THE INFLUENCE OF COMPANY CHARACTERISTICS AND LEADERSHIP MOTIVATIONS ON THE CIRCULAR ECONOMY OF SMALL MANUFACTURERS

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Contents

LIST OF FIGURES

LIST OF TABLES

I. Introduction

The circular economy (CE) is increasingly being recognized as a framework for achieving sustainability (Suarez-Eiroa et al. 2019). Policy makers and the private sector suggest that the principles supporting CE (i.e., strategic objectives that together enable full CE implementation) have the potential to address local, national, and global sustainability goals (Barreiro-Gen and Lozano 2020; Pieroni, McAloone, and Pigosso 2019). Businesses have identified the CE as a pathway to implement more sustainable practices (Govindan and Hasanagic 2018; Moktadir et al. 2018) and have been attracted to the CE because of its emphasis on enhancing resource regeneration and utilization rates, optimizing system performance, and enhancing industrial symbiosis (Stumpf, Schöggl, and Baumgartner 2021). Researchers have developed varying conceptual models of the CE (Ellen MacArthur Foundation 2019; Velenturf et al. 2019) and have started to evaluate how to administer CE Practices within industry (Gusmerotti et al. 2019; Hultberg and Pal 2021). Research and case studies that involve sustainable, green, or CE Practices mostly favor larger companies (García-Quevedo, Jové-Llopis, and Martínez-Ros 2020). Thus, research is limited in addressing the use of CE Practices within small and medium sized businesses, with fewer studies documenting practices, characteristics, and decision making of small manufacturers (Ashton, Russell, and Futch 2017). Understanding the factors that lead small businesses to CE Practices is critical to achieving sustainability goals.

Globally, there are approximately 400 million small and medium sized businesses, representing approximately 90% of all businesses and more than 50% of employment (The World Bank, n.d.). Together small and medium sized businesses provide significant contributions to local, regional, and national economies; however, their aggregated environmental impacts outweigh their larger company counterparts (Bakos et al. 2020; Hillary 2017). In particular, manufacturing has been found to produce more pollution than other industries (Zeng et al. 2010) due to their frequent use of large quantities of freshwater, hazardous chemicals, and toxic substances (Quintero-Angel and Peña-Montoya 2020). The manufacturing industry, however, is critical to the supply chain, playing a significant role in the design, material use, assembly, and

deconstruction of products (Ashton, Russell, and Futch 2017; Ellen Macarthur Foundation 2014). Given this, the implementation of sustainable practices by manufacturers is vital to the CE evolution (Giurco et al. 2014). For example, material reduction and life cycle analyses within manufacturing can reduce raw material use and decrease waste (Mendoza et al. 2019). Manufacturers may also implement energy and environmental optimization strategies to lessen their environmental impacts (Peng et al. 2018). By adopting such practices manufacturers can strive toward net-zero greenhouse gas emissions, as these measures help to reduce direct emissions and emissions within the supply chain. For example, CE practices could be vital to United States manufacturers net-zero carbon goals, where 55% of U.S. manufacturing emissions could be reduced and provided through cleaner, renewable energy inputs, and 45% could be achieved by adopting the CE.

Yet, the extent to which manufacturers adopt sustainable and CE Practices is often influenced by a variety of factors. Researchers have found that company decisions are related to business characteristics and owner motivations. Business characteristics, such as business size, age, ownership structure, industry type, and location, are unique to a company but some of these characteristics influence sustainability decision making (Balasubramanian et al. 2021). Similarly, the implementation of CE Practices by small businesses are also related to owners' and managers' motivations. For example, research has shown that company leadership's motivation toward the environment, whether internally or externally driven, affect implementation of environmental practices (Lewis & Cassells, 2010; Marylène & Deci, 2005; Yacob et al., 2019). Therefore, studies of sustainability in small businesses need to be specific to both leadership's motivation for CE Practices (Battisti & Perry, 2011; Testa et al., 2016) and consider unique characteristics, such as a specific location, industry, or size that have been shown to influence the extent to which small businesses implement sustainable practices (Gusmerotti et al., 2019).

Given the large proportion of small businesses, their cumulative environmental impact, and the importance of manufacturers to local, regional, and national economies, small businesses represent an extraordinary opportunity to advance CE and sustainability. Few studies have documented the interplay

between CE practices, company characteristics, and leadership's motivations for small manufacturers (Ashton, Russell, and Futch 2017). Notably the United States, make up less than five percent of similar global studies (Bakos et al. 2020).. Therefore, it is important to understand how small manufacturers' practices align with CE Principles as a method to track sustainability progress. This may be achieved by measuring the extent to which small businesses have adopted CE Practices and how these practices demonstrate specific CE Principles (Suarez-Eiroa et al. 2019; Ellen MacArthur Foundation 2015b). It is also important to understand what factors influence the adoption of CE Practices and CE Principles. Further insight into the contributions of small businesses to the CE will inform business owners, consultants, and researchers interested in advancing sustianability goals.

Within the United States, the Dallas-Fort Worth Metroplex (DFW) has a diverse and active manufacturing industry. To date, little sustainability research encompassing the use of CE Practices and CE Principles has targeted the region, even though DFW manufacturers are an important component of the local, regional, and state economies, as manufacturing tends to lead to overall economic growth (Cañas and Kerr 2014; Wright 2018). Hence, the purpose of this research is to analyze the CE Practices of small manufacturing establishments and to assess the extent to which business characteristics and business owners' motivations affect firms' decisions for implementing CE Practices. The research questions that guide this study are:

> RQ1: What CE Practices and CE Principles have small manufacturing establishments implemented within DFW?
>
> RQ2: To what extent are company characteristics and company leadership's motivations related to the implementation of CE Principles?

Understanding the answers to these questions will allow not only DFW's small manufacturers to transition more fully to CE Practices that benefit sustainability goals, but also promises to inform other small businesses and their implementation of similar practices.

II. Literature Review

Circular Economy

The CE provides an alternative to our current linear system of production and consumption (Das, Konietzko, and Bocken 2022). Linear systems are a take-make-dispose structure (Hultberg and Pal 2021). In comparison, the CE is underpinned by three principles: eliminate waste and pollution, keep products and materials in use, and regenerate natural systems (Ellen MacArthur Foundation 2021). The CE is regularly defined as a model that is "restorative and regenerative" (N. Millar, McLaughlin, and Borger 2019, 7), meaning that designing to retain a circular, closed loop system is imperative. By doing so, the model prevents consumption that exceeds planetary limits and natural systems. Thus, proponents often refer to the CE as closing the loop in industrial ecosystems (Ellen MacArthur Foundation 2013; Tomić and Schneider 2018). A more recent interpretation redefined the CE as a regenerative production-consumption system with a goal to keep rates of resource extraction, waste generation, and emissions within the limits of the planetary boundaries (Suarez-Eiroa et al. 2019). These elements are key to designing a system that is both restorative and regenerative for the planet's natural systems on which humans rely.

Some researchers claim that the CE only aids in the achievement of economic and ecological objectives (Geissdoerfer et al. 2017; Sauvé, Bernard, and Sloan 2016); however, there is discussion of how the CE's Principles incorporate social objectives, thereby aligning within the principles of sustainable development as well (Murray, Skene, and Haynes 2017; N. Millar, McLaughlin, and Borger 2019). Research has started to investigate the relevance of the CE in achieving the United Nations Sustainable Development Goals (SDGs), with studies analyzing which United Nations SDGs align with the CE (Schroeder, Anggraeni, and Weber 2019). Research suggests that the CE has a major contribution in meeting the aims of SDG 12 (Responsible Consumption and Production), SDG 7 (Affordable and Clean Energy), SDG 6 (Clean Water and Sanitation), and SDG 8 (Decent Work and Economic Growth), but could also contribute to SDG 11 (Sustainable Cities and communities), SDG 15 (Life on Land), and SDG 9 (Industry, Innovation and Infrastructure) (Panchal, Singh, and Diwan 2021; Rodriguez-Anton et al. 2019;

Khairul Akter et al. 2022; Dantas et al. 2021; Valverde and Aviles-Palacios 2021; Ellen MacArthur Foundation 2021). CE models that align with the three pillars of sustainability and the United Nations SDGs are important because they demonstrate how the CE can evolve to help manufacturers, the supply chain, and consultants develop practical applications to improve environmental and social governance (ESG) and to provide value that is not only economically driven but benefits communities and the planet.

Various CE models and frameworks have been proposed, but not all models are aligned to achieve environmental, social, and economic sustainability (Suarez-Eiroa et al. 2019). A variety of literature conceives the CE model as addressing the three R's: reduce, re-use, recycle (Pan and Li 2016). For example, the textile industry has identified recycling and reuse as key to developing a CE model to mitigate the amount of textiles destined for disposal (Shirvanimoghaddam et al. 2020). Research has examined numerous textile waste applications, including its use in the construction sector as thermal insulation or in the design of light weight concrete or bricks (Ahmad et al. 2016; Briga-Sá et al. 2013). Some researchers add remanufacture and repair to their CE models (Barreiro-Gen and Lozano 2020), whilst others focus on recovery, such as the recovery of metals from electronic waste (Isildar et al. 2018) or the recovery of minerals within wastewater treatment systems (Lin et al. 2016). Reike *et al*. (2018) defined the various "re" words within CE models as "R-imperatives", and identified 38 different combinations of R-imperatives within the CE literature. Other CE models consider input and output materials, such as substituting non-renewable inputs, such as energy sources, for renewable inputs, whilst promoting the recycling and recovery of outputs and emissions with an objective to improve and sustain material availability (Piezer et al. 2019).

The examples described above, however, do not distinguish how the CE models align with sustainability. Models that poorly demonstrate how they contribute to sustainability can make it harder to convince people to adopt a CE approach, especially as examples proliferate that are not harmonized with SDGs (Korhonen, Honkasalo, and Seppala 2018; N. Millar, McLaughlin, and Borger 2019). To prevent poorly positioned models, the relationship between CE and sustainable development needs strengthening (Schroeder, Anggraeni, and Weber 2019). Therefore, businesses' use of the CE should align with models that show an integrated relationship with sustainability (Velenturf et al. 2019).

Suarez-Eiroa *et al*. (2019) proposed seven operational Principles of the CE that align with the three pillars of sustainability (Table 1). The operational CE Principles were created under a sustainable development framework with an intent to disconnect economic development from the extraction of finite resources. As such, the CE Principles aim to keep extraction and generation rates within planetary and natural systems limits. Moreover, the seven principles illustrate practices that could be implemented to achieve each CE Principle. Therefore, adoption of the principles offers a method to meet sustainability goals.

CE Principle 1 is concerned with minimizing and eventually eliminating inputs of non-renewable resources, whilst adjusting the input of renewable resources to limit exceedance of planetary boundaries (Yuan, Bi, and Moriguichi 2006; Ellen MacArthur Foundation 2015a). CE Principle 2 considers adjusting outputs, such as minimizing output materials and other emissions, but also defining technological and biological outputs. Outputs should be minimized and their value sustained for as long as possible to prevent over-consumption of the biosphere and the planets natural adsorption rates (Desing et al. 2020). Like various circular economy models, CE Principle 3 denotes "R- imperatives" as factors to closing the system. A waste management hierarchy of prevention, re-use, recycle, recovery, and finally disposal is imperative to CE Principle 3. If prevention, re-use, or recycling within the system is not possible, then energy recovery of wastes should be next prioritization (Tomić and Schneider 2018; Ellen MacArthur Foundation 2015b). CE Principle 4 aims to sustain resource value within the system by improving product durability, and recirculating resources through the various stages of a product's life cycle. Enhancing industrial symbiosis is paramount to CE Principle 4, which involves industry's collective approach to exchange materials, energy, water, and other by-products (Oughton et al. 2022). Whilst remanufacture, repair, and regular maintenance are further key to CE Principle 4, including the importance of software updates to reduce obsolescence (Dantas et al. 2021; Barreiro-Gen and Lozano 2020; Fan et al. 2021) which is key to sustaining the system's value. CE Principle 5 is concerned with reducing the size of the overall system. It aims to reduce the quantity of products required by customers and end-users, thereby evolving to expand the CE to include consumer's responsibility, because their actions and decisions are pivotal to the overall size of the

system (Sakai et al. 2011; Ki, Park, and Ha-Brookshire 2021). CE Principle 5 also strives to improve the overall sustainability of products, from product transparency to procurement opportunities (Peschel and Aschemann-Witzel 2020; Centobelli et al. 2021; Bao et al. 2019), such as the emergence of digital product passports to declare the circularity and sustainability of materials and products throughout the supply chain (Walden 2021). CE Principle 6, design, and CE Principle 7, education, are defined as transversal elements for achieving a circular economy model aligned with sustainability (Suarez-Eiroa et al. 2019). CE Principle 6 includes the design of packaging and products using local resources, products made to order, and also the design of business models and strategies in favor of a circular economy (Korhonen et al. 2018; Mendoza et al. 2017). Finally, CE Principle 7 is concerned with the education needed to transition to a circular economy. Education includes not only awareness, but the aim to holistically transform values and behaviors of producers and consumers so that they can understand societal benefits of a circular economy (Sauvé, Bernard, and Sloan 2016; Muranko et al. 2019; Korsunova, Horn, and Vainio 2021; Bassi et al. 2021). Table 1 below provides a list of the 7 CE Principles, their goals, and examples of practices to achieve each CE Principle.

Table 1. The seven Circular Economy (CE) Operational Principles and their overall aim as proposed by Suarez-Eiroa et al. (2019), plus CE Practices that can be adopted in line with each principle.

CE Principle	Goal of CE Principle	Examples of CE Practices to achieve the CE Principle
1	Adjusting inputs to the system to regeneration rates	- Using renewable inputs, and energy - Saving energy and materials - Reducing toxicity of inputs - Fostering renewable, and energy efficient mobility
2	Adjusting outputs from the system to absorption rates	- Considering outputs, such as emissions, by-products, or wastes when choosing system inputs - Using processes that generate less waste, such as using by-products instead of raw materials
3	Closing the system	- Segregating hazardous wastes - Segregating wastes and recyclables to sustain higher recycling quality - Remanufacturing products and components - Take-back systems, recycling by-products and off-cuts - Energy recovery by converting waste into heat, electricity, or fuel
4	Maintaining resource value within the system	- Industrial symbiosis, such as redistributing second-hand goods, and sharing by-products - Promoting reparability, preventive maintenance, and repurposing - Software updates to reduce obsolescence
5	Reducing the system's size	- Informing through eco-labelling and product labelling - Purchase or procure to reduce environmental impacts, such as green purchasing or procurement - using local suppliers and materials - Manufacturing on demand
6	Designing for circular economy	- Eco-design packaging for re-use and recyclability - Designing and manufacturing products to be produced in other places based on local resources - Designing new business models and strategies to guarantee continual improvement, and promote sustainability and circular economy
7	Educating for circular economy	- Educating to promote and up-skill for the circular economy - Promoting knowledge and values to enable the circular economy, such as environmental certifications and awards, sharing knowledge through stakeholders and industry - Promoting employee habits and actions that favor the circular economy

Company Characteristics

Studies have shown that company characteristics influence the implementation of CE and similar environmental practices (Bakos et al. 2020; Brammer, Hoejmose, and Marchant 2012). Common company

characteristics studied in relation to the uptake of such practices include company age, size, industry type, revenue, and location (Balasubramanian et al. 2021). For example, a study conducted on small U.S. manufacturing firms found that companies implementing environmental practices were older, had higher annual sales, or more employees. Additionally, the researchers found that companies with environmental certifications are more likely to adopt environmental practices. In particular they found that companies whose annual sales were exceeding $10 million (USD), over ten years of age, or contained at least one hundred employees, were more likely to have implemented twice the amount of environmental practices than other small manufacturers surveyed (Ashton, Russell, and Futch 2017).

Similarly, a study of Italian manufacturers found companies with high annual turnovers and poor client trends had low CE performance, while companies with the best CE performance had an increase in employee numbers and low turnover. The research collected data through a questionnaire survey of over eight hundred manufacturing firms in Italy (Gusmerotti et al. 2019). The study used confirmatory factor analysis to find clusters related to CE characteristics and business orientation. Companies that were grouped as "green marketers," "optimizers," and "circular companies" had internalized the principles of the CE, whilst "information-oriented companies" and "linear companies" had the poorest CE performance. In particular, "linear companies" had the poorest CE performance, and the worst annual turnovers and client trends. Comparatively, "circular companies" had the best CE performance and business trends, such as low turnover (Gusmerotti et al. 2019). The results not only demonstrated that company characteristics influence CE uptake, but also that adopting the CE provides business improvements. Moreover, the results indicate that company characteristics can be used as indicators to demonstrate how CE performance can improve business (Ellen MacArthur Foundation 2015b; Dev, Shankar, and Qaiser 2020).

Company ownership can also influence the implementation of sustainability practices (Gundry et al. 2014). Most studies that examine ownership, however, only focus on the economic dimension of sustainability within a linear system (e.g., business growth and competitiveness; Sustainable Growth Rates) (Adebayo et al. 2021). Thus, there is little research focusing on business practices, including the use of CE Practices, related to social and environmental sustainability and their relationship to business ownership

characteristics (Esa, Zahari, and Nawang 2018; Wang et al. 2014). However, it is useful to understand if certain ownership characteristics, such as disadvantaged businesses, including woman- or minority-owned businesses, impact CE implementation or sustainability practices in general.

Within the United States, disadvantaged businesses include members of designated groups that are socially disadvantaged (13 CFR §124.103 (b)(1), 2011), including, African American, Asian, Hispanic and/or Latino, Native American and/or American Indian, Native Hawaiian and other Pacific Islander, and multiracial (Cunningham 2022; United States Census Bureau 2021b). A social disadvantage could also include a feature related to race, ethnic origin, gender, physical handicap, or long-term residence in an environment isolated from mainstream American society (13 CFR §124.102 (c)(2), 2011). Therefore, the U.S. Small Business Administration names the following as disadvantaged businesses: veteran-owned, service-disabled-veteran-owned, woman-owned, LGBTQ+ owned, Native American-owned, and minority-owned (Small Business Administration, n.d.).

