University of Tennessee, Knoxville
Trace: Tennessee Research and Creative Exchange

University of Tennessee Honors Thesis Projects   University of Tennessee Honors Program

5-2018

Supplier Network Mapping for Sustainability Dispersion

Frank X. Murphy
fmurphy2@vols.utk.edu

Supplier Network Mapping
for Sustainability Dispersion

Frank Murphy

Advisor: Dr. Wendy Tate

The University of Tennessee, Knoxville

Global Leadership Scholars 2018 Class

March 30, 2018

TABLE OF CONTENTS

ABSTRACT

Implementing sustainable practices in supply chains has grown to be a major point of academic studies and corporate strategies. Due to increased competition and globalization, supply bases now consist of hundreds of companies around the world. Such orientation opens many multi-nationals to higher regulatory risk as society continues to push for sustainability in every facet of business. As more companies embrace sustainable initiatives into their own functions, they are witnessing that this not only flourishes public relations, but can cut costs and increase efficiency. However, it is often not enough for a firm to implement these environmental, social, or economic changes in their organization exclusively. Companies must communicate these initiatives throughout their supplier base to realize sweeping these benefits in full.

This paper focuses on understanding a firm's position within their supply network and how it relates to the communication and dispersion of sustainable initiatives. Using social network analysis tools, the results can respond to the questions surrounding the best method to implement sustainable practices in all tiers of a supply base. The research selects two competing companies to analyze, each with a different background regarding corporate social responsibility. The assessment of these two outwardly similar companies and their networks contribute to the idea that structural alignment of power in a supply network can provide insight into aiding diffusion of a focal firm's sustainable initiatives.

1. INTRODUCTION

Sustainability is a word we see appearing more and more in various contexts, especially in business. However, the term sustainability lacks a common definition and meaning particularly as it relates to business. According to Andrew Savitz's book *The Triple Bottom Line,* a sustainable corporation can be defined as one that "creates profit for its shareholders while protecting the environment and improving the lives of those with whom it interacts" (Savitz, 2006). Since 2000, the number of Corporate Social Responsibility (CSR) reports issued annually by companies has increased. Consumers' choices are heavily based on the values and environmental track record of the parent company more so than ever before. Organizations are realizing how important sustainable business practices are not just to customers, but to all shareholders. Studies note that investors increasingly consider a company's strategic position when looking at climate change and environmental risk, resulting in discounted stock price (Lash and Wellington, 2007). Many observers of the business sector have written on the paradigm shift from 'being sustainable is good' to 'being sustainable is necessary'.

This idea that sustainability 'creates profits' while 'protecting the environment' reinforces the new thinking that focusing on environmental impact can do more than increase public opinion; these practices can cut costs and increase revenue. Yet even as the inclusion of sustainable projects and efforts becomes progressively more attractive, it is no easy feat to implement. Companies that report on CSR do so after heavy consideration on what areas to increase efficiency or where to target funding. Organizations must understand their business strategies and values to best determine the areas of interest for these efforts.

One key area of sustainable practices is tied to a company's supply network, most importantly in relation to its suppliers. In fact, the state of their supply network has implications

beyond sustainability; some companies purchase inputs or resources from outside suppliers totaling up to 80% of cost of goods sold (COGS). Sustainability reporting has grown; however, companies tend to focus solely on their performance and not that of their supply chain. One main reason for this seems to be that it is difficult to quantify and obtain data on supplier's measurements of carbon footprint and other environmental records.

This is because suppliers may withhold information that may shed light on sustainable performance for several reasons. Furthermore, when these companies do report on sustainability metrics, they often do not report using a formal or standard set of measures; rather, they focus on their strengths and tailor the results to them. Another challenge that prefaces gathering the data is determining what organizations are members of the main company's supply chain network. With multiple tiers stemming deep beyond a company's major suppliers, one must define 1) how far down the network should an organization concern itself with sustainability outcomes, 2) what is the risk and with what supplier/area is it concentrated, and 3) what responsibilities the company has regarding these risks or lack of efforts. Yvon Chouinard, the founder of Patagonia, was once quoted saying, "When you're trying to clean up your supply chain, you can't believe how deep you need to go."

Defining the network is the first step in developing tactics to increase awareness of the focal company's sustainability efforts and begin to implement change. It is regularly difficult for companies to see what is happening beyond their first tier of suppliers. The ideal end goal of this practice is the dispersion and eventual adherence of the focal company's policies and tactics throughout their network. This research aims to display the implications attainable from network mapping. More specifically, the purpose of this paper revolves around how analyzing a company's position can reveal insight on their surrounding network and can offer suggestions for

how to improve connectivity and responsiveness of those surrounding them. Resulting analysis can answer questions regarding relational power within a network, and how a company can best spread its sustainable efforts throughout the network. Two competing companies' supply networks are analyzed to begin to understand how organizations can position themselves and develop or potentially manipulate an interconnected, sustainable supplier network. In summary, the following analysis will address the question: How can companies use network ties and linkages to diffuse sustainability initiatives?

Data and business connections are aggregated using Bloomberg, a financial service tool. This data is analyzed with UCInet, network mapping software. Various social network analyses and regression tests are run to assign values and ranks. After cleaning and running the collected data, there are interesting and differing results between the two selected companies regarding their power and influence within their networks. However, before the analysis, the importance and overall definition of social network analysis and its associations are reviewed in Section 2. Sustainability is also reviewed in order to enhance its purpose and position within a company as well as supply chain. Section 3 focuses on the methodology and selection of the test companies and Section 4 discusses the analysis metrics used in detail. Section 5 will contain the results of the network analysis, and Section 6 will contain implications of the results and offer recommendations for future enhancement or practical embracement of this study.

2. LITERATURE REVIEW

Sustainable SCM

The idea of implementing sustainable business practices into a company's core competencies can be traced to the publication of the Brundtland Report in 1987. The report was

the end result of the World Commission of Environment and Development (WCED), a UN-sponsored committee to formulate long-term solutions to growing environmental concerns and social inequity (Jarvie, 2016). In it, the commission outlined the definition of sustainable development and listed guidelines to infuse the concept into business operations (Brundtland, 1987). The report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Jarvie, 2016).

The resulting evidence for the inclusion of sustainable efforts sparked many research papers and case studies aiming to identify companies that can be defined as sustainable and how firms can best follow these guidelines. However, many of the papers focused on strictly green or environmental adherence, not social (Seuring and Müller, 2008). Another term for the topic has been developed in the past decade: Sustainable Supplier Relationship Management (SSRM). Cited in a published journal, Schiele's 2007 publication stated that SSRM includes various aspects of business, including supplier selection, evaluation, and development (Leppelt, et al., 2013). The inclusion of environmental records and sustainable policies in determining supplier decisions has only increased due to companies wanting to limit economic and reputational risk.

Industry experts have cited boycotts and climate change as growing areas of concern to which sustainable development can help mitigate (Anderson, 2009). Furthermore, a survey conducted by Deloitte in 2016 reported that roughly 41% of the respondents' procurement departments outsource, and 29% indicated they will increase that amount in the near future (Deloitte, 2016). Increasing external production, global supplier interdependence, volatile markets and importance of public opinion all have made SSRM and the research thereof crucial to helping massive corporations handle mounting pressure to act 'sustainable'.

A paper published in the Journal of Cleaner Production attempted to create a framework outlining how to practice SSRM based on the study of several chemical companies identified as very active in the realm of sustainability (Leppelt, et al., 2013). The research listed five major pillars of SSRM practice. The first, *Foundation*, discusses the development of CSR initiatives such as supplier risk assessments and governance policies. *Communication* is the following pillar and focuses on the spread and awareness of these guidelines throughout the company and direct partners. *Guidance* deals with aiding stakeholders and business functions in implementation and upkeep of the established guidelines. *Outcome* assesses how the initiatives impacted the company and how the results could facilitate change in operations. Underlying these is *Reconnection*, which addresses the constant monitoring and measuring of the overall SSRM practices (Leppelt, et al., 2013). The conclusion of the academic paper stated that among other things, coordinated corporate strategy alignment of these SSRM practices has a positive association with the firm's ability to achieve a sustainable, socially responsible business strategy (Leppelt, et al., 2013). This research paper will dive deeper into the *Communication* pillar and identify how network mapping can facilitate efficient and effective dispersion of sustainable policies.

Closed-Loop SC: A Discussion

A recent area of focus in the academic study of supply chain management is that of closed-loop supply chains. Often referred to as the reverse supply chain, a closed-loop supply chain adds several activities or functions to normal supply chain operations, including product acquisition, refurbishment, remarketing, and product end-of-life disposal. While an overlooked concept due to the perceived idea that this is not a value-adding process, studies have highlighted

the "largely incremental and insufficient" benefits that exist from increasing process manufacturing efficiency (Towards the Circular Economy, 2014). Closed-loop strategies correspond closely with sustainable concepts of limiting waste, reusing parts, and collaborating with strategic suppliers to develop green and efficient products or parts. Companies that spend time, money, and energy on developing some level of a closed-loop are seeing more than just financial benefits.

