview control from uncontrolled to structured. For my research I wanted to be able to understand those specificities in greater depths, but this research is not so specific where a structured interview is necessary. This solidifies the pursuit for a semi-structured interview path. Harrell and Bradley state that, "[s]emi-structured interviews are often used when the researcher wants to delve deeply into a topic and to understand thoroughly the answers provided" (p. 27).

DeJonckheere and Vaughn, 2019 further cemented my decision to use semi-structured interviews, in which they describe a key purpose of semi-structured interviews as seeking and collecting exploratory data in relation to the research topic. From this data I used it to validate findings, triangulate other data sources, and identify new information to increase the integrity of this research. Moreover, the type of data received from semi-structured interviews contributed to a more accurate completion of the comparative analysis through the utilization of thematic analysis.

1. Interview Design and Interviewee Selection

There were 10 interviews: five were semi-structured, five were narrative (see Table 5 for details). Each one ranged between 45 minutes and 2 hours each. The interviews were conducted virtually via Zoom and Teams as all interviewees were geographically distant from me. The interviewees represented their respective organizations as subject matter experts in business intelligence, visualization design, supply chain, and those that utilize business intelligence visualizations in their everyday roles. The purpose was to collect qualitative data from their expertise on business

intelligence visualization design processes at their respective organizations. Each interview session was recorded in order to ensure all relevant data was collected and reviewed. When conducting these semi-structured interviews, I utilized my Business Intelligence Visualization Framework, derived from my comprehensive literature review, as a roadmap to guide the interview flow and ensure that any pivots were in line with the intent of the interviews.

The narrative interviews were conducted in an effort to garner a better understanding of user experience in regard to visualizations/dashboards. All narrative interviews were conducted via Zoom or Teams. I started all narrative interviews with a singular question, "as a subject matter expert and end-user, could you please describe the experiences you have had with visualization specifically with the ones you use?" In terms of the narrative interviews, I utilized my knowledge gained from literature review and the semi-structured interviews with SMEs to guide the flow of the interview.

Table 5. Interviewees

Interview Type	Number of Interviews	Organization	Title
Semi-Structured	2	USAF AFICC BICC	Chief, Business Intelligence Branch
Semi-Structured	2	Flex Ltd.	Senior Manager, Supply Chain Solutions
Semi-Structured	1	SAF/AQC (prior)	Chief, Procurement Branch
Narrative	1	Flex Ltd.	Chief, Procurement and Supply Chain
Narrative	1	SAF/AQC	Chief, Sourcing and Transformation
Narrative	1	Flex Ltd.	Senior Director, Supply Chain Management
Narrative	1	SAF/AQC	USAF Category Management Advisor
Narrative	1	Flex Ltd.	Manager, Supply Chain

2. Question Design

The design of the interview questions were also derived from my literature review and the aforementioned framework (see below for interview questions). The first theme was goal identification and establishments, from my literature review I gathered that having a goal was typically the first step to creating a visualization in. I wanted to understand if these two organizations set goals prior to visualization and how they set these goals.

Second, I looked into the pertinence of collaboration and team sizes to carry out the set goals – through my literature review, I learned that every source argued against

working in a vacuum or in a silo alone, rather collaboration and teaming is imperative. To that effect, I wanted to understand if the two organizations had teams, what were the sizes of typical teams, and who were the key players.

Third I looked into what the organization's decision factors were and how they were made in terms of visualization of business intelligence within procurement and supply chain. These questions also included the next framework theme of data hygiene and cleanse, specifically how these two organizations decide what data is to be utilized, how they down select and filter what data is necessary, as well as how they cleanse the data to be ACCT data.

Next, I wanted to understand what decision factors went into selecting the types of visualization they used, what factors determined whether or not those visualizations became dashboards, and how they were managed. Finally, I wanted to understand how the two organizations extracted data from those visualizations, what visual cues and signals were ideal, and how they know if they have met their goal.

1. How are firm/entity goals are created?
2. If the firm/entity utilizes collaboration and teaming to carry out business intelligence (BI) goals, how are these teams created, organized, managed?
3. What decision factors are at play when the firm/entity decides what data is to be used and how it is collected?
4. How does the firm/entity understand and limit the data they focus on for decision-making?
5. How does the firm/entity decide which BI functions require visualizations and dashboards?
6. What efficiencies are enjoyed/what best practice does the firm/entity have or utilize in cleansing data?
7. How does the firm/entity conceptualize and design their visualizations? Are they done individually, in small groups, or large user groups?
8. What factors go into selecting which visualization cues are necessary when analyzing data visualizations?
9. How does the firm/entity translate info/data into the context of a situation, and leverage that info/data into actionable insights?
10. What is the firm/entity's definition of real-time?
11. How are the firm/entity's visualizations/dashboards maintained?
12. How does the firm/entity utilize privileges/accesses for the visualizations/ dashboards?

13. How does the firm/entity unite the archipelago of different sectors to gather data? How is real-time data managed across the different sectors?

C. DATA ANALYSIS

After conducting interviews and collecting qualitative data I used thematic analysis to analyze the responses to validate my research, triangulate new information, and synchronize key themes in each area using key elements from the literature review. Thematic research "is a method for identifying, analyzing and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). The use of a thematic analysis approach aligns perfectly with this type of research. Use of thematic analysis allowed for flexibility as it, "minimally organizes and describes [my] data set in (rich) detail," (Braun & Clarke, 2006, p. 79) and "captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set" (Braun & Clarke, 2006, p. 82).

Using Zoom and Teams proved to be a benefit as each session was able to be recorded. Recording the sessions allowed me to be fully immersed in the interview process and direct the flow of conversation while also being able to probe validating or new data, instead of being overly focused on ensuring no data was missed during note taking.

After all sessions were complete, I reviewed each recording and utilized my proposed BI Visualization Framework as a guide to categorize each interview question and new findings into the relevant thematic groups within the proposed framework using a Microsoft Excel Sheet. Lastly, I created a table to consolidate the key themes, similarities, differences, and best practices of both organizations (USAF AFICC BICC and Flex Ltd.). Through all the interviews, I identified certain areas within the findings that my proposed BI Visualization Framework did not capture or was misinformed in. I modified/changed my proposed framework accordingly after having evaluated, analyzed, and compared all findings and literature review.

D. SUMMARY

In this section I discussed the overview of how information was gathered through semi-structured and narrative interviews, and thematic analysis between Flex Ltd. and United States Air Force – Air Force Installation Contracting Center's Business Intelligence Competency Cell. I also discussed why I chose a semi-structured and narrative interview structure, how I designed and created the interview questions, and reasons for my interviewee selection choice. In addition, I presented reasons why I chose the thematic analysis approach and how I collected, cleansed, extracted, categorized, and compiled the information utilizing the thematic analysis approach.

In the next Chapter, I present the findings from my research, the identified themes and thematic analysis, my comparative analysis, recommendations to both organizations, major changes to my proposed BIV Framework, and present my final BIV Framework Model.

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IV. FINDINGS, ANALYSIS, AND RECOMMENDATIONS

A. INTRODUCTION

In this Chapter I discuss my findings from the semi-structured and narrative interviews and present answers to my original research questions:

1. How are firm/entity goals are created and if the firm/entity utilizes collaboration and teaming to carry out business intelligence (BI) goals?
2. What decision factors are at play when the firm/entity decides what data is to be used and how it is collected?
3. How does the firm/entity understand and limit the data they focus on for decision-making?
4. How does the firm/entity decide which BI functions require visualizations and dashboards, as well as the design decisions to be made using visualization signals and interactivity?

I manually transcribed and took notes from all the interviews and analyzed the findings for themes. I then analyze the findings in terms of answering the primary focus of this research: what are each organizations best practices when it comes to goals, data collection, data cleansing and extracting, visualization signals and design decisions, and data analysis. After presenting findings and themes from both organizations, I present lessons learned. Lastly, I will provide my recommendations for both organizations.

B. FINDINGS AND ANALYSIS

1. Introduction

After completing the literature review, I identified six common themes that align with how to effectively utilize visualizations within business intelligence for procurement and supply chains. Those six themes were establishing goals, creating teams for collaboration, decision factors, data hygiene and cleansing practices, visualization/ dashboard characteristics and decisions, and visualization cues and data analysis. I utilized those six factors to create the first iteration of my business intelligence visualization framework.

By the end of my literature review, it became apparent that my first iteration was not correct. I created a second iteration (figure 13) that combined teams with goals. Using

the second iteration of my proposed framework, I organized my semi-structured interview questions into sections corresponding to themes to better organize and analyze the findings.

Figure 16 reflects the semi-structured interview questions with corresponding phases of the proposed framework. My findings from semi-structured interviews have changed some but not all of the factors and themes within the overarching framework. However, my research shows that my original question organization and binning was not completely accurate. Based on semi-structured interview responses and indicators, I made several changes throughout the framework. Throughout this chapter, the findings from both organization interviews and research showed me that my proposed framework needs to be changed in one of four (4) ways

- Validate Factors and Themes (i.e., Goals, Data Collection, Data Hygiene)
- Validate the Indicator (i.e., keep a question under the same factor I identified)
- Add/remove a Factor (i.e., add Test and Evaluation)
- Add/remove/move an indicator (i.e., moving question 4 to a different framework factor)

By doing this I then was able to enrich my proposed framework based on qualitative exploratory findings to enhance what I found in my literature review. Second, I was able to use that enriched framework to compare/contrast Flex and AFICC BICC.

Interview Questions Categorized by BI Visualization Framework	
Goals	1. How are firm/entity goals are created? 2. If the firm/entity utilizes collaboration and teaming to carry out business intelligence (BI) goals, how are these teams created, organized, managed? 5. How does the firm/entity decide which BI functions require visualizations and dashboards?
Data Collection	3. What decision factors are at play when the firm/entity decides what data is to be used and how it is collected? 13. How does the firm/entity unite the archipelago of different sectors to gather data? 13a. How is real-time data managed across the different sectors?
Data Hygiene & Cleanse	6. What efficiencies are enjoyed/what best practice does the firm/entity have or utilize in cleansing data?
Visulization & Design Decisions	7. How does the firm/entity conceptualize and design their visualizations? Are they done individually, in small groups, or large user groups? 8. What factors go into selecting which visualization cues are necessary when analyzing data visualizations? 10. What is the firm/entity's definition of real-time? 11. How are the firm/entity's visualizations/dashboards maintained? 12. How does the firm/entity utilize privileges/accesses for the visualizations/dashboards?
Data Analysis	4. How does the firm/entity understand and limit the data they focus on for decision-making? 9. How does the firm/entity translate info/data into the context of a situation, and leverage that info/data into actionable insights?

Figure 16. Semi-Structured Interview Questions Categorized by Proposed BI Visualization Framework

2. Flex Ltd. Findings

During my semi-structured interview with Flex Ltd., I noticed quite a few repeated key themes. After reviewing and analyzing the findings from my interviews with Flex, I have identified those key themes as:

- Teams are goal-oriented (i.e., frequent reference and the understanding why they are doing what they are doing)
- Usage and dependency on real-time data
- Ensuring a single source of truth is preserved
- Accuracy and speed of BI processes and iterations
- Efficiency-driven processes
- All stakeholders have high levels of feedback and communication
- Every design should be human centered with simplicity and consistency

I utilized Figure 16 to better organize the findings from the semi-structured interviews. The Flex Pulse team's basic framework of how a new category gets built into Pulse consists of questions shown in the list below.

- Where is the data is coming from?
- What does the ownership structure look like?
- How the end-user wants it organized

Their building phase includes actions as show below.

- Sit down with the end-user
- Ask the end-user, what do they need to see and what story do they need the data to tell?
- What is the point of the visualization? (e.g., HR states they need to see percentage of men and women in a certain grade and a certain tenure)

The intent is to work with end-users/stakeholders to organize the thought process around the data, and identify the data needed to support the through process. After carefully understanding Figure 16 and Flex Pulse teams' basic framework, the Flex Pulse team will create the minimum viable product[1] to excite feedback to identify and analyze if they are meeting the end-user/stakeholder's needs.

a. Goals

When discussing goals, the corresponding interview questions are 1, 2, and 5 (see Figure 17).

Goals	1. How are firm/entity goals are created? 2. If the firm/entity utilizes collaboration and teaming to carry out business intelligence (BI) goals, how are these teams created, organized, managed? 5. How does the firm/entity decide which BI functions require visualizations and dashboards?

Figure 17. Goal Themed Questions

Before Flex Ltd. creates a visualization or dashboard, they identify an issue, understand the data, verify whether or not a visualization is the answer, then begin their design process. These issues are either presented by other employees at Flex or internally within their own team. Flex Ltd. utilizes a business intelligence digital supply chain solution called Pulse. Flex Pulse is a "software-based supply chain visualization tool gives real-time visibility across your sourcing, transportation, manufacturing and inventory" (Flex Ltd., n.d.b). Figure 18 depicts a visualization in the form of an

[1] According to Eric Reiss (2011), "the minimum viable product [MVP] is that version of a new product which allows a team to collect the maximum amount of validated learning about customers with the least effort".

infographic, it represents the key characteristics of Flex Pulse – their methodology, foundations, who they support, the benefits, number of dashboards, types of delivery methods, and their functional areas.

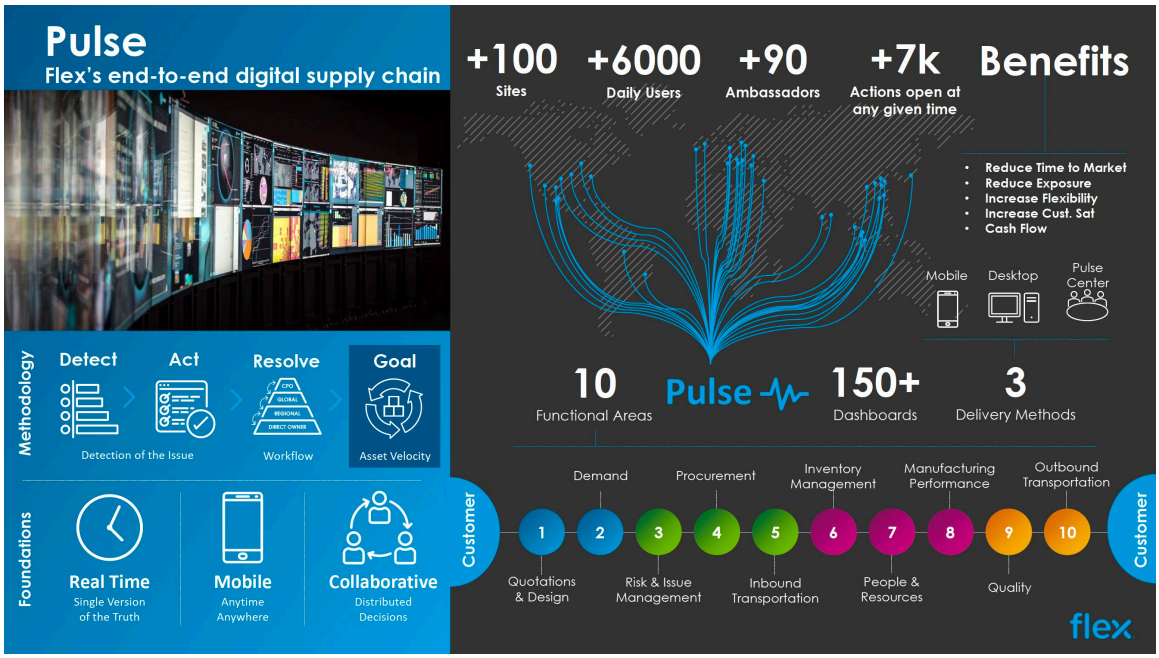

Figure 18. Flex Pulse Overview. Source: Flex Ltd. (n.d.).

