REDUCING HUMANITY'S CARBON SHOEPRINT

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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It is not a commonly known fact that the fashion industry is notorious for being one of the highest contributors to water pollution and greenhouse gas emission (Remy et. Al, 2016). Specifically, footwear is the product of dye, chemical adhesives, and coal-powered machinery with very few forms of recycling (Rawes, 2017). In recent years, the footwear market has seen a great spike in attention and scrutiny in the fashion, sports, and tech worlds. As shoes are used by most people every day, production of shoes has reached "more than 20 billion pairs of shoes manufactured each year" according to writers of The Shoe Industry blog (2014, para. 1). With more shoes produced than there are people on Earth, what happens to all these leftover shoes? According to Rawes (2017), over 85% of shoes, either leftover or recycled, are dumped in landfills, and the harsh chemical adhesives that keep the shoe together and the materials themselves do not degrade typically. To counteract this ominous trend, a fundamental change must occur in the industry's manufacturing processes and materials and in society's view of fashion and function of shoes. The technical capstone seeks to show how 3D printed shoes can lead the way in patient customization and performance relative to time invested. The STS question asks how DIY processes like artisan makers or 3D printing reduce the carbon footprint of the shoe industry and its manufacturing practices. These topics are tightly coupled since the technical project also serves as a possible solution to the STS question.

ENVIRONMENTAL IMPACT REDUCTION

THE CARBON SHOEPRINT

The term carbon footprint is used to measure the "biocapacity… [used]… to take care of our untreated carbon waste and avoid a carbon buildup in the atmosphere" according to Global Footprint Network (para. 2). Increased carbon emission and resulting carbon footprint result in

overcompensation from the Earth's atmosphere to absorb and neutralize the carbon dioxide from the fossil fuels leading to trapping of greenhouse gases and global warming. McLoughlin (2020), a sneakerhead industry expert and writer for athletic shoe website, RunRepeat, found each pair of shoes emits 14 kilograms of carbon emissions on average throughout its lifecycle. Of the 14 kilograms, most emissions are byproducts of materials processing and manufacturing. That amount of carbon emission is equivalent to keeping a 100-watt light bulb powered for one week (Chu, 2013, para. 1). Jennifer Chu reports indications that most greenhouse-gas emissions in the manufacturing process come from shoe plants in China where coal is the main source of electricity. China is the location where a significant amount of the world's shoe manufacturers resides (2013, para. 5).

Three components make up a shoe dubbed the upper, midsole, and outsole. The upper refers to the material used for containing and covering the foot. The midsole refers to the cushioning and section of the shoe where the upper is connected to the lower portions of the shoe that touch the floor. Finally, the outsole refers to the very bottom of the shoe where a traction pattern is carved out of the rubber or ground contact compound. Each shoe component has its own contributions to the downsides that shoe creation and disposal have on the environment (McLoughlin, 2020). The processing of both natural materials like leather and synthetics like polyester in the upper contribute to 4 kilograms. The manufacturing processes used to sew the upper to the midsole and to mold the midsole and outsole emits 9.5 kilograms. The remainder accounts for the delivery and shipping of the shoe and the disposal (McLoughlin, 2020). Shoes also have an unhealthy impact post-sale since disposal and recycling efforts for shoes are almost non-existent as about 85% of shoes are tossed in landfills (Rawes, 2017). According to Wes (2019), the average number of shoes a single woman owns ranges from 17 to 27 pairs. The

number can be assumed to be less for most men. However, with the rise of sneakerhead and hypebeast culture, more men are purchasing shoes that are made in China and storing them instead of wearing (Smith, 2014). The hype behind sneakers has allowed for more used shoes to be seen as valuable. Certain Jordan 1 models are going for over $500 dollars used. However, such shoes are not made to last, and they will eventually be thrown out when not useful to the user.