A case study on the reverse logistics efforts of seven companies stated that one firm attributed increased brand loyalty, environmental responsiveness, and profitability to its remanufacturing and recycling efforts (Mollenkopf and Closs, 2005). While this paper does not examine closed-loop supply chains in detail, this brief discussion was added to add significance to the importance of the overarching theme of sustainability and its growing value in achieving success in decades to come.

Sustainability Measuring and Reporting

As the importance of sustainability efforts and CSR reporting increased, so did the need to quantify their adherence and highlight top performances. This spurred the formation of many organizations and committees with the purpose of creating guidelines on reporting sustainable efforts. Oftentimes, these are NGO-driven and not put in place by governmental functions; they served to fill holes surround government regulations (Bennett, et al., 2017). Society continues to push for more transparency of multi-national companies beyond cost and pricing; people increasingly are being told sustainable companies are the best companies. Therefore, standardized measures have made the evaluation of companies comparable and understandable. For companies, the importance of being recognized by these various agencies or listed on indices

has been shown to intensify the rate that they pursue SSRM efforts (Leppelt, et al., 2013). This is because it takes an internal or passive statement and acknowledge real, sustained efforts to improve in the realm of CSR; this in turn creates trust and engagement with their stakeholders.

This section will briefly discuss a few of the more recognized agencies and measures in sustainability reporting. It is important to note that many of these and many of all sustainability reporting focuses on the 'traditional' areas like environmental impact and corporate philanthropy, as they tend to gain more attention (Kolk, 2003). Furthermore, it is easier to quantify and provide rankings on metrics like carbon emissions than ethical policy adherence.

- **Global Reporting Initiative (GRI)** (globalreporting.org) – Founded in 1997, this independent international organization has developed sets of standards for reporting on economic, social, and environmental standards (Global Reporting Initiative). They have grown over the past decade to be a powerful influencer based on their holistic and in-depth approach to CSR reporting; they also help companies develop plans to implement their structure to existing reports. Companies that correct use GRI standards are given an accreditation; the most recent standards offer G-4 Level Reporting to those companies that utilize the full set of GRI standards. These standards help keep companies accountable and builds trust with stakeholders.

- **Dow Jones Sustainability Index (DJSI)** (sustainability-indices.com) – This index was launched in 1999 and geared towards "investors who have recognized that sustainable business practices are critical to generating long-term shareholder value and who wish to reflect their sustainability convictions in their investment portfolios" (RobecoSAM). Every year, thousands of companies from various industries are invited to complete applications assessing their performance in the social, environmental, and economic

fields. The DJSI inclusion criteria are updated annually and companies must reapply

every year to stay in the family (RobecoSAM). The DJSI is a major achievement due to

the vast pool of applicants and the reward gained from increased visibility to investors.

- **ISO** (iso.org) – The International Organization for Standardization is an independent

   NGO that focuses on creating families of standards to ensure quality, efficiency, and

   safety (International Organization). With 22,063 standards published, ISO standards

   encompass all industries and sections of the supply chain. Companies aim to gain

   certification in these various ISO families, as they imply a high level of quality and

   minimal negative impact. One of the more popular standards is ISO 14000; this measures

   environmental impact of a firm. Some of the standards may look at effect on climate

   change while another may analyze the auditing and communication of environmental

   practices. Another example of a meaningful metric is the ISO 20121, which evaluates the

   social, environmental, and economic effects of corporate events and gatherings

   (International Organization). These best practices help companies with identifying ways

   to cut costs and create sustainability in all aspects of their business. ISO lays out 'world-

   class specifications,' which their website states is "instrumental in facilitating

   international trade."

There are many other well-known organizations like the Carbon Disclosure Project

(CDP) that exist to develop methods to create accountability for corporations in the field of

sustainability. Many have voiced criticisms of these measures; 'going green' may not actually

mean a company is doing anything beneficial, and recognition from certain NGO's may be based

on future promises with no responsibility. Yet despite the backlash, sustainability reporting and

measuring has grown tremendously and needs to continue to grow. Failure to recognize even

small achievements and steps in the right direction may deter others from recognizing the importance of sustainable practices and the reporting thereof. Some of these organizations, among others, are mentioned in Section 3 of the paper as well as throughout other areas in the analysis.

Social Network Analysis

One paper attempting an overview of this field of social network analysis (SNA) states that it "means analyzing various characteristics of the pattern of distribution of relational ties… and drawing inferences about the network as a whole or about those belonging to it considered individually or in groups" (Introduction to Social Network Analysis). It is important to understand the terms and definitions associated with SNA that are used as a foundation for network assessment. Several key concepts are defined, and a summary of SNA is performed. The metrics and measures used in this research are further discussed in Section 4.

The following terms are defined for clarification of further discussion of the social networks analyzed later in this paper. While there are a multitude of measurements and terms utilized in SNA studies, this research discusses a few basic measures, and therefore will only include the terms needed for understanding. These definitions are derived from papers from O'Malley & others (2017) and Wasserman, and universally used for SNA exploration.

- **Actor:** Either individual, corporate, or collective social units. An Actor can be a person, country, or agency. For this paper, actors will be representing companies. One may also see this referenced as 'node'.

- **Relation/Tie:** Links that connect actors to one another. This can range from the sharing of information, monetary exchange, biological or physical (road or bridge) connection.

Relations can also be referenced as a collection of specific ties between actors, however this research addresses only one type of tie. For this paper, ties will be determined by purchasing agreements.

- **Subgroup:** a subset of actors in a network and the connections among them. Subgroups are often formed by actors with similar traits or motives, and usually seemed more interconnected among themselves than with the rest of the network.

- **Group:** often noted as networks or actor sets, we define this as the total sum of all actors and ties to be analyzed.

- **Social Network:** The collection of actors and subgroups and the ties and relations connecting them. Social network is often synonymous with a group, however some academics label social network as a group with the 'presence of relational information'.

In the past several decades, much research in the behavioral science field has been focused on implications and patterns that arise through social relationships. The ability to understand the 'if' and 'how' of influence among social structures has significance across a breadth of backgrounds, such as political or economic. Social network analysis (SNA) differs however from the traditional theories of sociology, primarily because the area of importance stems not from the impact from the actions of an actor or node but rather the possible impact based on the relationship between actors (Fredericks and Durland 2005).

Initial studies looked at small dyads (two actors) or triads (three actors) and the value of the connections between them, or lack thereof (Wasserman and Faust, 1994). These initial studies were very time-intensive to calculate the algorithms, and it wasn't until the development of computer software tools such as Borgatti's UCInet in the 1970's that larger groups were able to be analyzed (Fredericks and Durland, 2005). While these social networks were usually drawn

out as graphs depicting points and lines, this new software allowed for easier visualization of ties, the value of those ties, and centrality of nodes (Introduction to Social Network Analysis). Now, research addresses not only individual actors, but subgroups and how their collective relations weigh on influence and perceived network behavior.

Subgroups have also been named 'cliques', and studies have analyzed how many larger social networks are built from a cohesion of several cliques (Hanneman and Riddle). When addressing how SNA can be quantified, researchers have taken several approaches based on the desired implications. A common theme originated with the measuring of perceived influence or power in a network. Often, matrix regression and algorithms would deem the actor with the most ties, strongest relations, or most centralized to be the most powerful. While some networks do result in this conclusion, measuring centrality and closeness to other nodes is a valuable calculation, other examinations into this area created new metrics. A notable one talked about in this paper was proposed by Phillip Bonacich; his evaluation of perceived power resulted in the creation of Beta Centrality, which considers the power of a focal actor's direct ties, as well as dependency on the focal actor (Bonacich, 1987).

SNA clarifies multiple methods of assigning value and power to actors in a network. This research highlights key metrics that allow for a comprehensive but high-level analysis of social networks consisting of hundreds of actors. Explanation and literature on SNA is included to set a foundational understanding of how these definitions and subsequent outlined metrics relate to finding influence within a focal firm's supplier network. The utilization of these metrics and data collection process are outlined next.

3. METHODOLOGY

Industry Selection

The first step was to determine the primary industry from which to analyze sustainability efforts. To remain consistent and make comparison, the two firms were selected from the same industry. The technology and electronics industry was chosen to be analyzed for a few reasons. For one, technology companies have large influence and overall wealth, allowing them to champion sustainable efforts with actual force. For that same reason, the public eye is much more focused on their achievements in CSR due to their massive image and revenues. Further evidence stems from the founding of the Electronic Industry Citizenship Coalition in 2004. A United Nations initiative, the EICC "works to create better social, economic, and environmental outcomes for all those involved in the electronics supply chain" (Electronic Industry Citizenship Coalition). This 'Code of Conduct' helps to monitor things like worker conditions and environmental friendliness through global assessments and resources.

