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## **Content Details:**

<b>Michael Adeloje Adebamowo(Author)</b> <i>University of Lagos</i>	<b>Leadership Traits and Business Innovation in Construction Industry: Perspectives of Artisans in Lagos, Nigeria</b>
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### **Abstract**

This study examines the influence of leadership traits on business innovation of construction companies in Lagos State from the viewpoints of artisans that carry out most of the operational activities. The aim of the study is to qualitatively investigate how adaptability leadership, risk-taking, team-building, and flexibility leadership drive business innovation of artisans in construction industry with the use of leadership trait theory. The study applied survey method with the use of interview schedules by conveniently and randomly selected 10 experienced artisans working in 5 indigenous construction companies in Lagos State out of which 8 participants responded representing 80% response rate. Thematic analysis was deployed to qualitatively analyse the perception of the selected artisans about the influence of adaptability leadership, risk-taking, team-building, and flexibility leadership on business innovation of artisans working in construction companies in Lagos State. The outcomes of the study revealed that the four leadership traits as examined in the study have influence on business innovation, though with the fear of unknown that innovation may render the activities of artisan unusable. The study, therefore, recommends that leaders in construction industry should continuously consider artisans in every policy they make by improving their skills for them to be relevant in any innovation disruptions considering their roles in construction operations.

**Keywords: Leadership Traits, Business Innovation, Artisans in Construction Industry, Lagos Nigeria**

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# 1.0 INTRODUCTION

## 1.1 Background of Study

The theory of leadership traits, initially posited by researchers like Ralph Stogdill has been a key stone in the study of effective leadership but its applicability to individual contributors, especially artisans remain largely unexplored. In order to close this gap, this study seeks to investigate how leadership traits theory aligns with and influences the innovative practices of artisans. Given that the challenges faced by the construction industry require not only technical expertise but also innovative thinking. It is therefore essential to recognize the leadership traits that encourage business innovation among artisans in the construction industry for sustainable growth and competitiveness.

At the core of economic advancement, the construction industry functions not just as a driver for infrastructural expansion but also as a crucial link that connects and propels diverse sectors, thereby assuming a central role in a nation's overall fortunes. This has demonstrated why leadership that can drive innovation of this industry needs to be widely discussed in the literature given the fact that business environment is convoluted and not static. The ability to innovate has become essential and synonymous with survival, therefore, leadership traits and business innovation plays a critical role in shaping the adaptive capacities of artisans (Asriati et al., 2022; Lestari et al., 2020). However, the application of leadership traits to drive business innovation of artisans in each country varies.

Over the past few years, the construction industry in the United States has experienced a transformative surge of innovation, utilizing state-of-the-art technologies and strategic methodologies to improve efficiency and sustainability. Similarly, China's construction sector is in the midst of a notable innovation surge, propelled by a blend of technological progress and a dedication to sustainable development. Within the Nigerian construction industry, a noticeable upswing in business innovation is apparent, marked by the sector's adoption of technological advancements to address challenges and champion sustainable development. Achieving innovation feats in construction industry still require innovative leadership to drive the key actors of the construction companies (Jackson, 2020; Maqbool et al., 2023).

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Li et al (2023) emphasized the urgent need to understand that mechanism that empower artisans to not only adopt but also innovate in the face of exceptional challenges. The implication of this demonstrates why leaders in construction companies have to develop traits that can enhance the innovation of artisans for them to be able to cope with changing conditions like the recent covid-19 pandemic where there was a total global lockdown. This is because, leadership traits could encompass qualities like vision, adaptability and communicative powers are integral components shaping organizational dynamics.

## 1.2 Statement of the Problem

Despite the utmost important role of artisans in construction industry, no in-depth study has been done in addressing how leadership traits affect their capability and capacity to promote business innovation. Because its complexity and dynamic nature of construction industry, this poses unique challenge for artisans. Their ability to innovate and adjust to emerging trends and technological advancements may be hindered by the absence of effective leadership strategies. The dynamic industry demands adaptive strategies. Smith et al (2022) highlight leadership's role in innovation while Johnson (2021) emphasizes adaptability in construction. The development of business innovation in the Nigerian construction industry could heavily rely on leadership traits, yet several challenges persist in attaining this goal.