Within the United States, these businesses are seen to have a disadvantaged business growth, so government funding is available to all the ownership types mentioned through the U.S. Small Business Administration (Dilger 2021). Research has also shown how disadvantaged businesses are affected, for example, there are fewer Black-owned manufacturing businesses in the United States (Sharpe 2019), and Black woman-owned small businesses face obstacles that limit their business growth (Jarriett 2020). Less is known about the status of other disadvantaged businesses' sustainability practices, including LGBTQ+ owned, veteran-owned small businesses, and service disabled veteran-owned, especially within the United States (Kassinis et al. 2016; Glass, Cook, and Ingersoll 2016; Balasubramanian et al. 2021). Therefore, it is important that researchers examine how company ownership affects implementation of the CE, as well as investigating other company characteristics.

Motivation toward the environment

Within businesses, leadership's motivation toward the environment can affect the uptake of environmental practices (Sawe et al. 2021; Govindan and Hasanagic 2018). The level of motivation is often measured using the Motivation Toward the Environment Scale (MTES). MTES consists of a 24-item

questionnaire where participants rate how often their reasoning for an environmental behavior corresponds with a prescribed set of statements. The statements correspond with levels of motivation defined on the self-determination continuum (Pelletier et al. 1998; Villacorta, Koestner, and Lekes 2003). Amotivation and intrinsic motivation lay on either end of the self-determination continuum. The continuum includes the source of motivation and the level of self-determination, which ranges from motivation that is impersonal (or non-self-determined) to motivation that is internally sourced (or self-determined). Extrinsic motivation exists between amotivation and intrinsic motivation. (Table 2) (Deci and Ryan 1985; Ryan and Deci 2000).

Table 2. The Self-Determination Continuum, and its relationship with motivation and regulatory style, as defined by Ryan & Deci (2000).

Level of motivation	**Amotivation**	**Extrinsic motivation**				**Intrinsic motivation**
Regulatory style	Non-regulation	External regulation	Introjected regulation	Identified regulation	Integrated regulation	Intrinsic regulation
Source of motivation	Impersonal	External	Somewhat external	Somewhat internal	Internal	Internal
Level of self- determination	Non-self-determined ⟷ Self-determined					

Understanding whether intrinsic or extrinsic motivation influences the implementation of CE is critical to advancing sustainability goals (Lewis and Cassells 2010; Testa et al. 2016). For example, regulatory compliance is an externally sourced motivation for CE (Battisti and Perry 2011) because it is motivated by the desire for an external reward, or through the fear of punishment of noncompliance (Deci and Ryan 1985; Stern 2018), and as such, it would reduce the level of self-determination. Comparatively, an internal source of motivation for the uptake of CE would be personal commitment or responsibility to the community (Lewis and Cassells 2010; Hart and Dowell 2011) because the activity identifies or aligns with one's internal values or goals (Pelletier et al. 1998), and would increase the level of self-determination.

When motivation is driven by internal sources, individuals within company leadership, such as owners or managers, may feel self-directed and autonomously motivated. A higher level of autonomy results in external drivers affirming competence, as when individuals feel they have the skills for success, they are more likely to achieve their goals. This can lead to intrinsic motivation which improves self-determination. Motivation driven by external sources, may result in a higher level of control, which can undermine intrinsic motivation, and result in leadership being non-self-determined. Leadership may feel incompetent, non-valuing, or feel a lack of control (Tafvelin and Stenling 2021; Marylène and Deci 2005). For example, studies have demonstrated that regulatory compliance facilitates a non-strategic, reactive response, where small businesses act to meet the basic level of compliance or perceive the punishment for noncompliance is less burdensome than implementation costs (Revell and Blackburn 2007). This type of motivation illustrates non-self-determination through amotivation. Financial benefits related to business practices, through either cost savings or return on investment practices, are perceived by company leadership as factors that motivate them; however, these factors regularly lead to the use of waste practices within a linear system to gain quick profits and are perceived as quick rewards (Ashton, Russell, and Futch 2017; H.H. Millar and Russell 2011). Businesses engage in these practices because they are easy to implement. This is an example of extrinsic motivation from a source that is somewhat internal; it relies on cost-benefit analyses and reduces self-determination. Intrinsic motivations, on the other hand, include actions that demonstrate a commitment to environmental stewardship as a matter of personal importance, which will improve self-determination and lead to the use of practices that are harder to implement (Pelletier et al. 1998; Vihma and Moora 2020).

Applying the MTES to investigate company leadership's level of self-determination, and how it impacts CE uptake is a unique research technique that this paper trials. Future research may continue to use this method to investigate how company leaderships' level of self-determination toward the environment affects the adoption of CE Practices. Comparatively, most research touches on the topic by asking companies what factors they perceive as motivators or barriers for the adoption of similar practices. The findings from research that used this method are discussed in the next section.

Perceived sources of motivation and barriers

Understanding what motivates or prevents a company's use of CE Practices can help researchers, consultants, governments, and other interested parties, find focus points for future improvements to help the overall uptake of CE Practices. Some sources of motivation have already been described in the previous section; however, the aim of this section is to review literature that has investigated what a company perceives as a factor that motivates or prevents them from implementing CE or similar sustainability practices.

Garcia-Quevedo *et al.* (2020) conducted a study to understand what barriers were present to the CE in European small and medium-sized firms. They sampled over 10,000 businesses that mostly contained between one to nine employees, but the largest employee count was 250. The firms were in several European countries and multiple industries, but most businesses were from retail and services. Their study defined CE Practices as activities that minimize water, waste, and energy, such as the use of renewable energy, and product and service redesign to minimize materials. The most common CE Practices used were those involving waste, where 59% of respondents had implemented measures such as recycling, reusing, and selling waste to customers. Next, they found that 43% of respondents had implemented energy efficiency practices. Only 20% had minimized water usage, and 18% used renewable energy as their predominant energy source. The study named regulation as the biggest barrier to the use of CE Practices, notably the complex administrative or legal procedures, and costs associated with meeting regulations and standards. One fifth of businesses perceived human resources as a barrier, and another notable barrier was lack of CE expertise. These perceived sources of motivation and barriers would reflect external and introjected regulation, which falls further toward non-self-determination (Ryan and Deci 2000).

Although Garcia-Quevedo *et al.* (2020) identified regulation as the biggest barrier across various European small businesses, Yacob *et al.* (2019) found that small manufacturers fail to see market opportunities, creating a barrier for CE. They examined motivations of Malaysian small manufacturers and their use of sustainable practices. The study investigated energy, water, and waste practices, such as

minimization, recycling, monitoring, and target setting. The research found energy management and measuring activities as the most frequent practice implemented, driven by return of investment through local government programs. Waste practices were the second most common sustainable practice used, driven by high economic penalties for illegal dumping. Finally, fewer companies used water conservation techniques. The study found that companies were motivated to reduce effluent production to reduce costs. Overall, the companies surveyed were less motivated to use sustainable practices when they were unable to see market opportunities or benefits.

Similarly, a study conducted in Bangladesh, evaluated what drivers affect the use of sustainable and circular economy practices within the leather industry (Moktadir et al. 2018). Drivers analyzed were "knowledge about circular economy," "customer awareness," "leadership and commitment from top management," and "government support and legislation." The results show that knowledge of the circular economy was the greatest driver for larger companies to adopt CE. The major driver for smaller industries was government support and legislation, which is similar to the study by Garcia-Quevedo *et al.* (2020).

Lewis and Cassells (2010) determined drivers and barriers to implementing environmental improvements and defined whether the motivation was internal or external. They named internal drivers as financial benefits, community responsibility, and personal commitment, whilst external drivers included compliance with legislation, firm reputation, consumer demand, and public pressure. The findings proved that cost, an internal motivation, was the major barrier (cost as a financial barrier), but also the main driver (Profit and cost savings as a financial driver) to environmental improvements. This finding reflects that financial benefits can improve motivation because they are a form of an internal reward (Ryan and Deci 2000).

In the United States, within small manufacturing firms, researchers investigated the adoption of green and environmental practices. Forty percent of companies perceived cost savings as a key motivation, and 63% of companies were internally motivated to improve business performance, competition, and commitment to environmental stewardship (Ashton, Russell, and Futch 2017). Such motivations show how

extrinsic motivation that is internally, and somewhat internally sourced (identified, integrated, and intrinsic regulatory styles) improves self- determination, and can lead to further uptake of environmental practices (Villacorta, Koestner, and Lekes 2003).

This research highlights the importance of distinguishing whether a motivation that influences the uptake of the CE is internally or externally driven (Ashton, Russell, and Futch 2017; Lewis and Cassells 2010; Testa et al. 2016) and can help distinguish the level of self-determination within company leadership.

III. Methods

Site and situation

The U.S. Small Business Administration (2020) reported 2.8 million small businesses, with 50,669 of these in the manufacturing industry in Texas. And Texas is second in the nation for number of manufacturing firms, with a high diversity of manufacturing industries, from petroleum and chemical, to computer and technology manufacturing, and the automotive sector (Texas Economic Development and Tourism, 2021). The Texas economy is dependent on these manufacturing firms (Wright, 2018), and Texas manufacturers are expanding at a rate far quicker than the rest of the United States (Cañas & Kerr, 2014).

Within Texas, the Dallas-Fort Worth-Arlington Metropolitan Statistical Area (DFW Metroplex) an eleven-county area, locally referred to as the DFW Metroplex, comprises the study area (Figure 1). The DFW Metroplex is in the northeast of Texas and is the largest Metropolitan Statistical Area (MSA) in Texas with a population of 7.5 million people in 2019 (Hegar 2020). It had the largest numeric population gain since 2010 of any MSA, showing a 19% population increase. Specifically, Tarrant, Dallas, and Collin counties were listed in the top ten U.S. counties to increase in population between 2010 and 2019 (United States Census Bureau 2022). Furthermore, the City of Fort Worth was the fastest growing city in the United States between 2000-2016 (United States Census Bureau 2021a; City of Fort Worth 2022).

As DFW Metroplex's population increased, so did employment opportunities. Small businesses were identified as responsible for most of the employment growth. For example, in Dallas County where small businesses with one to four employees contributed to 76% of total businesses in 2016 (Zeuli and

O'Shea 2017). Furthermore, Fort Worth's economic plan identified growth in small businesses as key in developing a dynamic local economy and discussed how to promote their growth even further (Palmer 2016). The U.S. Census Bureau (2017) reported a total of 130,881 small businesses within DFW, with 4,859 of these small businesses within the manufacturing sector, and over 50% consisting of less than 10 employees (Table 3). Additionally, manufacturers have expanded in Texas at a rate faster than the rest of the United States (Cañas and Kerr 2014), and Texas hosts a high diversity of manufacturing operations (Wright 2018). DFW Metroplex currently hosts more manufacturing firms than other highly populated urban areas in Texas, including the greater Houston area (Hooper 2018) (Figure 2). Approximately 86% of the manufacturing firms in DFW Metroplex had less than 500 employees (United States Census Bureau 2017).

Similarly, the manufacturing industry is an established sector within Fort Worth (City of Fort Worth 2022) and elsewhere within the DFW Metroplex. Manufacturing makes up 7.3% of the regional economy by employment and has more manufacturing activity than any other metroplex area in Texas. Additionally, the manufacturing industry is diverse, covering many types of manufacturing businesses (Hooper 2018). The Dallas Regional Chamber (2022b) visualized the geographic clusters of DFW Metroplex's manufacturing industries on a heat map with a total of 6,875 establishments mapped, including those industries larger than 500 employees (Figure 3). Notably, the clusters of manufacturers correlate with the counties discussed above (e.g., Tarrant, Dallas, and Collin) that have witnessed the largest population increases.

Table 3. Small manufacturing establishments located in DFW Metroplex, per number of employees (US Census Bureau 2017).

Enterprise employment size	Number of establishments
<5	1,785
5-9	826
10-19	721
20-99	998
100-499	429
Total	**4859**

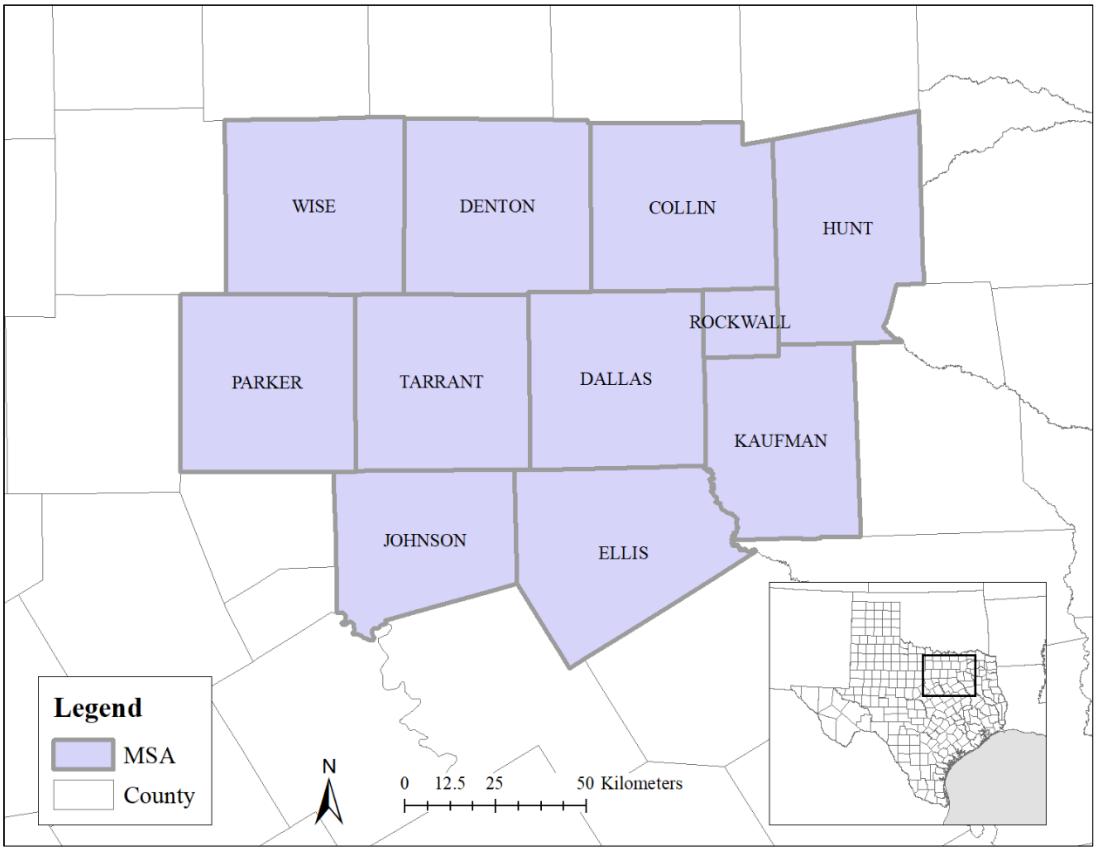

Figure 1. A map of Dallas-Fort Worth-Arlington Metropolitan Statistical Area (MSA), Texas, U.S.A., and the eleven counties that make up the MSA's geographic boundary.

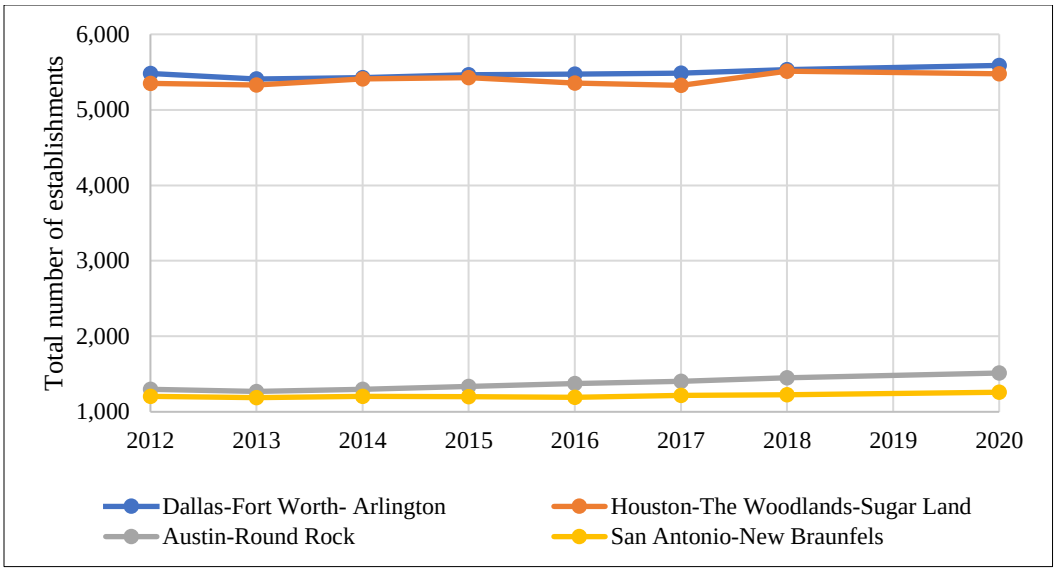

Figure 2. Data from United States Census Bureau (2022) showing the quantity of manufacturing establishments over time (2012-2020) within the four largest urban areas in Texas, U.S.A.

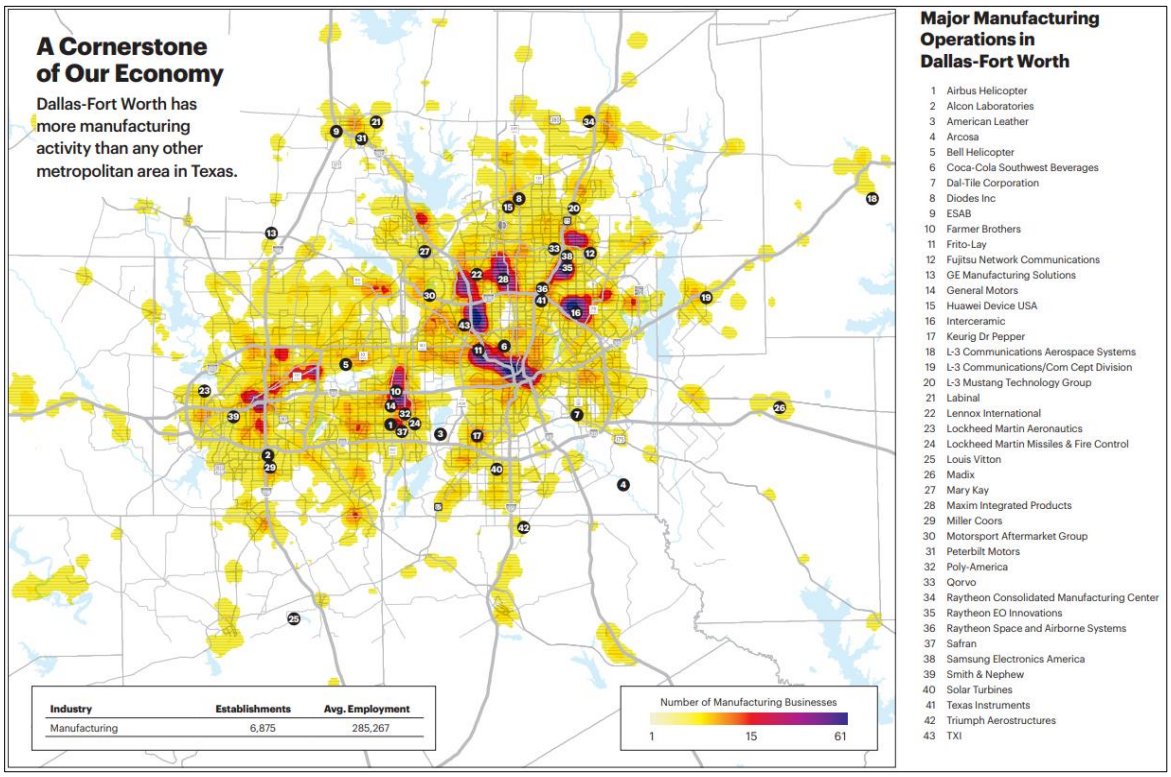

Figure 3. A heat map of DFW Metroplex and the locations and clusters of manufacturing industries (Dallas Regional Chamber 2022b).