Flex Pulse originally started with a singular goal with an identified inventory problem. Stakeholders met to discuss and identify the best way to resolve the issue. However, they were unable to identify the root cause of the issue. Their drive followed the old adage, you can't fix what you can't see, as a result they sought a way to visualize everything. Flex believed if they were not able to identify the cause, at the very least they needed the ability to see (visualize) what was going on – where those problems are, analyze it, find the cause, and subsequently, the solution.

Flex typically operates around two types of goals: preemptive goals, and reactive goals. Preemptive goals are conceptualized as problems or issues identified and brought forward by end-users. At Flex, preemptive goals are not considered emergencies. Flex identifies a preemptive goal as one that roots from end-user identified issues. More specifically, an issue an end-user has found that visualization could be a course of action to maximize profit in one form or another (i.e., improve productivity, mitigate risk, reduce cost). For example, when an HR team identifies a potential goal of being able to

better track/identify attrition or diversity. Flex notes that the current process may not be broken or suffering from a crippling issue, however, the end-users have identified there may be a visualization solution that would make data tracking and analysis more efficient. I.e., augment a human's capability to perform their work faster via faster data extraction.

On the other hand, reactive goals are the opposite of preemptive goals. In this instance the problem or issue appears unexpectedly and causes a shockwave that has potential major detrimental impacts in the company's performance. For example, during COVID-19 (March 2020), shortages were a huge issue as supply chains and manufacturing started to shut down. In response to the shortages, Flex's C-suite reached out to the Pulse team to assist in creating a visualization/dashboard in order to see these shortages. The goal was to be able to visualize and understand where they are, where they are coming from, what the key piece is to end the shortage, etc. This constitutes a reactive goal because this specific issue's magnitude was so large and sudden it took immediate priority over everything, in other words, an emergency. The Flex Pulse team was able to turn around a first iteration dashboard within 24 hours. That capability was possible because Flex already had an abundant amount of ACCT data and access to it.

Whether a preemptive goal or reactive goal, the issues brought forward must first pass the first test. Given the business problem, the Flex Pulse team collaborate with end-users and decide if the problem can be solved with visualization and if the data exists somewhere and in some form.

The determining decision is dependent on understanding the needs of the end-user through conversations, meetings, and collaboration with the subject matter experts (SMEs), e.g., end-users, data owners, and ambassadors. Figure 19 depicts the Flex Pulse organizational structure; it depicts the ambassadors as the centralized touchpoints from information technology team down to the end-users.[2]

[2] When I am referring to the Flex Pulse Team, I am referring to the Worldwide (WW) Support, specifically the supply chain solutions team.

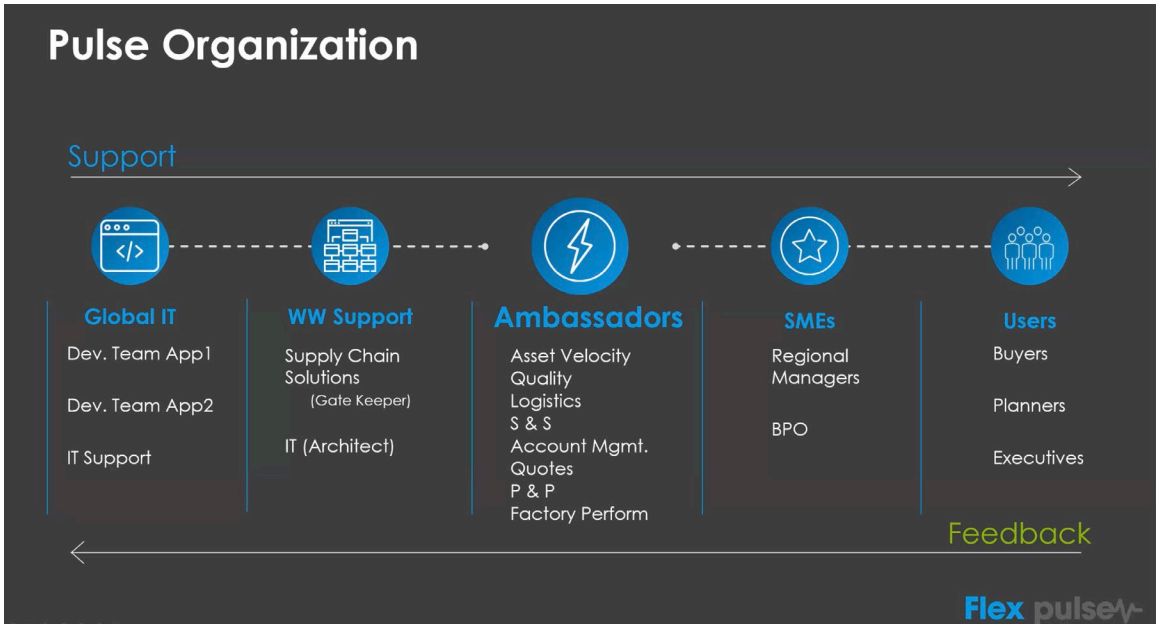

Figure 19. Flex Pulse Organization. Source: Flex Ltd. (n.d.).

When Flex team collaborates with SMEs, end-users, and stakeholders, they typically keep the teams to a minimum (usually no more than six). This ensures the speed of productivity and efficiency is not hindered. Should additional information be required, those within the communication circle will branch out to their respective groups to collect data before reconvening. According to Flex, not everything makes it into Flex Pulse. Flex is very stringent when it comes to what makes it into Pulse. The Pulse team heavily analyzes the global benefits to decide whether or not issues/problems needs to be a visualization or a dashboard. If a large proponent of the organization cannot benefit from the proposed visualization/dashboard (i.e., too niche), they may still create the visualization/dashboard, but will not upload and distribute to Pulse. Sometimes the solution is even more simple such as improving a process the end-users already use (e.g., improving a local excel workbook via macros and scripts, or creating a dashboard from existing excel workbooks/databases.

b. Data

Once the Flex Pulse team has fully understood the needs of the end-user, identified that a visualization/dashboard is the correct path to take, and has developed a goal, they begin the data phase. In reference to Figure 16, the corresponding interview questions are 3, 6, 13, and 13a, however, after analysis of the findings I have discovered

that Flex's process includes the analysis of data prior to designing the visualizations. Therefore, I have also included the data analysis section here, in reference to Figure 20, the corresponding interview question also includes data analysis question number 4.

Data Collection	3. What decision factors are at play when the firm/entity decides what data is to be used and how it is collected?
	4. How does the firm/entity understand and limit the data they focus on for decision-making?
	13. How does the firm/entity unite the archipelago of different sectors to gather data?
	13a. How is real-time data managed across the different sectors?
Data Hygiene & Cleanse	6. What efficiencies are enjoyed/what best practice does the firm/entity have or utilize in cleansing data?

Figure 20. Data Themed Questions

Flex has been an industry leader in the supply chain sector for decades, as such, they have access to an abundance amount of data. Therefore, having the access and enough data necessary to build the visualization/dashboard is not typically an issue for them. When it comes to what data is collected, Flex collects all data, even those that are local excel workbooks (those are collected and digitized). Flex's data management practice ensures that when data is collected, it is collected to their standards and is consistent, clean, useful, and correct. I.e., how they standardize each unit of data (their systems will fill in preidentified categories (e.g., part number, how many units per box, size, price, etc.). Although the raw data is not automatically synced into the data warehouse, data owners collect it to the lowest level database managed. When the Flex Pulse team receives requirements, they utilize systems that will pull the identified required data from the ERP system.[3] In effect, this ensures the raw data is organized and standardized which allows for ease of cleaning and transformation into ACCT data when called for.

This aforementioned requirement is based off of the previously defined goal, however, the ambassadors (centralized touch points for each end-user), data owners, and metric owners will lead the way in shaping the requirement. An important concept that Flex stresses is that these requirements and decisions are not IT driven. The requirement

[3] According to Oracle, an Enterprise Resource Planning (ERP) system is a: …complete, integrated platforms, either on-premises or in the cloud, managing all aspects of a production-based or distribution business… These integrated systems act as a business's central hub for end-to-end workflow and data, allowing a variety of departments to access (Oracle, 2021).

should be coming from the actual employees at the tactical level who are doing the work, the data owners and metric owners telling the Flex Pulse team the requirement.

I have identified different routes Flex takes when collecting data. These routes are dependent on whether or not the data exists fully, partially, or not at all. Given the maturity of Flex's data collection process, it is rare that data does not exist at all. In most of these situations, the data exists in low volumes (because it is very niche) and/or outside the main database.

If data exists in different forms and/or exists partially, Flex takes a temporary measure or reach out to end-users/SMEs. If data exists but is unstructured, they identify the key characteristics required to construct the data they do not have and create an algorithm that combines the data from those identified characteristics and provide a 90% accurate result.

If data exists partially, Flex collaborates with the end-users/SMEs to identify prior methods that worked and try to create a better solution, or work together to seek local data (e.g., a single employees downloaded the data into their own excel workbook and filtered/manipulated the data themselves). With local data, they can create either a new calculation metric, algorithm, or a subset of information in which the Flex Pulse team can transform that data into a standardized form and upload it into their database.

c. Visualization and Design Decisions

Once all the required data has been identified and collected, the next phase is visualization and design decisions. When referencing Figure 21, the corresponding interview questions are 7/8 and 10–12. After analysis, I have determined that question 9 should be included in this section as it aligns better with this section than data analysis. Question 9 aligns better with visualization and design decisions because it is paramount in guiding designers' design choices to meet the end-user/stakeholder's needs.

Visualization & Design Decisions	7. How does the firm/entity conceptualize and design their visualizations? Are they done individually, in small groups, or large user groups?
	8. What factors go into selecting which visualization cues are necessary when analyzing data visualizations?
	9. How does the firm/entity translate info/data into the context of a situation, and leverage that info/data into actionable insights?
	10. What is the firm/entity's definition of real-time?
	11. How are the firm/entity's visualizations/dashboards maintained?
	12. How does the firm/entity utilize privileges/accesses for the visualizations/dashboards?

Figure 21. Visualization and Design Decision Themed Questions

When designing any visualization and/or dashboard, the Flex Pulse team makes it a point to ensure that the end-user (human centered design) is at the forefront of the design. It is not only important to understand the goal (reason) of the visualization, but Flex also understands it is important to understand the users' data literacy level (to include technological literacy levels). According to Flex, data literacy is considered when designing the visualization/dashboard for the end-user. Flex's design team is able to assess end-users/stakeholders' data literacy level and determine which visualizations/ dashboards are suitable for their needs with a compatible data literacy level. Having the ability to decern data and technology literacy levels of an end-user/stakeholder is possible through the level of experience that their designers have.

Aside from data literacy concerns, the design decisions stems from two different key themes, clarity and consistency. One of the key design goals is to reach the fastest speed of understanding, to see a visualization and immediately grasp and process the data (generally five seconds or less). Flex Pulse includes categories other than supply chain, however in terms of the supply chain-based dashboards, Flex Pulse's design language strategy is ensuring the nucleus of the dashboard look the same for the purpose of consistency.

Through consistency, Flex is able to reduce the learning curve of each visualization. As a result of the reduced learning curve, efficiencies are enjoyed across the teams. This is because users are essentially using the same visualization design, interactive functions, and user interface (UI). Naturally one size does not always fit all, however, in those scenarios the Flex Pulse team answers the question, "what do end-users need to understand when looking at this, and what is the visually most responsible way to

go about it?" It is also important to understand not only what the end-users want to see, but why they want to see what they are asking to see, i.e., understanding the goal.

In addition to the key themes of clarity and consistency, Flex Pulse follows a basic four question framework understanding the goal of portraying the dashboards and the story it's supposed to tell:

- What is the big number/where are we right now (e.g., if it is inventory – how much total inventory do we have, what is the average weighted lead time, etc.)?
- Who or what is the biggest contributor to that (e.g., a list or graph that can be sorted/filtered/manipulated to further assist in identifying the data/ solution to solve the problem at hand)?
- Where is this going (e.g., because most dashboards are cyclical in nature, making sure within the cycle it is staying within scope)?
- Who is doing something about the problem (Flex built an action tracker into dashboards to ensure all stakeholders understand the status, expected dates of completion, and who owns that problem)? Ultimately it provides a quick representation and understanding of where we are of the specific problem.

Although the design decisions for each visualization/dashboard is intuitive to the designers, the Flex Pulse team acknowledges that sometimes the typical solution is not the best solution. Design requires a constant flow of communication between the design team, the ambassadors, and the end-users, and sometimes it requires trial and error, i.e., iteration.

Ultimately, when it comes to design – Flex Pulse has identified that simplicity is key. Because each dashboard seeks to solve a specific business problem, in utilizing a consistent base for all visualizations with consistent visual encodings (color, length, descriptions), it all results in a lowered learning curve. By keeping a consistent and simplified design of each dashboard, users only need to learn it for the first time one time and be able to understand what problem each dashboard is designed to help solve instantly. In effect end-users/stakeholders can easily identify the purpose of each dashboard and proceed to analyze and manipulate/filter through the dashboard to find the answers for their current taskings.