The majority of research on leadership within the construction context has predominantly concentrated on leadership at the project level (Burke & Barron, 2014; Graham, Nikolova & Sankaran, 2020; Zhang, Cao & Wang, 2018). This emphasis may stem from the nature of construction organizations, which are project-centric and heavily reliant on effective project execution. Consequently, there remains a dearth of research on leadership traits that could drive business innovation of construction companies from the perspective of artisans. This study, therefore, sets out to examine the influence of leadership traits on artisans' innovation business of construction industry in Nigeria.

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### 1.3 Aim and Objectives

The aim of this study is to empirically examine the influence of leadership traits on business innovation of construction industry in Nigeria with a focus on artisans in Lagos, while the specific objectives are to:

- i. Understand the perception of artisans about adaptability leadership to drive business innovation of construction companies.
- ii. Investigate the perception of artisans about risk-taking leadership for business innovation of construction companies.
- iii. Explore the perception of artisans about team-building leadership in stimulating business innovation of construction companies.
- iv. Analyse the perception of artisans about flexibility leadership on business innovation of construction companies.

## 2.0 REVIEW OF RELEVANT LITERATURE

### 2.1 Leadership Trait Theory

The relevant literature on leadership traits highlights qualities such as drive, self-confidence, integrity, cognitive ability, emotional stability and social skills as traits that contribute not only to effective leadership but also promote innovative culture within a business organization not leaving out construction sector. Understanding of how those traits manifest among artisans can provide valuable insights into their role in driving innovation. The leadership trait theory posits that specific attributes set leaders apart from other individuals (Alward & Phelps, 2019; Schyns, Kiefer & Foti, 2020).

Early theorists posited that natural-born leaders possessed specific physical traits and personality characteristics that set them apart from non-leaders (Khan, Nawaz & Khan, 2016). Trait theories, however, did not address the question of whether these leadership traits were inherent or acquired (Khan et al., 2016). In other words, Jenkins identified two types of traits: emergent traits, heavily influenced by heredity (such as height, intelligence, attractiveness, and self-confidence), and effectiveness traits, based on experience or learning, which included charisma as a crucial element of leadership (Ekvall & Arvonen, 1991). Max Weber coined charisma as the most significant revolutionary influence, capable of instigating a wholly fresh perspective among followers and

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fostering unwavering personal devotion to leaders perceived as possessing nearly mystical, supernatural, superhuman qualities, and powers (Khan et al., 2016).

The initial emphasis on intellectual, physical, and personality traits that distinguished leaders from non-leaders foreshadowed a line of research that suggested only minor differences between followers and leaders (Burns & West, 2003). The inability to identify common traits among all effective leaders led to the decline of trait theory as a prominent component (Khan et al., 2016). In the realm of business innovation, the leadership trait theory posits that specific inherent attributes in individuals, such as creativity, adaptability, and a willingness to take risks, can enhance their effectiveness as innovative leaders (Kodama, 2019; Verawati & Hartono, 2020). Recognizing and harnessing these traits play a crucial role in cultivating an innovative culture within a business, encouraging the creation of new ideas and solutions.

Leadership traits theory is relevant in this study because leaders of construction companies in Nigeria need to apply the kind of traits that can enhance business innovation of artisans for competitiveness and survival. However, the critique directed at leadership trait theory revolves around its inability to consistently pinpoint a universally applicable set of traits that unequivocally differentiate effective leaders, resulting in a deficiency of comprehensive and practical guidance for leadership development (Gehring, 2007; Khan et al., 2016).

## 2.2 The Concept of Business Innovation

Business innovation is the proactive pursuit of new ideas and strategies to enhance process, products or services encouraging growth, adaptability and a competitive edge in the market place. In construction, business innovation involves applying new concepts and technology to improve project sustainability, efficiency and overall outcome; in order to gain competitive advantage in the industry.

Business innovation involves introducing fresh ideas, products, services, or operational methods to instigate positive change within an organization (Davila, Epstein & Shelton, 2012; Tidd & Bessant, 2020). This process requires a proactive approach to problem-solving and a readiness to explore innovative solutions that can improve competitiveness, efficiency, and overall success (Bocken, Short, Rana & Evans, 2014; Damanpour & Aravind, 2012). Innovation in business can

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take various forms, such as technological advancements, enhanced business models, creative marketing strategies, and more (Baden-Fuller & Haeffliger, 2013; Saebi & Foss, 2015). It is propelled by a culture that promotes experimentation, embraces risk-taking, and values continuous improvement (Damanpour & Aravind, 2012; Tidd & Bessant, 2020). Successful business innovation not only nurtures the creation of distinctive offerings but also empowers organizations to adjust to evolving market conditions, outpace competitors, and meet the changing needs of customers (Williamson & De Meyer, 2020; Wiraeus & Creelman, 2019). Embracing an innovative mindset is vital in today's dynamic and competitive business environment, where adaptability and innovation are key to achieving sustained growth and success (Davenport, Leibold & Voelpel, 2007; Holbeche, 2023; Karneli, 2023).