CHANGES IN THE MAKING

When users have gotten their wear out of a shoe, it is placed in the trash where it is sent to the landfills to sit for many years while diffusing harmful chemicals and fossil fuels into surrounding mountains of chemicals from shoes. Goldenberg reports that a research group at MIT found the manufacturing of those goods in Chinese countries with coal machines involved 360 different steps in the process to assemble one shoe (2013). In general, McLoughlin (2020) shows in the data that real change needs to come from the manufacturing as it contributes more than 64% of carbon emissions regardless of what materials are made from. In Figure 1 on page 4, the general network of Nike's manufacturing plan involving all their changes to practices is shown with codes, standards, and areas of improvement. Nike's plan is to halve the environmental impact through implementing changes on a per unit measurement while doubling production (McLoughlin, 2020). However, the total carbon emission and environmental impact as a whole is still negative as 35% carbon emission reduction per unit while doubling units produced is still a net increase of emission. One of Nike's goals is to transition to 100% clean renewable energy such as wind power. Currently, coal practices are the prevailing practice in the factories in China. McLoughlin states that wind power carbon emissions are only 1.5% of coal carbon emission. If the factories went completely wind powered, the total carbon power would

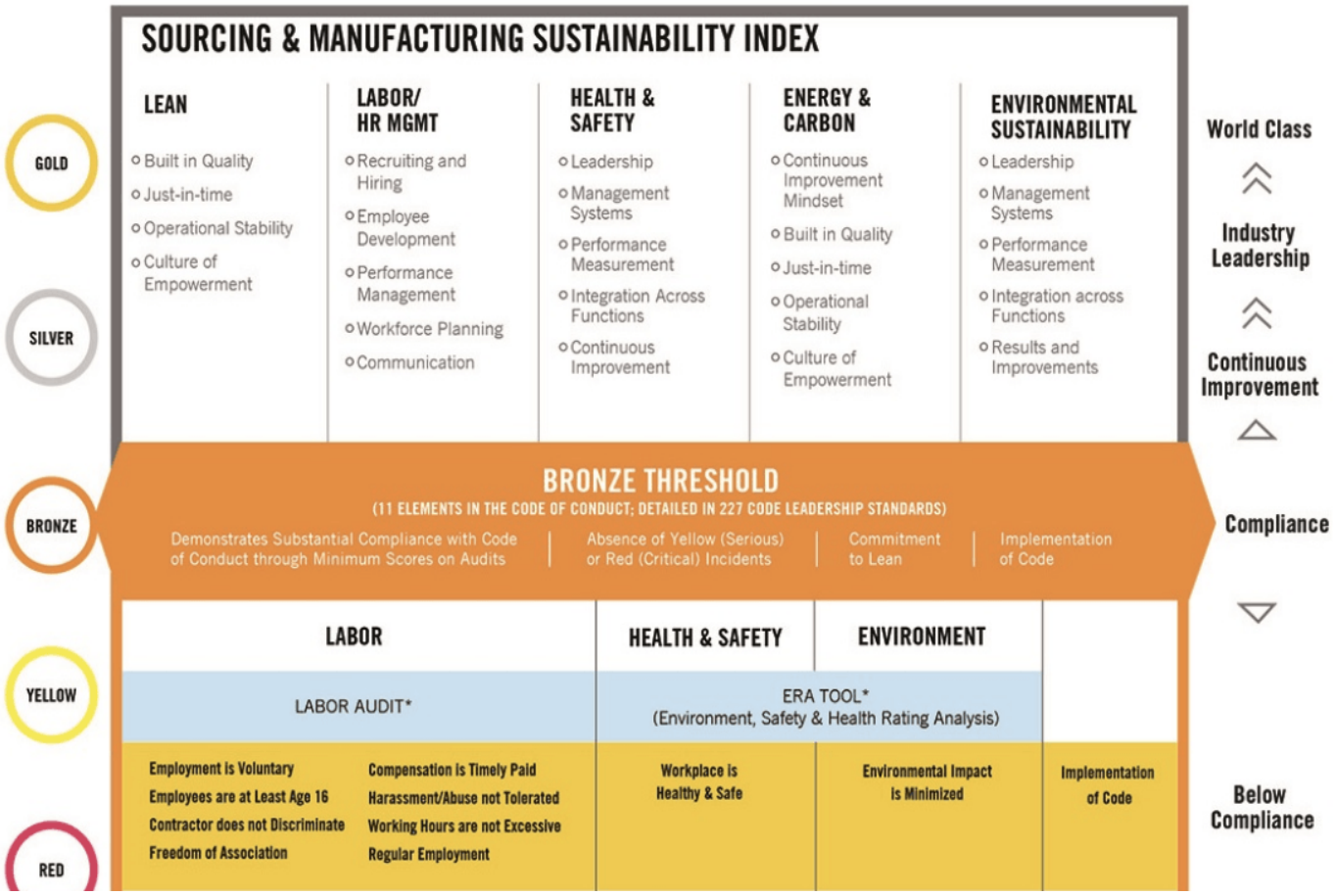

Figure 1: Nike's Sustainability Index. This graphic shows where Nike sees where it needs to grow and improve on based on code standards in terms of sustainability. (Nike, 2019)