Founded by a generation of young, educated millennials, many of these companies pride themselves in achieving zero-impact levels of environmental damage to our world; for example, technology giants Apple, Google, and Facebook have worked to power their extensive data centers on 100% renewable energy instead of fossil fuels like coal (Gilpin, 2015). This industry innovates and adapts faster than any other industry, allowing it to enact new codes and guidelines and abide by them due to the nature of the industry and motivation of those involved. And more so than any other industry, the competition is fierce.

With investors and consumers valuing the triple bottom line more than ever, these firms must be constantly aware of their rivals' environmental footprint and ready to match or beat their efforts. Another large factor for choosing this industry involves the availability and transparency

of data and the sustainable track record. Due to the points listed above, many electronic firms

have documented their projects and impact to let customers and stakeholders peer "under the

hood" of their operations. The electronic industry is a budding, innovative, powerful sector with

roots to sustainability, making it an ideal area of study.

Identifying two competing firms within the industry was next. To really see the

disparities and importance of network orientation on sustainability, the two companies should

have relatively different track records when looking at their relationship with sustainability. A

handful of elements factored into the decision: 1) Is the firm a publicly traded, Fortune 500

company? 2) Has the company appeared on the Dow Jones Sustainability Index (DJSI), and how

often? 3) How long has the company issued environmental or CSR reports? 4) How do those

reports measure in terms of GRI compliance? And 5) What is the overall public opinion

regarding said company's sustainability efforts? The two firms, IBM and Apple, are discussed

next.

IBM

Founded in 1911, IBM has been a massive player in the electronic industry for decades.

They are a publicly traded company and currently sit at 32 on the Fortune 500 list with 2017

revenues of over $79 billion (Fortune 500 List). IBM's Bloomberg information page states that

"IBM provides computer solutions using advanced information technology. The company's

solutions include technologies, systems, products, services, software, and financing"

(Bloomberg, 2017). It's obvious that IBM puts substantial money and effort into CSR projects;

their website contains an entire section addressing their various projects and achievements. The

webpage contains the header, "*Our Approach: Pursuing the highest standards of corporate responsibility in every aspect of our business*" (Corporate Responsibility at IBM).

Corporate Register, a website that serves as a directory for corporate responsibility reports of over 15,000 organizations, has 38 reports listed for IBM dating back to 1992 (About CR). IBM has been formally issuing CSR reports longer than any of its competitors, and has gained considerable admiration for their sustainable efforts over the years. IBM also issues their reports to GRI, and has recently been given G3, G4, and GRI-citing levels of compliance, showing a commitment to meaningful change and measurable performance (Global Reporting Initiative). In addition, IBM has appeared in the DJSI World Index seven times since the index's origin, most recently in 2011 (RobecoSAM).

In 1990, IBM developed a company function named Corporate Environmental Affairs (CEA) (Henderson and Barido, 2009). The group consisted of industry experts with background in legal, environmental, and energy efforts. The objective of this function was to develop IBM's sustainability management strategy, oversee company implementation, and publicly emphasize and communicate CEA's efforts (Henderson and Barido, 2009). Initiatives such as the CEA have paid off for IBM; the company has noted financial savings based on these sustainable policies, and have been awarded and recognized dozens of times. A few notable achievements include earning the EPA's SmartWay Excellence award, which acknowledges companies with strong freight efficiency and clean-air supply chains (SmartWay), and recognition from WWF's Climate Savers organization for their initiatives towards climate & emissions solutions (Henderson and Barido, 2009). IBM's early and consistent dedication to corporate responsibility efforts has cemented their reputation as a company with the desire to operate sustainably and the internal blueprint to do so effectively.

Apple

Sitting at the 3rd spot on the Fortune 500 with revenues of $215 billion is one of the largest icons of millennial-era technology companies. Reuters.com states that Apple "designs, manufactures and markets mobile communication and media devices, personal computers and portable digital music players…(Apple) sells a range of related software, services, accessories, networking solutions and third-party digital content and applications" (Reuters). Due to the nature of their product and their popularity in societies worldwide, Apple has become one of the most recognizable brands in the world. However, as the famous saying goes, with great power comes great responsibility.

Apple has significant attention surrounding all aspects of their business, and more recently that attention has homed in on their performance in CSR efforts. According to Corporate Register, Apple has issued 19 CR reports, dating back to only 2007 (About CR). The technology giant has never appeared on the DJSI World or North America indexes (RobecoSAM), and while they have been utilizing GRI guidelines and issuing their CR reports to the organization, they have not been given G2, G3, or G4 levels of compliance when looking at their economic, environmental, or social reporting principles (Global Reporting Initiative).

There are many critical articles written about Apple, stating that while they are heading in the right direction with their environmental relationship, they got off to a late start and are not picking up the pace of innovation. One such article states that while Apple has made significant progress in the areas of development and other functional operations, their manufacturing/supplier base accounted for 24.8 million metric tons of gas emissions (their total emissions were 34.2 million metric tons in 2014) (Freedman, 2016).

When looking at the sustainability impact webpage on Apple.com, one can see the headline of "Here's what we're doing. Here's how we're doing." Following is their most recent CR report as well as specific product environment reports (Apple Environment). It is not until near the bottom of the page that there are links to such initiatives such as supplier development and recycling. This is not to say that Apple does not care or does not have strong efforts in the field of CSR; they do. The issue arises with the apparent focus on profitability and power within their business and supply network. It seems Apple has historically been more 'reactive' to trends toward sustainability in contrast to a company like IBM, which can be described as 'proactive.' While Apple wants to meet quality standards, IBM wants to exceed them.

These two companies serve as, more or less, opposites in the realm of measuring emphasis and effectiveness on environmental and social standards. The similarities involve operating in the same industry sector, being massive global companies, and at least recently reporting on various CSR efforts. The selection of these two firms offers two unique backgrounds in sustainability, allowing for a wider scope of inquiry into the importance of network orientation in relation to the dispersion and adherence to sustainable practices. The variance between the two firms may also result in different recommendations of how to connect with prominent players in the supply network based on resulting structural embeddedness.

Data Gathering

The next step in the research was to conduct the supplier network analysis. The goal was to map out the focal firm's supplier network, through 3 tiers. To gain this information, Bloomberg terminals were used, in particular the <SPLC> (Supply Chain) function. This displays a company's publicly traded suppliers and customers, ranked by either percent of spend

or nominal monetary value of the relationship. Below you see a screenshot of the SPLC display

page (SPLC Screenshot).

Figure 1: Bloomberg Screenshot of SPLC Function

For this research, the suppliers were ranked by percent of spend (spend category was

either COGS, Capex, or SG&A). First, the focal company was identified, either Apple or IBM.

Then, their top ten suppliers by percent spend were recorded; these were the focal firm's 1st Tier

Suppliers. Next, each of the focal firm's top ten suppliers were analyzed, and their top eight

suppliers were recorded; these served as focal firm's 2nd Tier Suppliers. This process was

repeated once more with each of the 2nd Tier Suppliers, recording their top eight suppliers and

rounding out the 3rd Tier Suppliers. This is demonstrated in Figure 2 below; the black arrows

represent a connection, and the number of said connections is shown in the text boxes alongside

the top flowing chain. It's important to note that some suppliers, often based in Asian countries with little information, may have only had one or two suppliers if any.

After the list was created, each company was cross-checked with every other company in the matrix; for example, the cross-checking would create the relationships the red arrows in the figure below depicts. This allowed for relationships to and from companies (i.e. Microsoft could both be a supplier and customer to Intel). Companies therefore had at least one relationship, up to eight buying relationships, and an unlimited number of supplier relationships.