Flex Pulse's key considerations also includes the idea of ensuring all visualizations and dashboards present a single source of truth at real time. Flex Pulse was

designed with collaboration in mind and thus this single source of truth allows collaboration and communication to be flawless as discussions, meetings, conferences, etc., are all based on the same data within the visualization. Flex defines real-time not as live constant updates, rather an agreed upon data update frequency as it pertains to data freshness need.

The agreement of how frequent a dashboard's data is to be updated is made through collaboration between design teams, ambassadors, data owners, and end-users. Although new data is constantly flowing in and available, one constraint is how often new data exists. Ultimately, the main goal real time data is to ensure that all data on each visualization within a dashboard presents the right data, at the right time, in the right way, to the right people.

In certain cases, Flex Pulse's dashboards have an agreed upon update frequency (refresh rate) of 30 mins perpetually (in this case it is inventory management). This is because new data is constantly flowing-in, readily available, and end-users' need is high. In contrast for example, the material requirements planning (MRP) dashboard is updated every 30 minutes in the morning until noon, then retards to every four (4) hours. This is not because there is no end-user need, but rather in the afternoon, new data is not readily available as often.

Once the visualizations/dashboards are built, contrary to common belief, they do not require much maintenance as long as the data is flowing. Usually, the identified issues are not visualization issues but rather data issues in which the dashboard owners will work with the data owners to rectify those issues.

In terms of updates and enhancements, this falls on the dashboard owners. In those cases, the dashboard owners will work with the end-users to confirm whether or not these updates or enhancements are beneficial to them, if so, the dashboard owners will work with the design team to make those adjustments.

However, there is one consideration that Flex holds to high priority, and that is security. Flex considers security, accesses, and privileges very important after the design of visualizations and dashboards. In order to ensure the right data is available at the right

time to the right people, Flex created their own internally built security system, which is currently two layers, but will soon include three.

This security system gatekeeps who has access to which categories and which specific dashboards. Beyond that, there are filter-based security layers based on job positions which is validated by the data ownership group (i.e., if you are a global account manager in the U.S., you will only see data within the U.S.). This level of filtering/access request is typically enacted and approved when new employees are on-boarded and changed only if their roles change.

The last level of security is human-resources (HR) credentials based and is currently a work in progress. This level is exception based meaning the default setting is to reject all accesses unless your HR credentials annotate specific codes/flags. This is to ensure there is no spillage of customer data and that only the right people have access to that data. The measure of security ensures that the Flex's notion of single source of truth is not hindered or compromised.

This is important because single source of truth means one dashboard will include all relevant data for one supply chain solution, including confidential data. Once access is granted for a specific dashboard, Flex is confident including confidential data on dashboards because users who have access have already been filtered through their security layers, i.e., category security layer, dashboard security layer, and an additional security layer within dashboards depending on the data.

d. Summary

This section discussed the findings from semi-structured interviews conducted with Flex. The Flex Pulse team uses a basic feedback framework/loop that starts by asking: what's working, what's not working, what can work better – then they build a minimum viable product or suggestion and send it out to ambassadors (centralized touchpoints of communication between Flex Pulse and end-users. Flex has these across all levels of operation; regions, sites, categories).

The ambassadors then give it to the end-users and receive feedback to funnel it back to the Flex Pulse team to which the cycle restarts. This is all with speed, clarity, and

consistency in mind to ensure they get the right data to the right people at the right time so that they can make informed data driven decision faster and more efficiently. As a whole, the majority of my findings align with my proposed BI Visualization framework except data collection, data hygiene and cleanse, and data analysis.

In relation to Flex Ltd. after analysis, I found that data collection and data hygiene and cleanse were a single step, therefore I reported the findings in a single section. In terms of data analysis and their questions corresponding interview questions (questions 4 and 9) aligned better when presenting questions 4 with data and question 9 with visualization. In place of the evaporated final step, Data Analysis, I found the need to add Test and Evaluation. Through conversations with Flex, it is apparent that the last step of any visualization/dashboard goes through internal testing (i.e., does the UI work as intended) and evaluation (i.e., is the visualization/dashboard meeting user intended outcomes – UX/goals).

After these interviews, I observed and analyzed that the final phase was the test and evaluate the product they have made for their end-user. I continue this analysis through analyzing the findings from USAF. Flex Ltd.'s BI visualizations framework supports my BI visualization framework because the phases are correlated. They both seek to identify goals as a first phase, then collect data and extract the relevant ACCT data that pertains to the goal, and finally Flex designs the visualization and/or dashboard with a human centered design theory in mind while understanding the data literacy level of their end-users.

3. USAF AFICC BICC Findings

During my semi-structured interviews with USAF AFICC BICC, I noticed a few repeated key themes. After reviewing and analyzing the findings from my semi-structured interviews with BICC, I have identified those key themes as: accurate, correct, complete, timely data is paramount, transparency and visibility, data collection/cleanse is difficult. Other key themes are that the organization is mission focused, standardization and collaboration is a necessity, and visualizations/dashboards are minimal and simple. Although Flex and USAF AFICC BICC are completely different organizations, through semi-structured interviews, it is prevalent that they take similar steps to take an issue and

create/design a visualization/dashboard. Therefore, in this case, I utilized the same thematic binning for USAF AFICC BICC.

Using an example provided from USAF BICC, we can understand how they collaborated with their end-users/stakeholders, collected data and cleansed it, and how effective visualization/dashboards are. USAF AFICC BICC created a dashboard a few years ago called the Big 3 Dashboard that includes the top three common services of spend across all USAF bases (excluding contingency bases, i.e., deployed locations): custodial services, grounds maintenance, and integrated solid waste management) (see Figure 22 for Custodial Services Dashboard). Figure 22 presents a slide that shows the user interface and user experience features of a cost distribution for each level of service in Air Force Common Output Level Standards and features for a certain base in regard to different areas of spend.

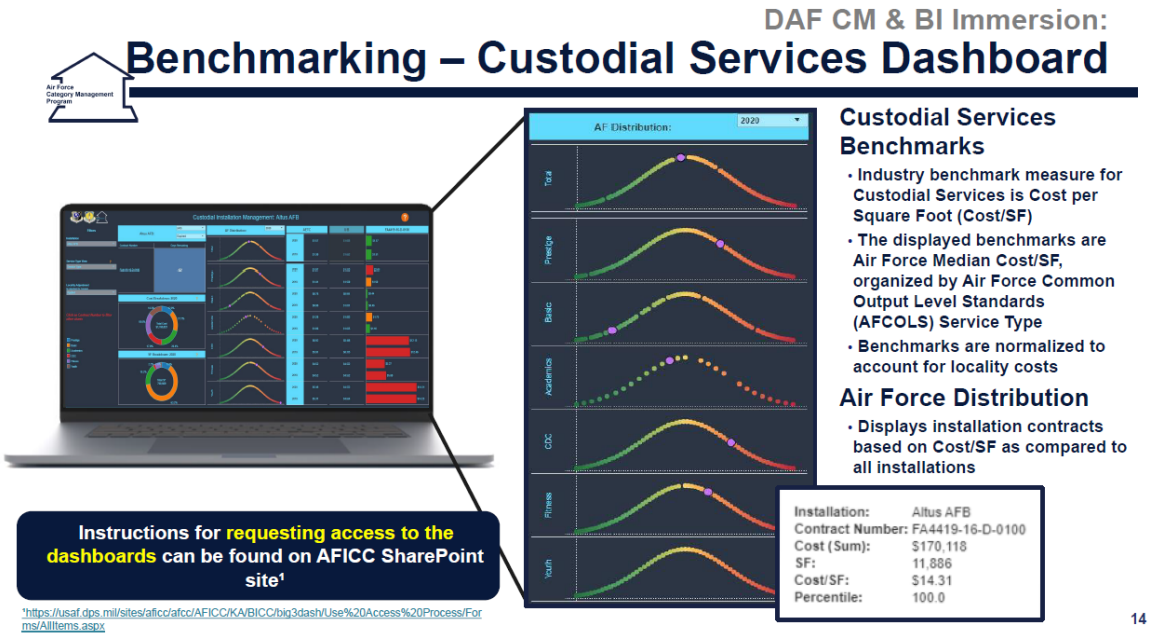

Figure 22. Custodial Services Dashboard. Source: AFICC (n.d.).

These three contracted services abide by the Air Force Common Output Level Standards (AFCOLS) and are generally standardized at conception through performance work statements (PWS) or statements of work (SOW). Buildings on USAF bases are generally standardized and similar therefore AFCOLS provides a custom template for a PWS/SOW for a new contract based on the type of service. For example, if it is a

custodial services contract – considerations include: what type of facility is it (child development center, gymnasium, hospital, administrative), what type of flooring, how many restrooms, square footage etc.

During times of cost evaluation and metric reporting, USAF tends to only analyze these services contracts by cost per square foot across all bases. When comparing different bases using this singular variable (cost per square foot) results in poor decision making as it does not explain away the erratic cost differences. Cost per square foot, by itself, does not consider any other external factors nor provide a fair or accurate comparison between the bases. I.e., it does not consider if the cost differences are caused by locality, vendor density, contracting office performance, or something else; nor does it show where specifically within a base the cost anomaly is coming from. As a result, when/if there are budget cuts, USAF tends to reduce cost across the board, which is objectively inefficient and unfair.

With the budget cut issue at hand, BICC collaborated with end-users/stakeholders to create a visualization/dashboard that increased visibility into the issue and showed total cost per square foot that compared bases. In addition, that dashboard also presented details that specificized between the different levels of services that allows BICC to produce distribution and control charts with upper and lower control limits. In effect, they are able to filter the data down – allowing them to accurately triage the issue and provide more accurate budget requests and drive down costs.

BICC emphasizes the necessity and importance of ACCT data for dashboard/ visualization and continues to collect data. This allows them to validate and verify the data extracted to show completeness and flag certain bases that are outliers to the upper and lower control limits, and it explains the why. For example, the data interactivity of the dashboard allowed all bases to understand their current standing as compared to other bases (goal/mission/spend etc.). As a result of transparent comparisons, this added an extra level of transparency and visibility that influenced data contributors to provide more ACCT data. More ACCT data drove stronger support for their requested budget (e.g., if a base exceeds the upper control limit. Through the ACCT data provided, the visualization/ dashboard can tell the story of why certain bases are reflecting certain metrics. For

example, perhaps they are in a rural location and there are not many vendors, or maybe they have a larger hospital/child development center than average that requires more specific services).

a. Goals

When discussing goals, the corresponding interview questions are 1, 2, and 5 (see Figure 23).

Goals	1. How are firm/entity goals are created? 2. If the firm/entity utilizes collaboration and teaming to carry out business intelligence (BI) goals, how are these teams created, organized, managed? 5. How does the firm/entity decide which BI functions require visualizations and dashboards?

Figure 23. Goal Themed Questions

USAF AFICC BICC supports many customers, their main goal is to provide enterprise solutions to meet the mission, questions, challenges for various customers. They take issues/problems presented by others and craft a solution that they manipulate/ filter to find the information they need to meet their goals. BICC identified that their issues/problems are receive from nearly anyone and everyone – the top down (SAF/AQ), bottom up (individual tactical units), and laterally with other functional communities. In addition, the issues/problems are provided from units under the Air Force Category Management Program to include, but not limited to: information technology, professional services, facilities and construction, logistics.

USAF AFICC BICC identified that there are differences in utilizations of visualizations/dashboards, i.e., there are two paths you can take – those are reporting and analysis. In terms of reporting data, they take the standard form of the data and solely present the cleaned and transformed data (think simplified visualization with no calculations and/or formulas). Simple variables include, product service code, contract number, contract actions, dollar amount, etc. Whereas the analysis path requires much more in-depth pre-analysis, calculation and/or formulas, e.g., how much money we spend on a particular requirement, who are those vendors, what do their supply base look like, what does the supply chain look like.

Once data is represented in dashboard/visualization form, people immediately trust that data. However, there is no control or measure to show if the data was verified, validated, or ACCT. AFICC BICC has identified that the mitigation factor is rooted to collecting proper useful data and thoroughly clean the data prior to inputting it into a visualization or dashboard.

Just as Flex filters the need for interactive visualizations/dashboards, BICC also identified that not everyone needs a dashboard. From BICC's point of view, if you're answering questions for a single point in time, you probably don't need a dashboard. A designer can provide a solution to that issue/need with a single graph or chart. Dashboards require sustainment of the visualization, collaboration with end-users in order to identify if the UI is working as intended, and what the UX feedback is (is the data being fed to the dashboard – is it automated or manual, is it ACCT).

At the inception of the problem/issue being identified, USAF AFICC BICC initiates a meeting with stakeholders to understand goals and use cases. The first thing on the agenda is to understand whether or not a dashboard/visualization is a viable option/ solution; this is achieved through asking the right questions and understanding the why behind the ask/need for a dashboard/visualization. In other words, to understand what the end-user requirements are and empathize with their environment to better diagnose potential courses of action. It is important to note that a dashboard/visualization does not solve all the problems, its purpose is to augment an end-user's capabilities and provide direction for deeper research and analysis. If visualization/dashboard does turn out to be a viable solution, the BICC team uses the findings to create a pseudo-minimum viable product and presents it to the end-users and stakeholders.

The communication entails review of the initial meeting outcomes (BICC's understanding of the end-user/stakeholder's requirements) and the individual correlated pseudo-minimum viable product's functionality/specifications (BICC's proposed solution) as a prototype. The point of this is to see if it aligns with what the end-user/ stakeholder's had envisioned. Often times, this open flow of communication drives more questions (more specific/focused/better) tangentially helps the end-user/stakeholders understand their requirement better. This open flow of communication and back-and-

forth discussions drive better more accurate visualization/dashboards that will meet the end-user/stakeholders' needs.

Workforce and available time are one of the primary constraints for the BICC team. BICC's data team is only seven personnel that support all of USAF AFICC which "…is responsible for managing and executing above-Wing-level operational acquisition solutions, across the Air Force enterprise" (AFICC, n.d.) (see Figure 24 for BICC team overview). The slide shows BICC's overarching task catalog of commonalties and differences between the data analytics team and BI support team and the organization structure).