be down 62.9% represented visually and quantitatively in Figure 2 illustrated on page 5. However, due to most factories' location in China, Nike does not pressure the Chinese factories or add extra funds to make transitioning more feasible. According to McLoughlin (2020), Nike shines over other companies like Adidas in its end-of-life programs and options. Nike has programs like Nike Grind and Reuse-a-Shoe where unwanted shoes can be ground and repurposed as running tracks or basketball courts for example. On the other hand, Adidas had no real options until recently. The Adidas Futurecraft Loop is a series of shoe models made with 100% recyclable plastic and includes a circular product model where the customer can recycle

their shoe after using it and getting a new model with that same plastic used after recycling (Adidas, 2019). The process is not fully disclosed but one can assume that the manufacturing and recycling process has a possibility of saving more carbon emission in the long run. Adidas has not implemented the strategy as of the time of writing but having a renewal plan is beneficial for everyone. These two companies are considered by many as the largest movers in footwear with the largest amount of production facilities. Unexplored micro-companies may have better practices, but do not have the authority and draw of these giants. The flagship shoe companies should lead the way in changing their manufacturing methods. The cause is larger than just money as change is required for the long-term livelihood of the world. Nevertheless, the majority of shoes do not have plans like these and still end up in landfill.

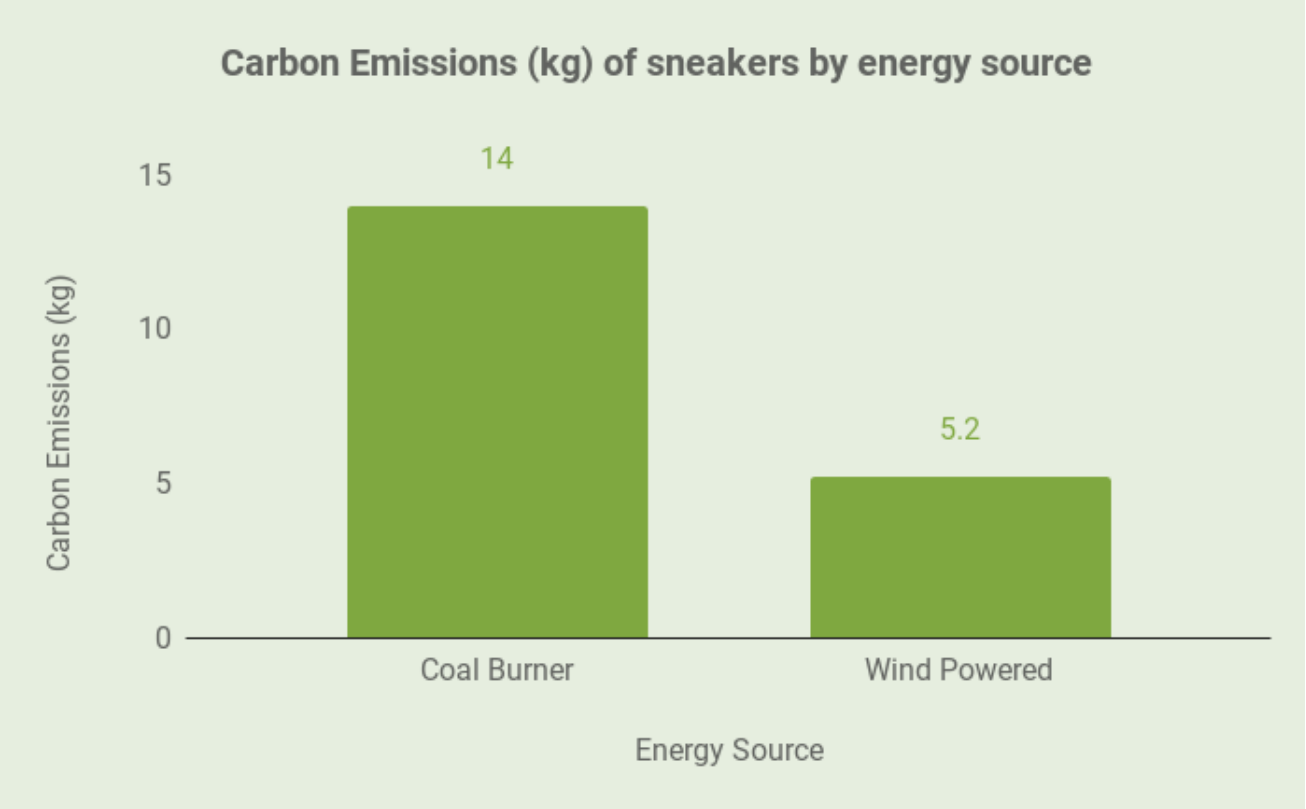

Figure 2: How Energy Sources Affect Carbon Emission. The graph above compares the carbon emission in kilograms per produced shoe made in two categories, fossil fuel and renewable energy. The difference is 8.8 kilograms (McLoughlin, 2020, section “100% Renewable Energy”).

SUSTAINABLE SHOES

Eco-friendly sneakers have been marketed to customers as a carbon-emission reducer. The majority of green sneakers only involve using recycled plastic materials. Other elements of eco-friendly include recycled rubber, insoles, outsoles or leather, and biodegradability. Adidas frequently markets their Parley line where the company teamed up with Parley for the Oceans and sold millions of sneakers where the knit upper of the shoe was made with recycled ocean plastics from bottles in the ocean instead of regular polyesters (Business Insider, 2018). In total that leads to a 1.33-kilogram reduction in carbon emissions and riddance of harmful bottles in the ocean. The 1.33-kilogram reduction is only a small portion of the total 14 kilograms of carbon emission from creating the whole shoe (McLoughlin, 2020). Even if the whole shoe itself were made with 100% recycled