## **2.3 Adaptability Leadership and Business Innovation**

Adaptability in leadership fuels business innovation. Embracing change stimulates creativity which helps the organization to overcome challenges and prosper in the dynamic markets and evolving environment. Adaptive leadership in construction sector drives innovation by leveraging technology and optimizing workflows.

In the face of today's complex challenges, managers are finding it more crucial to cultivate adaptability within their organizations. The advancement of business innovation hinges on the critical aspect of leadership adaptability (Amit & Zott, 2020). Amidst the swiftly changing business terrain, leaders capable of adeptly navigating uncertainty and embracing change make significant contributions to instilling a culture of innovation within an organization (Amit & Zott, 2020; Doz & Kosonen, 2010). Leaders with adaptability comprehend the significance of staying informed about market trends, technological advancements, and evolving customer needs (Faulks et al., 2021; Ismail et al., 2023). They endorse a flexible and open-minded approach, placing value on diverse perspectives and ideas of the workforce (Ismail et al., 2023; Peterson, 2009).

By cultivating an environment where employees feel empowered to experiment and take well-calculated risks, adaptable leaders establish the groundwork for business innovation (Doz & Kosonen, 2010; Zhang et al., 2017). Their capacity to shift strategies, respond to emerging challenges, and seize opportunities positions the organization not merely to survive but to thrive

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in dynamic markets (Amit & Zott, 2020). Ultimately, leadership adaptability serves as a catalyst in nurturing a forward-thinking and innovative organizational culture, propelling continuous improvement and sustainable success through employees (Mandagi et al., 2023; Zhang et al., 2017).

## 2.4 Risk-Taking Leadership and Business Innovation

Risk taking leadership and business innovation drives business innovation by taking bold decisions by encouraging experimentation, embracing uncertainty and promoting a culture that learns from failures; driving organizations to push boundaries and achieve breakthroughs, this enable the organization to stay ahead in the industry landscape.

The business landscape is characterized by its dynamism (Akbar et al., 2017), where embracing risk is a crucial aspect of leadership responsibilities and preparedness for change (March & Shapira, 1987). In the opinion of Zaltman et al (1973), risk-taking is an inherent element of the innovation process. Individuals carefully weigh the possibilities of success and failure before making decisions (Kogan & Wallach, 1964). Particularly in significant processes like organizational change, leaders' propensity for risk-taking becomes pivotal in the decision-making process to initiate and implement change (Akbar et al., 2017). While risk is often viewed as undesirable in organizational life, efforts are directed towards minimizing and eliminating it (Chicken & Posner, 1998).

The study of Slovic (1972) notes that risk-taking tendencies vary among individuals and depend on different situations. In a study by Sitkin and Pablo (1992), individual characteristics, organizational context, and problemrelated features were identified as direct influences on individual risk behaviours, particularly in decision-making within risky situations. The propensity for risk-taking is shaped by factors such as individual values, beliefs, and leadership approaches (Fischhoff et al., 1981), decision makers' identity and experience in risk decision situations (Kennedy, 1998), and situational or environmental factors (Slovic, 1972).

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## 2.5 Team-Building Leadership and Business Innovation

Team building leadership boosts or succinctly put energizes corporate innovation by generating dynamic atmosphere where creative ideas that promotes the growth of business is welcomed through collaboration culture leveraging on diverse skills and perspectives driving business innovation by streamlined processes, efficient and effective project execution and industry advancements.