Because the DFW Metroplex has a diverse and active manufacturing industry, it is a compelling area to investigate what CE Practices these companies may be implementing, and to understand the extent to which the seven CE Principles have been adopted. For example, CE Principles could be measured by investigating what CE Practices DFW Metroplex's manufacturers have adopted. CE Practices could involve overall material reduction, including reducing raw materials, life cycle analysis, and practices aimed at decreasing wastage (Mendoza et al. 2019; McDonough and Braungart 2002). Overall, there are various energy and environmental optimization opportunities within manufacturing, which highlights the importance for thorough research on sustainability within the industry (Peng et al. 2018). Little research has targeted the DFW Metroplex even though their small business manufacturing industry is so crucial to the area, Texas, and United States (Dallas Regional Chamber 2022a; Ashton, Russell, and Futch 2017; Bakos et al. 2020).

The research population for this project consists of small manufacturing firms with less than 500 employees, equivalent to the definition of "small business" by the U.S. Small Business Administration (SBA). SBA further uses the defined North American Industry Classification System (NAICS) code assigned along with the number of employees to define small business for manufacturing.

The NAICS code is an industry classification system that groups industries based on the similar production processes, and it replaced the U.S. Standard Industrial Classification (SIC) for the first time in 1997 (Executive Office of the President 2017). The SBA (2022) published size standards matched to defined NAICS codes. Manufacturing NAICS codes include chapters 31 to 33 within the regulations, which this study targets. These manufacturing NAICS codes showed that the number of employees ranged from 500 to 1,500 and the average total number of employees allowed to qualify as a small business was 500.

It is important to note that the definition used for a small business varies throughout the United States, throughout industries, and globally (Hryhorash et al. 2018; Hegstad 2020; Raczyńska 2019). However, this study used the SBA standard for manufacturing of 500 employees, as did similar research conducted within the United States (Ashton, Russell, and Futch 2017).

Accessing the population

The data collected on number of manufacturing establishments within DFW Metroplex indicated a total of 4,859 manufacturers, as listed by the United States Census Bureau (2017a). It was highly unlikely that all 4,859 companies would be willing to take part in this research study. Therefore, I sampled a portion of DFW manufacturers and chose a confidence level of 95%, with a confidence interval of 5% for the results to be representative. I ideally required 356 manufacturers to take part in the research. To improve the likelihood of meeting my representative sample size, I chose to conduct my research using an electronic survey rather than using interviews or focus groups, which would have removed anonymity for respondents, and would have increased time and resources. For interviews, I concluded that I would not have been able to interview more than ten individuals, which is similar to other previous research (Williams and Schaefer 2013; Oxborrow and Brindley 2013). Comparatively, paper surveys do not align with sustainability goals, and would have required a large quantity of paper, ink and energy. Further, it would have required an extensive amount of time to package and post the individual surveys, with no guarantee of receipt (Huffman and Klein 2013). I therefore decided an electronic survey method would allow me to share the survey efficiently and promptly with many recipients (Bailey 1994). It also allowed me to share follow up emails and efficiently check completion rates.

Once I had chosen my survey method, I investigated procedures for sharing the electronic survey. I identified that I could share an HTML link through websites, social media, or third parties, but I could also directly email an electronic link to the survey using direct emails for my targeted population. The United States Census Bureau, however, does not list individual identifiable companies, and this data was not otherwise publicly available. So, I required access to a private enterprise holding such records. I evaluated several companies that could supply access to the appropriate data. It was particularly important that I could identify what companies in DFW were listed as manufacturers with no more than 500 employees. After consideration, I approached Dun & Bradstreet (D&B) – an American based company

providing business analytics and insights to clients – to establish costs for such data (Dun & Bradstreet 2022).

D&B provided me with a trial of their software, called D&B Hoovers, an online database that offered dynamic search and list building capabilities and comprehensive company profiles (Dun & Bradstreet 2021). The trial allowed me to verify that I could filter, sort, and extract the relevant data. I asked D&B for a quote for this software, where access was partially funded through a TCU Graduate student research fund from the Science and Engineering Research Center (SERC). Once I was granted full access to the software, I began filtering the dataset for the information. I sorted and filtered the data by geography and selected the counties that form the DFW Metroplex. Next, I filtered by number of employees, and set employee maximum to 500. The database allowed me to filter businesses by NAICS codes, so I selected the NAICS codes for manufacturing (i.e., 31, 32, and 33). Then, I filtered by contact type, which allowed me to include company information that held an email address and a senior contact from the company. Once I verified the filter options, I ran the query and the database summarized that there were 4,320 results. Data fields specified for download from the database included company name, contact name, email address, job function, number of employees, and other company information. Once I selected the relevant fields, I downloaded the results into an Excel format. I then extracted email addresses, first, and last names on a separate spreadsheet that I uploaded to Qualtrics XM, the online survey platform that I used to construct and share my survey. I also planned to share my survey using social media, and through local Chambers of Commerce.

The survey instrument

To visualize my research flow, I created an operational model of my research design, survey validation procedures, and analyses (Figure 4). The survey design, validation, and survey published procedures are discussed below.

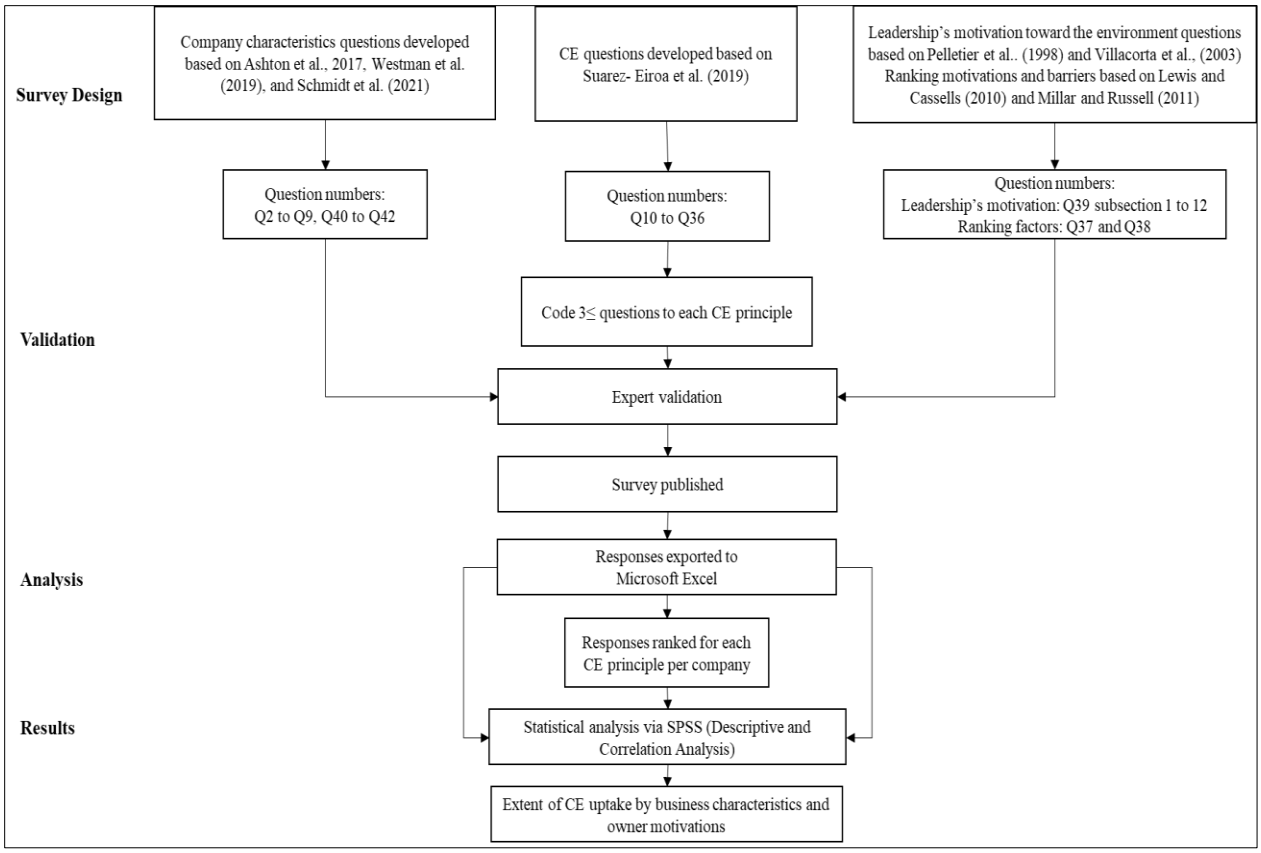

Figure 4. Operational model that defines the method of survey design, validation, analysis, and results for research that investigated the adoption of CE Practices and Principles, and the influence of leadership's motivations, and company characteristics on CE uptake. Question numbers listed refer to Appendix A.1.

Survey Design

I designed the survey in three specific sections: Section 1 included questions related to company characteristics; Section 2 contains questions regarding CE Practices in use; and Section 3 investigated leadership's motivation toward the environment. I constructed most of the questions to be multiple choice, with options to list appropriate information, but the survey does contain some write-in or open text questions. The questions in each section are based on similar research. Section 1 contains questions 2 through 9, and 40 through 42. Questions 40 through 42 are write-in questions that could have turned respondents away from the survey because they needed more time and thought for respondents to answer, and I needed to prevent respondents losing focus at the start of section 1. If respondents lost interest, they

could exit the survey before continuing to section 2, so I presented these three questions later in the survey design. Section 1 included questions investigating number of employees, respondent's role in company, North American Industry Classification Code, annual gross sales, and company age. Questions also investigated whether the company identified as a disadvantaged business. I based questions on similar research such as Westman *et al.* (2019), Ashton (2017), and Schmidt *et al.* (2021). Appendix A contains the questionnaire.

Section 2 contains questions 10 through to 36. I selected CE Practices that corresponded to one of the seven CE operational Principles proposed by Suarez-Eiroa et al. (2019), and each CE Principle included questions on three to five associated practices (Table 4). The number of questions (i.e., practices) for each principle differed due to input from external experts who validated questions, as discussed in a later section. Question 30 regarding supplier locations was open ended, where respondents were asked to list U.S. States, or external countries where they have operations. I drew on questions from a variety of similar research that investigated topics such as energy use, resource efficiency measures, waste reduction and recycling, and environmental stewardship (Brammer, Hoejmose, and Marchant 2012; Williams and Schaefer 2013; Ashton, Russell, and Futch 2017; Gusmerotti et al. 2019; Hitchens et al. 2003; H.H. Millar and Russell 2011).

Table 4. A summary of the survey question numbers that were assigned to each CE Principle. The question summary demonstrates what CE Practice each question referred to.

CE Principle	Question number	Summary of the question and what CE Practice it referred to
		Adjusting inputs to the system to regeneration rates
1	18	Substitute inputs for materials that reduce the quantity of inputs
	19	reduce toxicity of inputs
	21	Use renewable energy on site
	23	Use energy efficient transport
		Adjusting outputs from the system to absorption rates
2	12	Direct re-use of outputs in manufacturing process
	15	take- back outputs originating from system to reduce raw material inputs
	20	Consider output of emissions from manufacturing process
		Closing the system
3	10	Waste management activities
	11	Recycling activities
	46	Use waste recovery options to generate energy
		Maintaining resource value within the system
4	16	Supply product repair guides, or return product for repair
	17	Donate or sell by-products, parts, or materials to other companies
	25	Preventative maintenance
	26	Update software to prevent obsolescence
	27	Purchase products that can be repurposed or dismantled
		Reducing the system's size
5	24	Manufacture on demand
	28	Consider environmental impacts in purchasing decisions
	45	Use suppliers that are local (within 250miles, or half a day drive)
		Designing for circular economy
6	13	Design packaging for re-use
	14	Design packaging to be recycled
	31	Design products to use materials closest to your manufacturing location
	32	Design and discuss business strategies to incorporate circular economy
		Educating for circular economy
7	7 and 8	Environmental certifications or awards
	33	Provide employee training on the circular economy
	34	Encourage employee actions or habits that benefit the circular economy
	35	Share circular economy knowledge with other companies or manufacturers

Section 3 regarding leadership's motivation toward the environment used a modified MTES design (Question 39, subsection 1 to 12). Similar to MTES questionnaires, I used a five-point Likert scale to

measure motivation responses (Pelletier et al. 1998). MTES is a 24-statement survey; however, to improve the response rate and shorten survey response time, I asked respondents to express how often they felt that company leadership identified with each of the twelve sub-section statements. Therefore, my survey asked two statements per the regulatory style associated with the corresponding motivation level (Table 5) rather than four statements in MTES. I randomized the order of the twelve MTES statements to improve objectivity of the results.

Table 5. The twelve sub-section statements asked within Question 39 of the survey, and what regulatory style each question referred to according to the Motivation Toward the Environment Scale

Level of motivation	**Regulatory style**	**The twelve sub-section statements**
Intrinsic motivation	Intrinsic regulation	• We are proud of using sustainable practices • Our company strives to master new ways to use sustainable practices
Extrinsic motivation	Integrated regulation	• Sustainable practices are a fundamental part of our company identity • Using sustainable practices is an integral part of how we manage our business
	Identified regulation	• Sustainable practices are a sensible thing for our company to use • Our company understands that it is a good idea to use sustainable practices
	Introjected regulation	• Company management are discouraged when we do not use sustainable practices • When we do not use sustainable practices, our company regrets it
	External regulation	• We avoid criticism by using sustainable practices • Our company uses sustainable practices because others insist that we do
Amotivation	Non-regulation	• Our company cannot see how using sustainable practices will help us or the environment • Nothing will improve if we use sustainable practices

Section 3 also gathered data on motivations and barriers for CE uptake within companies (Questions 37 and 38). I used these two questions to identify factors that motivate or prevent CE uptake, asking respondents to rank their top five factors from most to least important that motivate or prevent uptake of CE. I used motivations and barriers from earlier research related to the use of the CE and sustainable

practices. (Schmidt et al. 2021; Ashton, Russell, and Futch 2017; Williams and Schaefer 2013; Lewis and Cassells 2010; H.H. Millar and Russell 2011; Gadenne, Kennedy, and McKeiver 2009; Revell, Stokes, and Chen 2010). Some earlier studies presented these questions in a binary format; however, I felt that this format lost significance of the answer, as these barriers and drivers can vary in importance from one individual to another. I also allowed the respondent to rank "other" and supply further information, which could highlight other factors unique to the sample population.

At the end of the survey, question 44 enabled respondents to answer Yes/ No to supply their contact information. If the respondent selected "No" the respondent was taken to the end of survey, thanked for completing the survey, and provided my contact information if they had any questions. However, if the respondent selected "Yes" then the respondent would be automatically directed to a second active Qualtrics survey with two questions: one question asked the respondent to supply an email address if they would like to receive a copy of the aggregated data, and the second question asked for an email address if they wanted to be entered into the prize draw to receive an Amazon gift card. By redirecting to a second survey, the contact information they provided could not be traced back to their original survey answers. I completed the survey direction within Qualtrics Survey Flow, where I customized the conditions for each answer. Appendix B shows the format of the survey that I redirected respondents to.

Validation

Expert validation was a vital step in checking the survey design. I used external validation to ensure that questions were clear, interpreted appropriately, and not ambiguous. Questions needed to be readable for manufacturing workers and accessible to a range of people, who may have little knowledge of sustainability, the CE, or environmental practices. I sought experts within TCU from a range of academic fields including qualified professionals and professors within the College of Science of Engineering and the Neely Business School. Externally, I found volunteers within the manufacturing industry who supplied feedback on the survey design including business owners, directors, managers, and consultants with locations from DFW, other areas of Texas, and the United States. Two volunteers were manufacturing

business owners in the United Kingdom, which helped to further identify how small changes in cultural language, can cause individuals to interpret the questions and answers differently. In total, 9 experts supplied feedback during survey design and validation, three from within TCU and six external. Validation was especially important because it helped to design and map questions to each CE Principle. The purpose of mapping dedicated questions to the associated principles allowed for further interpretation of the results.

IRB process

Prior to formally sharing the survey, I obtained approval from the Institutional Review Board (IRB) at TCU, who approves research that involves human subjects. I developed the survey to stay anonymous and designed the email collection system so that anonymity was secure and untraceable. I also constructed my informed consent template, which I displayed as the first question within my survey. IRB also requested approval of my recruitment processes; therefore, I developed social media and email recruitment templates. The IRB approved my methods on 13 November 2021 (Approval #2021-227). The approved templates were the versions that I used throughout my recruitment process and for the final survey.

Survey published

I uploaded the IRB approved survey to Qualtrics XM online survey platform. The survey was available from 17 November 2021 until 19 February 2022. I distributed the survey through three routes: 1) Qualtrics direct email function, 2) local Chambers of Commerce, and 3) social media (Figure 5). I originally shared the survey via Qualtrics direct email mid-November 2021, with reminders scheduled early and mid-December, and a final reminder scheduled early January 2022, after holiday season. I shared the survey via social media early December 2021, and I contacted the Chambers of Commerce mid-January 2022 (Figure 5).