materials the carbon savings would only reach 24%. Other sustainable sneakers have achieved lesser results according to McLoughlin (2020). Other companies are marketing some of their shoes as biodegradable regarding certain sections like the midsole as mentioned by McLoughlin (2020). However, the post-disposal carbon emissions only amount to 0.5 kilograms while the majority of emissions are still taking place in the manufacturing phase as aforementioned. While having a biodegradable shoe is commendable for taking away space in the landfills, the company's efforts could be focused on improving biocapacity by working on manufacturing practices.

Sadly, most companies' markup their eco-sneakers by 69.4% meaning they profit from consumers wanting to help with pollution in the world. In truth, the most carbon-emission-friendly practice is to buy less shoes. However, it is extremely difficult for these footwear brands to tell their customers to buy less shoes (McLoughlin, 2020). Footwear is increasingly becoming

intertwined with the world of fashion. Fashion itself is shifting trends at a surprising rate faster than anything prior especially to the public. Celebrities and designers used the opportunity of social media to reach a wider audience with their outfits and designs. In the famous-centric world of today in 2020, others aim to be like them starting with their attire (Skeldon, 2019). Fast fashion brands feed on that desire by imitating the designer brands that the celebrities wear for a cheaper price but at the cost of quality. At the same time, these fast fashion companies are dubbed "fast" because they release new collections of clothing much faster and with higher frequency than the seasonal collections of designers. This worrisome trend has caused average consumer purchases of clothing articles to increase by 60% as reported by Remy et. Al (2016). The same principles have carried over to shoes as well. Fast fashion stores who market themselves as clothing companies have imitated shoe designs from popular brands with much lower quality and lesser materials to expand their market. The trends led to an increase in disposed clothing and shoes.

Quality and durability can be a rare commodity in the shoe world especially in sneakers. In countless online forums like Reddit and Tennis Wearhouse (2018), many customers are reporting lowered quality resulting in lackluster durability and need for replacement. For some sneakerheads, buying shoes is an addiction or a secondary income. Evidently, sneakerheads may feel buying a certain shoe and having it in their collection entitles them to a degree of respect in the community. Some sneakerheads purchase in-demand or hype sneakers with the express intent to sell on the resale market (Smith, 2014). Sneakerheads can have collections ranging from seven sneakers to a thousand.