In the contemporary, rapidly changing, and intricate business environment, teams play a pivotal role in the success of any organization (Belbin & Brown, 2022). A team constitutes a group of individuals sharing common objectives, collaborating to achieve these goals, and harnessing individual resources (Jassawalla & Sashittal, 1999; Patel, Pettitt & Wilson, 2012). Effective teams are highly valued in modern organizations for their ability to demonstrate creative problem-solving skills (West, 2012). Establishing an effective team requires substantial effort, with organizations working diligently to devise strategies that foster engagement among employees and contribute to overall organizational effectiveness (Carmeli, Gelbard & Reiter-Palmon, 2013). Team-building strategies involve the art of integrating the talents and strengths of individuals into a collective force that surpasses the sum of its parts (Hardy and Crace, 1997). In the opinion of Dyer (2015), the process of intervention aimed at enhancing organizational productivity is defined as team building.

Teams play a crucial role in driving organizational innovation, with their effectiveness being influenced by the organizational context in which they operate (Buljac-Samardzic et al., 2010). Organizations that prioritize team building experience enhanced problem-solving skills and increased morale among their employees (Fapohunda, 2013). In the opinion of Fay, Shipton, West and Patterson (2015), argue that greater teamwork correlates with higher innovative capabilities within an organization. This assertion is substantiated by Moore, Everly and Bauer (2016) findings, indicating that collaboration among individuals from diverse backgrounds fosters creative thinking, enabling more effective responses to the challenges of a constantly changing environment. Moore et al. (2016) further emphasize the significance of team building for improving problem-solving abilities and fostering a healthier work environment as measures to enhance organizational outcomes.

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## 2.6 Flexibility Leadership and Business Innovation

A dynamic workplace culture that values creativity and continuous improvement in changing marketplaces is encouraged by flexible leadership. It promotes agility in decisions-making and adaptive change culture. The flexibility enables the organization to traverse challenges, seize opportunities and stay at the forefront of the innovation in ever-evolving business landscape. The agility enables swift response to challenges, promotes efficiency in construction processes and positions the sector for sustained growth amidst dynamic demands of the industry.

Flexibility in leadership plays a crucial role in fostering business innovation (Ni et al., 2020; Zhu & Jin, 2023). In the constantly changing business landscape, leaders who demonstrate flexibility are better prepared to navigate uncertainties, adjust to evolving market demands, and guide their teams toward inventive solutions (Johansen, 2012; Yukl & Lepsinger, 2004). These leaders recognize that rigid, one-size-fits-all approaches may fall short in complex situations (Zhu & Jin, 2023). They promote a culture of experimentation and learning from failures, creating an environment where creativity and innovative thinking can flourish (Johansen, 2012). By embracing diverse perspectives and staying receptive to alternative strategies, flexible leaders empower their teams to explore fresh ideas and approaches (Hashimy et al., 2023; Ni et al., 2020). This adaptability not only enables organizations to swiftly respond to shifting market trends but also positions them to proactively identify and seize emerging opportunities (Yukl & Lepsinger, 2004; Zhu & Jin, 2023). Ultimately, leadership flexibility acts as a catalyst for cultivating a culture of ongoing innovation, propelling the organization towards sustainable growth and success in today's competitive business landscape (Hashimy et al., 2023; Johansen, 2012).

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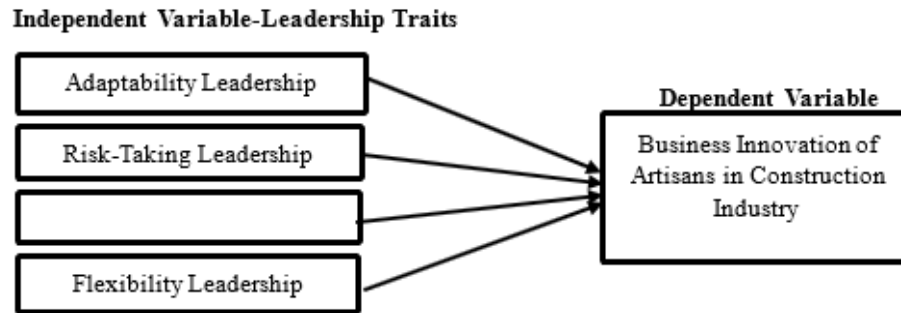
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## 2.7 Conceptual Model



**Fig 1: The Study Conceptual Model**  
**Source:** Researcher's Field Survey (2023)  
 Leadership

Team-building

## 3.0 RESEARCH METHODS

To gain a deeper understanding of leadership traits among artisans in the construction sector and their impact on business innovation. This study primarily employed qualitative research methods. This approach focuses on indepth interviews with artisan leaders and key stakeholders in the construction sector; through open ended discussions. The emphasis on rich, context-specific narrative provides a deeper understanding of the interplay between leadership practices and innovative outcomes within construction projects led by artisans.