Figure 2: Example Matrix Development
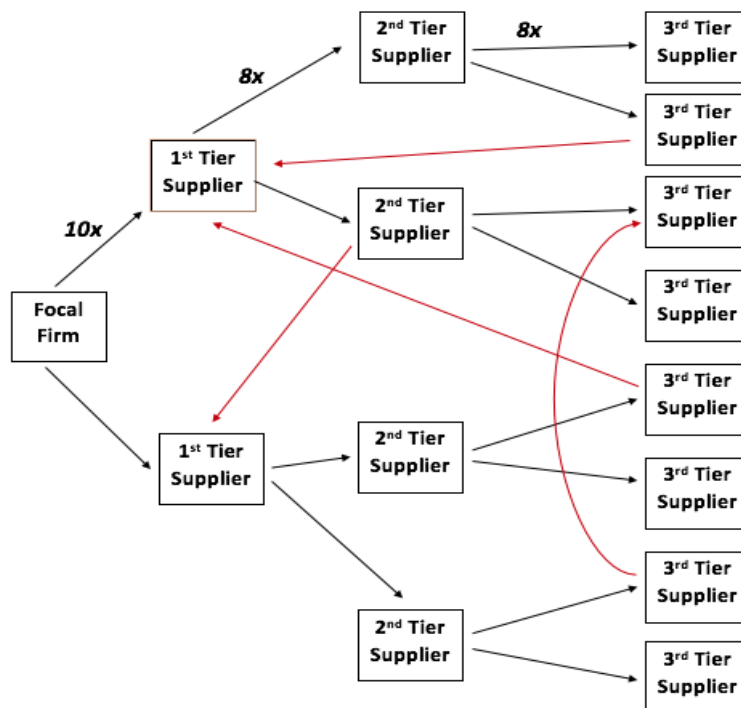
The matrix had replicated x and y axis values, resulting in the ability for a company to both supply and buy from another. These excel spreadsheets were expansive; for example, Apple's network contained 285 firms. This resulted in a matrix with 81,225 cells (285 x 285). On the following page is a screenshot from Apple's finished matrix. While there are over 81,000 cells with values, only around 1% of them have a value greater than 0. A cell value of 0 indicates

no relationship. To read this matrix, one looks at the row (buying company), finds a relationship (x > 0), and identify the column (supplier). For example, Applied Materials Inc (row 18) purchases 2.45% of their total COGS from Advanced Energy Industries (column E).

Figure 3: Segment of Completed Apple Matrix

#	A	B 3M Co	C Activision Bl	D Adhi Karya P	E Advanced Energy Industries Inc	F Advanced Micro Devices	G Advanced Semiconductor	H Advanced Wirel	I Advantest Corp	J AIXTRON SE	K Alibaba Group Holdings	L Amada Hold	M Amazon.com Inc
1	APPLE MATRIX												
2	3M Co	0	0	0	0	0	0	0	0	0	0.031	0	0.0024
3	Activision Blizzard Inc	0	0	0	0	0	0	0	0	0	0	0	0
4	Adhi Karya Persero	0	0	0	0	0	0	0	0	0	0	0	0
5	Advanced Energy Industries Inc	0	0	0	0	0	0	0	0	0	0	0	0
6	Advanced Micro Devices	0	0	0	0	0	0	0	0.0329	0	0	0	0
7	Advanced Semiconductor	0	0	0	0	0	0	0	0.0328	0	0	0	0
8	Advanced Wireless Semiconductor Co	0	0	0	0	0	0	0	0	0	0	0	0
9	Advantest Corp	0	0	0	0	0	0	0	0	0	0	0	0
10	AIXTRON SE	0	0	0	0	0	0	0	0	0	0	0	0
11	Alibaba Group Holdings	0	0	0	0	0	0	0	0	0	0	0	0
12	Amada Holdings Co Ltd	0	0	0	0	0	0	0	0	0	0	0	0
13	Amazon.com Inc	0	0	0	0	0	0	0	0	0	0	0	0
14	Ambarella Inc	0	0	0	0	0	0.0686	0	0	0	0	0	0
15	Amkor Technology	0	0	0	0	0	0	0	0.0164	0	0	0	0
16	ANSYS Inc	0	0	0	0	0.0095	0	0	0	0	0	0	0
17	Apple Inc	0	0	0	0	0	0	0	0	0	0	0	0
18	Applied Materials Inc	0	0	0	0.0245	0	0	0	0	0	0	0	0
19	Applied Optoelectronics Inc	0	0	0	0	0	0	0	0	0	0	0	0
20	APS Holdings Corp	0	0	0	0	0	0	0	0	0	0	0	0
21	Arista Networks Inc	0	0	0	0	0.0083	0	0	0	0	0	0	0
22	ASM Pacific Technology Ltd	0	0	0	0	0	0	0	0	0	0	0	0
23	ASML Holding NV	0	0	0	0	0	0	0	0	0	0	0	0
24	Atlas Copco AB	0	0	0	0	0	0	0	0	0	0	0	0
25	Audix Corp	0	0	0	0	0	0	0	0	0	0	0	0
26	Avaco Ltd	0	0	0	0	0	0	0	0	0	0	0	0
27	Avail Data Corp	0	0	0	0	0	0	0	0	0	0	0	0
28	Avatec Co Ltd	0	0	0	0	0	0	0	0	0	0	0	0
29	Axcelis Technologies	0	0	0	0	0	0	0	0	0	0	0	0
30	BASF SE	0	0	0	0	0	0	0	0	0	0	0	0
31	BE Semiconductor Industries	0	0	0	0	0	0	0	0	0	0	0	0
32	Blackline Inc	0	0	0	0	0	0	0	0	0	0	0	0
33	Brady Corp	0	0	0	0	0	0	0	0	0	0	0	0

After the matrix was filled and boundaries established, it was loaded into the UCInet software. UCInet is a social network analysis software developed by Steve Borgatti. The software can import various types of data, mainly matrices, and conduct ego network, centrality, and statistical analysis based on input values (Borgatti, et al., 2002). For this project, the software ran various centrality measures as well as role analysis. The measures exported from the software included Beta Centrality or Bonacich Power, inCloseness, outCloseness, Betweenness, Outdegree, Indegree, and Brokerage values. These measurements were selected to best explain the importance of centrality for dispersion of a firm's sustainable efforts. If what has been stated earlier holds true, Apple and IBM should rank rather differently in these measures in their respective supply networks. The next section contains descriptions of the above-listed measures and the value added through them.

The collection of data resulted in 257 nodes, or companies, in IBM's matrix/network, and 285 in Apple's matrix. After the analysis discussed in this section was completed, there were 915 ties, or relationships, in IBM's matrix, and 950 ties in Apple's matrix.

4. NETWORK MEASURES

Beta Centrality/Bonacich Power - This looks beyond the basic idea of centrality, which bases power on the number of connections a node has with other nodes. Bonacich looks at the connections the nodes that the central node is connected to. For example, does Bob's friends have a lot of friends, and are they well connected. If Bob is not incredibly well connected but Bob's friends are well connected, that boosts Bob's centrality. However, power is said to come from dependence on others. So, if most of Bob's friends are not well connected, they are more dependent on Bob and increase his power. With these two approaches to this measure, one must

be selected: is power found in firms with well-connected friends, or is power found in those firms whose friends are dependent on them?

Phillip Bonacich, the discoverer of this measure, wrote a paper on the topic in 1987. In it, he concedes that his measure cannot include or count for all the varying scenarios of social network. Instead, this measure should be used with either a positive or negative beta value, depending on the situation; positive beta gives power to those with powerful friends, while negative beta gives power to those with power over their friends. "There is a core similarity in all these situations: one's status is a function of the status of those one is connected to," Bonacich acknowledges (Bonacich, 1987).

Since relationships are based on purchases from a company, the former is more powerful than the latter. If we used the latter, it would assume that said company could not find an alternative company if they did not spread sustainable efforts to those who buy from them. Also, we want to identify companies with lots of ties, since they can touch more nodes easier. The efforts may not be followed as heavily for every company than if we looked at a node with many dependents, but the message and efforts will be spread farther and through more companies. Also, those not-connected friends of said powerful companies may not be very big, or influential in a world setting, since we are looking at percentages of spend, not dollar amounts. We need to identify those large companies who are well connected and buy from others who are well connected to create relationships in the sharing of sustainable practices.

Bonacich Power will serve as a useful tool in identifying well-connected, powerful players in the networks; these are the firms either IBM or Apple will want to be aware of, not only out of possibility of threats. More so, because those are the companies they should partner with to best spread sustainable efforts thanks to their centrality.

Closeness (in & Out Measures) – According to a faculty member at Louisiana State University, Closeness "is a measure of the degree to which an individual is near all other individuals in a network. It is the inverse of the sum of the shortest distances between each node and every other node in the network" (Bratton). Closeness helps to identify nodes that, when looking at the whole network, have to take the fewest amount of 'steps' to reach every other node. *inCloseness* refers to how easy it is to reach the central node or firm from all other nodes. Identifying if the focal firm or their immediate connects can easily be accessed is important to determining overall centrality and dispersion power. *outCloseness* looks at how easy it is for the central node to reach all other nodes. If the focal firm has a high ranking in this category, they will be better suited to spread the efforts as they will be able to reach others with less steps. While these closeness measures are not the most complex or telling of whether the focal firm is centralized, it ties in with other measures and simply identifies, when referring to distance, how central is the focal firm.

Betweenness - Essentially, this looks at how much information passes through a node. Let's say Tom wants to ask for paid time off, and that can only be approved by plant managers. Being a shift worker, Tom's application may have to go through his line manager, then the shift leader, then possibly one or two other levels before reaching the plant manager. The people or nodes in between Tom and the plant manager gain power due to the fact the information must pass through them. This is Betweenness. The higher a company ranks in this measure, the more information is relayed through them, simply because they are a connector on the line from Point A to Point B. This is like the brokerage scores, but may consider the amount of information

while the brokerage score only looks to see if it's a connector for two unconnected nodes.