Route 1 allowed me to distribute the survey to the 4,320 direct email addresses that I had purchased and exported from D&B. I extracted first and last names, company name, and email addresses into a separate Excel file which I uploaded into Qualtrics XM. I used Qualtrics XM distribution email function and prepared a template that would automatically email individuals a unique survey link used to access the

survey. I used the unique survey link method because it allowed me to supply reminder emails, and Qualtrics would save respondents survey positions for them to re-access at their convenience. It also allowed me to check full and partial completion and understand where respondents were exiting the survey. If respondents contacted my TCU email to be removed from the distribution list, I could access and remove contact details from Qualtrics XM. I preset three reminder emails via Qualtrics XM. Qualtrics also summarized the number of email addresses that did not send which is presented in the results.

Route 2 required me to ask local Chambers of Commerce to distribute an anonymous link to their members. I compiled a list of all the Chambers located within the DFW Metroplex and associated counties. I manually searched online for Chambers of Commerce websites and found the most appropriate committee members to contact. I compiled contact names and email addresses on an Excel document so that I could manually track responses. I then emailed an IRB approved email to each individual chamber contact, asking if they would volunteer to share my survey with their members. If the Chamber responded and agreed to share my survey information then I provided them a one-page summary of the research, with a general anonymous link for participants to access the online survey platform.

I completed Route 3 by sharing the survey via LinkedIn and Facebook. I used the IRB-approved social media recruitment template that I had created. To reduce the risk of irrelevant individuals accessing the survey, I searched for private groups on Facebook and LinkedIn such as the Small Businesses of Dallas-Fort Worth and DFW Small Business Platform on Facebook, and the DFW Manufacturing Networking Group on LinkedIn. Once I was approved for each group, I shared the social media recruitment template. My post contained a general anonymous link to the survey.

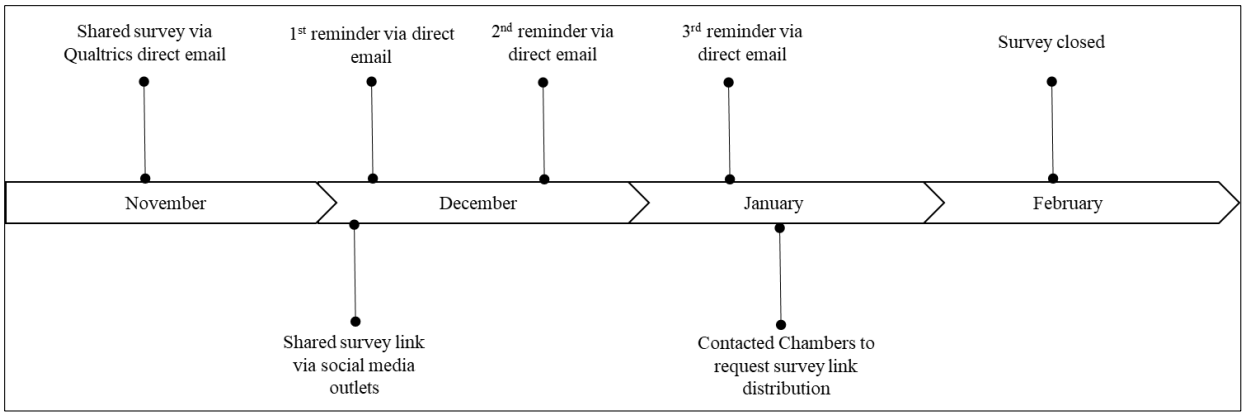

Figure 5. Timeline of when the Qualtrics online survey was shared with respondents and the distribution methods used. Timeline refers to November 2021 through the survey close date in February 2022.

Data analysis

Once I closed the survey on Qualtrics XM, I downloaded the results and saved the raw data to a Microsoft Excel spreadsheet. From here, I was able to prepare the data for further statistical analysis and export to IBM's Statistical Package for the Social Sciences (SPSS) software (Version 27).

Data preparation included filling in any blank cells from unanswered questions using "9999." Questions with written answers were inappropriate for analysis using SPSS and were not included in the upload to SPSS. Once uploaded to SPSS, I used the Variable View tab to display each question's data as a unique variable, verified each variable type, and selected each variable's measure (scale, ordinal, or nominal).

SPSS allowed me to examine linkages between CE implementation, company characteristics, and leadership's motivations, while the written answers (in Excel) allowed me to use qualitative analysis and interpretation of results.

Company Characteristics

Using SPSS, I descriptively analyzed the following company characteristics, to show frequency and overall percentages within my results:

- respondent's role within the company,
- company size,
- company age,
- the manufacturing industry of the company,
- whether the company held any environmental certifications or awards,
- annual gross sales pre (2019) and post (2020) COVID,
- Whether the annual gross sales displayed an increase, decrease, or sales stayed the same.

Circular Economy Practices and Principles

To examine the implementation of CE Principles, I coded the answers regarding implementation of each practice as binary data ("Yes" = 1, "No" = 0). By doing so, I quantified how many CE Practices had been adopted by each respondent. I aggregated the data and descriptively analyzed it to show the overall frequency and percentage of adoption. Next, I presented the results in order by CE Practices so that the reader could relate each CE Practice to its corresponding CE Principle.

Next, I categorized the level of implementation for each CE Principle by calculating the frequency of adopted practices by each firm. Each CE Practice showed binary data, so within SPSS, I developed one new variable for each CE Principle such that SPSS could count the defined CE Practices for a given CE Principle. (e.g., CE Principle 5 was correlated to Questions 24, 28, and 45). This allowed SPSS to count the level of adoption for each CE Principle using values ranging from "0" through to ">3", since some CE Principles have more than 3 associated CE Practices. These numeric values allowed me to show the number of CE Practices implemented for each CE Principle. Next, I used this numerical count to rank the overall CE Principle implementation by firm, using four rankings that I defined: "no practices used" (N=0), "limited implementation" (N=1), "transition phase" (N=2), to "circular implementation" (N=>3). For example, if a firm had adopted three or more CE Practices for CE Principle 1, I ranked the principle as having achieved "circular implementation" for CE Principle 1. If they adopted two practices, the firm would

be given the "transition phase" status; if they adopted only one, they would be ranked as "limited implementation," and so on. Next, I aggregated all firm's rankings and measured the frequency and central tendency across the entire data set. The rankings allowed me to ascertain which CE Principles businesses were implementing, where CE implementation could be improved, and which might require further investigation.

MTES, Motivations, and Barriers

I analyzed the MTES data using SPSS by coding the five-point Likert scale to numeric values. I first verified that the MTES data showed how amotivation and intrinsic motivation results were correlated with each other by completing a Spearman's rank-order correlation analysis (Spearman 1904). By doing this, it allowed me to verify that the 12 statements matched the levels of motivation. Next, I conducted another Spearman's rank-order correlation analysis using SPSS, but this time, I completed the analysis by selecting the variables that I had created to show CE Principle adoption, and the variables that contained the data for the 12 MTES statements.

I analyzed the data that I gathered on motivations and barriers that affect CE uptake within companies (Questions 37 and 38) separately on Microsoft Excel. The original questions asked the respondent to rank their top five most important factors (1 being the most important, and 5 being the least important). There were 13 motivations listed within question 37, and there were 12 barriers listed in question 38 (each included the option, "other" that had an additional box for further information). I used the "COUNTIF" function to count the number of responses per rank (1 to 5). No respondent selected the fifth value (selecting only1 to 4), so my ranking analysis only included four ranks. As respondents had in some cases selected "other" and provided a description, I used their results to construct another motivation entitled "Motivated to help the environment" because this motivation incorporated the write-in answers that I received. I designed a figure that could clearly demonstrate the frequency of where each motivation and barrier was ranked (1 to 4).

MTES, Company Characteristics, and their uptake of Circular Economy Principles

To analyze the extent to which company characteristics and leadership's motivations affect the adoption of CE Principles, I conducted a Spearman's rank-order correlation analysis (Spearman 1904). I selected this method of bivariate correlation analysis because the data showed a non-normal distribution and the variables contained ordinal ranked data. A low survey response rate influenced the methods of statistical analysis, and because of this, I used pairwise deletion to maximize valid responses across all questions answered.

I further evaluated company characteristics' influence on the uptake of CE Principles by descriptively analyzing data via SPSS. I focused this analysis on the significant correlations that I found using the Spearman's rank-order correlation analysis. I constructed figures and tables to show these results.

IV. Results

Although I downloaded 4,320 emails from D&B, there were 22 duplicates in the dataset, so Qualtrics XM sent a total of 4,298 emails. A total of 258 emails bounced back as undeliverable and I was unable to verify whether the rest of the direct email addresses were still active. One person opted out using the opt-out link, reducing the total to 4039. Overall, 112 people accessed the survey through Qualtrics direct email and began the survey, whilst 14 respondents accessed the survey through the anonymous link. It was not possible for me to distinguish fully whether the anonymous link was accessed via social media or via the Chambers of Commerce, however response completion dates correlated closely with publishing on social media channels. Only 84 respondents answered the IRB consent question (83 selected "Yes, I consent", 1 selected "No, I do not consent). Overall, I received 81 survey responses. Twelve of the 81 responses were considered invalid because the responses were from manufacturers with more than 500 employees, or the establishment was located outside of the study area. Final results include responses from 69 manufacturers in the DFW area. Fifty-nine respondents responded to the Qualtrics email, and 67 (97%) of the surveys used for analysis had a completion rate above 70% (Table 6).

Table 6. Total number of surveys accepted for analysis (N=69). The completion rate shows the percentage of the survey completed per respondent. The distribution route shows the total number of accepted surveys gathered via Qualtrics email, versus through an anonymous survey link shared via Social Media and Chambers of Commerce.

Completion rate	**(N)**
23%	1
33%	1
72%	1
77%	1
84%	3
88%	2
100%	60
Total	**69**
Distribution route	**(N)**
Qualtrics Email	59
Anonymous link	10
Total	**69**

Characteristics of respondents

Respondents held either a senior level role (91.3%) or worked directly with the manufacturing systems and processes (8.6%) (Figure 6), indicating that respondents had appropriate knowledge of their firm to answer the survey questions. I found that 65.2% of companies had less than 100 employees (65.2%). Thirty-four companies (49.3%) were less than four years old. Almost half of the firms (49.3%) reported annual sales less than $5 million USD. The COVID-19 pandemic affected 46% of companies through a decrease in sales since the start of the pandemic (Table 7). Firms that took part in the survey spanned 14 different manufacturing subsectors. I received the most responses from the fabricated metal product subsector (15.9%; Figure 7).

Twenty-nine percent of respondents identified as a disadvantaged business. Only 18% of respondents held an environmental certification or received an environmental award including packaging

design and size, plastic recycling, and environmental excellence (Table 7). Company certifications included Six Sigma, ISO 14001, ISO 2001, and Forest Stewardship Council Chain of Custody.

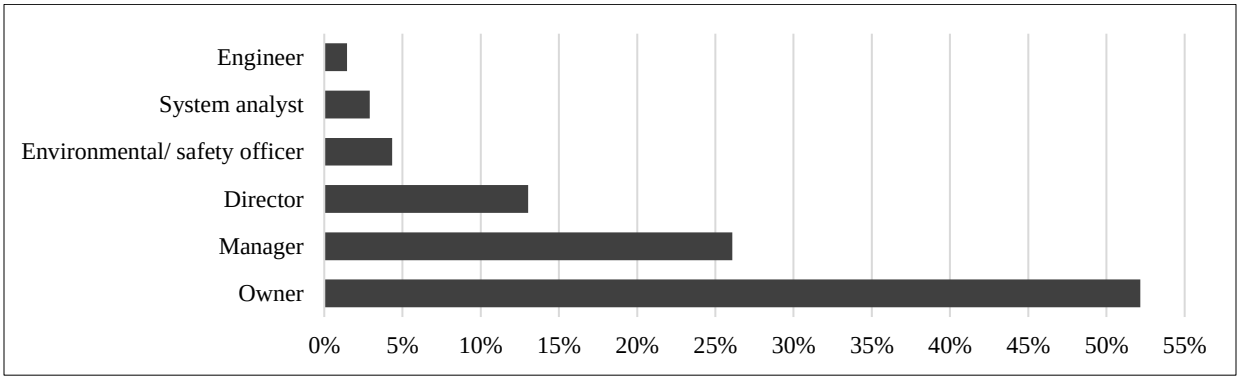

Figure 6. The percentage of respondents with differing company roles (N=69).

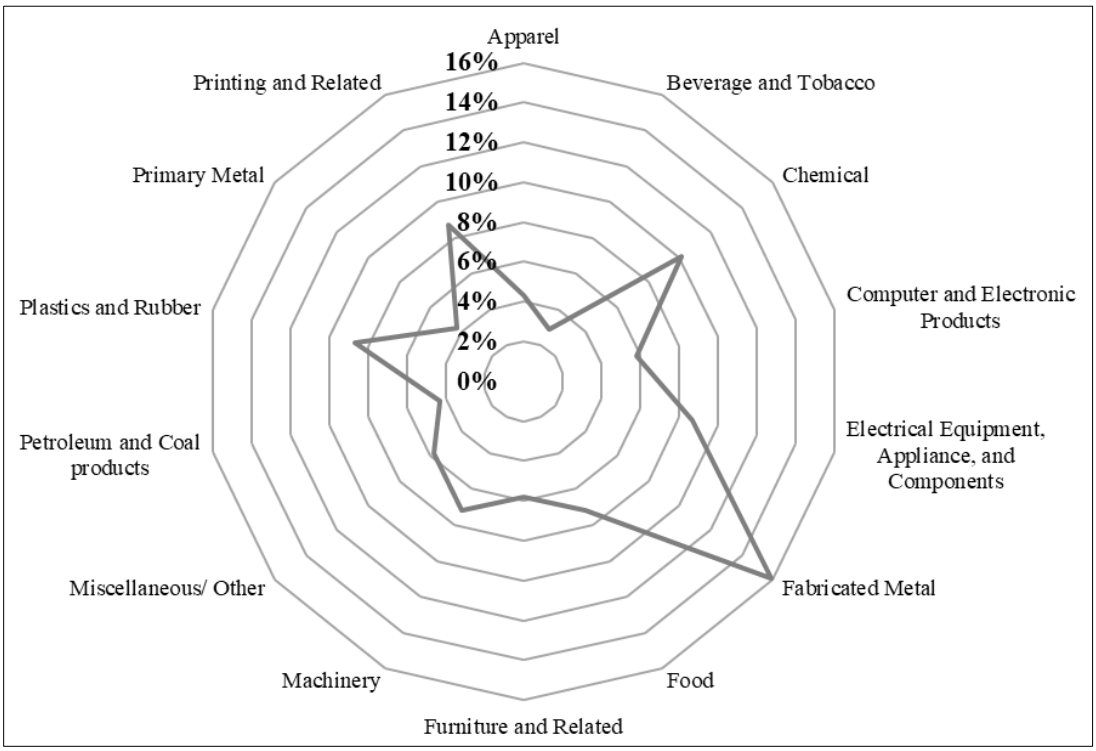

Figure 7. The percentage of different manufacturing industries surveyed (N=69).

Table 7. Company characteristics of firms (N=69) that took part in the survey. Results show the number of firms, and the corresponding percentage.

Company characteristics	**Number of firms**	**Percent**
No. of employees		
< 5	18	26.1
5 - 19	13	18.8
20 - 99	14	20.3
> 100	24	34.8
Total	**69**	**100**
Firm age		
< 4 years	34	49.3
4 < 11 years	3	4.3
11 < 20 years	22	31.9
> 20 years	10	14.5
Total	**69**	**100**
Annual gross sales 2020 (USD)		
< $5M	34	49.3
> $100M	1	1.4
$10- < $100M	8	11.6
$5M - < $10M	8	11.6
Confidential	18	26.1
Total	**69**	**100**
Annual sales pre and post Covid-19		
Sales decreased	32	46.4
Sales increased	12	17.4
Sales stayed the same	7	10.1
Confidential	18	26.1
Total	**69**	**100**
Obtained environmental certification or award		
No certification or award obtained	57	82.6
Holds certification or award	8	11.6
Confidential	4	5.8
Total	**69**	**100**
Ownership identified as disadvantaged		
Not owned by disadvantaged group	49	71
Disadvantaged-owned business	20	29
Total	**69**	**100**

Circular economy Practices and Principles

The implementation of CE Practices within each CE Principle varied (Table 8). On average, manufacturers adopted more practices within CE Principles 3, 4, and 5 respectively. Practices with the least adoption included Principles 6 and 7. The most widespread practice for CE Principle 1 was reducing toxicity of inputs (39.1%). Fostering energy efficient transport was the least adopted practice within CE Principle 1 (10.1%). For CE Principle 2, most respondents considered output emissions when deciding on material inputs (52.2%). Within CE Principle 3, most respondents indicated that they implemented waste management activities (87%). This was also the most adopted CE Practice overall (87%). Recycling was also a highly adopted practice (63.8%) within CE Principle 3. Energy recovery from waste was the least used practice in CE Principle 3 overall, with only two respondents indicating implementation of energy recovery practices. For CE Principle 4, most respondents indicated adopting two practices: reducing software obsolescence (84.1%) and preventative maintenance (85.5%). Manufacturing on demand (69.6%) was the most used practice within CE Principle 5, but few companies were making green purchasing decisions (27.5%). Packaging design for recycling (56.5%) and re-use (50.7%) were the most adopted practices by manufacturers within CE Principle 6, whilst the least deployed practice within CE Principle 6 was discussing CE business strategies (23.2%). Practices within CE Principle 7 had lowest levels of adoption, including knowledge sharing (4.3%).

Table 8. Circular Economy (CE) Practices, and total firms that adopted each CE Practice. CE Practices are grouped to the CE Principle that each practice helps to achieve. Results show number of firms adopting each practice, and that result represented as a percentage (N=69).