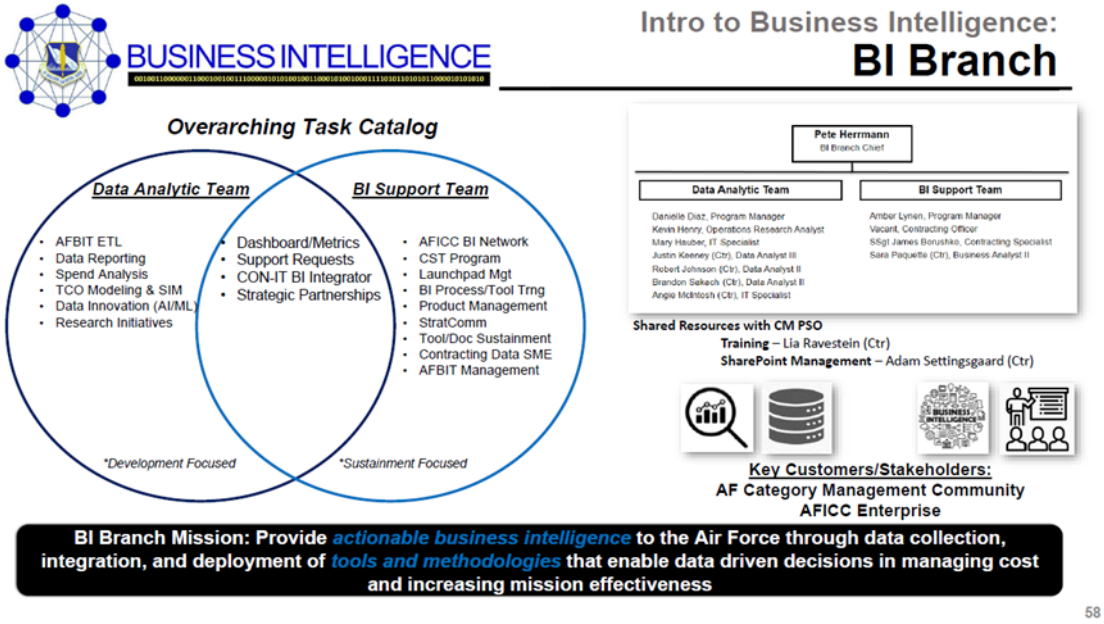

Figure 24. BICC BI Branch Overview. Source: AFICC (n.d.).

BICC's seven personnel is a comparison to Flex's team; they have 7–10 people whose job is 95%+ Flex pulse in the company. However, they have another 100–125 other people who have some responsibility to Pulse as part of their larger roles. Flex has dedicated developers who are almost entirely Pulse focused as well as other developers who are developing solutions both inside and outside of Pulse.

BICC's data team enjoys the efficiency of having multi-faceted personnel within their teams in addition to specialized roles (data engineers, data scientists, data analysts). Most if not all, have the ability to create visualizations and dashboards, albeit some are

more experienced than others. BICC's chief notes that the team embodies the figure of speech, Jack of All Trades, Master of None, with a twist by exchanging none to some. This is prevalent because the BICC data team not only creates visualizations and dashboards, but they also carry out modeling, simulations, and optimizations.

b. Data

In reference to Figure 16, the corresponding interview questions are 3, 6, 13, and 13a as shown in Figure 25.

Data Collection	3. What decision factors are at play when the firm/entity decides what data is to be used and how it is collected?
	4. How does the firm/entity understand and limit the data they focus on for decision-making?
	13. How does the firm/entity unite the archipelago of different sectors to gather data?
	13a. How is real-time data managed across the different sectors?
Data Hygiene & Cleanse	6. What efficiencies are enjoyed/what best practice does the firm/entity have or utilize in cleansing data?

Figure 25. Data Themed Questions

BICC is faced with two challenges in data, they are limited by the amount and type of data available and by the end-user's data literacy and subject matter expertise. First and foremost, BICC understands and limits the data they focus on for decision-making through understanding the end-user/stakeholders' goals and requirements. Through communication they are able to identify what the required data is and identify if this work has been done before. This is an added measure to reduce duplication of efforts. Because the process of creating a dashboard/visualization is painstaking and, in an effort, to ensure there is only a single source of truth there are times that BICC invests in identifying other potential stakeholders/benefiters. If there are other potential stakeholders/benefiters, they may increase the scope to better create a single source of truth, benefit from economies of scale, and reduce possibilities of duplication of effort by creating it right the first time.

Once the issue/problem has passed the validation for a need of visualizations/ dashboards and the identification of the types of data needed to collect, BICC beings the next actions. BICC's next actions are: to identify if that data is readily available, what the data's quality level is, what is the data's completeness, and being a government organization – what is the data access level. Often times not all the required data is

available, however BICC's data team does not let perfect be the enemy of good and constantly seeks to be directionally correct. For example, if the question posed is what the supply chain look like for widget X. To that effect, AFICC BICC can identify a directionally correct number of how many contracts and with whom, what companies we are buying them from… but without supply chain data there will not be able to integrate. I.e., If 80% of the spend is from five different suppliers, it is not possible to integrate without information/data on suppliers and who they are working with (second, third, and fourth suppliers).

Without useful ACCT data, it would not be possible to visualize what the supply chain looks like nor is it not possible to answer those questions. But when required data is not readily available, BICC conducts data calls, aggregates unstructured data, end-users' opinions, and relevant data. By the same token, if required data is non-existent/new data or requires enhancement, that role falls on the end-user/stakeholders. AFICC BICC is not in the new data collection business, however, they will provide recommendations and best practices to end-user/stakeholders to collect said data. When enough required data has been collected, BICC enters a process called extract, transfer, load (ETL). There are certain types of data that are extracted with assistance from automation using artificial intelligence (AI) via a verification/validation logic code. However, automation is not 100%, rather it allows the BICC team to operate in by exception. No manual input needs to be made unless there is an anomaly. Such anomalies are highlighted and flagged by a composed script created by the BICC team and that brings attention to the BICC team. For example, if the intended outcome is to identify what is being purchased on a contract line-item number (CLIN), the scripted algorithm will flag a CLIN description that states, funding for CLIN 1005. This is because the scripted algorithm recognizes that the CLIN description does not actually describe what is being purchased.

The second challenge of data literacy does not pose the same threat as data. As BICC is a Jack of All Trades, Master of Some they are able to better understand how to properly adjust the data literacy level of the visualization/dashboards they create. At the tactical level, those who ask for a dashboard to augment their everyday workload are generally data literate. They understand their subject matter and understand how dashboards can streamline their processes, make decisions quicker, and make better data-

driven decisions. Those at the tactical level within USAF that AFICC BICC work with understand the nuances of innovation and what it means to be mission focused business leaders.

However, at the senior leader level, they will want an exquisite and unique solution, but will not typically understand if the data is there or what it takes to actually get there. In short, there is a more realistic appetite at the tactical level than there is at the strategic level.

c. Visualization and Design Decisions

When referencing Figure 26, the corresponding interview questions are 7/8 and 10–12 from Figure 16.

Visualization & Design Decisions	7. How does the firm/entity conceptualize and design their visualizations? Are they done individually, in small groups, or large user groups?
	8. What factors go into selecting which visualization cues are necessary when analyzing data visualizations?
	9. How does the firm/entity translate info/data into the context of a situation, and leverage that info/data into actionable insights?
	10. What is the firm/entity's definition of real-time?
	11. How are the firm/entity's visualizations/dashboards maintained?
	12. How does the firm/entity utilize privileges/accesses for the visualizations/dashboards?

Figure 26. Visualization and Design Decision Themed Questions

BICC holds simplicity in high regards, i.e., having too many visualizations and dashboards presents InfoObesity as a result end-user/stakeholder are left in an analysis paralysis and over choice conundrum. This concept is in line with Clark and McGill's research, visualizations should avoid unnecessary complication and should seek to make data extraction as simple as possible (Clark & McGill, 1984). By creating too many visualizations/dashboards, it inundates and confuses end-users (causing overchoice/ choice overload). In other words:

> Cognitive impairment that occurs during a decision-making process when we are presented with too many options we cannot easily choose between. Our ability to make a good decision is reduced by the overload of choices, as is our satisfaction with the final decision. (Kras, 2022)

To capitalize on simplicity and mitigate user confusion, misalignment of data literacy, and the learning curve, BICC embeds a help screen for each page. They are focused on ensuring their visualizations and dashboards through employment of trusted agents and surveys. A trusted agent's role is to engage with the visualization/dashboard and provide raw honest feedback, their data literacy skills vary from no experience to very experienced. By utilizing a spectrum of data literacy, the BICC team is able to garner feedback from a sample size that encompasses the entire spectrum.

BICC self-identified a best practice that they are trying to achieve is akin to Flex's ambassador program. BICC fully understands the necessity of open flow communications and engagement with their end-users/stakeholders. Currently the BICC team organically completes the engagement with their end-users/stakeholders, however the size of their workforce limits communication frequency and potentially the quality of communication. In this sense, if there was a position/role that could mediate the communication between the creators, end-users, and every role in between, it would prove drastically helpful in increasing efficiencies.

When it comes to decisions of visualization and design, BICC relies heavily on their visualization/dashboard designers' intuition and experience. They note the type of visualization used is based heavily on designers' experience and intuition after understanding your audience, i.e., end-user/stakeholders. For example, the innate understanding of a time series based (trends over time) versus a geographic representation and likewise different from a search-based visualization.

In general, one best practice they have identified is to blend the different features of visualizations, i.e., pictures/graphs on top, descriptions below, key performance indicators (KPIs) on the side. This is in line with Dewan's research, "If we really want others to remember something, we should use words and pictures together. Because we store visual and verbal memories separately, we have the best recall when we are able to access one or the other" (Dewan, 2015, p. 2). However, BICC reminds us that sometimes too many types of data presented could be excessive, in which case it is important to reassess your audience's data literacy and subject matter expertise level, i.e., your end-users/stakeholders.

d. Summary

This section discussed the findings from semi-structured interviews conducted with USAF AFICC BICC. Once provided an issue/problem, they begin by calling together a meeting with end-users/stakeholders to better understand and empathize with the players and situation at hand.

First, they start by validating whether or not the issue/problem can be solved with a visualization/dashboard noting that not everything can be solved with visualizations/ dashboards. If the solution to the issue/problem can be helped using visualization, BICC quantifies if the goal is reporting or analysis.

Next, they collaborate with end-users/stakeholders to better understand their goals and why they need visualization to which they analyze the type of data they need, assess whether or not it exists or if new data is required, and begin the collection process. With initial collection, they create a pseudo-minimum viable product to provide to end-users/ stakeholders to verify if the product produced aligns with their goals and needs.

Once the sufficient ACCT data is collected and cleansed, they move on the visualization and design decision phase where they rely heavily on their designers to align the end-users/stakeholders' needs with their data literacy. Finally, once complete, they run, publish, and test the visualization/dashboard. To ensure the visualization/ dashboard stays aligned with the goals of the end-user/stakeholders, they employ trusted agents to provide unfiltered feedback and utilize surveys to solicit feedback.

4. Narrative Interview Findings (Flex and BICC)

In this section, I present the narrative interviews findings from both Flex and USAF AFICC BICC. These interviews included some structure but was not as structured as the aforementioned interviews. These interviews were mostly narrative to ensure subject matter expertise and end-user experience was drawn out. I started all narrative interviews with a singular question, "as a subject matter expert and end-user, could you please describe the experiences you have had with visualization specifically with the ones you use?" Some interviewees had four to seven years of experience with their organization's dashboards/visualizations. Some other interviewees were new to the

organization's dashboards/visualizations, but not new to visualization in general with two to four years of experience.

These four verbal interviews all ranged between 45 and 60 minutes. The interviewees positions varied from manager to chief/director. After analyzing all the interviewees, I found there were several themes that aligned with previous semi-structured interviews as well as my literature review. Those themes are: data visibility, availability of single source of truth, access to real-time data, standardization/consistency of metrics/data, and exponentially faster and easier to extract data versus without visualization. In addition to user experience findings, they also presented areas of improvement/recommendations. I included the findings from these narrative interviews, in the next section (V), when I provide my consolidated recommendations to Flex, BICC, and both organizations.

a. Flex Narrative Findings

I identified a few notable themes that aligned with my research, specifically: visibility, availability of a single source of truth, metric/data standardization/consistency, and speed of data extraction. The Chief Procurement and Supply Chain Officer, expressed Pulse/visualization as a fundamental tool used daily stating:

> With a press of a button, Pulse gives me visibility across our entire supply chain network and allows us to quickly identify focus areas. It's used a lot during reviews to have a common data baseline to drive discussions, debate and make data driven decisions. As part of our dashboard catalog we have some dedicated summary dashboards to help consolidate our key metrics for me and my leadership team in different consolidated views, which I use a lot to keep track of our key metrics. The other element I use often is the action tracker and the related summary dashboard, which gives me the visibility of our key supply chain actions we are currently driving in the organization. It also supports me to identify where I personally need to jump in to work on resolving certain issues as part of the escalation path.

Other interviewees also echoed the Chief Procurement and Supply Chain Officer's user experience of Pulse identifying that it is a huge improvement to quality of life when it comes to extracting data. Not only are the interviewees able to extract data within minutes or even seconds, but they are also able to utilize the interactive features to

extract data that is specific to their needs. Although I identified there were a few areas of improvement the end-users would like to see implemented (generally in regard to UI and UX), the general consensus show that Pulse has a tremendous positive impact. One interviewee stated, "[w]e are better off today than where we were 5–10 years ago. This is especially in terms of real-time availability of data and a single source of truth. We've come a long way."

b. BICC Narrative Findings

Air Force Contracting's (SAF/AQC) Chief of Sourcing and Transformation expressed BICC's dashboard as a force multiplier. He pointed out that not only do the dashboards/visualizations elevate employees' capabilities and outputs, but they also augment their ability to extract more data, analyze data better, and learn much quicker. In terms of UI/UX, he notes there is more to a visualization/dashboard than pretty pictures and aesthetically pleasing graphics. I found that the themes that hold great importance are standardization, clarity, and simplicity.

When dealing with $400+ billion and 250,000 contracts, a single source of truth, a clear and common understanding, and standardized dashboards/visualizations are paramount. The less time an end-user needs to spend on extracting data from a dashboard/visualization, the better. This is true for all end-users across the various different dashboards. This is why standardization is important, the consistency reduces the learning curve for end-users. A reduced learning curve means less time spent trying to figure out the dashboards and more time executing the mission at hand.