Combined with the other measures, Betweenness will show the importance of a firm's

participation to the spread of information, which is crucial to dispersion of sustainable practices.

Brokerage – This term is used to describe the extent to which a firm plays in between two firms

and their ego networks. Often called 'bridges,' there are five major types of broker roles

depending on the focal firm's membership to groups and connection to others. Below is a

screenshot from a paper that explores broker relationships and competition (de Nooy, et al.,

2011). An important note: many other researchers use the synonym 'consultant' for the 'itinerant

broker' role below.

Figure 4: Brokerage Relationships
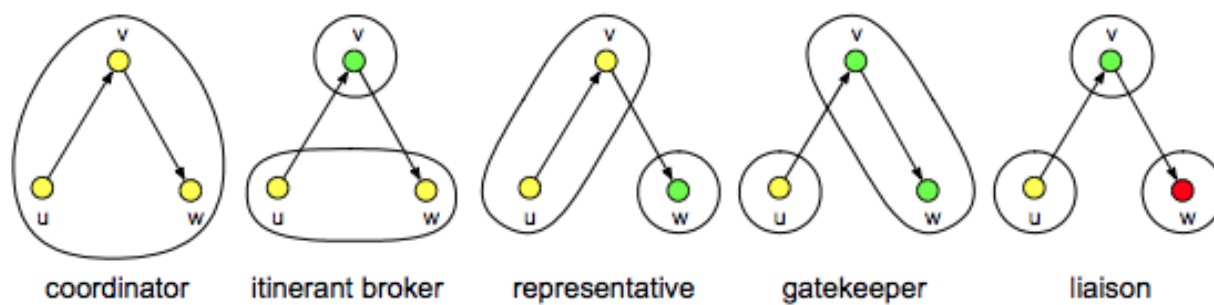
These graphics depict relationships with node v as the focal firm. Understanding what roles the

focal firm (either IBM or Apple) fill as well as what other companies play significant positions is

crucial to the eventual exchange of information & standards. Those firms with several roles

would be needed to spread messages and ideas throughout the network. UCInet takes the matrix

and based on the ties between all the nodes, assigns companies to subgroups or ego networks. In

the results section of this paper, it is noted that due to the vast number of connections within both

networks, the only role any firm or node plays is that of the coordinator. That is, UCInet

considers all nodes to be interconnected enough that no subgroups exist. However, there is still importance behind playing a role of a coordinator; like Betweenness, these players serve as a vital connection tying indirectly connected firms together.

Indegree Centrality – Degree centrality is the basic concept that two nodes are both connected to each other if there is at least one relationship; it does not look at the direction of the arrow. There are then two types of degree centrality, one being Indegree. A firm or node with a high level of Indegree Centrality receives lots of ties, and is often characterized as a 'prominent' figure in the network. This measure will identify those firms who many people purchase from. While they might not have power when looking at Bonacich or other measures, this will help in finding companies to relay sustainable practices to; as they implement higher standards, their products and processes may improve and overall environmental impact may be lessened down their supply chain.

Outdegree Centrality – Essentially the opposite of Indegree, Outdegree measures the amount of ties a node exerts. In this research, this would be a company that purchases from many different firms. Compared to Indegree and regarding the focus of this paper, this measure carries less weight. For one, the nature of the methodology meant most companies had eight connections if available, spare IBM and Apple who had ten each as the focal firm. Also, identifying companies that buy from several places is not as important as finding those who sell to various firms, as those firms have the chance to directly affect the supply chain in a positive manner. However, Outdegree is still useful as identifying those with a high ranking can help with asking companies with multiple suppliers to increase their standards. This may trickle down to suppliers, or the

firms may switch to more sustainable suppliers, either way making a conscious decision to improve in the CSR area.

5. FINDINGS

This section will follow the structure of the previous section. We will first lay out the overall summary from the analysis on a company level, then analyze results on a per metric basis. The scores for each of the metrics were ranked highest to lowest, and companies were given corresponding ranks based on their performance compared to others. A screenshot of the compiled data is shown below. This is from IBM's matrix, with IBM bolded in row 28. As mentioned above, when sorted by descending value for Beta Centrality, IBM ranks 27th out of 257 firms for that metric. As noted in Section 3, there were 257 nodes, or companies, in IBM's network that resulted in 915 ties, or relationships. There were 285 nodes in Apple's network that resulted in 950 ties.

Figure 5: Sample of Compiled Results

|	A	B	C	D	E	F	G	H
1	Company	Beta Centrality	inCloseness	outCloseness	Betweenness	Brokerage (Coordinator)	Outdegree	Indegree
2	Applied Materials Inc	845.683	75.217	74.8	1818.041	36	0.234	0.743
3	Lam Research Corp	696.11	80.033	65.512	1674.862	72	0.3	0.752
4	Tokyo Electron Ltd	675.873	81.933	73.5	3216.992	47	0.025	0.714
5	Ultra Clean Holdings	510.655	59.162	0	0	0	0	0.177
6	ASML Holding NV	509.935	80.397	62.395	2043	80	0.249	0.702
7	Carl Zeiss SMT AG	473.716	56.998	0	0	0	0	0.176
8	Taiwan Semiconductors	453.291	85.8	74.417	2138.398	103	0.689	4.567
9	MKS Instruments Inc	329.551	60.417	1	17.177	3	0.009	0.083
10	Ichor Holdings Ltd	313.687	57.698	0	0	0	0	0.079
11	Advanced Energy Industries	232.143	57.448	56.924	138.093	4	0.005	0.057
12	KLA-Tencor	222.998	79.633	78.717	2946.683	77	0.133	0.442
13	Broadcom Ltd	184.031	79.467	71.35	996.59	116	0.362	0.642
14	Samsung Card Co	171.98	46.112	61.617	0	0	0.06	0.702
15	Intel Corp	171.474	92.533	75.45	3333.365	203	0.747	1.216
16	RR Donnelly & Sons	166.239	59.405	52.314	1027.668	11	0.001	0.052
17	Gigamon Inc	162.917	55.9	76.417	544.81	6	0.125	0.491
18	Celestica	159.048	73.067	81.45	3181.571	37	0.19	0.138
19	Hon Hai Precision	154.166	82.4	78.317	3274.078	109	0.179	1.784
20	Samsung Electronics	137.672	86.583	78.633	4921.463	126	0.446	0.829
21	Advanced Semiconductor Engineering	131.8	79.733	59.867	348.569	24	0.145	0.663
22	Jabil Inc	123.088	76.6	75.317	2793.7	58	0.053	0.475
23	Kawasaki Heavy Industries	113.284	56.781	48.487	49.621	2	0.028	0.031
24	Sanmina	102.477	72.967	75.33	1478.377	38	0.063	0.308
25	Samsung SDS Co	98.441	64.183	83.333	2762.249	67	0.103	0.22
26	Avnet Inc	93.465	75.983	85.083	2861.605	57	0.503	0.188
27	United Microelectronics Corp	92.722	68.033	73.45	297.274	32	0.218	0.231
28	**IBM**	89.65	87.517	99.667	15140.754	178	0.14	0.371
29	EMCOR Group Inc	83.719	58.895	51.514	293.562	4	0	0.098
30	Micron Technology Inc	81.846	76.017	81.717	1639.241	73	0.748	0.25

After running the matrices through UCInet, the mapping and structural positions showed clear differences between IBM and Apple. IBM, as mentioned before as being a pioneer in technology sustainability efforts and reporting, saw themselves more centralized within their network. Apple's matrix contains 28 more companies (nodes) than IBM's, and this can be attributed to the less overlap of suppliers within Apple's network. In other words, not as many of the 1st and 2nd tier firms buy from one another, resulting in addition of more companies. With more companies, we would assume a larger number of ties or relationships. While Apple did have 950 ties compared to IBM's 915, the average ties per node for IBM was higher (3.56 vs. 3.33). So even though Apple had more ties overall, they simply are not as interwoven as IBM's network. IBM's stronger position allows for easier diffusion of ideas and policies throughout their supply base, due to their interconnectedness and importance beyond their 1st tier suppliers.

The next two figures depict the mapping of the networks. Each blue square represents a node, and an arrow represents a buying relationship. The arrows are not weighed based on size of the buying relationship, since it would result in the inability to read or see what little there is to see currently. Initially, it appears these networks look very similar in size and immense complexity. However, trying to determine anything from only these visuals is near impossible; one thing for certain is that both networks contain a vast amount of connections and nodes, spanning beyond a basic line from 1st tier to 2nd tier to 3rd tier. The importance lies in finding where the focal firm (either IBM or Apple) sits in the cluster, and how much information passes through them and power exudes from them. Note: Apple's matrix has one node off to the side with no connections; it was later found to not have any significance or strong connection, however was already interlaced in the matrix analysis and so remained a node.