This study applied a survey method using primary source of data. The primary data involved interview schedules to extract information from artisans in Lagos State construction companies because of their knowledge and experience in the construction operations. Lagos is considered in this study because the state has more construction companies than others states in the country being a commercial hub. The study further considered 80 top indigenous construction companies in Lagos State based on their technical ability, management capability, and health and safety performance among other as established by Lawani (2022). Indigenous construction companies are considered in this study because in recent times, several indigenous companies are progressively taking the lead to change the narratives.

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However, the study conveniently selected 5 from the 80 top indigenous construction companies in Lagos State and further randomly selected 2 experienced artisans each from the 5 companies making a total of 10 participants for interview schedules because they are regarded as category of artisans that can give germane information. The 5 companies are: Vita Construction Ltd, Construction Kaiser Ltd, Planet Projects Ltd, 225MM Construct Ltd and AMA Designs Ltd. The study deployed thematic analysis to examine and analyse the perception of artisans in these construction companies about the influence of leadership traits on business innovation.

#### **4.0 ANALYSIS**

##### **Presentation and Interpretation of Qualitative Results of Interview with Artisans in Lagos State using Thematic Analysis**

Themes associated with leadership traits with respect to business innovation of construction companies from the perspectives of artisans in Lagos State were analysed. Responses from the 10 artisans randomly selected from indigenous construction companies in Lagos State established a validation of the findings from the research objectives. Some germane and indispensable findings that could not be captured by using quantitative approach were observed and reported in this study. The findings from transcribed themes were discussed as follows:

##### **i. Understand the perception of artisans about adaptability leadership to drive business innovation of construction companies**

From the responses of the eight participants interviewed with respect to this objective, it is sufficing to say that artisans in construction companies in Lagos State are having good perception about the adaptability leadership to drive innovation. However, they have doubt if the leaders in this sector are well prepared to imbibe the practice.

##### **ii. Perception of artisans about risk-taking leadership for business innovation of construction companies**

The outcomes of this particular interview question revealed that majority of the participants were of the opinion that risk-taking leadership trait can enhance innovation of artisan but with fear of unknown whereby such development may

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render the activities of artisan useless as a result of adoption of modern technology in the construction industry.

### **iii. Perception of artisans about team-building leadership in stimulating business innovation of construction companies**

Generally, the opinions of the participants have shown that they have positive perception towards teambuilding leadership in driving innovation of construction projects because there is strength in collaboration. **iv. Perception of artisans about flexibility leadership to enhance business innovation of construction companies**

The opinions of the participants have generally demonstrated that they appreciate flexibility leadership in driving innovation of artisans. However, they have reservations for the negative implications to the artisans because some of them are not well technically equipped.

## **5.0 DISCUSSION OF FINDINGS AND CONCLUSION**

The perspectives gleaned from interviews with artisans in the Lagos, Nigeria construction industry offer valuable insights into the intricate interplay between leadership traits and business innovation. The research illuminates the pivotal role of adept leadership in nurturing an innovative culture within construction enterprises. Artisans consistently underscored the significance of leaders displaying attributes such as visionary thinking, effective communication, and the ability to inspire and motivate teams. These leadership qualities emerged as key catalysts for establishing an environment conducive to innovation, where artisans felt empowered to contribute their expertise and ideas, thereby enhancing business practices and processes. This demonstrates team-building skills and risk-taking propensity of leaders in the construction sector as supported by Belbin and Brown (2022), and Akbar et al., (2017).

In addition, the study accentuates the necessity for tailored leadership development initiatives geared towards the distinct context of the construction sector in Lagos. As the industry undergoes continuous evolution, leaders are urged to adapt and cultivate traits that resonate with the dynamic

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nature of construction work. This demonstrates the flexibility and adaptability skills of leaders in the construction sector as supported by Amit and Zott (2020), Ni et al (2020), and Ismail et al (2023). By delving into the perspectives of artisans, this research not only enriches the academic dialogue on leadership and innovation but also furnishes practical insights for industry professionals and policymakers aiming to elevate business strategies within the Lagos, Nigeria construction sector. Ultimately, nurturing effective leadership in the construction domain proves indispensable for propelling innovation, elevating overall business performance, and contributing to the sustainable growth of the sector and nation's GDP. On this background, this study concludes that leadership traits through adaptability leadership, risk-taking, team-building, and flexibility leadership can influence innovation business of artisan in the Nigerian construction industry.