PROFESSIONAL AND HOMEMADE ARTISANS

Before the 1500s, shoes were custom-made for each individual client since the machinery to create more shoes on a larger scale did not exist yet. When more efficient ways of producing shoes emerged, shoemakers began mass-producing according to standardized sizes and stocking them for instant transactions (Independent Shoemakers, n.d.). As a result, carbon emissions were little to none back in those days when it came to shoe-making. The materials prescribed were mostly the same involving mostly leather of some form and wood and eventually rubber. The nature of leather's composition allows in to be an incredibly tough material that can flex when broken in. These artisan-crafted pure leather and stitching shoes were special, expensive, and durable. In contrast, the materials in today's shoes involve raw materials like leather, but also many forms of synthetics such as polyesters for the uppers and polyurethane foams for the midsole. In the current age of industry, there are more processes that involve carbon emission and automation. As a result, the need for personal human attention has dwindled. Certain companies pride themselves in keeping the traditional crafts alive by incorporating machines but add a human touch such as Allen Edmonds and Alden. These types of companies create specific shoes that allow for a resole process which replaces the worn-down lower half of the shoe with a new outsole and midsole. Specific stitches that connect the upper to the midsole called a welt will be required, and human hands with welting tools are needed to perform the process up to the heritage standards. From these forms of techniques, the upper can remain the same while the used sole can be replaced, extending the life of the shoe for potentially a human lifetime. The technique is limited only by the condition of the upper as it remains through every "reincarnation." These techniques are seen as standards of quality in more formal men's

footwear (Murray, 2019). Furthermore, quality has been a growing standard for hipster groups who see higher quality as reducing waste. These hipsters and millennials have arrived at handmade or DIY shops and forums such as Etsy or this linen shop for millennials (Canal, 2017). Potentially by seeking out these contemporary artisans, the average consumer can wear their shoes for a longer period of time.

ACTOR NETWORK

Bespoke services are services that create items "made from scratch to…[one's] specifications" custom-made exactly to the client's preferences including style, fit, and color (GQ, 2001). The cost of bespoke clothing and shoes is expensive, but has a certain niche in the market especially for the wealth. Carrying bespoke forward on a smaller scale, the maker movement is essentially the experimental process of do-it-yourself or DIY expanded to all walks of life including bespoke articles like clothes and shoes. If shoe creation is taken from the maker movement's point of view, it is important to consider who the maker is working with and how they have access to their materials. As the maker is creating the product with a specific demographic in mind, it is up to him to decide what manufacturing process would meet his needs in terms of numbers. The maker also decides what materials he will use as according to the specifications of the project and of the client. If he is considering making the product for several people, he should consider more machinery usage at the cost of personal hand-stitching and welting. Inherently, most DIY projects will have much lower carbon emission values than shoe manufacturing factories as there is less automation and less access to machines and materials. 3D printing has allowed for use of recyclable plastic to create usable products customized to the user. Instead of emitting large amounts of carbon dioxide to assemble and treat materials for products, additive manufacturing methods like 3D printing eliminate many steps and can build

an assembly without the need for negative manufacturing steps (Weitecamp, 2019). Kai Goerlich of *The D!gitalist* backs up the idea that DIY practices such as 3D printing has been shown to revolutionize how bespoke items are made including the speed in which they are made and the quality of the final product (2015, section 2). 3D printing also has the chance to use recycled plastics allowing for repurposing and maybe total carbon emission reduction. Figure 3 (p.10) shows the network analysis of technological change that forms when an individual "maker" decides to make a shoe. A maker is any human essentially that partakes in creation but a participant in the maker movement is a DIY hobbyist including engineers and artisans (Gantt, 2013). Actor Network Theory is used to "illustrate a method of social analysis that takes the technical aspects of the engineer's work to be profoundly social," and see how interactions with stakeholders and institutions impact the design process (Law and Callon, 1988). In this case, the structure of the network is centered around the maker who is impacted by the customer as the