CE Principle	CE Practices mapped per CE Principle	No. of firms	%
1	Adjusting inputs to the system to regeneration rates		
	Reduce toxicity of inputs	27	39.1
	Substitute inputs for materials that reduce input volume	21	30.4
	Use renewable energy on site	12	17.4
	Use energy efficient transport	7	10.1
2	Adjusting outputs from the system to absorption rates		
	Direct re-use of outputs in manufacturing process	40	58
	Consider output of emissions from manufacturing process	36	52.2
	Take-back system outputs to reduce raw material inputs	15	21.7
3	Closing the system		
	Use waste management activities	60	87
	Use recycling activities	44	63.8
	Use waste recovery options to generate energy	2	2.9
4	Maintaining resource value within the system		
	Preventative maintenance	59	85.5
	Update software to prevent obsolescence	58	84.1
	Donate/ sell by-products, parts, or materials to other companies	20	29
	Purchase products that can be repurposed or dismantled	18	26.1
	Supply product repair guides, or return product for repair	17	26.6
5	Reducing the system's size		
	Manufacture on demand	48	69.6
	Consider environmental impacts in buying decisions	19	27.5
	Use local suppliers (within 250 miles, or half a day drive)	40	58
6	Designing for circular economy		
	Design recyclable packaging	39	56.5
	Design packaging for re-use	35	50.7
	Design products to use materials close to manufacturing location	30	43.5
	Design and discuss business strategies to incorporate CE	16	23.2
7	Educating for circular economy		
	Encourage employee actions or habits that help the CE	22	31.9
	Provide employee training on the CE	9	13
	Hold environmental certifications or awards	8	11.6
	Share CE knowledge with other companies or manufacturers	3	4.3

Furthermore, my assessment of CE Practices per manufacturer also highlights areas with strong CE implementation (i.e., "circular implementation and "transition phase") and areas that need improvement (i.e., "limited implementation" and "no practices used"). I found that over 50% of respondents were rarely adopting practices from CE Principle 7 (Figure 8). Only 10.3% of firms were at or beyond the transition phase for CE Principle 7. In contrast, all respondents had implemented at least one practice for CE Principle 4, and many had reached circular implementation of CE Principle 4 (43.5%). While most respondents met the transition phase for CE Principle 3 (59.4%), only one firm reached circular implementation of CE Principle 3. Finally, my results show that CE Principles 4, 5, and 6 were the only CE Principles to have 10 or more firms meeting circular implementation. Firms were uncounted from these results if the respondent missed a question that mapped to a specific CE principle.

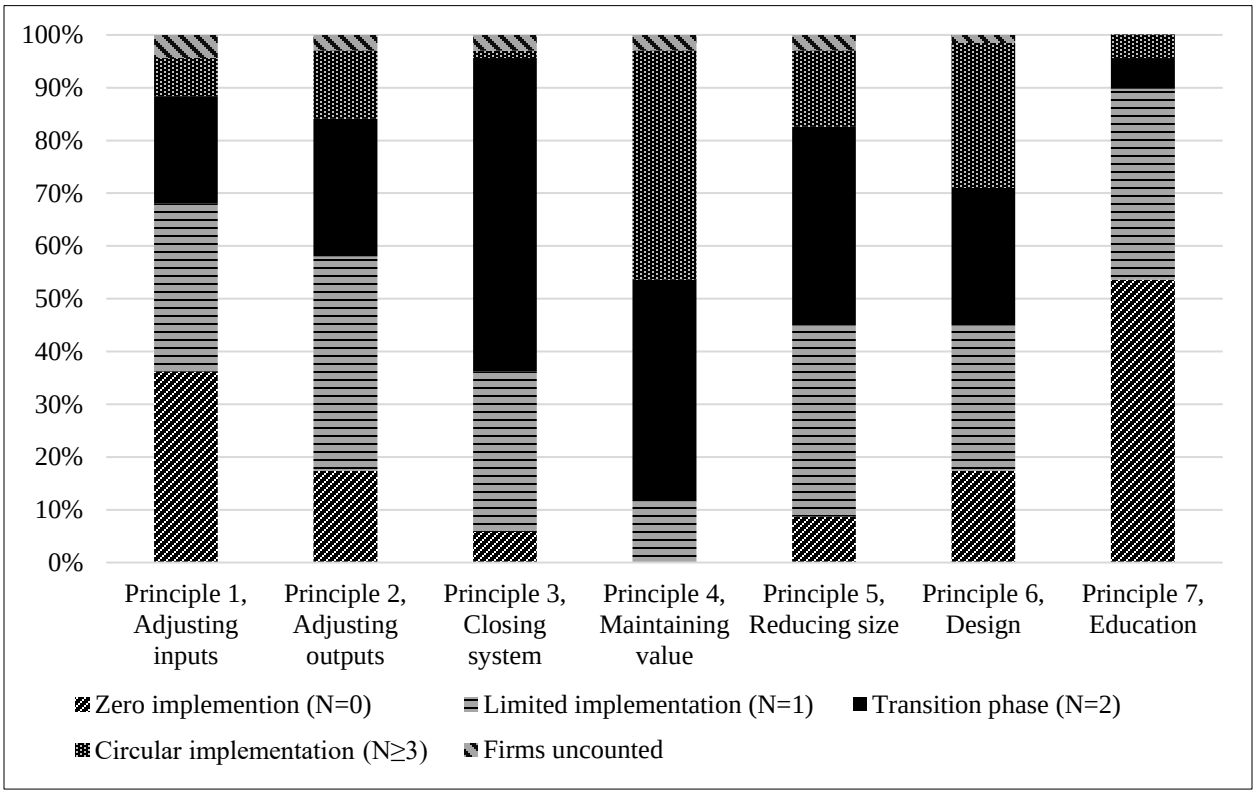

Figure 8. Implementation of the seven Circular Economy Principles (P1 to 7), and the percentage of firms meeting each level of implementation (N=69).

Motivations and the adoption of Circular Economy Principles

The results of the correlation analysis found several significant relationships between CE Principles and levels of motivation. Correlations showed significant positive relationships between intrinsic motivation and CE Principles 2, 5, 6, and 7 (≥ 95% confidence level: Table 9). Correlations also showed a relationship between extrinsic motivation and CE Principles 1, 2, 3, 6, and 7 with both questions related to integrated regulation positively correlated with CE Principles 2 and 7, and both questions related to introjected regulation positively related to CE Principle 2 (≥ 95% confidence level). The two questions related to amotivation showed a significant negative relationship between non-regulation and CE Principle 7 (95% confidence level). Overall, my results show that as the level of motivation moves from intrinsic motivation (i.e., self-determined and internal) toward amotivation (i.e., non-self-determined and impersonal), their relationships with CE Principles move from positive to negative.

Table 9. Spearman's rank correlation coefficient for the Circular Economy Principles and their relationship with leadership's motivation. (Sub-sections refers to the 12 MTES statements)

		Sub-section	Circular Economy Principle						
			1 Inputs	2 Out-puts	3 Waste	4 Value	5 Size	6 Design	7 Education
Intrinsic motivation	Intrinsic regulation	1	0.259	**0.497****	0.241	0.206	**0.324***	**0.324***	**0.373****
		2	**0.320***	**0.309***	0.161	0.224	**0.284***	**0.316***	**0.546****
Extrinsic motivation	Integrated regulation	3	0.257	**0.377****	0.175	0.086	0.149	**0.308***	**0.388****
		4	**0.308***	**0.372****	**0.285***	0.201	0.230	**0.428****	**0.498****
	Identified regulation	5	0.085	0.193	0.123	0.233	0.194	0.098	0.245
		6	0.123	0.189	-0.029	0.098	-0.011	**0.361****	0.152
	Introjected regulation	7	0.215	**0.303***	**0.381****	0.191	**0.274***	0.249	**0.359****
		8	0.094	**0.332***	-0.038	0.119	0.260	0.170	0.109
	External regulation	9	0.222	0.158	0.076	-0.002	-0.004	-0.022	-0.061
		10	0.257	0.214	0.255	0.242	0.219	0.148	0.152
A-motivation	Non-regulation	11	-0.021	-0.257	-0.209	-0.155	-0.117	-0.164	**-0.266***
		12	-0.030	-0.140	-0.223	-0.200	-0.100	-0.103	**-0.285***

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

Perceived sources of motivation and barriers

The results from ranking the various motivations and barriers that influence a company's use of CE Practices found financial and cost benefits as a popular motivating factor (N=31), with 15 respondents ranking it as their most important (Rank 1), and 10 ranking it as their second most important (Rank 2; Figure 9). Motivations that were regularly ranked included whether the CE Practices fitted the company's vision or mission (N= 25), and if the practices helped to meet customer demands (N= 23). Other high scoring motivating factors included regulatory compliance (N=21), and company reputation (N=20). Two

respondents ranked "other" and listed how motivation to help the environment as a crucial factor. Cost was identified as the main barrier; 18 individuals found cost as the most important barrier (Rank 1; Figure 10). In the results for both perceived motivation and perceived barriers I found that cost had the largest proportion of votes (cost as a motivation N=31; cost as a barrier N=30). Barriers involving lack of internal knowledge gained a high frequency of votes. For example, 19 respondents listed "not knowing how useful or productive the practices will be" as a top barrier; and 10 respondents ranked it as their most important barrier. Additionally, 23 respondents highlighted "not understanding how the processes fit into the business" as a key barrier (Rank 2 gained 8 responses, Rank 3 gained 6 responses).

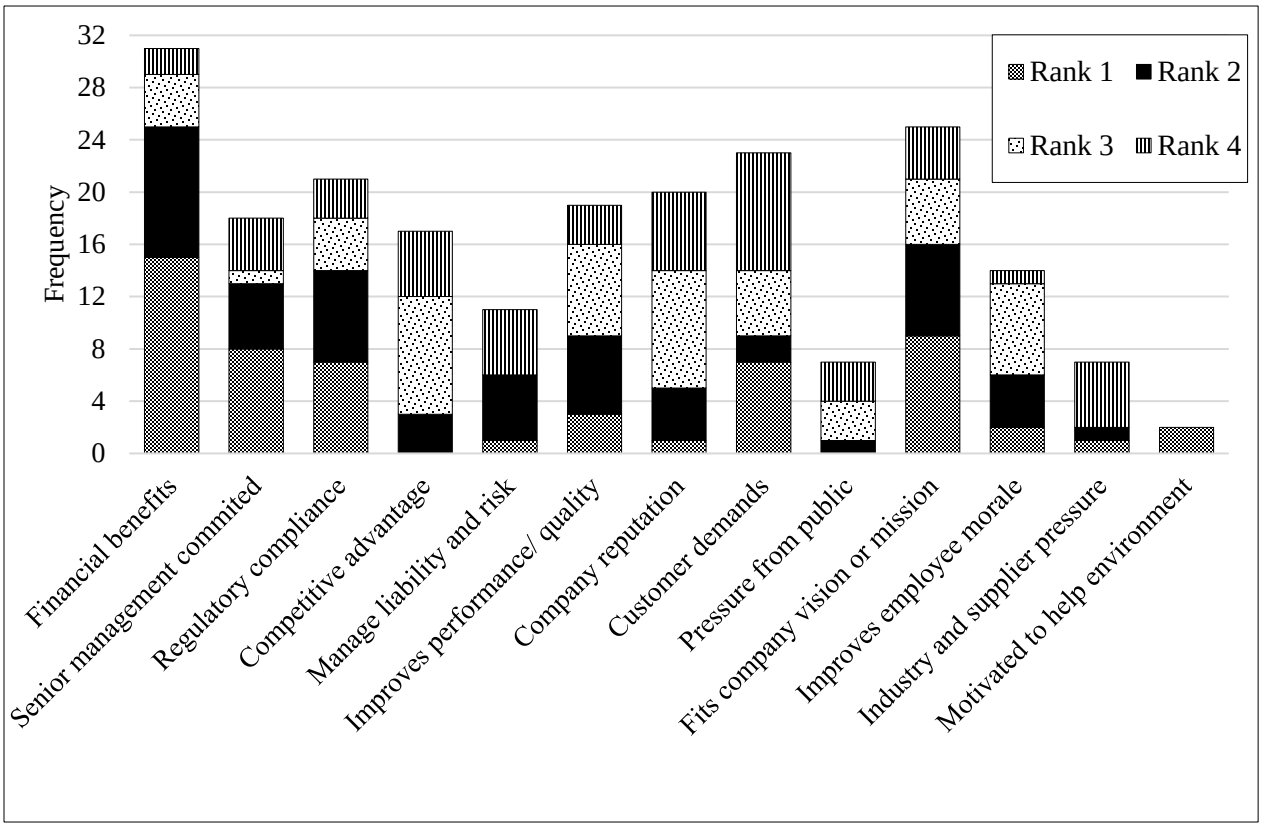

Figure 9. Company leadership's aggregated ranked responses where they ranked the top five factors that they perceived motivated their uptake of circular economy practices within their company (Rank 1 being the most important, and Rank 4 being the least important).

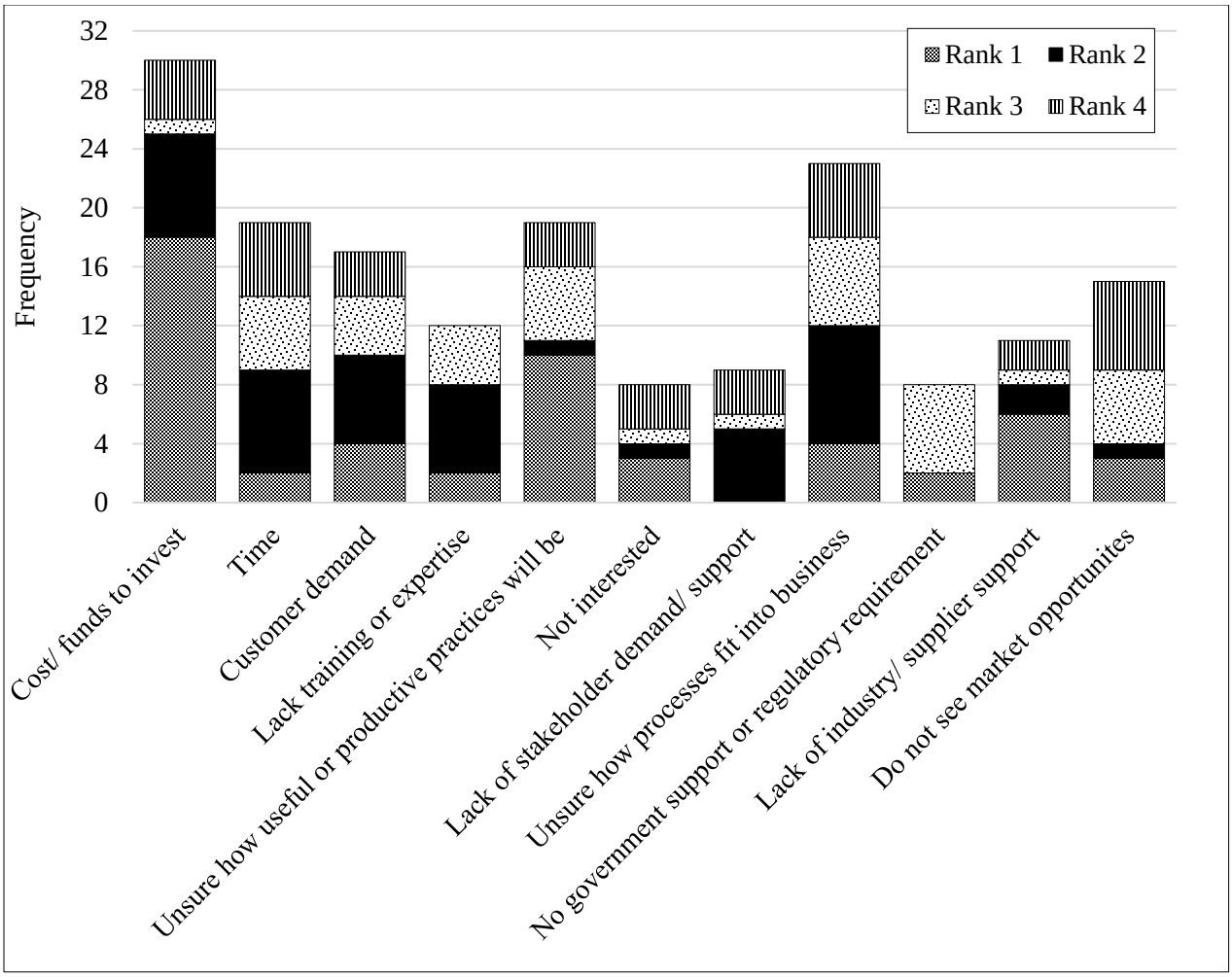

Figure 10. Company leadership's aggregated ranked responses where they ranked the top five factors that they perceived prevented uptake of circular economy practices within their company (Rank 1 being the most important, and Rank 4, being the least important).

Company characteristics and the adoption of Circular Economy Principles

The results of the correlation analysis also found several significant relationships between company characteristics and CE Principles (Table 10). Results showed a significant positive relationship between environmental certifications or awards and CE Principles 1, 3, and 6 (95% confidence level) and between disadvantaged businesses and CE Principle 5 (99% confidence level). The results also showed significant positive relationships between annual gross sales and CE Principle 3 (95% confidence level), and between

company size and CE Principle 1 (95% confidence level). There was no relationship between company characteristics and CE Principles 2 and 4.

Table 10. Spearman's rank correlation coefficient for the Circular Economy Principles and their relationship with company characteristics.

	Circular Economy Principle						
	1 Inputs	2 Out-puts	3 Waste	4 Value	5 Size	6 Design	7 Education
Annual gross sales 2020 (USD)	0.208	0.035	**0.352***	0.238	-0.028	0.266	0.091
No. of Employees	**0.304***	0.118	0.054	0.030	-0.238	0.189	0.085
Firm age	-0.029	-0.115	-0.180	-0.014	-0.008	-0.114	-0.072
Environmental certification/ award	**0.279***	0.192	**0.249***	0.139	0.134	**0.255***	0.150
Disadvantaged business	0.095	0.023	-0.028	0.070	**0.314****	0.204	0.184

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

Deeper descriptive analysis of the company characteristics found further information about the significant correlations presented in Table 10. Firstly, 1% of companies who expressed annual gross sales greater than $10 million (USD) had no CE Principle 3 practices adopted. The results also found that 23% of respondents who reported sales less than $10 million (USD) had none of these practices in use (Figure 11). Further, the findings identified that 3% of respondents who met circular implementation of CE Principle 1 were smaller companies, with less than 50 employees, and 26% of the smaller companies used no CE Principle 1 practices. Whilst larger companies (> 50 employees) resulted in 10% adopting no CE Principle 1 practices, with many of these larger companies meeting both the limited implementation (19%) and transition phase (12%; Figure 12). Results further showed that 7% of respondents that identified as a disadvantaged business had not implemented any CE Principle 5 practices, and 30% were within limited implementation (Figure 13). Those respondents who identified as a disadvantaged business largely met the transition phase for CE Principle 5 (13%), and 9% had accomplished circular implementation. The results also found that the level of implementation, "no

practices used", was 32% (CE Principle 1), 4% (CE Principle 3), and 14%, (CE Principle 6) when no environmental certifications or awards were obtained (Table 11).