## 6.0 POLICY IMPLICATION

The outcomes of this research hold substantial implications for policy development. Policymakers and industry stakeholder' sought to contemplate the integration of leadership development initiatives specifically tailored to the distinctive requirements of the construction sector in Lagos. Recognizing the pivotal importance of adaptability and risk-taking leadership, effective communication, and motivational skills could be meticulously crafted to enhance these particular traits among leaders in the industry. By investing in such targeted leadership development endeavours, leaders in this industry can actively contribute to shaping a workforce that excels not only in technical proficiency but also in fostering an innovative culture. This, in turn, has the potential to elevate the overall resilience and competitiveness of the construction sector in Lagos.

In addition, there exists a pressing need for policy interventions aimed at fostering collaboration, team-building and knowledge-sharing within the construction industry. The study underscores the significance of cultivating an environment where artisans feel empowered to contribute their ideas and skills towards enhancing business practices. The outcomes of this study play a pivotal role in facilitating the creation of platforms, networks, or forums that encourage the exchange of innovative ideas and best practices among artisans, leaders, and other stakeholders in the construction sector. By actively nurturing a culture of flexibility leadership, construction

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companies in Nigeria can instigate collective problem-solving and innovation, thereby propelling the advancement and sustainability of the industry in Lagos, Nigeria. These underscore the potential effectiveness of targeted interventions in augmenting leadership capacities and fostering a collaborative innovation ecosystem within the construction sector, setting the stage for enduring growth and development. Consequently, there is need for leaders in this industry to continuously consider artisans in every policy they make by improving their skills for them to be relevant in any innovation disruptions.

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<p><b>Steven Suehring(Author)</b></p> <p><i>Computing and New Media Technologies, University of Wisconsin-Stevens Point</i></p>	<p><b>Cybersecurity Implications of External JavaScript on University Web Resources</b></p>
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### Abstract

Externally-hosted JavaScript can have serious security and privacy implications. The scripts may change without knowledge of the website owner, allowing the host of those scripts to access information in an unauthorized manner. This researched examined a portion of the public-facing website from a regional campus in the University of Wisconsin system, identifying externally-hosted JavaScript programs. The research found 20,446 externally-loaded JavaScript programs, noting duplication of scripts across pages. Of the 20,446 scripts, some used Subresource Integrity (SRI). However, the research found 212 unique scripts loaded from external sites with no resource integrity attribute attached.

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## **Cybersecurity Implications of External JavaScript on University Web Resources**

Using services and resources that are external to a website can be problematic for both security and privacy. While it may be clear when context switching between websites, the loading of external resources like JavaScript within the same website can have serious implications for the end user (Zimba, et al., 2020). Developers and stakeholders may not understand the implications of external software or may feel the need to work outside of normal processes, as is the case with other forms of Shadow IT (Haag and Eckhardt, 2017). This research paper provides evidence of how widespread the problem is by examining a sample of a public university website and the links and resources used on that site.

### **Defining the Problem**

Websites use a combination of HyperText Markup Language (HTML), Cascading Stylesheets (CSS), and JavaScript to create an engaging experience for the visitor. The HTML can be stored as files on a server or produced dynamically, drawing data from a database. Assets like images are also an important aspect of the user experience.

Resources such as CSS and JavaScript can also be stored locally as files but are also frequently hosted on external, third-party domains. When resources are stored locally, the end user's browser requests each of those resources from a server that is under the control of the website owner. When resources such as CSS and JavaScript are stored externally, such as through a Content Delivery Network (CDN), the website owner no longer maintains control over those resources.

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This is a concern because JavaScript is program code that then executes on an end user's device but has access to data being transmitted and received between the website and the end user's device.

When stored locally, the website owner controls the content of the JavaScript files. This includes the version of the resources and the code that is eventually executed on the end user's device. As part of the development lifecycle, the website owner tests the site, including the version of JavaScript resources being uploaded to their server. This level of control enables the website owner to certify that the security and privacy of the end user has not been compromised. The contents of each script has been verified and cannot change without knowledge and positive action by the website owner.