IBM Network Map

31

Apple Network Map
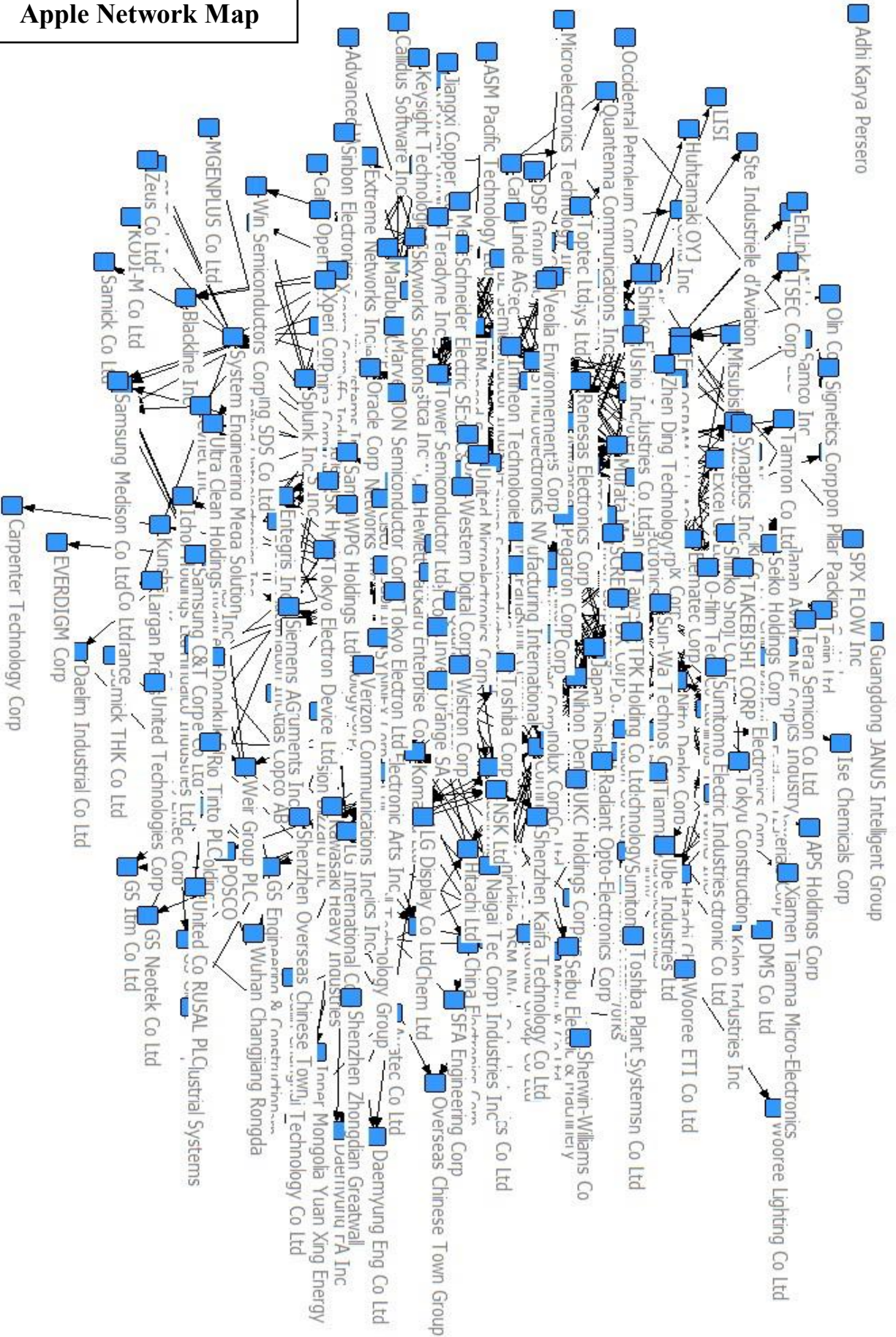
Metric Summary

The table below summarizes the rankings of the two focal companies in comparison to the other

firms in their network when measuring the embeddedness metrics discussed earlier. The number

of total nodes and connections for each network is also listed. Please use this table as a reference

for the following pages, which discuss each company's position in more depth.

Table 1: Ranking by Network Analysis Metrics

Company	IBM	Apple	Metric Importance
Number of Nodes	257	285	Describes size of social network; the larger, the more spread out buying is. Less nodes means many firms buy from same firms.
Number of Connections	915	950	Describes the number of buying relationships within network; more means higher interconnectedness and easier flow of information.
Beta Centrality	27	131	Those with direct ties with powerful, prominent suppliers. Identifies firms who are possible future partners to help facilitate sustainability measures based on position.
inCloseness	2	175	How easy it is to be reached by every other firm. Identifies companies easy to reach, but also finds firms hard to reach, allowing for change in approach.
outCloseness	1	1	How easy it is to reach every other firm. Finds companies that have large spread of relationships and can help implement efforts throughout network quicker.
Betweenness	1	8	How much information passes through a node. Identifies firms that either facilitate or serve as an information bridge and can provide insight on sustainability performance of others.
Brokerage (Coordinator)	2	70	Similar to Betweenness; how often a company serves as a connector of two firms not directly touching. Important in mapping routes to spread CSR efforts or knowing how to reach far-away suppliers.
Outdegree	64	1	How many ties exerted and their strength. Finds firms with concentrated COGS, allowing for more control over suppliers. Partners here can use leverage to make suppliers adhere to CSR efforts quicker.
Indegree	18	65	How many purchasing ties, or companies lots of firms buy from. Implementing sustainable practices with these firms can immediately trickle downstream.

Beta Centrality – With this being the most telling metric, we want to see a significant difference in ranking here between the two companies, and there is one. IBM (27th) sits over 100 positions higher than Apple (131st), meaning those companies that IBM is connected to are themselves much more well connected to IBM's 2nd and 3rd tier suppliers than Apple's direct connections are to Apple's 2nd and 3rd tiers. As mentioned earlier in this paper, centrality and power can often be derived from those companies who have well-connected partners, not necessarily being highly connected themselves. However, the results for this measure are surprising for both networks. Being the focal firm, the assumption was they would both be the most powerful or centralized company in their respective networks, yet neither were even in the top 10. This is something to be aware of for both companies (especially Apple) as it identifies several other companies as having substantial power in their own supply network.

While many of the companies in these networks are not direct/major competitors of the focal firms, IBM and Apple should both recognize their position relative to others in their industry, particularly those at or above their ranking. Regarding IBM's results, we do not see any competitors ranking above them. However, several of them fall right around IBM's power value, including Oracle (ranked 33rd), Hewlett-Packard (50th), and Super Micro Computers (63rd). In addition, it should be noted that major multinational companies comprise of several subsidiaries, many of which are nodes in each of these networks. For example: in both data sets, Samsung Group has seven different nodes with their own ties and connections. While we cannot combine these into a single value without forfeiting data accuracy, we can identify their individual locations and surmise their overall power.

When looking at IBM's network, three of these Samsung subsidiaries (Samsung Card Co, Samsung Electronics, Samsung SDS Co) rank higher in centrality than IBM does, and while this

may initially be seen as a threat and monitoring should take place, IBM should also view Samsung as a valuable partner in the dispersion of sustainable efforts due to their centrality and global reach. IBM can also use this metric to identify and be proactive to increasing supplier power; an example would be understanding the potential consolidation of centrality and power for possible mergers like the current news with Broadcom and Qualcomm, who rank in IBM's network at 12th and 38th, respectively.

For Apple, this metric may mean a shift in their approach to supplier relations. Apple likely would have measured higher if centrality was derived from having firms heavily reliant on them, as they buy substantially from a handful of suppliers. However, while they have absolute power over a few companies, they tend to close themselves off to all others, preventing centrality and connection beyond their 1st tier. They should be concerned with their position, and even more so with their competitor's positions. For example, Microsoft and many of Samsung's subsidiaries rank in the top 60 most centralized nodes, and IBM sits at 12th in Beta Centrality ranking in Apple's network, higher than they are in their own matrix! Apple should use this as a tool to identify threats as well as opportunities to develop relationships and increase their power and embeddedness.

inCloseness – As mentioned in the earlier sections, this metric focuses on the ease of reaching the focal firm from all other firms. Ranking only behind Intel Corp, IBM is extremely central in terms of the number of 'steps' needed to reach them. This allows for increased collaboration and the ability to see or hear changes or adherence of their sustainability initiatives. Apple's 175th ranking demonstrates the result of keeping their supply base narrow and hard to reach. Their low score in this metric indicates a hindrance to Apple as they may not readily see if their

sustainability initiatives are being implemented due to the several 'steps' the information must take to reach them.

outCloseness – Functioning as the opposite of inCloseness, this measures the ability of the focal firm to reach all other firms with minimal steps. This is an important metric as it is the simplistic answer to how easily the focal company can spread their initiatives; in other words, how fundamentally central they are. By basic logic, we would assume both focal companies to be ranked 1st in this metric as the network was built from them out. IBM and Apple both scored the highest rank in their respective networks, which is good news; it means at best they are still in a central location when looking at their network orientation. outCloseness would be incredibly telling if they were not 1st, meaning another company or node is better positioned to reach all other suppliers, which would be massively concerning. This is more of a reassuring measure than a crucial measure.