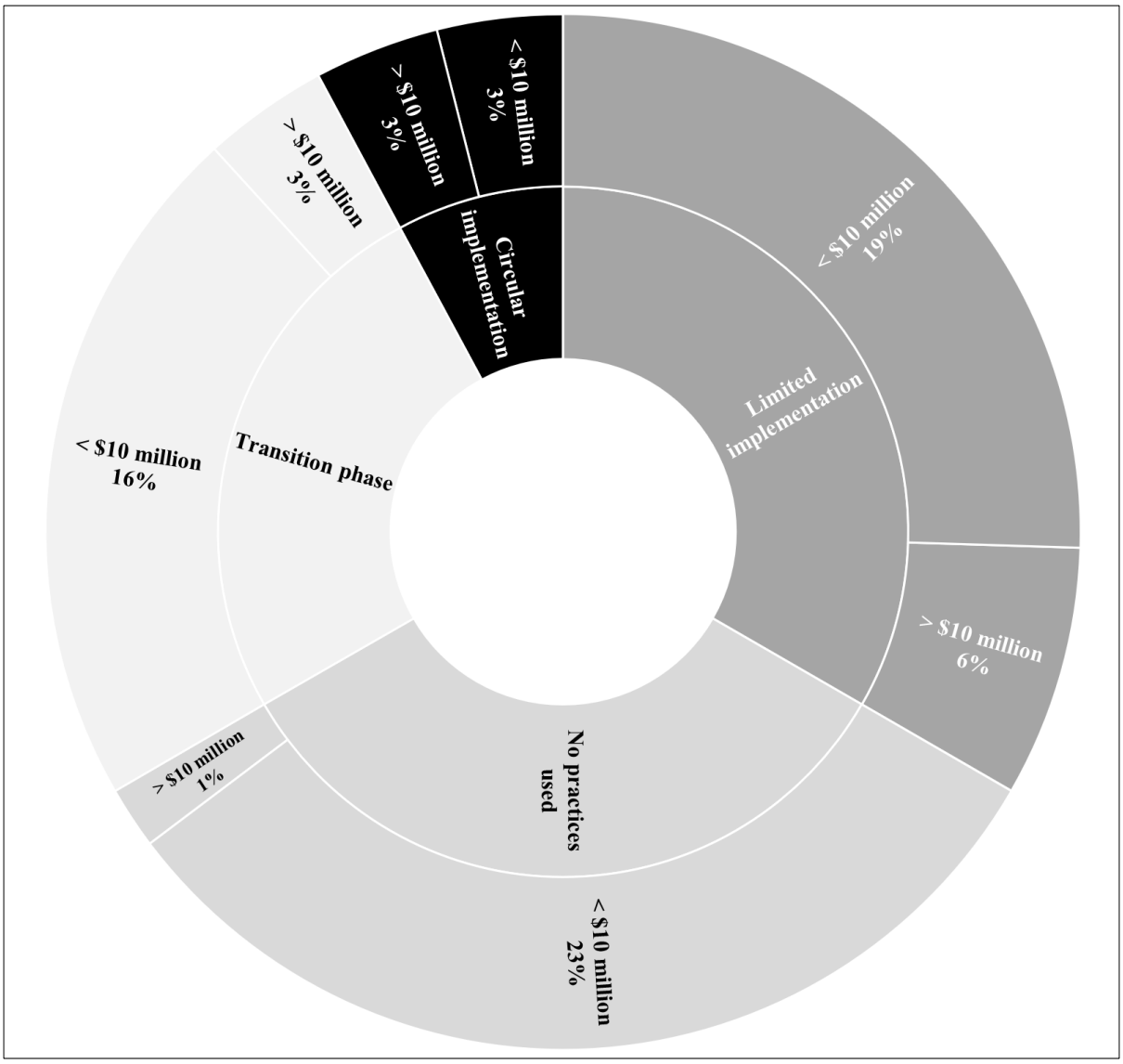

Figure 11. The effect of annual gross sales 2020 (USD) on the implementation of Circular Economy Principle 3 (N=69)

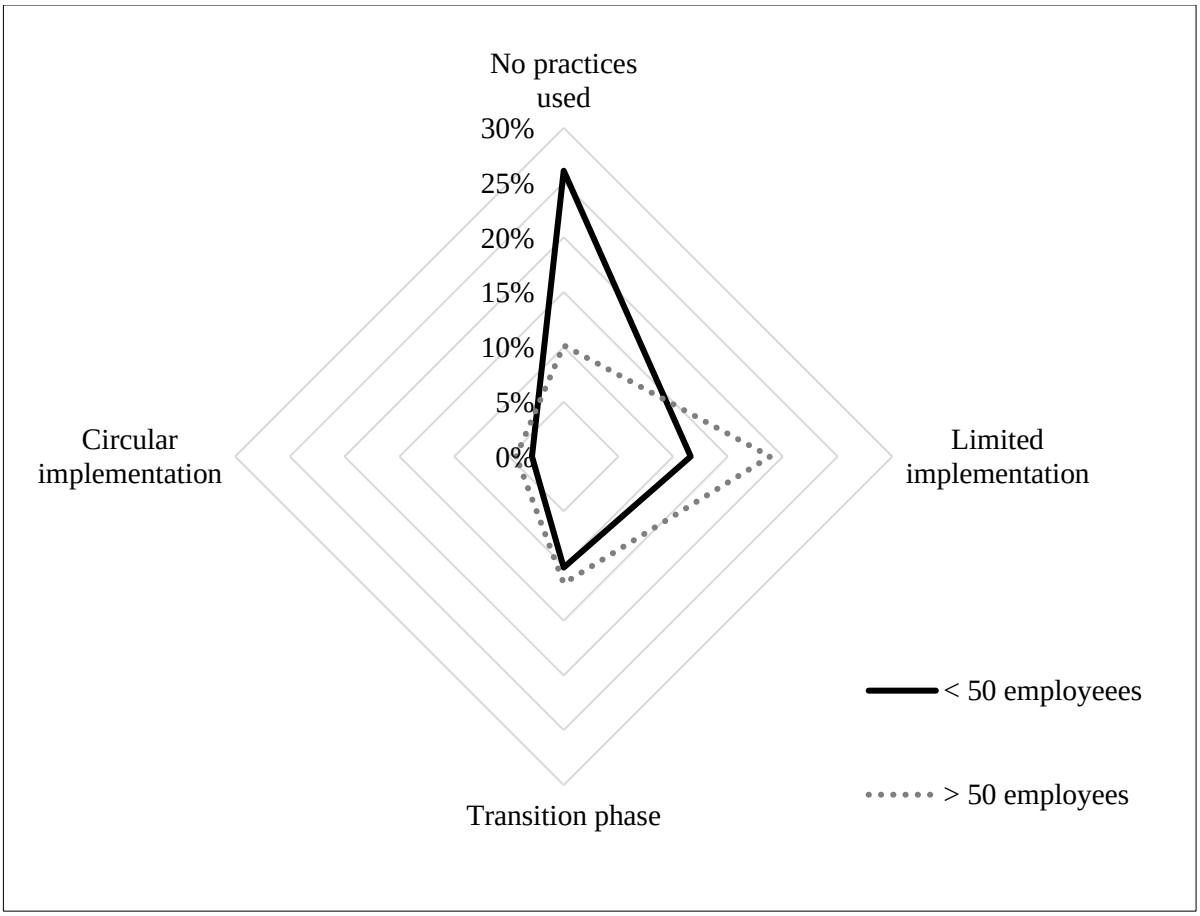

Figure 12. The effect of company size on the implementation of Circular Economy Principle 1 (N=69)

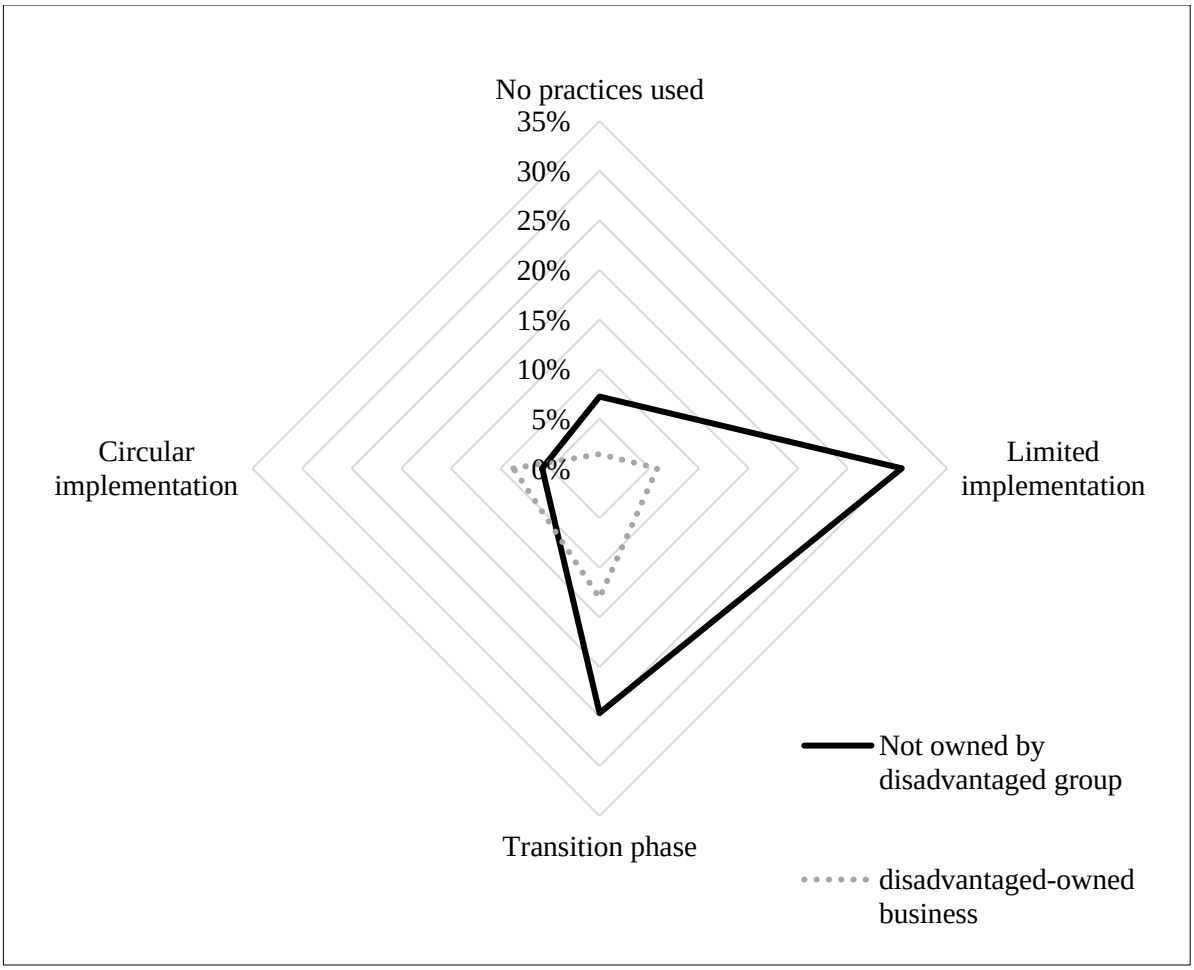

Figure 13. The effect of Company ownership on the implementation of Circular Economy Principle 5 (N=69)

Table 11. The effect of companies holding an environmental certification or award on the implementation of Circular Economy Principle 1, 3, and 6 (N=69)

CE Principle	Level of implementation	No certifications	Holds certifications or awards
	Adjusting inputs to the system to regeneration rates		
1	No practices used	32%	1%
	Limited implementation	25%	3%
	Transition phase	17%	4%
	Circular implementation	4%	3%
	Closing the system		
3	No practices used	4%	0%
	Limited implementation	29%	1%
	Transition phase	46%	9%
	Circular implementation	0%	1%
	Designing for circular economy		
6	No practices used	14%	0%
	Limited implementation	26%	1%
	Transition phase	20%	4%
	Circular implementation	20%	6%

V. Discussion

I documented the CE Practices and CE Principles that manufacturers in the DFW Metroplex have adopted and assessed the extent to which company characteristics and leadership's motivations affected the adoption of CE Principles. I sent over 4000 direct email messages to DFW manufacturers; yet, I had a low response rate. I had a large majority of undeliverable emails which I assume occurred because some messages may have automatically registered as junk mail. At the same time, survey distribution via direct email through Qualtrics accounted for most of my valid responses. Moreover, it is also difficult to assess the accuracy of the email addresses purchased through D&B, because I do not know how often company information is updated. Nonetheless, results provide initial information on the implementation of CE Practices and CE Principles by manufacturers in the DFW area, as well as the relationships between CE Principles and business characteristics and leadership's motivations.

Circular Economy Practices and Principles

Results indicate that manufacturers have adopted a range of CE Practices; however, some practices were more popular than others. I found the least adopted practice was the use of energy recovery options, which could be due to the increased capital costs and strategic approach required for its implementation (Peiry, Khanna, and Sahajwalla 2012), with one respondent listing that they recover waste water for energy recovery purposes. The second least adopted practice was knowledge sharing with other companies or manufacturers. Respondents that answered "yes" explained that it is "federally mandated to pass rigorous environmental regulations", and another summarized that "our whole industry does." Both answers suggest that it is a requirement rather than an optional action, however the last respondent seemed to be more internally motivated and explained that "we keep up with positive industry practices that we may be able to incorporate and improve our environmental impacts." This finding could demonstrate that small manufacturers need further inclusion in relevant stakeholder or industry knowledge sharing activities (Balasubramanian et al. 2021). It also shows that we need to learn how best to align stakeholders with higher tiers of the supply chain to further develop small manufacturers' ability to obtain CE knowledge. I found that the most used practice was the implementation of waste management activities, a CE Principle 3 practice, which is a non-strategic practice and easily implemented (Ashton, Russell, and Futch 2017). Further, manufacturers may often adopt waste practices because of regulatory requirements with the Resource Conservation and Recovery Act and similar environmental regulations. Future research could investigate what environmental permits and regulations manufacturers hold to demonstrate whether regulations affect uptake of CE Principle 3. Results could further be compared to manufacturing industry and NAICS Code. Similarly, the most common level of implementation for CE Principle 3 fell within the transition phase as a result of the elevated level of waste management activities. This result is similar to the finding uncovered by Yacob *et al.* (2019) who found that waste practices were the second most common adopted practice. My research shown that DFW manufacturers waste activities included waste segregation of general garbage from recyclables, hazardous waste separation, baling of recyclables on site, zero waste to landfill measures, and sending waste materials to be recycled or recovered off-site. However, only one

manufacturer met full implementation of CE Principle 3, as the costs and strategic requirements of energy recovery are difficult for companies to navigate to fully implement CE Principle 3. CE Principle 7 not only had the second least adopted practices but the principle itself was rarely adopted to any measure. This suggests that there is likely a need within DFW to promote the implementation of practices within CE Principle 7.

CE Principles, business characteristics, and leadership's motivations

Results indicate that the implementation of CE Principles was related to company characteristics, and leadership's motivations. Moreover, results show that the characteristic that influenced adoption the most was environmental certifications and awards, but although company characteristics positively correlated to four of the seven CE Principles, motivations were much more strongly correlated, significantly positive or negative, toward six of the seven CE Principles. I discuss these differences and relationships below to situate my research within the broader literature on the CE.

The finding that company characteristics are related to different CE principles was expected based on previous research that found business characteristics influence the implementation of similar practices (Bakos et al. 2020). My results show environmental certifications influenced the uptake of CE Principles 1, 3, and 6, and it proved to be the strongest characteristic influencing CE implementation overall. My result was similar to the research discussed in my literature review by Ashton et al. (2017), who found that companies who adopted certifications were more likely to use environmental practices. I found when companies held certifications or awards their level of implementation tended to move beyond "no practices used", especially for CE Principle 3 and 6 where the results showed zero companies meeting "no practices used" when they held certifications of awards. However, it is important to note that most companies that took part in my research did not hold certifications or awards, so the frequency of companies meeting the differing levels of implementation for CE Principle 1, 3, and 6 overall looked greater compared to those holding no certifications. My results suggest that DFW manufacturers with environmental certifications may implement these CE Principles to a greater degree than those without certifications. This finding is

corroborated with other similar research that shows environmental certifications lead not only to implementation of CE Practices, but can increase strategic business thinking and continual improvement (Brouwer and van Koppen 2008; Ni et al. 2019). Moreover, certifications require firms to find and reduce environmental impacts and regularly evaluate their performance. For example, to assess environmental improvements, businesses often begin by recording and reporting waste reduction and energy conservation metrics to meet certification criteria (Singh, Brueckner, and Padhy 2015). My results reflect improvement in implementation with certification: certifications reported by respondents were primarily associated with CE Principle 1 practices, specifically the practice of renewable energy adoption, and CE Principle 3 practices, namely waste, recycling, and re-use. Respondents that held certifications or awards and answered "yes" to the use of renewable energy adoption all said that they use skylights or natural lighting to reduce their use of artificial lighting, and one had further adopted biomass or biofuel. It makes sense then that the pursuit and accrual of environmental certifications are related to these CE Principles because continual improvement is a key feature of environmental certifications. The accrual of them most likely explains their relationship with CE Principle 6 as well, which requires businesses to discuss strategies and make continual improvements to company operations, processes, product and packaging design, and the supply chain (Mendoza et al. 2017). Because of this, environmental certifications and awards enable companies to transition toward CE implementation (Brammer, Hoejmose, and Marchant 2012; Hoogendoorn, Guerra, and van der Zwan 2015).