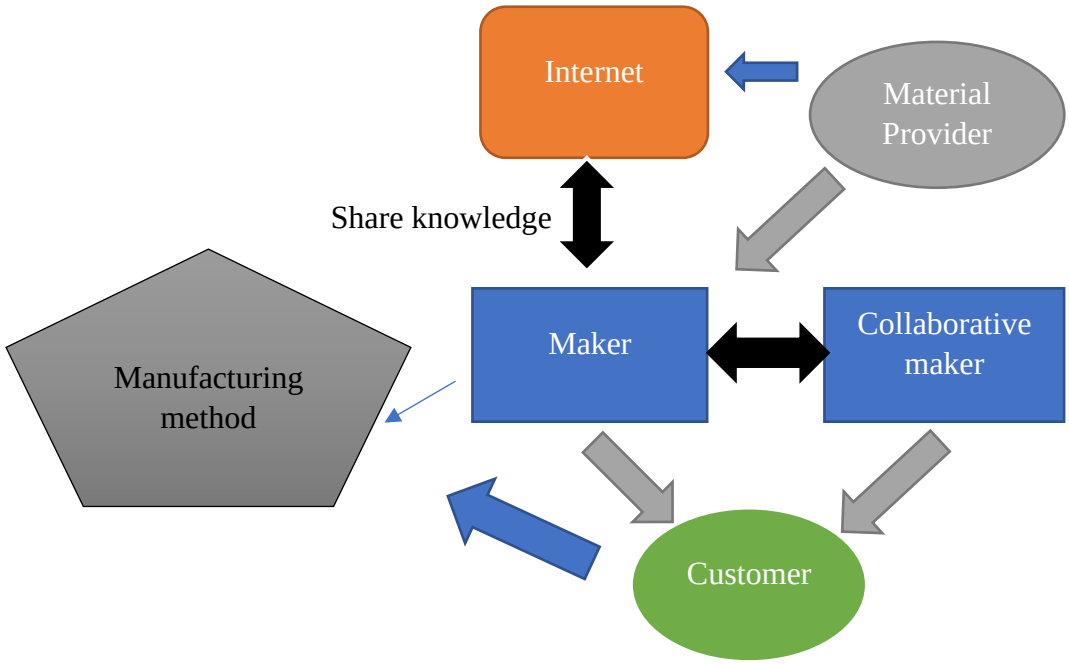

Figure 3: Actor Network of Maker Movement. By finding a compromise in manufacturing methods, both the makers and the customer can obtain high quality products and lower carbon emission. It is possible for the maker to be the customer himself as DIY projects are for himself. (Phan, 2020)

main stakeholder. These various influences will shape how the end product is realized. By analyzing each actor in the network, it is possible to see how DIY can significantly reduce carbon emission in creating shoes.

CUSTOM SHOES

Fit and comfort are drastically important to the long-term satisfaction and performance of a shoe especially sport-focused sneakers. Certain shoes in the market allow for foot molding for shoe interiors like cork footbeds. However, there are other more automated methods that allow for a true identical fit of the shoe. It would be beneficial to consider how custom shoes fair in terms of waste and find whether they have an advantage in terms of recycling and sustainability. The discussion expressly connects the STS question to the technical project. In the technical project, the capstone team developed and 3D printed a midsole contoured to a patient's foot based on a 3D scan of their feet. By modulating certain areas of computer-generated infill and support structures in the midsole, the team aims to provide customized support in the arches and heels to help lower foot pain such as plantar fasciitis. By customizing the midsole cushion according to the patients' needs and afflictions, the capstone team hopes to allow for optimized comfort and performance. This technology may alleviate the patient's desire to have multiple pairs of sneakers. The custom midsole can be designed to attach to any upper allowing it a freedom limited only by the formality of the shoes and the imagination of the designer. By having one unique go-to sneaker, consumers will reduce their spending on shoes while purchasing smarter.

CONCLUSION

In order for true environmental change to occur, manufacturing practices must be updated and upheld to a certain engineering code of standards. The engineers in charge of these manufacturing practices must be incredibly mindful of the future of their practices as those before them lacked the technological literacy to act with knowledge of their potential consequences. The maker movement offers a true way to obtain knowledge, high quality goods, and lower carbon emissions as the maker is in charge of all facets of the production process. The end result will likely be cheaper and last longer due to more personal craftsmanship. A greater durability in objects will help the environment in the long run as buying less is maybe more for the world. No one loses when approaching a small business artisan for a quality product or when trying to make something new for the first time. Creating something and failing always allows one to learn from their mistakes and keep working, alone or with others, to overcome their weaknesses. Everyone is a potential maker in the DIY sense and buying excessive amounts of shoes from a corporation takes that potential away for many consumers. There is no carbon emission cost for taking the power to create into one's own hands and mind.

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