Betweenness – As defined earlier, this metric identifies how much information passes through a node or company. When looking at IBM, they ranked at 1st by an enormous amount, more than doubling the next highest company's score. However, IBM's network orientation may have skewed this metric. One of IBM's 1st tier suppliers is Sodexo, a food service company. Sodexo has hardly any overlap in their supply network with those of the rest of IBM's 1st tier, technology/electronic oriented companies. This created few ways for companies to access Sodexo and their partners, one of which being IBM. More evidence of this metric being skewed is that Sodexo is ranked 2nd behind IBM; this is further evidence that IBM and Sodexo are vital connectors of the 'food related' branch of IBM's network to the rest of the suppliers. While IBM

would likely still be 1st in this metric without the Sodexo relationship, it may not be by such a large amount.

Apple ranked 8th in their network for Betweenness, again falling behind competitors such as Samsung. This may cause serious issues; the implications could mean that if Apple wants to reach throughout their supply network to gain insight on sustainable practice and adherence, they may have to work through their competitors. Prior tensions and bad relations may inhibit Apple's data gathering or initiative spreading based on the amount of information that must pass through these massive rivals.

Brokerage – The various types of brokerage relationships are depicted in the earlier section. For the sake of this analysis, we will only look at the role of coordinator; that is, where all three companies are part of the same group, with one firm being the connector to another. Essentially, this is a simplified version of Betweenness. Where Betweenness looks at the amount of information passed through a node, the Brokerage metric looks at how often a node must be used to pass information or connect two indirectly connected parties.

IBM ranked 2nd, again behind Intel. While not 1st, IBM should feel empowered by this metric. Just looking at a relational level, IBM has positioned themselves to where firms trying to connect to certain other firms will use IBM as a coordinator. Not only does this build a relationship between IBM and both companies and increases IBM's status, it boosts the information sharing between IBM and its supply network, expanding visibility of events in their direct and indirect supplier base.

When it comes to Apple, we continue to see a lackluster ranking. Placing in 70th for this measure, Apple leaves itself vulnerable to companies within their supply network to seek out

other companies like Samsung, Hewlett Packard, or Microsoft (all in top 10 for Apple's network) for relational support, bypassing the focal firm. Ironically, Intel also took 1st in Apple's matrix, demonstrating their ability to be a liaison and connector throughout the technology industry.

Outdegree – This measure, though less important, offers some insight on those companies which have a broad 1st tier supplier list, or spend considerable COGS % on their 1st tier suppliers. Identifying those buyers or companies that exert lots or major ties can help with finding those who can help facilitate sustainability initiatives down through their suppliers. This was IBM's worst performance, ranked at 64th. For Apple, this was a bright spot, as they scored 1st in their network. However, this measure should be discounted due to the sheer nature of the analysis. Both focal firms automatically were given two more ties than the rest of the companies. We likely see the difference in IBM and Apple based on the % COGS spend on their 1st tier suppliers. IBM's highest COGS spend on one supplier was 4.54% for Super Micro Computers; Apple, known for a short supplier list with massive contracts and spend, saw 57.46% of COGS going to Hon Hai Precision, also known as Foxconn. This allows for a substantial amount of influence over Foxconn and presumably other 1st tier suppliers, therefore propelling them to the top for this metric.

Indegree – As stated earlier, the purpose of this metric involves determining companies that many people buy from. IBM scored 18th place in their network, right outside of the top 10%. While this is not a bad position, IBM should be aware of those near the top. Taiwan Semiconductor, ranked 1st, scored over 250% higher than Hon Hai Precision (2nd), and over 1200% higher than IBM. However, this poses more of an opportunity than a threat. Identifying

those major suppliers in the whole network can aid in the quick spread of sustainable products and services. IBM can partner with firms like Taiwan Semiconductor and Hon Hai Precision (a 1st tier supplier for IBM) and change production or procurement processes from the source, which will trickle down to those buying from these prominent suppliers. Apple, ranking 65th, can follow the same advice just listed; their network contains many of the same prominent suppliers, including Taiwan Semiconductor as the highest ranked.

6. CONCLUSION

We started this research by asking the question: How can companies use network ties and linkages to diffuse sustainability initiatives? The network comparison of two seemingly alike electronic companies contributed to the idea that understanding the structural alignment of power in a supply network does help with the diffusion of a focal firm's initiatives.

Research & Managerial Implications

From a theory perspective, this paper uses actual financial data from Bloomberg terminals and analytical mapping software UCInet, which services many academic studies on social network analysis. Bloomberg is commonly linked to financial research; utilizing the software with a supply chain focus contributes to the available resources for future research in the field. It also adds the ability to gather large amounts of data from one source with consistent formatting. Otherwise, the data may vary on different sites or by company to company. An area of interest arises surrounding the lack of varying brokerage relationships in these interconnected networks. Normally, one would witness the appearance of more than just a Coordinator role (see Section 4.4 for reference). With no subgroups within the network emerging, questions regarding

the ability to maintain network power can be explored. The approach and results of this study help further the idea that finding prominent nodes and ties within supply networks can aid in planning the distribution and spread of information regarding a focal firm's efforts and initiatives (Ellram and Tate, 2016).

For practical purposes, metric and mapping analysis sheds light on the position and embeddedness of the focal firm in their supply base. This practice is vital for two main reasons. Primarily, the analysis helps in assigning power and ranking to the focal firm while identifying avenues to which disperse initiatives. IBM and Apple have two varying scores when it came to perceived power, and therefore should react differently based on their position in the network. Companies like IBM who score fairly high in the several metrics used should aim to identify the powerful relationships and partnerships that have facilitated the embeddedness. Firms could manipulate their network to see how future contracts or procurement decisions may impact their relative position. Apple, showing a more mediocre performance, can analyze the model of companies like IBM and categorize the differences. Apple may want to spread out purchasing more or more openly seek relationships with 2nd and 3rd tier suppliers to gain prominence within their network.

In addition to assigning power to the focal firm, the analysis gives value to all other companies, allowing for identification of prominent players. As discussed in the sub-metric results, using this data can help the focal firm in finding powerful 1st tier or indirect suppliers in which facilitation and dispersion of initiatives can best be channeled. Identifying sources of power based on embeddedness or brokerage roles can help supply chain managers focus on who they can influence and who they may be influenced by. At the same time, it offers insight and awareness of competitors' overall power, as was the case with Apple and Samsung.

For a manager, the most important points to take away from this analysis is the acknowledgement that only looking at 1st tier suppliers as partners in sustainability is both inefficient and short-sighted. The SNA results showed that most of the time, the best implementers for supply networks lie beyond the focal firm's direct buying relationships. Supply chain managers need to understand the various metrics of SNA to find the companies in their supply base best suited for immediate and widespread dispersion of initiatives. It is not enough to reach out to the largest supplier or the easiest to communicate with. Resources should be allocated effectively, resulting in increased relationship with the prominent suppliers. Only then can managers best spread CSR efforts throughout their whole supply base.

This research and methodology could easily be applied and implicated among other industries, such as CPG or construction. The overarching theme is that social network analysis offers unforeseen knowledge of a company's supply network as well as techniques to best influence those around them. This idea can be a powerful device for any organization in any background, extending beyond publicly traded companies, if the data can be accessed.

Future Contributions & Limitations

While this research paper contributes to existing academia on SNA and supply network mapping, there are limitations to the analysis. Understanding social network analysis, the basic metrics, and what they can tell us does not directly help with adherence of sustainability initiatives, or aid in their formation of those efforts. Rather, it gives advice for how best to implement the dispersion based on key players and relationships within a supply network. As we have seen, neither the focal firm nor their 1st tier is constantly the primary influencer for a said network. Other limitations include the use of only two companies within a singular industry.

Most of these implications likely carry over through multiple industries, but this cannot be

assumed for all results and for all sectors. Another limitation stems from the inclusion of only a

small subset of all the SNA metrics calculated through UCInet. The group of measures used can

allow for implications from the results, however a deeper academic background in social

network theory and statistical measuring may yield additional methods to gauge prominence and

power.