Results also show that CE Principle 3 adoption was significantly correlated with an increase in annual sales. I found that when companies reported annual sales over $10 million (USD) they were less likely to have no CE Principle 3 practices in use, compared to the substantial number of companies who earnt less than $10 million (USD). However, my results also found that companies earning less than $10 million (USD) were meeting limited implementation and the transition phase, which begins to demonstrate that annual sales may not be as impactful in preventing CE implementation as I had assumed. As discussed earlier, previous research conducted in the United States concluded that companies earning over $10 million

(USD) regularly adopted twice the number of environmental practices (Ashton et al., 2017), whist I found that circular implementation was equally adopted by companies both exceeding and below the $10 million (USD) annual sales threshold. My results suggest that CE Principle 3 practices can easily be adopted by manufacturers earning less than $10 million (USD) because there is ample evidence in the literature that waste management activities, such as minimizing, recycling, and re-using wastes, greatly reduces the costs associated with traditional waste disposal techniques (Ellen MacArthur Foundation 2013; Geyer and Doctori Blass 2009). So, these practices are ubiquitous across industries and easy to implement. Other research defines these practices as "low hanging fruits," "waste minimization," and "ad hoc" (Ashton, Russell, and Futch 2017; Revell, Stokes, and Chen 2010). The fact that these practices are cost effective and easily implemented explains the relationship between annual sales and CE Principle 3. Despite this relationship, most respondents had not implemented any energy recovery practices. Energy recovery options require technical and economic feasibility studies for sound integration within a system and require a more strategic, self-determined approach (Peiry, Khanna, and Sahajwalla 2012). Companies with high annual sales most likely have the funds to explore and implement energy recovery practices; however, my results indicate that other implementation barriers exist and may require further exploration.

Another important characteristic that affected CE implementation was company size. My results found that company size was related to the implementation of CE Principle 1. Notably, smaller companies regularly had no CE Principle 1 practices in use and rarely met circular implementation. Larger companies mainly achieved limited implementation and met circular implementation. My results suggest that larger companies will adopt CE Principle 1 practices compared to their smaller company counterparts. Notably, I found that the CE Principle 1 practice: reducing toxicity of inputs, was influenced by size. This result is similar to research that has shown larger firms have more opportunities to try and substitute input materials, whilst smaller companies may not have the leverage with stakeholders or the needed resources and capability (Brammer, Hoejmose, and Marchant 2012). However, my results do not fully support the findings published by Garcia-Quevedo *et al.* (2020) who found that larger companies adopt the CE because

of increased CE knowledge. If my results correlated with this research, I would have seen an increased uptake of CE Principle 7 within larger companies, however CE Principle 7 was not influenced by any company characteristics.

The role of disadvantaged businesses and the implementation of CE Principles are understudied within the literature. I received responses from 20 DFW-area disadvantaged businesses, which formed 29% of all respondents. My analysis found a relationship between disadvantaged manufacturers and the uptake of CE Principle 5. Specifically, disadvantaged manufacturers were more inclined to make green purchasing decisions. I identified that disadvantaged-owned businesses were mainly meeting the transition phase of CE Principle 5. Research suggests this result could be related to disadvantaged businesses looking to satisfy client demands and improve competitiveness. Yet it could also reflect that disadvantaged manufacturers, whether that be a racial, sexual, cultural, gender, or a physical disadvantage, tend to be more aware of their social responsibility, as well as the connection between social issues and environmental sustainability because of their different life experiences (Thornton et al. 2013), or it could be driven by contractual requirements within the supply chain, where other supply chain tiers contract manufacturers who are disadvantaged because it meets their social responsibility. Therefore, driving disadvantaged-owned manufacturers to make sustainable purchasing decisions. Disadvantaged businesses that took part in my survey included woman-owned, minority-owned, LGBTQIA+ owned, and veteran-owned, but as there was such a small quantity of respondents across the varying disadvantaged business profiles, I was unable to fully verify if any specific disadvantaged business type influenced CE implementation. However, the results indicate that a disadvantaged status is related to CE implementation, and further research is needed to more fully understand their contributions to the CE.

There was no significant relationship between CE Principle 4 and company characteristics. This is most likely explained by respondents' universal adoption of practices within CE Principle 4, including preventative maintenance and software updates. Businesses maintain and update software to improve business operations and processes (Bonilla et al. 2018; Ellen MacArthur Foundation 2015a). Likewise,

manufacturers have favored preventative maintenance because it extends the life of equipment and machinery. Further, I found CE Principle 4 was not affected by leadership's level of motivation. It appears that this result is indicative of the wealth of understanding on how performance and competitiveness can be sustained through CE Principle 4 practices (Lazim et al. 2019; Zhou, Qi, and Liu 2020).

There was also no significant relationship between CE Principle 2 and company characteristics. However, my analysis showed a significant positive relationship with CE Principle 2 and the regulatory styles associated with intrinsic and extrinsic motivation. Both motivation styles develop from a source that includes some level of internal motivation. I expected this correlation because CE Principle 2 practices, such as direct reuse and emissions reduction, are not easy to adopt and require more effort and planning (Revell, Stokes, and Chen 2010). Notably, the consideration of output emissions was linked to intrinsic motivation, which suggests that respondents implementing this practice have a personal connection with the environment and work to improve their manufacturing processes in line with their environmental convictions. This finding provides needed information on how motivation influences more-difficult-to-implement CE Practices and has the potential to help CE advocates target areas in support of balanced emissions relative to planetary limits (Hansen et al. 2013; Persson et al. 2022).

Similarly, the highest perceived sources of motivation that my study uncovered are associated with regulatory styles. Respondents consistently ranked financial rewards as a top perceived motivating factor that affects their willingness to adopt CE Practices, which would reflect introjected regulation, as it is an internal reward and somewhat impersonal. Secondly, whether the adoption fits the company's vision or mission, or the commitment of senior management would demonstrate identified regulation, which is somewhat internally motivated. Additionally, the perceived motivation listed as "motivated to help the environment" was not an original choice listed on the survey; however, two respondents answered "other" and descriptively answered "because it helps the environment" and "it the right thing to do." Both individuals had adopted CE Principle 2 practices, with one adopting all practices associated with Principle 2. Although it is hard to define exactly if the perceived motivations are linked to the scale of self-

determination, it does begin to create a picture that those with a higher level of self-determination, may be more inclined to adopt the more difficult-to-implement CE practices. It is important to highlight that respondents' views of perceived motivations could vary over time, especially as pressure around ESG and carbon net-zero heightens within supply chains. Some perceived motivations and barriers identified by respondents could be indirectly affected by ESG pressures, so future research may want to consider "ESG pressure" as a perceived motivation. By doing so, it could show whether ESG pressure is affecting leaders' self-determination towards the environment, or whether it affects uptake of CE Principles.

I also found the adoption of several other CE Principles could improve when a firm's leadership is more self-determined toward the environment, especially for CE Principles 6 and 7, which are vital to the delivery of a sustainable CE. Principle 6 was also correlated with environmental certifications; however, the association was weaker than what I found for level of motivation. The uptake of CE Principle 6 by manufacturers was highly influenced by increasing self-determination and intrinsic motivation. As mentioned above, discussing strategies to continually improve CE is pivotal to Principle 6, but so are its other practices, including design and innovation (Verghese and Lewis 2007). Innovation in product and packaging design, in particular, help firms move away from current linear systems while also working to achieve other CE Principles (Suarez-Eiroa et al. 2019). CE Principle 7, on the other hand, encourages employee actions and employee trainings relative to CE Principles to further integrate CE Practices within firms. I found that CE Principle 7 was not influenced by any company characteristics; however, it was significantly related to a high level of self-determination and intrinsic motivation like CE Principle 6. Taken together, this suggests that efforts to improve self-determination and transition toward intrinsic motivation would strengthen uptake of CE Principles 6 and 7 across all firms regardless of company characteristics. My results are similar to the research discussed by Gusmerotti et al. (2019) where "circular companies" had internalized CE implementation, and with that, were achieving the best business performance, which demonstrates that motivation is key to adoption, because company leadership can see the importance and usefullness from implementing the CE.

Interestingly, a variety of perceived barriers could be addressed by promoting the uptake of these two transversal CE Principles: 6 and 7. Particularly, the second and third most ranked barriers, "unsure how processes fit into business," and "unsure how useful or productive practices will be," but also "lack of training and expertise," "lack of stakeholder demand and support," and "lack of industry demand and support." Adoption of CE Principle 7 practices would begin to expand knowledge sharing opportunities and supply educational routes to bridge the perception of these barriers. It is important to resolve these barriers for further CE adoption because a lack of control leads to amotivation, resulting in non-self-determination. Another consistently ranked barrier was "do not see market opportunities". The study I discussed earlier, by Yacob *et al.* (2019), found that companies were less motivated to use sustainable practices when they were unable to see market opportunities. Their result corroborates with my findings, and, again, the adoption of CE Principle 7 could help to prevent this barrier.

Another important finding was the role that cost plays as a perceived barrier, but also as a perceived motivation in CE adoption. My results found that the most often ranked perceived motivation for CE uptake was "financial benefits", but I also found cost as a perceived barrier: "costs or funds to invest", was ranked the most by respondents. This result shows the huge influence that cost plays in the uptake, or avoidance of CE Practices. My finding corresponds to Lewis and Cassells (2010) who identified that cost played a significant role as both a motivation and barrier in the use of environmental practices. Similarly, Ashton et al., (2017) also found cost savings as a key motivation. Taken together, cost's influence on motivation demonstrates how extrinsic regulation that is internally sourced can improve self-determination. As my results prove, cost is regularly percieved as a motivation for CE uptake, therefore understanding costs motivational value could help to improve CE implementation.

It is also important to note that as progress is made to address barriers, it will be a continual process to improve leadership's level of self-determination. Although some respondents demonstrated that they are motivated by identified, integrated, and intrinsic perceived motivations, other company's leadership will be further down the scale of self-determination. Leadership at these lower levels are typically motivated

through non-regulation or external regulation, such as those that listed “not interested”, “regulatory compliance”, “manage liability and risk”, “customer demand”, and “company reputation” as perceived motivations and barriers.

Taken altogether, my results suggest that amotivation prevents CE uptake across all seven CE Principles. Research has shown that non-regulation or external regulation, such as governments enacting stricter legislation, leads to amotivation within firms, which limits knowledge sharing and education (Masurel 2007). Although some firms may believe that legislation, and other external regulators, motivates businesses to implement CE (Lewis and Cassells 2010), my results suggest that non-regulation and external regulation only go so far. This result is important to address because “regulatory compliance” was the fourth most ranked perceived motivation for CE adoption, but what individuals perceive as a motivation may not truly improve self-determination, as compliance is an externally regulated style. This result is similar to other studies that have found businesses implement practices that are easy to adopt (Ashton, Russell, and Futch 2017; Revell, Stokes, and Chen 2010). Thus, to enable firms to evolve into circular implementation, there is a need to understand how business leadership acquires the level of motivation needed to advance practices in support of the CE. Moreover, company characteristics provide less influence on CE improvement within my study, and instead seem to support the implementation of specific CE Practices, like the relationship between disadvantaged businesses and green purchasing decisions, or the effect of company size and reducing toxicity of inputs. Therefore, my results indicate that intrinsic motivation toward the environment plays an important role in manufacturers willingness to adopt CE Principles and finding ways to increase leadership's self-determination will further aid transition efforts.

VI. Conclusions

The purpose of my research was to examine the implementation of CE Practices and Principles of small manufacturers in DFW, and to determine the extent to which company characteristics and leadership’s motivations toward the environment affected the adoption of CE Principles. My study used a modified MTES to ascertain the extent that leadership’s self-determination and motivations influenced the adoption

of CE Principles. I also measured the impact of company characteristics on CE Principles, including the role of disadvantaged businesses in CE implementation – an unexplored topic within the existing CE literature. I found that DFW manufacturers adopted a variety of CE Practices; however, some practices were more widespread than others. Similarly, businesses adopted CE Principles to differing degrees. CE Principle 3, including ad-hoc waste practices, was the most implemented CE Principle, with all companies at the transition phase, and CE Principle 7 was the least implemented.

My research suggests that companies need further influence to progress from limited implementation and transition phases to achieving circular implementation. In particular, increasing self-determination and improving motivation toward the environment should enable manufacturers to adopt more CE Practices and improve wider CE implementation. Achieving full circular implementation of all CE Principles, however, likely requires a higher level of self-determination because firms need to take more strategic approaches rather than adopt easy, ad-hoc strategies. Another key finding was the influence that cost plays as a perceived motivation, which could be useful in the CE transition to improve self-determination and CE adoption. In comparison, I found that company characteristics did not influence CE uptake to the same degree as leadership's level of motivation. I showed that self-determination increased the uptake of design and education practices relative to CE Principles 6 and 7. These CE Principles take more effort, initiative, and determination to implement, and motivation is an important component leading to the development of more difficult-to-implement practices. To improve CE implementation, future research should continue to investigate the linkages between motivation and CE adoption. My research also showed that disadvantaged manufacturers within DFW had a higher uptake of CE Principle 5, related to green purchasing decisions. This suggests that disadvantaged businesses are implementing some CE Practices more than their non-disadvantaged counterparts. Further research into the role of disadvantaged businesses and disadvantaged business types should continue to investigate the importance of these firms in the CE transition.

Finally, small manufacturing firms are not homogenous; therefore, my findings may differ depending on location and industry type. Moreover, my sample may not be representative of the entirety of DFW manufacturers due to a low response rate. Yet, my analysis illustrates significant trends within the group of respondents. Future research should explore similar variables with equal vigor to provide a more complete understanding of business characteristics and level of motivation relative to CE Practices and CE Principles across all industry types, but especially within U.S. small manufacturers, who are underrepresented in the CE literature. This information is critical to not only expanding CE but achieving sustainability and aiding manufacturers in the carbon net-zero and ESG evolution.

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Appendix A

Template of the electronic survey published on Qualtrics XM as part of this study.

TCU Research Study - Sustainability Practices of Manufacturers in DFW

Start of Block: IRB consent

Q1 **Title of Research:** The influence of business characteristics and motivations on circular economy practices in small manufacturers
Principal Investigator: Dr. Brendan L. Lavy, Assistant Professor, Department of Environmental Sciences
Co-investigator: Kate Howe, Graduate Teaching Assistant, Department of Environmental Sciences

Overview: You are invited to participate in a research study. In order to participate, you must be at least 18 years of age.

Study Details: The purpose of this study is to document the environmental sustainability practices of small manufacturers in the Dallas-Fort Worth Metroplex and to understand the extent to which business characteristics and motivations affect the implementation of environmental sustainability practices. This study is being conducted via an online anonymous questionnaire using Qualtrics – a web-based survey platform. It should take about 15 minutes to complete.

Participants: You are being asked to take part in this study because you are either the owner of a small manufacturing company or responsible for day-to-day operations of environmental practices in your manufacturing company. If you decide to participate in this study, you will be one of approximately 150 participants in this research study at TCU.

Voluntary Participation: Your participation is voluntary. You may discontinue your participation at any time without penalty. If for any reason you decide that you would like to discontinue your participation, you may simply exit the survey screen. Each question is voluntary, so if you do not wish to provide an answer to a question, you can skip the question and move onto the next.

Confidentiality: Participants will not be identifiable through the survey instrument, and no potentially identifying information will be collected.

What is the purpose of the research? The purpose of this study is to document the environmental sustainability practices of small manufacturers in the Dallas-Fort Worth Metroplex and to understand the extent to which business characteristics and motivations affect the implementation of environmental sustainability practices. Your company does not need to have implemented environmental sustainability practices to participate in this study.

What is my involvement for participating in this study? Involvement includes an anonymous online questionnaire. We expect your participation to take about 15 minutes. You should not type your name, company, or any identifying information on the questionnaire.

Are there any alternatives and can I withdraw? You do not have to participate in this research study. You should only take part in this study if you want to volunteer. You should not feel that there is any

pressure to take part in the study. You are free to participate in this research. You may exit the survey at any time; however, your responses and data will be used up to the point of withdrawal.

What are the risks for participating in this study and how will they be minimized? We don't believe there are any risks from participating in this research that are different from risks that you encounter in everyday life.

What are the benefits of participating in this study? There are no direct benefits to participants. Anticipated benefits to society include information about the environmental sustainability practices of small manufacturers in the DFW Metroplex and understanding business's motivations for implementing environmental sustainability practices.

Will I be compensated for participating in this study? If you would like the opportunity to be compensated for this study, there will be an option to provide your email address at the end of the survey. If you provide your email address you will be entered into a drawing to receive a $100 Amazon gift card. There are 10 gift cards available that will be awarded to every 10th participant who enters the drawing. If you are chosen to receive a gift card, you will be contacted individually via email.

What are my costs to participate in the study? There are no costs to participate in this study.

How will my confidentiality be protected? You will not be identifiable through the survey instrument, and no potentially identifying information will be collected to protect the confidentiality of your responses. If you decide to provide an email address for the gift card drawing, then this information will be stored separately from your survey responses, so your responses will not be identifiable. Your email address will not be shared or published and will be deleted immediately after the drawing. This will be the only identifiable personal information that we collect.

What will happen to the information collected about me after the study is over? We will keep your research data to use for future research or other purposes. Your information that could possibly identify you will be kept secure and stored separately from the research data collected as part of the project. We may share your research data with other investigators without asking for your consent again, but it will not contain information that could directly identify you.

Who should I contact if I have questions regarding the study or concerns regarding my rights as a study participant? You can contact the principal investigator: Dr. Brendan Lavy, Assistant Professor, Department of Environmental Sciences, (817) 257-7273, b.lavy@tcu.edu, or co-investigator: Kate Howe, Graduate Teaching Assistant, kate.howe@tcu.edu with any questions that you have about the study, or Dr. Dru Riddle, Chair, TCU Institutional Review Board, (817) 257-6811, d.riddle@tcu.edu; or Dr. Floyd Wormley, Associate Provost of Research, research@tcu.edu.

By selecting **"Yes, I consent"** below, you are agreeing to be in this study and are at least 18 years of age. Make sure you understand what the study is about before you consent. If you have any questions about the study after you agree to participate, you can contact the study team using the information provided above. If you do not wish to participate in the research study, please decline participation by selecting **"No, I do not consent."**

- ○ Yes, I consent (1)
- ○ No, I do not consent (2)

End of Block: IRB consent

Start of Block: Section 1

Q2 What best defines your role in the company?

- ○ Owner (4)
- ○ Director (1)
- ○ Manager (2)
- ○ Environmental/ safety officer (3)
- ○ Other, please provide your title (5) _____

Q3 How many people (full-time equivalent) does the company employ?

- ○ Less than 5 employees (1)
- ○ Between 5 and 9 employees (2)
- ○ Between 10 and 19 employees (3)
- ○ Between 20 and 49 employees (4)
- ○ Between 50 and 99 employees (5)
- ○ Between 100 and 199 employees (6)
- ○ Between 200 and 299 employees (10)
- ○ Between 300 and 399 employees (11)
- ○ Between 400 and 499 employees (7)
- ○ More than 500 employees (8)
- ○ Not sure (9)

Q4 How many years has your company been in business?