The interviewees emphasized the need for more standardized dashboards/ visualizations through examples of the different platforms they use. Specifically, they found it difficult switching from one organization's dashboards to another's (e.g., BICC's AFBIT to AQX's PMRT to Government Services Administration's (GSA) Data 2 Decisions (D2D) dashboard). Nevertheless, visualizations are a huge added benefit in Air Force contracting; they noted that the learning curve is a small price to pay to the alternative. Without visualization/dashboards they do not have a single source of truth nor real time data. Organizations would have to individually identify data sources, clean and transform data, identify algorithms and calculations to compute data required, and

cross-examine different reports to ensure data is ACCT. All this to only to end up with expired/old data. Ultimately, findings show that it is better to have a BI visualization with some flaws than no BI visualization at all.

c. Summary

In this section, I presented the narrative interviews findings from both Flex and USAF AFICC BICC. The interviewees hold various positions within the organization that are depicted on Table 5. Their experience with business intelligence and visualizations ranged from three to seven years. The findings had prevalent themes throughout including: data visibility, availability of single source of truth, access to real-time data, standardization/consistency of metrics/data, and exponentially faster and easier to extract data versus without visualization. The findings show that although there are areas of improvement, that I discuss in the next section, there is overwhelming support for business intelligence visualization within supply chains and procurement.

5. Comparative Analysis

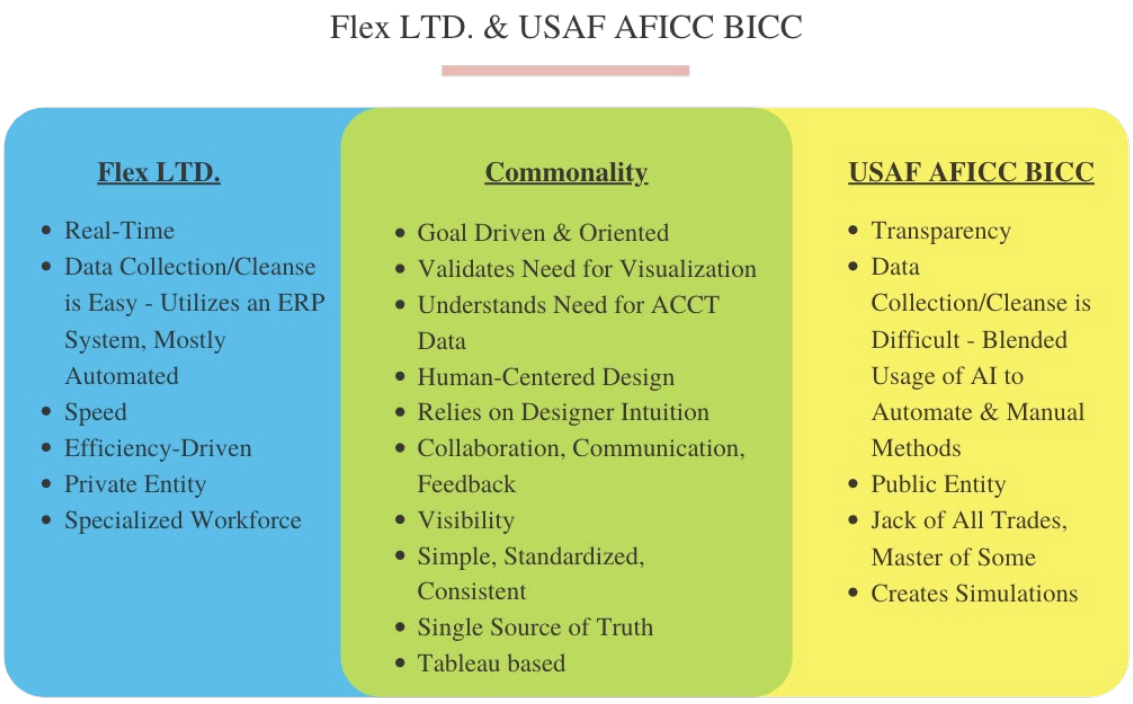

Figure 27. Venn Diagram of Flex Ltd. and USAF AFICC BICC

a. Commonalities

After thematic analysis of Flex Ltd.'s. and USAF AFICC BICC's semi-structured and narrative interview findings were complete, I created a Venn diagram to show the commonalities and differences between the two organizations (Figure 27). Overall, regardless of being a public or private entity, both Flex and BICC showed that they follow similar processes in taking an issue/problem to a visualization/dashboard. When they were presented an issue or a problem, they both began analyzing the issue/problem to ensure visualization could help augment human capabilities to find a solution. Both organizations then identified the necessary stakeholders that should be in the discussion with the design team and the end-users to ensure their vector is properly calibrated. They also note that organizations must have complete understating of the issue/problem, as well having an understanding why they are seeking visualization as a solution. After which, they take the information acquired and formulate their end target or goal.

My semi-structured interviews show that both organizations understand the importance of collaboration. Through collaboration, they and are able to identify the type of data that is needed and proceed to clean and transform the data to ensure it is useful and ACCT. Through ERP, Flex has the capability to collect cleaner data much faster. Since most of Flex's process is automated in which Flex operates through a by exception process. Although AFICC BICC is also able to enjoy data collection automation to some extent, there is still a large proponent of manual data collection to no fault of their own. This is because USAF personnel input data without understanding the underlying purpose.

In terms of visualization and design decisions, both organizations explained they relied on designer expertise and experience. This may be seen as a cause of concern as those designers will not stay in their position indefinitely. Without a standardized playbook, both organizations are susceptible to creating future/updating current dashboards differently than before, thus increasing the learning curve for end-users. With findings from the narrative interviews, it is apparent that the learning curve is of high concern to them. This is because none of their jobs operate in a vacuum and likewise no single dashboard/visualization is the solution for all issues. As such, this supports the

claim that reduction of learning curve is paramount for end-users. Although both organizations understand the concepts of user interface and user experience, additional investments to UI/UX can greatly benefit end-users.

Once the visualization/dashboard is complete, both organizations use their respective resources to test and evaluate their visualization and dashboard. Flex utilizes their ambassador program to solicit feedback from end-users, while BICC utilizes trusted agents to test the visualization/dashboards for them and provide unfiltered feedback.

Both semi-structured and narrative interviews show that both organizations understand the importance a visualization/dashboard's role in a single source of truth as well as updates and refreshes (as needed) to ensure data is real-time. Flex is able to conduct a more thorough real-time analysis than BICC because they have the workforce and data to support it, however, this does not mean BICC does not enjoy the benefits of real-time data. Both organizations utilize timestamps to reflect the visualization/ dashboard version accuracy. However, it is still ambiguous as to what the exact optimum refresh rate is for certain data.

Finally, another common best practice that both organizations enjoy is the implementation of the iterative/minimum viable product framework and partaking in a constant collaboration and feedback cycle with end-users and stakeholders. Through this, they are able to maintain the correct vector and modify the goal as needed to ensure the end-users/stakeholders' needs are met.

b. Recommendations

Through thematic analysis of semi-structured and narrative interviews, comparative analysis, and literature review, I present recommendations for Flex Ltd. and USAF AFICC BICC. While some recommendations are focused on one organization, both organizations may benefit from them as well.

(1) Common Recommendations

Within this section, there are recommendations that are focused on a particular organization (i.e., Flex Ltd., or BICC), however I believe that both organizations stand to

benefit from these recommendations. Within this section, there are two recommendations that can benefit both parties.

The first common topic of recommendation is influenced by narrative interviews and refers to right-time. At first glance, Flex's right-time data seems to be pristine and unflawed. However, through my narrative interviews and analyses I have identified that there are flaws with frequent refresh rates. For example, to have the most current data and pushing out refreshes every 15 or 30 minutes seems ideal, however the negative externality is confusion at the end-user level. Currently within the Flex Pulse Dashboards, there is not a way to identify or track changes from one version of data to another. In turn, this creates difficulty in identifying the source of the change. End-users resort to taking screenshots and/or notes of how they previously set data interactivity preferences (i.e., data viewing specification, manipulation, and/or analysis process or provenance) in order to track down the differences.

My research shows there are two viable recommendations. The first is to ensure that human centered design is kept at the forefront of decision making for visualizations/ dashboards; to re-evaluation what the right-time is for certain metrics or implement a track-changes to visualizations/dashboards. There may be a need to reevaluate or redefine what right-time is within the organization. This can be accomplished through a deep dive with stakeholders and end-users to understand what a more optimal refresh rate for visualizations looks like.

Both organizations understand data availability does not justify a need for a refresh. The interviews have proven that these deep dives do happen, however there may be a need to re-evaluate this in the near future. On the other hand, if current refresh rate is optimal, I recommend a track-changes feature that can be toggled on/off akin to Microsoft Word's track changes. This way, end-users are better able to quickly identify and extract the why and how the data differs from version to version. The inability to track changes and quickly identify the differences fails the general purpose of visualization, that is to efficiently extract useful and ACCT data from a dataset (Basole et al., 2016; Norman, 2013; Unzueta, 2022; Zhu & Chen, 2006).

The second recommendation also stems from narrative interviews and responds to the inconsistency of color designation. Although standard operating procedures may prove to be a hinderance in a rapidly changing environment (such as supply chain), I recommend a playbook be created for designers. The recommended playbook would include a tracker that shows what the color means corresponding to data throughout all dashboards. This will ensure that each color selection reflects the same data through all dashboards (see Figure 28 for example, 12 and <26 weeks is purple on the inventory ageing dashboard, while 12 and <26 weeks is orange on aging trend dashboard).

In addition to the previous recommendation for both organizations is the choice of visual cues. Although Flex and BICC do use a monochromatic scale that does not interfere with visual receptive channels as described by Zhu and Chen, the choice of color intensity does interfere with human cognitive abilities. In Figure 28, we can see the utilization of different intensities of yellow, however, it is not immediately separable to the human eye. According to Zhu and Chen and Clark and McGill, visualizations should be legible and be highly contrasted to differentiate different data points.

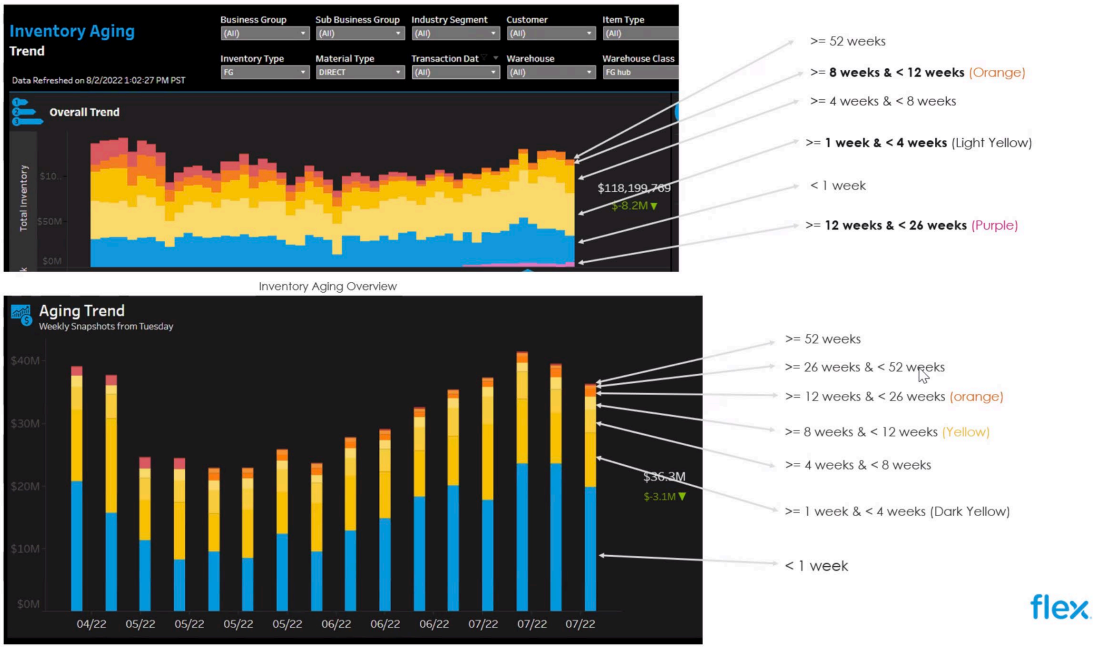

Figure 28. Screenshot of Flex Pulse Bar Graphs. Source: Flex, n.d.

Without a standardized playbook, both organizations are susceptible to creating future/updating current dashboards differently than before, as a result increasing the

learning curve for end-users. I have also observed that both organizations understand the concepts of user interface and user experience, however, more focus in UI/UX can greatly benefit end-users.

(2) Recommendations for USAF AFICC BICC

There are three recommendations I present for Flex Ltd. Some of which are best practices observed from USAF AFICC BICC, others are guided by semi-structured and narrative interviews along with my literature review. Although these recommendations are for Flex, BICC may also be able to gather lessons learned from this section. My recommendations include re-evaluation of right-time, UI/UX considerations (minimization/simplification, and consistency), possibilities of modeling and simulations with the same team, and creating a directory of dashboards.

Although Flex Pulse already considers human centered design model in creation of visualization/dashboards, there is a requirement for added focus on consistency and visual legibility. As a whole, Flex Pulse visualizations/dashboards are quite consistent between one another. Nevertheless, from end-users' perspective, there are nuances that increase the learning curve when switching between each visualization/dashboard. The challenge at hand is ensuring the user interface is the same throughout all dashboards. Currently many dashboards suffer from misplaced interactive buttons and drop downs (i.e., top left on a global dashboard, but top right on a regional dashboard; some dashboards have multiple report download buttons, some have only one). I recommend that designers collaborate with end-users to investigate the inconsistencies of these buttons to ensure that the user interface is standardized.

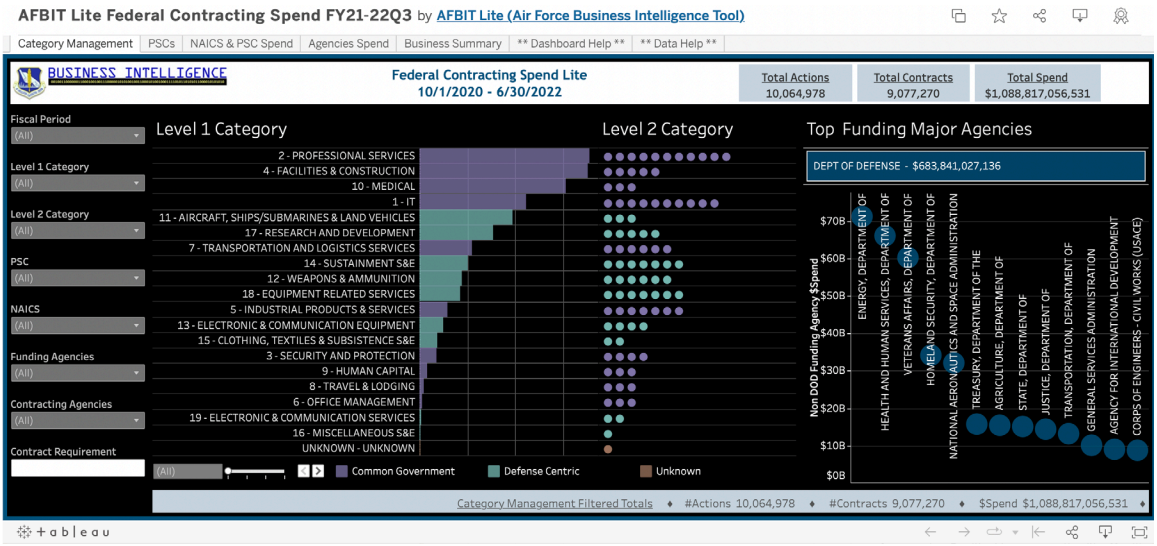

Figure 29. Screenshot of Air Force Business Intelligence Tool Dashboard. Source: AFICC, n.d.