However, when resources like JavaScript are stored at a third-party host such as a CDN, the website owner cedes control over those resources. There may be a point in time when the website owner tested their site but there is no fully-accurate means to verify that the script has not changed on the CDN. For example, if the third-party host has been compromised, any code under their control may also be compromised. The third-party host may maliciously alter the contents of those scripts at any time.

Workarounds do exist though: Technologies like Subresource Integrity (SRI) can be used to provide a cryptographic hash of the external resource, ensuring that the resource has not been changed from when it was last verified (Mozilla Developer Network, n.d.). However, an attacker may intentionally alter the script such that it provides the same hashed value even after being

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compromised. Such intentional collisions are well-known attacks against hash-based integrity verification (Safaryan, et al., 2021).

Although it does not directly protect the end-user, organizations can execute formal agreements when third-party software is used (Silverman, 2017). The vendor then indemnifies and assumes legal responsibility for ensuring that their code and service are secure. However, even if an agreement is in place, there remains the duty of care to protect end users and the potential for high impact negative publicity from privacy violations that occur (von Tigerstrom, 2018). As this research demonstrates, such legal agreements are often not in place or not available for third-party resources like JavaScript.

### **Purpose of the Present Study**

The goal of this research is to determine how widespread of an issue third-party hosted JavaScript is on a public-facing website that is subject to external regulatory requirements. Of concern within this research are script elements that load externally-hosted JavaScript which resides on a third-party server that is not under the control of the website owner. Further, this research examines script elements that do not have an integrity attribute to help indicate that the contents of the script changed.

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## **Method**

### **Sample**

A total of 1,994 pages were visited and processed. Within the 1,994 pages, there were 20,446 external script elements that loaded JavaScript, hosted locally and from third-party sites. Another 21,683 instances of script elements were found with JavaScript embedded within the document itself. Data collection was stopped when multiple repeated URLs were being recorded, indicating that those URLs did not need to be crawled a multiple times.

### **Instrumentation**

This research used programmatic means to access the public home page of the university website. When loaded, the program then parsed each anchor element within the page in order to identify other pages that are linked from the university site. The resulting URLs were then loaded into a database to be queued for future visits. The program also recorded all instances of <script> and <link> elements within each page as it was accessed.

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## Results

### External Scripts

Out of the 20,446 external script elements found, a total of 4,726 external scripts were loaded with no integrity attribute. There was significant duplication of script elements sources. If the resource was loaded on one page, then it may be loaded on another page as well. These were deduplicated and the final total of unique scripts loaded without an integrity attribute was 212.

### Discussion

Even with deduplication efforts, 212 unique scripts being loaded can have serious security and privacy implications for the end user. An authenticated user may be accessing or sharing sensitive data, subject to the Federal Educational Rights and Privacy Act (FERPA). There is no reasonable means to continually verify or validate what the 212 external scripts are doing.

Multiple requests were submitted to the university for the agreements covering use of the external services. The request included a partial list of domains and external services involved in serving pages associated with the website. The university was unable to provide agreements for any of the services, citing an inability to search without placing undue burden on the department involved in the search. An open records request would need to be made, incurring cost, in order to have the university search for the agreements. A request for a quote for the cost of that open records processing was not responded to by university administration.

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## Implications for Industry Practice

There are serious privacy implications with the JavaScript being loaded on the website examined in this research. For example, among the external scripts loaded with no integrity attribute was a script that, in turn, loaded another external script which was then appended to the original document within the university domain. The script is loaded as a "ping" and apparently used to track visitors to the site. It is unclear how this ping is used by the third-party and what the implications for privacy are for end users, both authenticated and unauthenticated.

Private website operators are encouraged to minimally include the SRI attribute to ensure integrity of the scripts being loaded onto their properties. Publicly-operated websites such as universities should be especially aware of the dangers and implications to sensitive student data when third-party JavaScript libraries are used. As such, websites should consider hosting all scripts locally in order to provide reasonable security that would be expected by visitors and users of the site.

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## Conclusion

Externally-hosted JavaScript can have serious security and privacy implications. The scripts may change without knowledge of the website owner, allowing the host of those scripts to access information in an unauthorized manner. As this research demonstrated, there are hundreds of scripts loaded from a university website with no integrity check and no reasonable means to verify or validate what is being executed within a visitor device. Some of the scripts have access to cookies and set cookies of their own, allowing them to collect and cross-referencing identifying information about the end user.

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