While limitations exist, these offer further exploratory research opportunities. This

research identifies the importance of relational influence and how best to use these ties to spread

information. However, one area of further interest would be adjusting the values of the

relationships (% COGS) to observe the net change in structural power. The implications of this

analysis could lead to increased awareness of dependency or embeddedness of a firm; that is, the

more the company is unaffected by decreased ties, the more vital the company may be due to its

independency from singular relationships. This extension of this research topic could offer a

practical value, giving managers the ability to see underlying threats that may arise as

relationships shift. As this enhancement is explored, the conducting of similar analyses with

different industries may yield new results. Industries with different buying relationships or

materials/processes used may require a modified approach to initiative dispersion.

While it would be rather hard to correlate, and would have to take place over an extended

period, it would be interesting to see if companies that position themselves prominently in a

supply network achieve the goal of dispersion and adherence of their initiatives. Identifying

suppliers and monitoring changes in reporting or sustainable efforts that mimic that of a powerful

partner would solidify the significance of network analysis as a supply chain tactic. Furthermore,

including the impact and relational power of Non-Governmental Organizations (NGO's) to

better analyze their importance to sustainable practice and company performance. The addition of a select few regionally powerful NGO's could help illustrate their influence, and possibly the importance of government regulations, which many NGO's use as a basic metric for company evaluations.

This research focused on two primary companies, IBM and Apple, and their corresponding networks. The information and ideas understood through this research can be broadened with future studies in this field. After acknowledging the impact of proper network mapping can have on a company's ability to influence is realized, more ways and theories to refine this basic notion will be discovered.

REFERENCES

About CR. (n.d.). Retrieved October, 2017, from http://www.corporateregister.com/about/

Anderson, D. R. and Anderson, K. E. (2009), Sustainability Risk Management. Risk Management and Insurance Review, 12: 25-38, from https://onlinelibrary.wiley.com/action/showCitFormats?doi=10.1111%2Fj.1540-6296.2009.01152.x

Apple Environment. (n.d.). Retrieved January, 2018, from https://www.apple.com/environment/reports/

Bennett, M., James, P., & Klinkers, L. (2017). *Sustainable Measures: Evaluation and Reporting of Environmental and Social Performance*. New York, NY: Routledge.

Bloomberg L.P. (2017) Company information for International Business Machines, Retrieved Nov. 6, 2017 from Bloomberg database. Used to gather all data for percent spend relationships, Retrieved Oct-Nov. 2017 from Bloomberg database.

Bonacich, P. (1987). Power and Centrality: A Family of Measures. *American Journal of Sociology,92*, 1170-1182. Retrieved from http://www.leonidzhukov.net/hse/2014/socialnetworks/papers/Bonacich-Centrality.pdf

Borgatti, S.P., Everett, M.G. and Freeman, L.C. 2002. Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.

Bratton, K. (n.d.). Network Analysis - Resources. Retrieved from https://www.lsu.edu/faculty/bratton/networks.htm

Brundtland, G. H. (1987). *Our Common Future* (Switzerland, United Nations, WCED). Geneva, Switzerland: United Nations. Retrieved March 2, 2018, from https://www.are.admin.ch/are/en/home/sustainable-development/international-cooperation/2030agenda/un-_-milestones-in-sustainable-development/1987--brundtland-report.html

Corporate Responsibility at IBM. (n.d.). Retrieved January 15, 2018, from https://www.ibm.com/ibm/responsibility/

Deloitte's 2016 Global Outsourcing Survey. (2016, May 1). Retrieved from https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/operations/deloitte-nl-s&o-global-outsourcing-survey.pdf

De Nooy, W., Mrvar, A., & Batagelj, V. (2011). *Exploratory Social Network Analysis with Pajek* (2nd ed.). Cambridge, UK: Cambridge University Press, from http://www.cambridge.org/us/academic/subjects/sociology/research-methods-sociology-and-criminology/exploratory-social-network-analysis-pajek-2nd-edition?format=HB&isbn=9781107002388#9LMQUoF8BIqmKZPT.97

Electronic Industry Citizenship Coalition. (n.d.). Retrieved from http://supply-chain.unglobalcompact.org/site/article/33

Ellram, L. M., & Tate, W. L. (2016). Mapping networks and the influence on the natural environment. *Implementing Triple Bottom Line Sustainability into Global Supply Chains*.

Fortune 500 List. (n.d.). Retrieved January, 2018, from http://fortune.com/fortune500/

Fredericks, K. A. and Durland, M. M. (2005), The historical evolution and basic concepts of social network analysis. New Directions for Evaluation, 2005, from https://onlinelibrary.wiley.com/doi/abs/10.1002/ev.158

Freedman, A. (2016, March 21). Apple brags about its environmental progress, but the truth is it still has work to do. Retrieved from https://mashable.com/2016/03/21/apple-environment-goals-consumerism/#9eTjruJUM8qi

Gilpin, L. (2015). How tech companies are propelling the environmental movement, and why it's time to do more. Retrieved from https://www.techrepublic.com/article/how-tech-companies-are-propelling-the-environmental-movement/

Global Reporting Initiative. (n.d.). "About GRI." Retrieved March 25, 2018, from https://www.globalreporting.org/Information/about- gri/Pages/default.aspx GRI Reports List obtained through student registration.

Hanneman, R. A., & Riddle, M. (n.d.). Introduction to Social Network Methods. Retrieved from http://www.faculty.ucr.edu/~hanneman/nettext/C11_Cliques.html

Henderson, R., & Ponce de León Baridó, P. (2009). Environmental Management at IBM (A): Making Sustainability Sustainable through Passion and Process. *MIT Sloan School of Management*. Retrieved from https://mitsloan.mit.edu/LearningEdge/CaseDocs/09-089.Environmental Management at IBM.A.Henderson.pdf

International Organization for Standardization. (n.d.). "All About ISO." Retrieved March 25, 2018, from https://www.iso.org/about-us.html

Introduction to Social Network Analysis. (n.d.). Retrieved from https://www.sagepub.com/sites/default/files/upm-binaries/35208_Chapter1.pdf

Jarvie, M. E. (2016, May 20). Brundtland Report. Retrieved March 3, 2018, from https://www.britannica.com/topic/Brundtland-Report

Kolk, A. (2003), Trends in sustainability reporting by the Fortune Global 250. Bus. Strat. Env., 12: 279-291, from https://onlinelibrary.wiley.com/doi/full/10.1002/bse.370

Lash, J., & Wellington, F. (2007). Competitive Advantage on a Warming Planet. *Harvard Business Review*. Retrieved November 28, 2017, from http://courseresources.mit.usf.edu/sgs/geb6930/module_3/read/competative_advantage.pdf

Leppelt, T., Foerstl, K., Reuter, C., & Hartmann, E. (2013). Sustainability management beyond organizational boundaries–sustainable supplier relationship management in the chemical industry. *Journal of Cleaner Production,56*, 94-102. Retrieved from https://www.sciencedirect.com/science/article/pii/S0959652611003829.

Mollenkopf, D.A. & Closs, D.J.. (2005). The hidden value in reverse logistics. Supply Chain Management Review. 9. 34-43, from https://www.researchgate.net/publication/284429000_The_hidden_value_in_reverse_logistics

O'Malley A.J., Onnela JP. (2017) Introduction to Social Network Analysis. In: Sobolev B., Gatsonis C. (eds) Methods in Health Services Research. Health Services Research. Springer, Boston, MA, from https://link.springer.com/referenceworkentry/10.1007%2F978-1-4939-6704-9_15-1

Reuters: Apple Inc. Overview. (n.d.). Retrieved January, 2018, from https://www.reuters.com/finance/stocks/company-profile/AAPL.O

RobecoSAM. (n.d.). DJSI Family Overview. Retrieved March 25, 2018, from http://www.sustainability-indices.com/index-family-overview/djsi-family-overview/index.jsp Historical data of indices downloaded as Excel file from website.

Savitz, A. W., & Weber, K. (2006). *The Triple Bottom Line*. San Francisco, CA: Jossey-Bass.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production,16*(15). Retrieved from https://www.sciencedirect.com/science/article/pii/S095965260800111X.

SmartWay Excellence Awardees. (2017). Retrieved from https://www.epa.gov/smartway/smartway-excellence-awardees Produced by the EPA.

SPLC Screenshot. (n.d.). Retrieved from https://lippincottlibrary.wordpress.com/2013/01/29/bloomberg-highlights-round-1/

Towards the Circular Economy (Vol. 3, Rep.). (2014). Ellen MacArthur Foundation. Retrieved from https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-3-accelerating-the-scale-up-across-global-supply-chains

Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications (Structural Analysis in the Social Sciences)*. Cambridge, UK: Cambridge University Press, from https://books.google.com/books?hl=en&lr=&id=CAm2DpIqRUIC&oi=fnd&pg=PR21&dq=social+network+analysis+wasserman&ots=HwHlxd2FKc&sig=AGITRdSTFvwpMaxOaIGYM1rr5h0#v=onepage&q=social%20network%20analysis%20wasserman&f=false