Through analysis of USAF AFICC BICC's dashboards (Figure 29 – AFBIT LITE home screen), they seem to be able to circumvent this challenge by reducing the number of interactive functions on a single dashboard to the bare minimum (seven interactive drop-downs on the lefthand side). If reducing the number of interactive functions hinders the usefulness of the visualization/dashboard, I recommend the general interactive functions, that are used across all dashboards, be placed in the same location; after which, the dashboard specific interactive functions be places sequentially after the general functions.

Another possible option is to explore the ability to hide manually hide the interactive drop downs when they are not in use. The benefit of being able to reduce or hide the number of interactive drop downs is in reducing overchoice, as well as allowing end-users to view more or larger visualizations within the dashboard.

The next recommendation stems from narrative interviews and that is the talent identification for the potential to conduct modeling and simulations in the future. This goal comes directly from the Chief Procurement and Supply Chain Officer of Flex, noting, "one area would be prediction/AI and the opportunities related to this field. E.g., If Pulse could show us the future and be better in predicting events it would be extremely helpful."

From my research and analysis of interviews, there are some commonalities between the subject matter expertise required for visualization/dashboard design for reporting/analysis and simulation/modeling. The interviews with Flex show that they have a culture that reduces people from working in a silo. However, I recommend embracing AFICC BICC's culture to be a Jack of All Trades, Master of Some. With their small team, they are already creating simulations/models. Designers currently working on Pulse may already have the ability and knowledge to create visualizations/dashboards for modeling/simulations. Nevertheless, it may not be identified if the question is not asked. For a first iteration, I offer using my proposed framework as guidance.

My final recommendation is also supported by narrative interviews. Flex considers security, accesses, and privileges to be very important after the design of visualizations and dashboards. In order to ensure the right data is available at the right time to the right people, Flex created their own internally built security system, which is currently two layers, but will soon include three (see Chapter III, Section B2c).

It is understood that visibility and accesses to different dashboards within Flex Pulse are controlled through Flex's three phase security system (unless an end-user has a certain role or a need-to-know classification, they will only be able to see dashboards that are automatically coded for their role within the company). The negative externality of Flex's three phase security system access prevents users from seeing all the dashboards that Flex Pulse has to offer (i.e., an employee working in human resources team cannot see dashboards that an employee working in finance team can see, and vice versa. However, the nature of their jobs are complimentary.

I recommend that a creation of a dashboard directory for employees. This would be beneficial in showing employees potential possibilities of completing a tasking using a different type of dashboard, i.e., discovering that their current issue/problem can be solved by an existing dashboard, that to their knowledge, does not exist. This is would also be beneficial in increasing communication and collaboration between teams that have complimentary roles (e.g., overage inventory and purchase order execution). This would reduce double-work, communication, and improve innovation. As American writer

Jonathan Raymond once said, "[y]ou can't know what you don't know. You can't know about things you have yet to discover."

(3) Recommendations for USAF AFICC BICC

There are four recommendations I present for USAF AFICC BICC. Some of which are best practices observed from Flex Ltd., others are guided by semi-structured and narrative interviews, and my literature review. Although these recommendations are for BICC, Flex may also be able to gather lessons learned from this section. My recommendations include aligning or partnership with other government visualization teams, adopting Flex Ltd.'s ambassador program, UX considerations (walkthrough videos for each dashboard), and creating a training program for data owners/end-users.

My semi-structured and narrative interviews with BICC have showed me that their data team is not the only team that creates visualizations and dashboards for all of USAF's business intelligence withing acquisitions. There are other teams within USAF that perform similar or same roles and responsibilities. As there are many different visualization/dashboard teams across USAF as shown by the narrative interviews. One huge inefficiency is the lack of consistency and standardization of user interface from one visualization/dashboard to another. USAF installations all perform different missions and have different objective and are also geographically separated. USAF personnel are prone to rotating through these positions every 2–5 years. The lack of intercommunication, consistency, and standardization greatly increases learning curves for USAF personnel.

Moreover, due to the lack of intercommunication, there is bound to be duplication of effort from data collection, cleansing, and ultimately visualization/dashboard creation. In the current state of operation, the unseen challenges a USAF personnel is faced with rotations is akin to a private sector employee switching companies. Not only will the data different, dashboards/visualizations will also be different; in effect multiplying the challenges of navigating new waters.

My semi-structured and narrative interviews show that a necessary recommendation for USAF is to consolidate investments in data teams that are involved in enterprise level acquisition-based business intelligence. For example, project

management resource tools (PMRT) is a dashboard that is used by many USAF enterprise acquisitions professionals (see Figure 30 for example. This figure shows an overview of number of contract actions, obligated dollar amount, awarded value, which organizations are making the awards, and an organization summary). PMRT was created by USAF Acquisition Integration (SAF/AQX). However, because the dashboards are created by two different organizations, there are hardly any consistencies between a BICC dashboard and an AQX dashboard.

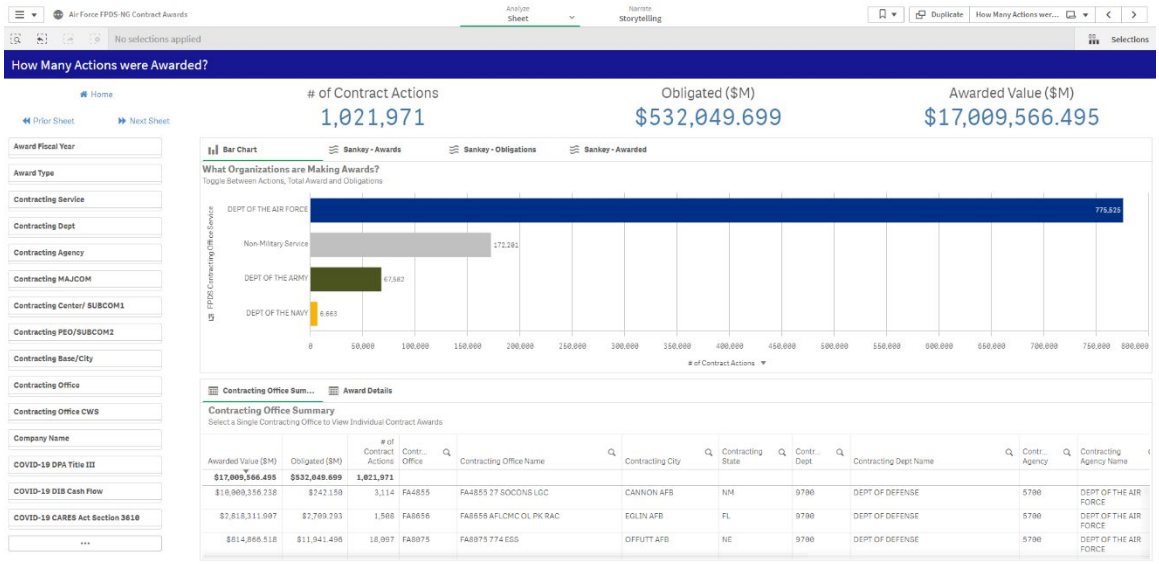

Figure 30. Project Management Resource Tool Dashboard Screenshot. Source: SAF/AQX (n.d.).

My recommendation, therefore, is to align all the individual acquisition business intelligence units that are working in a silo under one command/leadership; this is to ensure there is consistency/standardization across all acquisition organizations. Alignment means to unite and synergize methodologies, business data management, design principles, and best practices and lessons learned. This way USAF can truly achieve a single source of truth across all acquisition visualizations/dashboards and reduce learning curves for end-users. A positive extremality is the enjoyment of innovation clusters and communication of best practices.

The second recommendation identified through semi-structured interviews is to adopt a system akin to Flex's ambassador program. Their ambassador program is the central touchpoint between dashboard owners, data owners, end-users, and the design

team. The ambassadors not only streamline the flow of communication between all stakeholders, they also are able to consolidate and package feedback into designer vernacular. For USAF, an ambassador can be likened to the roles and responsibilities of a contracting officer representative (COR). The CORs help develop requirements, have some subject matter expertise at the tactical level, and mediate communication, performance, and feedback between contracting officers, customers, and vendors.

Currently, I have evaluated that BICC is the central touchpoint for all visualization/dashboard. With such a small workforce, it may prove to be time consuming and take away from their main role to create and design visualizations/dashboards for AFICC. Through semi-structured interviews with BICC, they showed me that they utilize a trusted agent system. Currently those trusted agents are only testing visualizations/ dashboards and providing unfiltered feedback. I recommend BICC transform the roles and responsibilities of a trusted agent system to an ambassador program (akin to DoD CORs). This way, the trusted agents are able to augment the BICC's design team as a representative.

My third recommendation is guided by narrative interviews and involves improving upon a UX feature BICC already has. Whether it is a new user or a returning user that does not have frequent interaction with BICC visualization/dashboards, learning a new tool can be daunting. Through interviews, I have learned that a walkthrough video may be helpful in reducing an end-user's learning curve and increase user experience. BICC can reduce the learning curve by leveraging Flex's best practice – creating short videos for each dashboard. These videos are accessible on each screen through a question mark button. The videos are stored on Flex's cloud database and are accessible anywhere anytime.

Flex's best practice in utilizing video walkthroughs of all the basic functionalities within a specific visualization/dashboard answer frequently asked questions. The current UX feature that BICC utilizes is a help screen tab for both dashboards and data. As the data and information already exists, it would only be a matter of screen recording a walkthrough. At the minimum, I recommend a general video walkthrough for all visualizations and dashboards to show users how to navigate the help tabs.

My final recommendation to USAF AFICC BICC is in more efficient and ACCT data collection. Through interviews, I was able to understand the painstaking process of manually collecting data only to find that the data is not ACCT. One identified root cause to this is that data owners and end-users who input data may not understand the importance of inputting ACCT data. The other identified root cause is that the data owners and end-users may not understand what ACCT data looks like. To ensure the ambiguities are cleared, I recommend BICC create a short training that can be sent to AFICC organizations. This training would include an explanation what accurate, correct, complete, and timely data should look like and why it is important to ensure the data is inputted that way. It may be beneficial to present prior achievements in cost savings to USAF AFICC BICC that may have trickled down to the end-users.

6. Major Changes to Proposed BIV Framework

In this section I present major changes made to the previous iteration as informed by semi-structured interviews and thematic and comparative analyses. I then present the final iteration of my Business Intelligence Visualization (BIV) Framework Model.

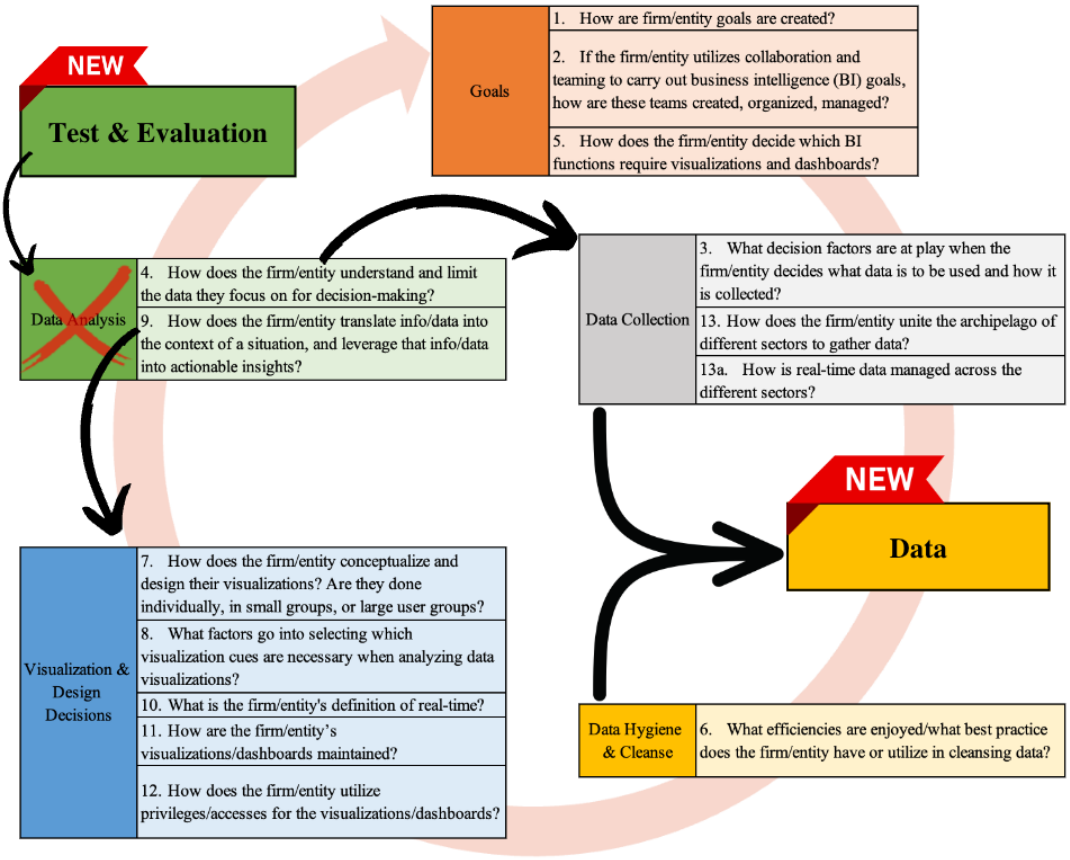

Figure 31. Visualization of Major Changes to My Proposed BIV Framework

The Goals factor, themes, and indicators remain unchanged. The literature review, semi-structured interviews, thematic and comparative analyses validated these factors and themes.