- ○ Less than 1 year (1)
- ○ Over 1 year, but less than 4 years (2)
- ○ Over 4 years, but less than 11 years (3)
- ○ Over 11 years, but less than 20 years (4)
- ○ Over 20 years (5)

Q5 What best describes your company's **primary** manufacturing industry type (or classification)? Please select one of the following:

- ○ Food Manufacturing (1)
- ○ Beverage and Tobacco Product Manufacturing (2)
- ○ Textile Mills (3)
- ○ Apparel Manufacturing (4)
- ○ Leather and Allied Product Manufacturing (5)
- ○ Wood Product Manufacturing (6)
- ○ Paper Manufacturing (7)
- ○ Printing and Related Support Activities (8)
- ○ Petroleum and Coal Products Manufacturing (9)
- ○ Chemical Manufacturing (10)
- ○ Plastics and Rubber Products Manufacturing (11)
- ○ Nonmetallic Mineral Product Manufacturing (12)
- ○ Primary Metal Manufacturing (13)
- ○ Fabricated Metal Product Manufacturing (14)
- ○ Machinery Manufacturing (15)
- ○ Computer and Electronic Product Manufacturing (16)
- ○ Electrical Equipment, Appliance, and Component Manufacturing (17)
- ○ Transportation Equipment Manufacturing (18)
- ○ Furniture and Related Product Manufacturing (19)
- ○ Miscellaneous Manufacturing (20)

○ Other, please specify (21) _____

Q6 Does your company identify with or hold a certification for any of the following?
Please select all that apply:

☐ Woman-owned business (1)

☐ Veteran, or service-disabled owned business (2)

☐ Family-owned business (3)

☐ Minority-owned business, for example, Black, Native American, Hispanic, Asian (4)

☐ LGBTQIA+ owned business (5)

☐ Disadvantaged business enterprise (6)

☐ Other(s), please specify (7) _____

☐ None (8)

Q7 Does your company hold any environmental, green, or sustainability related certifications?
(For example, ISO 14001, Certified B Corporation, Cradle to Cradle, Business Ambition for 1.5°C, Forest Stewardship Council Chain of Custody, 1% for the Planet, Zero Waste, Carbon Neutral)

○ Yes, please list certifications: (1) _____

○ No (2)

○ Not sure (3)

Q8 Has your company received any awards for environmental, green, or sustainable practices in the past 5 years?
(For example, awards or recognition for practices such as water reduction, solid waste reduction, recycling, or energy efficiency)

- ○ Yes, please list award(s): (1) _____
- ○ No (2)
- ○ Not sure (3)

Q9 Where in the DFW metroplex is your primary manufacturing facility located?
Please provide the zip code:

_____

End of Block: Section 1

Start of Block: Section 2: This section asks questions about your manufacturing operations

Q10 How does your company manage waste in the manufacturing process?
Please select all that apply:

- [ ] We send zero waste to landfill (1)
- [ ] We send scrap metal to a scrap metal recycler (2)
- [ ] We have separate bins for recyclables and general garbage (3)
- [ ] We send packaging back to the supplier (4)
- [ ] We bale recyclable materials on site (5)
- [ ] We separate hazardous wastes from general garbage (6)
- [ ] Other, please specify (7) _____
- [ ] Not sure (8)
- [ ] Not applicable (9)

Q11 Does your company **re-use** discarded materials, off-cuts, or by-products in the manufacturing process?
Please select all that apply:

- ☐ Metals, please specify (5) _____
- ☐ Plastics, please specify (6) _____
- ☐ Wood (1)
- ☐ Textiles (2)
- ☐ By-products from your process (3)
- ☐ Food fines, molasses, or fruit oils from processing (4)
- ☐ Paper or cardboard (7)
- ☐ Concrete (13)
- ☐ Aggregate (14)
- ☐ Used oil, fats, or greases (15)
- ☐ Food wastes (16)
- ☐ Water (17)
- ☐ Other, please specify (8) _____
- ☐ No (9)
- ☐ Not sure (10)
- ☐ Not applicable (11)

Q12 Does your company **recycle** any discarded materials, off-cuts, or by-products generated from your manufacturing process?
Please select all that apply:

- ☐ Metals, please specify (2) _____
- ☐ Plastics, please specify (1) _____
- ☐ Wood (10)
- ☐ Textiles (14)
- ☐ Glass (7)
- ☐ Solvents (8)
- ☐ Paper and cardboard (9)
- ☐ Concrete (11)
- ☐ Aggregate (12)
- ☐ Used oil, fats, or greases (13)
- ☐ Food wastes (15)
- ☐ Water (16)
- ☐ Other, please specify (17) _____
- ☐ No (18)
- ☐ Not sure (19)

Q13 Does your company design product packaging for **re-use**?
Please select all that apply:

- ☐ Yes, we use returnable pallets (1)
- ☐ Yes, we use returnable boxes (2)
- ☐ Yes, we use returnable bottles (3)
- ☐ Yes, other please specify (4) _____
- ☐ No (5)
- ☐ Not sure (6)
- ☐ Not applicable (7)

Q14 Does your company design product packaging so that it can be **recycled**?
Please select all that apply:

- [ ] Yes, we use plastics that can be recycled (1)
- [ ] Yes, we use card or paper that can be recycled (2)
- [ ] Yes, we use glass that can be recycled (3)
- [ ] Yes, we use untreated wood that can be recycled (4)
- [ ] Yes, other please specify (5) _____
- [ ] No (6)
- [ ] Not sure (7)
- [ ] Not applicable (8)

Q15 Does your company offer take-back programs, where components or materials can be re-used or recycled in your manufacturing process?
Please select all that apply:

- ☐ Yes, we remanufacture products or components (1)
- ☐ Yes, we dismantle products to re-use parts (2)
- ☐ Yes, we redistribute products as secondhand goods (3)
- ☐ Other, please specify (4) _____
- ☐ No (5)
- ☐ Not sure (6)
- ☐ Not applicable (7)

Q16 Does your company provide instructions to consumers on how to repair your product(s)?
Please select all that apply:

- ☐ Yes, we provide product repair guides (1)
- ☐ Yes, we provide instructions on how to return the product for repair (2)
- ☐ Yes, other please specify (3) _____
- ☐ No (4)
- ☐ Not sure (5)
- ☐ Not applicable (6)

Q17 Does your company sell or donate by-products, materials, parts, or equipment to other companies?

- ○ Yes, please specify (1) _____
- ○ No (3)
- ○ Not sure (4)
- ○ Not applicable (5)

Q18 Has your company substituted any heavy materials in your manufacturing process for materials that weigh less, or found a way to decrease the amount of materials used?
Please select all that apply:

- ☐ Yes, we use materials that weigh less (1)
- ☐ Yes, we use less materials to get the same result (2)
- ☐ Yes, other please specify (3) _____
- ☐ No (4)
- ☐ Not sure (5)

Q19 Does your company use alternative materials or liquids that are less toxic in the manufacturing process than conventional materials or liquids?
Please select all that apply:

- [ ] Yes, we substitute toxic chemicals for ones with lower toxicity (2)
- [ ] Yes, we use water-based paints or solvents (1)
- [ ] Yes, other please specify (3) _____
- [ ] No (4)
- [ ] Not sure (5)
- [ ] Not applicable (6)

Q20 When choosing a material or liquid input for your manufacturing process, does your company consider how polluting the input could be to air, water, or land?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q21 Does your company use renewable energy sources on site to power the manufacturing process? Please select all that apply:

- [ ] Yes, skylights or natural lighting instead of artificial lighting (1)
- [ ] Yes, solar panels (2)
- [ ] Yes, wind energy (3)
- [ ] Yes, hydropower (4)
- [ ] Yes, biomass / biofuel (5)
- [ ] Yes, other please specify (6) _____
- [ ] No (7)
- [ ] Not sure (8)

Q22 Does your company generate energy from byproducts of the manufacturing process? (For example, steam or waste materials)

- ○ Yes, please specify (1) _____
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q23 Does your company use energy efficient modes of transport, or alternative fuels, for transporting materials or products on or off site?
Select all that apply:

- [ ] Yes, we use hybrid, electric, biofuels, or other low emission **vehicles.** Please specify (1) _____
- [ ] Yes, we use hybrid, electric, biofuels, or other low emission **equipment.** Please specify (2) _____
- [ ] No (3)
- [ ] Not sure (4)
- [ ] Not applicable (5)

Q24 Does your company practice on-demand manufacturing?
(Where goods are produced only when they are needed and, in the quantities, required)

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q25 Does your company use preventative maintenance on manufacturing equipment?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q26 Does your company regularly, at least once per year, check and update software used in business and manufacturing operations?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q27 When purchasing manufacturing equipment and machinery, does your company select items because they can be re-purposed or dismantled at the end of their use?
Please select all that apply:

- [ ] Yes, we choose machinery that can be dismantled at the end of use (1)
- [ ] Yes, we choose machinery where the supplier will take it back and re-purpose it (2)
- [ ] Yes, other please specify (3) _____
- [ ] No (4)
- [ ] Not sure (5)
- [ ] Not applicable (6)

Q28 Does your company purchase or procure materials, supplies, or equipment to minimize negative environmental impacts related to the manufacturing process, such as, green procurement, or a green purchasing policy (GPP)?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q29 Are the majority of your suppliers local?
(within 250 miles, or approximately 1/2 day drive)

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)

Display This Question:

If Q45 != Yes

Q30 Where are the majority of your suppliers located?
Please list U.S. states, or external countries

_____

_____

Q31 Do you design and assemble products with the intention to source materials closest to your manufacturing location?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q32 Does your company design or discuss new business strategies to improve the environmental, green, or sustainable practices of your operations?

- ○ Yes, please list examples (1) _____
- ○ No (2)
- ○ Not sure (3)
- ○ Not applicable (4)

Q33 Does your company provide or source training for employees on environmental, green, or sustainable practices?

- ○ Yes, please list examples (1) _____
- ○ No (2)
- ○ Not sure (3)

Q34 Does your company encourage employee actions or habits that improve environmental, green, or sustainable practices?

- ○ Yes, please list examples (1) _____
- ○ No (2)
- ○ Not sure (3)

Q35 Does your company share knowledge or skills of environmental, green, or sustainable practices with other companies and manufacturers?

- ○ Yes, please list examples (1) _____
- ○ No (2)
- ○ Not sure (3)

Q36 Are there any other environmental, green, or sustainable practices that your company does that you would like to mention?

_____

_____

End of Block: Section 2: This section asks questions about your manufacturing operations

Start of Block: Section 3:

*

Q37 What **motivates** your company to implement environmental, green, or sustainable practices?

Rank the top 5 most important factors, where 1 is the most important, and 5 is the least important.

*My company is **motivated** to implement sustainable practices because…*

_____ It provide financial benefits (1)
_____ Senior management are committed to these practices (2)
_____ We need to comply with regulations (3)
_____ It provides a competitive advantage (4)
_____ We need to manage liability and risk (5)
_____ It improves manufacturing performance, or product quality (6)
_____ It improves our company's reputation or image (7)
_____ It meet customer demands (8)
_____ We feel pressure from the general public (9)
_____ It fits our company's vision or mission (10)
_____ It improves employee morale (11)
_____ We feel pressure from industry and suppliers (12)
_____ Other: (13)

Q38 What **prevents** your company from implementing environmental, green, or sustainable practices?

Rank the top 5 most important factors, where 1 is the most important, and 5 is the least important.

*My company is **prevented** from implementing sustainable practices because…*

_____ We do not have the funds to invest in them (1)
_____ We do not have the time (2)
_____ We do not have the customer demand (3)
_____ We do not have the training or expertise (4)
_____ We do not know how useful or productive the practices will be (5)
_____ We are not interested (6)
_____ We do not have stakeholder demand and support (7)
_____ We do not know how the processes will fit into our business (8)
_____ We do not have government support or regulatory requirements (9)
_____ We do not have support from industry and suppliers (10)
_____ We do not see market opportunities or benefits (11)
_____ Other: (12)

Q39 Please identify how often your company management or culture identify with the following statements.

	Always (1)	Very often (2)	Sometimes (3)	Rarely (4)	Never (5)
We are proud of using sustainable practices (1)	○	○	○	○	○
Our company strives to master new ways to use sustainable practices (2)	○	○	○	○	○
Sustainable practices are a fundamental part of our company identity (3)	○	○	○	○	○
Using sustainable practices is an integral part of how we manage our business (4)	○	○	○	○	○
Sustainable practices are a sensible thing for our company to use (5)	○	○	○	○	○
Our company understands that it is a good idea to use sustainable practices (6)	○	○	○	○	○
Company management are discouraged when we do not use sustainable practices (7)	○	○	○	○	○
When we do not use sustainable practices, our company regrets it (8)	○	○	○	○	○
We avoid criticism by using sustainable practices (9)	○	○	○	○	○

Our company uses sustainable practices because others insist that we do (10)	○	○	○	○	○
Our company cannot see how using sustainable practices will help us or the environment (11)	○	○	○	○	○
Nothing will improve if we use sustainable practices (12)	○	○	○	○	○

End of Block: Section 3:

Start of Block: Just a few more questions

Q40 Has the COVID-19 pandemic affected (either positively or negatively) your company's ability to implement or continue environmental, green, or sustainable practices?

○ Yes, please specify (1) _____

○ No (2)

○ Not sure (3)

Q41 To the nearest $100,000, what are the estimated annual gross sales for your company?

○ Annual gross sales pre COVID (2019) (1) _____

○ Annual gross sales during COVID (2020) (2) _____

Q42 Our study is meant to gather important information on the environmental, green, or sustainable practices of small manufacturers. If you have additional comments, please share them below:

_____

_____

End of Block: Just a few more questions

Start of Block: Voluntary email

Q44 Thank you for completing the survey, would you like to receive the incentive?

This includes a copy of the aggregated results of the data, and an option to be entered into a prize draw to win 1 of 10, $100 Amazon gift cards.

- ○ Yes (1)
- ○ No (2)

Appendix B

Template of the electronic survey that was published on Qualtrics XM and linked to the end of the original survey for participants to voluntary select.

TCU research email collection

Start of Block: Default Question Block

Q2 If you would like to receive a copy of the aggregated results from this survey, please provide your email here.

These are stored separately to your survey response.

○ Please provide an email address (1)
_____

Q1 If you would like to be entered into the prize draw to win 1 of 10, $100 Amazon gift cards, please provide your email here.

These are stored separately to your survey response.

○ Please provide an email address (1)
_____

End of Block: Default Question Block

Appendix C

Copy of TCU IRB approval letter

TCU Institutional Review Board

3101 Sadler Hall

Fort Worth, Texas 76129

DATE: November 13, 2021

TO: Brendan Lavy and Katie Howe

FROM: TCU Institutional Review Board

RE: Exempt Approval of Protocol 2021-227

Dear study team:

In accordance with applicable federal law governing the use of human subjects in research, the TCU Institutional Review Board ("IRB") has reviewed your proposed project entitled "The influence of business characteristics and motivations on circular economy practices in small manufacturers" and determined that your study is considered minimal risk, qualifying for an exemption from further IRB review under category 2. Specifically, 45 CFR 46.104(2)(i) identifies studies that are exempt from further IRB review, including research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if the information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects.

The IRB has determined that your proposed project falls under 45 CFR 46.104(2)(i). For these reasons, the IRB has determined that your proposed study is exempt from further IRB review.

Please note, all indoor interaction with human subjects in research studies must adhere to the current TCU COVID guidelines in place at the time of the interaction.

Remember that even though your project is exempt from further IRB review, the research must be conducted according to the proposal submitted to the IRB. Minor changes to this study generally will not require IRB review. Substantive modifications, however, will need IRB review, since the review category might change as a result of modification. Some examples of substantive modifications include: change in PI, study purpose, procedures, funding source, study population, level of risk, or identifiability of collected data. If at any time you are unsure as to whether a change is minor or substantive, please submit a question to Research Compliance for assistance.

If you wish to make substantive changes to the approved protocol, you must submit a Request for Amendment/Modification to Protocol form to the IRB. You may not implement any changes until you have received IRB approval of such changes. Also, please be aware that changes to the research protocol may prevent the research from qualifying for exempt review and require submission of a new IRB application or other materials to the IRB.

Please contact Research Compliance at research@tcu.edu or (817) 257-5070, if you need any additional information

Sincerely,
Research Compliance on behalf of TCU Institutional Review Boar

VITA

Kate Howe was born November 18, 1994, in Rugby, Warwickshire, United Kingdom. She is the daughter of Jane Howe and Mark Read and the first generation of their family to attend university. Kate originally studied her Bachelor of Science at the University of Northampton, U.K., where she was awarded an upper 2:1 in Environmental Science, specializing in waste management. Upon graduation in 2016, Kate was employed by the Environment Agency as a waste regulatory officer. After two years, she was promoted to a sustainable business advisor, where her role entailed helping to construct the Environment Agency's first Carbon Net Zero strategy and developing their first sustainability strategy encompassing the United Nations Sustainable Development Goals. To professionally develop Kate wanted to study abroad, and with her passion for horses and the outdoors she investigated Texas universities, where Kate found TCU's Environmental Science degree. Kate moved to Texas and started her master's program January 2021, and during her degree she worked as a graduate assistant gaining valuable teaching experience. Kate currently lives in the Dallas Fort-Worth area, with her long-term partner, James Glew, who she met in England in 2013.

ABSTRACT

THE INFLUENCE OF COMPANY CHARACTERISTICS AND LEADERSHIP MOTIVATIONS ON THE CIRCULAR ECONOMY OF SMALL MANUFACTURERS

By Kate Howe, MS, 2022
Department of Environmental Science
Texas Christian University

Thesis or Dissertation Advisor: Brendan L. Lavy, PhD

Becky Johnson, P.G.

Laura M. Meade, PhD

The circular economy (CE) is critical to advance sustainability. To advance sustainability, CE can be integrated into business' daily operations, yet CE uptake varies by industry. Small manufacturers, particularly impact regional-to-local sustainability conditions, so CE adoption by these entities provides sustainability information. This research aims to document CE practices and principles of small manufacturers in the Dallas-Fort Worth Metroplex and assess if company characteristics and business leadership motivation towards the environment impact CE implementation. I surveyed 69 manufacturers. I designed questions to investigate CE adoption, company characteristics and motivation. I analyzed responses via descriptive statistics and correlation analysis. I found that uptake of CE practices increased with improved motivation, and that company characteristics led to subtle differences in CE adoption. Minority-owned businesses implemented more CE principles than non-minority owned. Overall, my findings suggest that small manufacturers use easy to adopt CE practices, and motivations can significantly improve CE uptake.