The Data Collection and Data Hygiene and Cleanse factors and themes were validated by my research. However, I have determined through semi-structured interviews, thematic and comparative analyses that the indicators from both factors are not considered to be separate factors and themes in a real-world application. Although industry and government consider data collection and data hygiene and cleansing as two individual actions, they consider this to be a single phase. This is because in a real-world application these two actions are not completed in succession as I had originally thought. Collection and cleanse happens on a spectrum, rapidly, separately, and together.

For example, some organizations consider cleansing data before it enters a database, then collect, and cleanse again to standardize. Other organizations may retain

raw data, collect, then cleanse and evaluation, collect more, then cleanse again. Therefore, I have combined the two factors and joined the corresponding themes and indicators into one factor – data. In addition, research shows that a theme and indicator from my original data analysis factor belongs in this factor, which I will discuss after the next factor.

The original Visualization and Design Decisions factors and themes remained unchanged. The literature review, semi-structured interviews, thematic and comparative analyses validated these original factors. However, research shows that a theme and indicator from my original data analysis factor belongs in this factor, which I will discuss next.

Data Analysis	4. How does the firm/entity understand and limit the data they focus on for decision-making? 9. How does the firm/entity translate info/data into the context of a situation, and leverage that info/data into actionable insights?

Figure 32. Data Analysis Themed Questions

The original Data Analysis factor, themes, and indicators are completely different and have been removed/moved. Although my research validates this factor, my research shows this is not a single theme and that the indicators are more accurately aligned with the Data and Visualization and Design Decisions factors. Research shows that question 4 belongs in the Data factor.

Although data analysis requires limiting data for decision-making, research showed that it was incorrect in placing it so late within the framework. Prior to considering visualization and design decisions, it is paramount to understand and limit data to ensure there is no InfoObesity and data saturation. If there is too much data, it increases the interactive control complexity and hinders end-users and stakeholders from quickly and effortlessly extracting needed data. Research shows that it is important to keep human centered design at the forefront of design decisions. Designers must ensure UX/UI decisions align with accelerating speed and reducing effort.

Question 9 discusses the transformation of data into actionable signals. My original selection for this indicator does not stray from a data analysis factor. However, akin to question 4, this was misaligned and was originally place too late within the

framework. Through interviews, research and analysis shows that this question needs to be considered during the building phase of the framework. As designers, we must actively communicate and collaborate with end-users/stakeholders to understand not only why they are requesting the ability to visualize this data, but why they need to visualize the data. Only after completely fully understanding the why can designers properly make the most accurate visualization and decision factors required to augment end-users/ stakeholders for their intended needs.

The final major change is the creation of a new factor and theme, Test and Evaluation. Research shows that this is a very critical factor that I did not originally capture within my proposed framework. After the visualization/dashboard has been created and designed, industry and government show that it must be tested and validated. This is step within the framework where a majority of the feedback is received. There must be open channels of communication and deliberate collaboration with end-users/ stakeholders. When the visualization/dashboard is put through a test and evaluation phase, all interested parties can properly measure the success of the visualization and identify unintended outcomes, bugs, and basic operability. Ultimately, this phase answers the questions: does it work, does it fulfill the end-user/stakeholder's goal and intended outcome.

7. Business Intelligence Visualization Framework Model

In this section, I present the final iteration of my Business Intelligence Visualization Framework Model, step by step instructions, and the visualization and design decisions behind it. One key factor to note is that my framework model assumes that your design team is already in place. This is because this framework model is based on real-world environment and not an educational environment. This is not to exclude an educational environment. Should this be used in an educational setting, ensure you have a design team in place before engaging in my framework model.

The intended audience for this framework model includes designers that have little to no experience in creating visualizations/dashboards as well as designers that may have some experience designing dashboards but have not created a business intelligence visualization/dashboard within supply chain/procurement. In addition, the intended

audience also includes end-users/stakeholders. My framework model augments their learning capabilities to better understand the business intelligence visualization design process, key players involved, and roles and responsibilities of each key player.

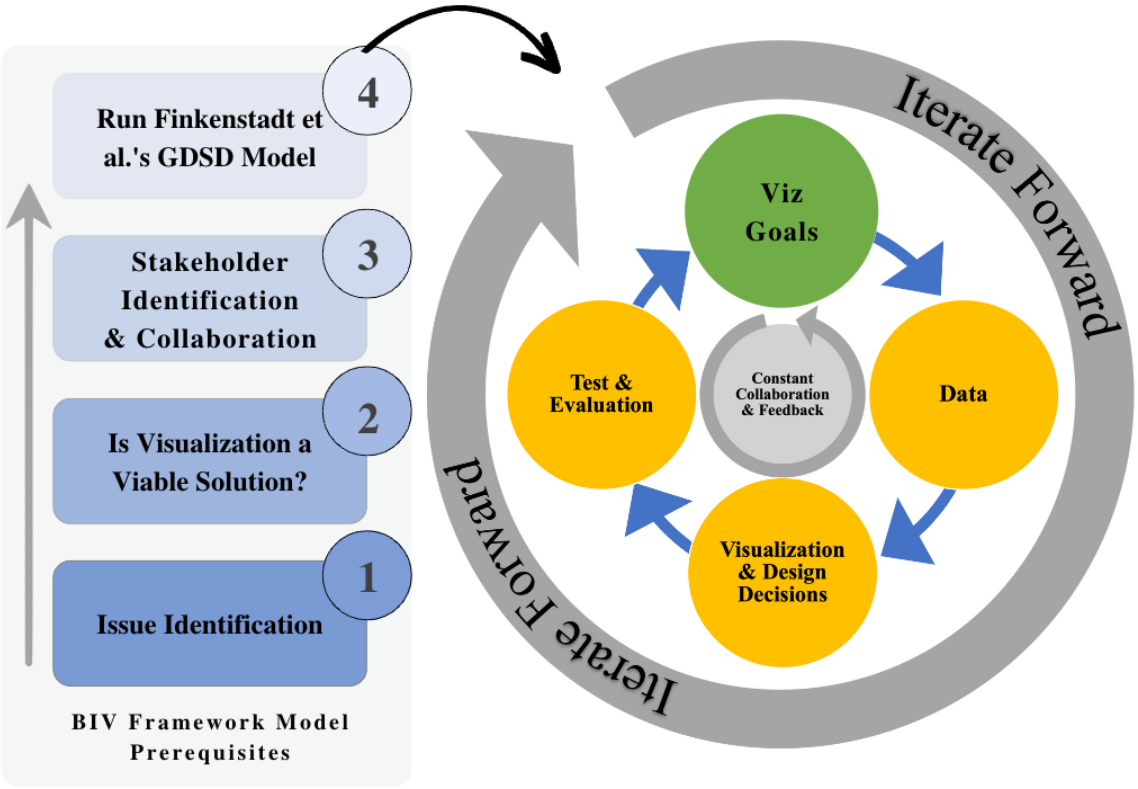

Figure 33. Business Intelligence Visualization Framework Model

a. General Instructions

My Business Intelligence Visualization (BIV) Framework Model is both a framework and a model. It includes a prerequisite, a set of steps that must be complete prior to engaging the cycle. The four steps of the prerequisite will only need to be completed once, unless the scope (issue) changes greatly – in which case this may be an indicator that a new visualization/dashboard may be required. Once the prerequisites have been fulfilled, designers will move onto the cycle and start with goals then proceed through Data, Visualization and Design Decisions, and Test Evaluation. Once completed, I recommend that designers revisit the cycle periodically to ensure the visualization/ dashboard still fulfills the end-user/stakeholders' intended goals.

Throughout the entire process, designers should keep three things in mind. First, create a minimum viable product as soon as possible and iterate via update/modify/change as informed/needed while progressing through each phase. Second, designers should take the iterations of the minimum viable product and collaborate with end-users/stakeholders to garner feedback and ensure they are still in line with their intended goals and outcomes – iterate as needed. Last, designers must remember to keep HCD in mind when creating visualizations, to consider their audience, and to remember to keep the design simple and effortless to increase the speed of understanding.

b. Prerequisite

I had originally included these phases within the goal phase of my proposed framework. However, research shows that these phases do not correlate with real-world application. Moreover, my research also shows that inclusion of these four phases interferes with the intended cycle. The reason they interfere is because these phases need not be repeated for a single scope/issue – if these four phases need to be repeated, it may be an indicator that a new visualization/dashboard is required.

The first phase is to identify the issue. Research shows that these issues may come in a variety of forms and from a variety of users. They may be preemptive issues identified and brought forward by end-users/stakeholders, or they might be reactive issues that appear unexpectedly and has potential detrimental impacts on the company's performance (e.g., COVID-19). Issues may also come from tactical (boots on the ground), operational, and strategic (C-Suite) end-users/stakeholders.

The second phase is to verify if visualization is a viable solution to the issue. Research shows that not all issues require visualizations. I.e., the intent of a visualization is to augment a person's abilities to extract large amounts of data quickly, therefore if the process can be entirely automated there is no need for a visualization (Munzer, 2015b). Once the designer verifies that visualization is a viable solution, the issue can move on to phase 3.

The third phase, after understanding that visualization is a viable solution is to identify the stakeholders and any end-users that may potentially benefit from this

visualization/dashboard. Research informs me that it is a best practice to expand the scope of a visualization or dashboard if two or more end-users have similar scopes/issues, that may benefit from an umbrella type visualization/dashboard. They key feature here is a designer's ability to include interactive functions within the UI so that the different end-users are able to focus on their respective needs.

The last phase of the prerequisite prior to beginning the cycle is to complete the first three steps of Finkenstadt et al.'s (2022), goals, decision, signals, data model. As a designer we must ensure the following: you are collaborating with your end-users and identified stakeholders to ensure the design team fully understand goals, why they need a visualization, how the visualization is intended to augment their capabilities, and why they have this goal. For example, when an issue is received from an end-user to have visibility on amount of aged inventory, designers should understand the root why derives from the end-user's goal to reduce inventory and save the organization inventory carrying cost).

Finkenstadt et al.'s (2022), first step is verify the goal and to ask, "[w]hat do I want to happen? What am I responsible for? What is the ideal outcome of my efforts?" Their second step, decision, involves asking, "[w]hat will I be called upon to decide on in order to meet goals/mission needs?" (Finkenstadt et al., 2022). And their third step, signals, involves asking "[w]hat do I need as a sign or compass to inform future decisions?" (Finkenstadt et al., 2022). After this is completed, some teams may already be able to create a minimum viable product. If so, verify its validity and assess what phase of the cycle you are on. Otherwise, record the goal and begin the cycle. For more information on Finkenstadt et al.'s (2022) GDSD model, please refer to the references for a link.

c. Visualization Goals

Ensure visualization goals are clearly identified, defined, and understood among all stakeholders as well as a common understanding of what the end product should look like (Finkenstadt et al., 2022). As each iteration of the visualization is created, refer back to this phase and make any changes/modifications to the goals as required.

This goal differs from the overarching goal that is established during the prerequisite phase. This differs from the previous because this phase of my BIV framework model seeks to solidify goals that designers should strive for when designing the visualization/dashboard.

d. Data

Business intelligence within supply chains have always been heavily reliant on data (Ali et al., 2022; Basole et al., 2016; Shao et al., 2022). In our day and age, there is no longer a problem of lack of data rather the problem today is too much data, or data saturation/InfoObesity (Finkenstadt et al., 2022; Whitler, 2018).

At this phase I adopt Finkenstadt et al.'s (2022) last step of their GDSD model, data. As a designer, "[a]sk yourself what data would lead to informative signals that can lead to intelligent decision-making within your focal value chain" (Finkenstadt et al., 2022). In the data collection phase, remember to have the goal in mind when collecting data. Do not collect data because it is available. Collect data it if it will be supportive in achieving the goal. There will be times the type of data you are seeking does not exist or exists in fragmented unstructured forms.

Research shows best practices for non-existent data is to identify the key characteristics required to construct the data. With the key characteristics create an algorithm that utilizes the key characteristics to combine the data for a 90% accurate result. In the case that data exists partially, collaborates with the end-users/SMEs to identify prior methods that worked and either utilize that data set or try to combine and create better data. The last option is to conduct a data call. Data may seem non-existent, but may actually reside on local databases (i.e., an employee's personal excel spreadsheet).

Data hygiene and cleanse comes in a couple forms, transforming, completing, combining, and/or standardizing. Unfortunately, my research does not include a best practice for data hygiene and cleanse that does not involve manual labor. Research shows one best practice for data hygiene and cleanse is during the data input phase. If near accurate, complete, correct, and timely data is inputted into the database, the level of

effort required to cleanse the data is minimal. Research shows that another best practice is to identify what right and ACCT data should look like and create a script that can automate the data collection and cleanse in one fell swoop. Designers take caution, your visualization/dashboard will only reflect what you input. If the data is not ACCT and standardized (i.e., garbage), you will get what you give (i.e., garbage).

e. Visualization and Design Decisions

At this phase of the cycle, it is a good time to reconvene with your end-users/ stakeholders and understand what the audience's data literacy level is. This will inform you on which visualizations and interactivity functions would be most suitable for them. For example, if your audience has never utilized a visualization/dashboard, consider simpler graphic choices with few variable factors and less interactivity functions available to prevent overchoice and analysis paralysis (i.e., pie charts, bar graphs, line graphs and only filter, sort, search options).

Next, understand that recall the purpose of creating this visualization is for your end-user, who are human. The answer to great user experience/interface (UX/UI) is human centered design. This requires receiving feedback from customer/client through communicating the proposed UX/UI or your iterated minimum viable product (Hartson & Pyla, 2019; Norman, 2013). Refer to Table 3 for a common set of graphics/charts used and their ideal usages.

f. Test and Evaluation

My research shows this is typically the final phase of designing and is no different when designing/creating business intelligence visualizations. This is phase within the framework model where a majority of the feedback is received. There must be open channels of communication and deliberate collaboration with end-users/stakeholders. When the visualization/dashboard is put through a test and evaluation phase, all interested parties can properly measure the success of the visualization and identify unintended outcomes, bugs, and useability (does the UI work as intended). Ultimately, this phase answers the questions: does it work, does it fulfill the end-user/stakeholder's goal and intended outcome.

g. Repeat

At this point, the designer would have completed one cycle of the model section of my framework model. However, research shows that it is not the end. Data visualizations are not static because they seek to solve a goal. Goals are not static because they seek to resolve an issue. Issues may change, but are not static, because they are a product of an ever-changing geopolitical world (e.g., Ukraine-Russian War, COVID-19, 40-year high inflation of 2022). Data today may be useful today but may be obsolete in a year, a month, a week, or even a second. As goals shift and change, so should the visualizations that support in augmenting the solution for the goal.

Finkenstadt et al. argue that continuous feedback is not only the key to ensure data remains relevant and useful for its purpose (ACCT), but it may also impact near and peer goals within the organization. I enforce this continuous feedback by creating my framework model using a cycle. Once one cycle is complete – we must ask ourselves if the visualization continues to meet the needs of the goal. If so, there is no need to repeat the cycle at this time. Revisit periodically to ensure the end-user/stakeholder's needs are met.

8. BIV Framework Model Visualization and Design Decisions

The lessons from this research have been applied directly into the design of the BIV Framework Model. These design decisions are guided by data collected during the literature review, semi-structured and narrative interviews, thematic analyses, and research. As my framework model was created for the western audience, I positioned the first steps of my framework model to the left. This takes advantage of the common reading patter in the western world where we read from left to right – as opposed to the eastern world where the read from right to left. Understandably the natural eye tracking pattern starts at the top left for the western world, I added visual cues in the form of arrows and chronologic scheme (i.e., 1–4).

My research informs me on the color decisions I made. I understood that the combined utilization of luminesce and color are detracting; therefore, I mitigated optical bandwidth limits by creating large contrast differences between the luminesce levels of a

single color. Additionally, the choices of colors also take advantage of human centered design and utilized green as a starting point for the cycle. Green in most societies indicated start and therefore creates the elementary connections that Clark and McGill's (1984) research suggests.

Lastly the usage of clockwise and counterclockwise directional arrows align with Norman's (2013) research. As humans, we collectively observe time moving forward in a clockwise fashion, and time moving back in a counterclockwise fashion. I utilize this in representing iterate forward as moving with time through the cycle. Likewise, I utilize the counterclockwise directional arrows to represent constant collaboration and feedback. This way, designers are reminded to stop and return to phase 1, goals, and ensure the iterations are vectored correctly and meeting the end-user/stakeholders' goals and needs.

C. SUMMARY

In this section I discussed findings from semi-structured and narrative interviews with Flex Ltd. and USAF AFICC BICC. Next, I presented findings from my comparative analysis between Flex Ltd. and USAF AFICC BICC using thematic analysis. Then I provided my research supported recommendations to Flex Ltd. and USAF AFICC BICC. Afterwards I presented the major changes to my proposed Business Intelligence Visualization Framework. Finally, I presented the final iteration of my Business Intelligence Visualization Framework Model, and informed readers on the step-by-step instructions to utilize my framework model. In Chapter V I will summarize my research, identify purpose and need for my research, what I discovered, limiting factors, and recommended areas of further research.

V. SUMMARY, LIMITING FACTORS, AND AREAS OF FURTHER RESEARCH

In this Chapter I summarize my research, and provide findings to my research questions, limiting factors to my research, and areas of further research.

A. SUMMARY OF RESEARCH

This report is comprised of five chapters. Chapter I introduced the topic of this thesis, the purpose of research, and a summary of Chapters I-IV.

Chapter II reviewed the background of the topic and literature related to a supply chain's business intelligence and current usages of visualization within the industry. Chapter II also reviewed literature about goal formation; data collection/hygiene and cleanse; visualization and design decisions; and test and evaluation. Lastly, I presented my proposed Business intelligence Visualization Framework with correlating findings from my literature review.

Chapter III discussed methodology used in this research, specifically how data was collected, understood, analyzed, and presented. I conducted semi-structured and narrative interviews with personnel from Flex Ltd. and USAF AFICC BICC. I then showed how I utilized thematic and comparative analysis to provide recommendations and best practices of both organizations.

In Chapter IV, I presented my semi-structured and narrative interview findings conducted with Flex Ltd. and USAF AFICC BICC. I then provided my comparative analysis between the two organizations and provided recommendations to each of them. Afterwards, I explained the major changes to my proposed business intelligence visualization framework model and unveiled the final iteration of my BIV framework model.

B. RESEARCH CONTRIBUTIONS

We needed this study to understand five topics:

1. How are firm/entity goals are created and if the firm/entity utilizes collaboration and teaming to carry out business intelligence (BI) goals?
2. What decision factors are at play when the firm/entity decides what data is to be used and how it is collected?
3. How does the firm/entity understand and limit the data they focus on for decision-making?
4. How does the firm/entity decide which BI functions require visualizations and dashboards, as well as the design decisions to be made using visualization signals and interactivity?
5. Review of the data that is presented by the created visualization, if after analysis the data fulfills the goals.

After research, it is apparent that diversity of expertise reigns supreme in the realms of business intelligence within supply chains. This idea of diversity of expertise solidified the need to incorporate not only the design team to the discussion, but the end-users, near and peer end-users, and all stakeholders as well.

My research shows that goals are not as simple as they appear on the surface. Goals require the collaboration of the design team, end-users, near and peer end-users, and stakeholders. As a team, designers, end-users, near and peer end-users, and stakeholders are able analyze and understand the issue better. Afterwards, the design team takes that well-defined requirement/needs/issues through Finkenstadt et al.'s GDSD model to identify an accurate goal.

Organizations' designers limit the decision-making data by focusing on the goals, i.e., understanding the end-user/stakeholders' needs and requirements. Through communication and collaboration, they are able to identify what the required data is and proceed with best practices to collect the required ACCT data.

Research shows analysis of the goals and issues provide an answer to *is visualization is a viable solution*. The purpose visualization is to augment a human's capability to better extract large amounts of data faster. Visualization proves to be superfluous if the issue/goal can be completely automated. Visualization proves to be unnecessary extra effort if the issue/goal is static. Rather, research shows visualization is most effective at fluid issues/goals (e.g., what was our inventory levels over the past quarter, what is the bestselling merchandise and to what demographic, or the spend-trend of an organization within the past five years).

My research shows that Norman's (2013) human centered design concept is the foundation for all visualization and design decisions. A visualization that does not consider HCD defeats the purpose of visualization. If HCD is not considered during design, the result is a difficult and complicated visualization. That visualization may functionally work, but the negative extremality is the added time end-users/stakeholders spend trying figure out how the visualization works. Clark and McGill's (1984) research agrees with Norman's HCD research. Clark and McGill's research states that visualizations should avoid unnecessary complication and seek to ensure data extraction is as simple as possible.

Finally, my research shows that the final step of any design/visualization requires a test and evaluation phase. I presented this phase within my framework model in Chapter IV. Ultimately, this product is created for your end-user/stakeholder. As a result, to ensure end-user/stakeholder needs are met there must be constant communication and deliberate collaboration with end-users/stakeholders. A test and evaluation phase is the final iteration where all interested parties measure and identify functionality, unintended outcomes, bugs, and areas of improvement. Ultimately, this phase evaluates if the product has met the intended visualization goals and BI goals.

C. LIMITING FACTORS TO MY RESEARCH

This research was limited by two factors – a single person conducted this research, room for diversity of research subjects, and lack of new/current research. The first limitation is that a single researcher completed this research. For future research on this topic, I recommend two or more like-minded researchers carry out my recommended areas of further research. Although most sections of this research are possible to complete alone, there are sections where working with a team can benefit from diversity of visualization knowledge and manpower.

The second limitation is that my real-world application research data is derived from two organizations. Nevertheless, those two organizations (Flex Ltd. and AFICC BICC) are highly representative organizations. They are both at an enterprise level representing more than just a couple organizations. BICC is highly representative of the

USAF contracting data and Flex is highly representative of supply chain business intelligence data for a large network of operations/firms it represents. Although these two organizations may be enough data to provide a foundation for such a niche topic, the product of my research (BIV Framework Model) should be put to the test with other enterprise level organizations to add, evaluate, modify, or disprove my framework model. Moreover, interviews with additional designers, data scientists, data engineers, and end-users would provide additional diversity/data points.

The final limitation is the availability of current and recent research in this area. This research investigated a very young and niche area of study. The studies of supply chain visibility, usage of software as a service, and visualization within modern business intelligence have only garnered academic interest and support within the last 10 years. My research navigated the limitations by connecting different areas of study (data visualization, visualization theory to include ontological studies, and business intelligence within supply chains). Though major concepts have been identified and sewn together, my research of the topic is mostly informed by literature between the 1980s and 2010s. As more studies become available, I am confident it will pave the way for more in-depth research opportunities.

D. AREAS OF FURTHER RESEARCH

I have identified three areas of further research. First future research to consider is psychology-based research into the intangible characteristics, innate capabilities, and thought process of industry leading designers. Second future research to consider is, akin to this research but, using an ontological approach to analyze business intelligence visualizations within supply chains. The final area of future research I recommend is comparing my Business Intelligence Visualization Framework Model to other industry leading supply chain organizations that have business intelligence teams. Another kindred recommendation is to present my BIV Framework Model to organizations that are new to visualization to solicit feedback that either adds, validates, modifies, or disproves my BIV Framework Model.

My first future research recommendation stems from the heavy reliance on a designer's experience and intuition. My curiosity is a result of two key data points: both organizations' level of trust on these designers and the amount of success resulting from it. I recommend researchers, interested in this topic, investigate how the minds of visualization/dashboard designers' work. Are these designers inherently talented in design and visualizations, or is it learned? If it is learned, what type of experiences do they have (academic or subject exposure) that may have influenced their capabilities and detail their thought processes when transforming an end-user's vision into reality. Once the findings and results have been collected conduct a comparative analysis. The comparative analysis can be between inherent talent and learned/acquired knowledge. Finally, record the results from the comparative analysis in a manual that can be presented to future designers.

My second future research recommendation is focusing on the ontological piece of visualization. Card et al., 1999; Cleveland and McGill, 1984; Munzer, 2015b; Liu and Stako, n.d.; and Zhu and Chen, 2006 have all sought to view visualization from an ontological perspective. I recommend interested future researchers deep-dive into the physical aspect of how a human processes images and transforms extracts data. My research shows that certain combinations of visual cues are more effective than others due to the way humans ontologically process visualizations. For example, color and luminance interfere with one another because those two types of visual cues are received through a single neuro-channel from eyeball to brain. This recommendation is target to those researchers that have an interest in anatomy. I recommend that the final deliverable is a tier list of modern visualizations/dashboards with accompanying research that shows why certain visualizations/dashboards rank higher or lower as it pertains to anatomy.

My final future research recommendation is a real-world application test and evaluation of my BIV Framework Model. Although research supports my BIV Framework Model, it has never been tested in a real-world setting. I recommend future researchers continue my research by comparing my Business Intelligence Visualization Framework Model to one of two types of organizations.

The first organization would be a mature organization with existing business intelligence processes and teams. I recommend interviewing, testing, and evaluation my BIV Framework Model with their subject matter experts to either add, validate, modify, or disprove it. The second organization would be an organization that does not have a mature business intelligence team or processes. I recommend taking my BIV Framework Model and applying it in a controlled environment. Researchers interested in this topic should be most fluent in this area of study in order to provide guidance and subject matter expertise to the new business intelligence organization/team. In both cases, as newer and more current research becomes available, researchers should also seek to identify similar design frameworks/models to evaluate and analyze.

E. CONCLUSION

The world continues to face significant supply chain disruptions. From COVID-19 to recurring geopolitical issues (e.g., War in Ukraine, China and Taiwan tension, etc.) to natural disasters (e.g., earthquakes, hurricanes, flooding, feminine, etc.) and human-caused failures (e.g., Suez Canal blockage, labor issues, etc.), leaders around the world are facing increasing supply chain disruptions that threaten industry viability, profitability, and operations as well as national security. According to Handfield and Linton, 2017, pg. 3, "these disruptions are no longer unique and rare; they are ubiquitous, and the time between disruptions seems to be shrinking. In fact, it is a rare day when no disruptions of any kind occur."

The increased frequency of these disruptions coupled with highly interconnected and dependent global consumer markets, adds urgency to the need for more visibility and insight into global supply chains. Increasing the effectiveness. efficiency, and resiliency of these systems is paramount for continued business and operational success (Handfield & Linton, 2017). The commercial sector has been the quickest to respond to this issue with increased investments into innovative business intelligence solutions designed to provide dynamic and timely insights into supply chains (McCrea, 2021; Handfield & Linton, 2022).

Unfortunately, the public sector, has been slower to respond and develop solutions to the issue.

Lagging slightly behind its commercial counterparts, the Department of Defense (DoD) has only recently acknowledged the need to seek solutions into its supply chain. In February of 2021, The President of The United States' (POTUS) released an Executive Order (EO) 14017 detailing the need for a "resilient, diverse, and secure supply chains to ensure our economic prosperity and national security" (Biden, 2021). Moreover, in the EO, POTUS also acknowledged that the geopolitical issues, previously mentioned, have a negative effect on American supply chains. POTUS notes that a "[r]esilient American supply chains will revitalize and rebuild domestic manufacturing capacity, maintain America's competitive edge in research and development, and create well-paying jobs" (Biden, 2021).

To achieve this, POTUS notes the need for close cooperation with allies and partners and further breaks down his vision for several government agencies, including the DoD. In February of 2022, the DoD responded to POTUS' EO with an action plan led by Dr. Kathleen Hicks, the Deputy Secretary of Defense. Dr. Hicks acknowledged the DoD's need for a more resilient supply chain and has called on all DoD Agencies to take action to increase the lethality and competitive advantage of our warfighters (DoD, 2022). Specifically, the action plan "details how the DoD—in coordination with other U.S. Government agencies, industry, and international partners—will address supply chain challenges that will improve America's overall national and economic security" (DoD, 2022, p. 6). Moreover, the DoD action plan calls on agencies to, "conduct data analysis: DoD will continue to build on previous efforts to expand its visibility into supply chains by collecting and organizing key data" (DoD, 2022, p. 3).

Through collaborative efforts between Flex Ltd. and USAF AFICC BICC, I presented research backed findings and recommendations for both organizations. Some of the recommendations are common recommendations, while others are directed at a specific organization. Nevertheless, both organizations can/may benefit from understanding the lessons learned that resulted from the directed recommendations.

Finally, I have taken all the best practices and lessons learned from my semi-structured and narrative interviews, thematic and comparative analyses, and comprehensive literature review and created a Business Intelligence Visualization

Framework Model. The BIV Framework Model developed during this study will be able to guide designers, stakeholders, and end-users in creating/designing business intelligence visualizations that will augment their capabilities to solve an identified supply chain issue.

My research has answered both POTUS' and DepSecDef's call for cooperation with allies and partners, and investments in creating a more resilient supply chain. Research has showed that supply chains are driven by data and that visualization is pivotal to business intelligence within supply chains to extracting large amounts of data quickly and effortlessly.

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