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The social impacts of products: a review

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ABSTRACT

Many agree that every product has economic, environmental, and social impacts on those who use and produce them. While environmental and economic impacts are well known and measures have been developed, our understanding of social impacts is still developing. While efforts have been made to identify social impacts, academics, and practitioners still disagree on which phenomena should be included, and few have focused on the impacts of products specifically compared with programs, policies, or other projects. The primary contribution of this review essay is to integrate scholarship from a wide array of social science and engineering disciplines that categorizes the social phenomena that are affected by products. Specifically, we identify social impacts and processes including population change, family, gender, education, stratification, employment, health and well-being, human rights, networks and communication, conflict and crime, and cultural identity/heritage. These categories are important because they can be used to inform academics and practitioners alike who are interested in creating products that generate positive social benefits for users.

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Introduction

Regardless of whether explicitly considered, every product has economic, environmental, and social impacts (Norman and MacDonald 2004). Economic impacts are typically tied to profitability, wages, and employment and have long been considered with respect to product development. More recently, environmental impacts have garnered much interest, resulting in valuable tools that allow engineers to understand better the environmental impact of design decisions (e.g. McDonough and Braungart 2002). Though exceptions exist, social impacts have not yet been the focus of significant research efforts or included in the calculus utilized by engineers to evaluate product design features. Yet, the concept of social impacts – the influence of a product ‘on the day-to-day quality of life of persons’ (Burdge 2004, p. 2) – has a long-standing tradition in the mechanical and manufacturing engineering professions, whose codes of ethics emphasize holding ‘paramount the safety, health and welfare of the public’¹ and considering ‘the consequences of [our engineering] work and societal issues pertinent to it.’² Despite the genuine and near-universal acceptance of these sentiments, most practitioners do not commonly characterize the social impact of products beyond the basic principles of mechanical and structural safety. Therefore, understanding the social impacts of design

frequently remains out of sight and reach of those who create and manufacture products.

Although literature on the social impacts of products has traditionally been scant, a growing number of resources have been published. Guidelines have been established, such as the United Nations Environment Program (UNEP) Guidelines for Social Life Cycle Assessment of Products, to promote the assessment of the social impact and sustainability of products. A variety of blog posts and other websites offer broad guidance and illustrative case studies. The academic literature devoted to social impacts of products lags behind the attention given to the topic by practitioners in the non-profit sector. Exceptions include Vanclay (2002), Epstein and Yuthas (2014), Fontes et al. (2016) who note that the relevance of particular social impacts often depend on the local context or community. Nevertheless, they discuss ways to identify relevant social impacts in these settings; identify broad topics to assess such as environment, community, health, and economy; and provide examples related to these topics.

While these efforts often result in lists of social impacts that scholars and practitioners would do well to consider and represent a useful and growing body of literature, their grounding in empirical research is often limited. Many of these sources that offer lists of social impacts have been generated from the authors’ experience or influenced by the authors’ ‘prejudices and biases’

(Vanclay 2002, p. 184). In this paper, we take a modest step toward addressing this issue by integrating a wide range of studies in the social science and engineering literatures with the intent to better inform our conception of products' social impacts. Accordingly, based on our reading of the literature we too have identified a range of social phenomena that are impacted by products and technology and that fall under the broad themes of population change, family, gender, education, stratification, employment, health and well-being, human rights, networks and communication, conflict and crime, and cultural identity/heritage. In addition to integrating a wide range of literature that comes from social science and engineering literatures on the social impacts of products, we suggest that additional efforts to articulate social impacts should build a cumulative body of research based on previous studies. These efforts should focus on systematically building findings and identifying scope conditions rather than relying on personal experience or bias. Before discussing these social phenomena that are affected by product use based on our literature survey, however, in the next section of the paper we provide an overview of the existing frameworks that call attention to the various dimensions of social life that are impacted by products.

Existing frameworks

A growing number of resources have been provided that outline social impacts to consider when designing and implementing a new program or product. Social impact assessment (SIA) is a well-established framework for examining the expected consequences of a planned intervention such as a new policy, program, or technological development on the well-being of a community (Esteves et al. 2012; Freudenburg 1986). Many development projects pursued by non-profit and government organizations today include an SIA component to better understand their consequences (Esteves et al. 2012). SIA, as outlined by Burdge (2004) highlights many dimensions of community life that may be affected. These include population impacts (e.g. influx of temporary workers or seasonal residents, relocated individuals, and the demographic composition of the population), community and institutional arrangements (e.g. interest group activities, changes in the size or structure of government, and changes in wages or employment), communities in transition (e.g. presence of outside agencies, level of inter-organizational cooperation, introduction of new social classes), individual and family level impacts (e.g. disruption of patterns of daily living and social networks, change in family structure, perceptions of public safety), and community infrastructure needs (e.g. change in community infrastructure, land acquisition and disposal, and effects on cultural or historical resources). Vanclay (2002) also provides perhaps the most extensive

summary list of social impacts identified to date. These include health and well-being (e.g. social capital, health and fertility, and mental health); quality of living environment (e.g. exposure to safety issues, disruption of daily activities, and recreational opportunities); economic and material well-being (e.g. standard of living property values, and occupational prestige); cultural impacts (e.g. loss of language or cultural heritage); family and community (e.g. changes in family structure or sexual relationships); institutional, legal, political, and equity impacts (e.g. viability of government, violation of legal rights, and access to legal procedures); and gender relations (e.g. women's reproductive rights, women's autonomy, and division of labor).

Epstein and Yuthas (2014) build on the insights of Life Cycle Assessment for which social impacts are related to the rights and safety of workers who manufacture a product (Benoît et al. 2010; Jørgensen et al. 2008) as well as the relevant social impacts of products for their users. The broad impacts that Epstein and Yuthas identify include the environment, community, health, and economy. Epstein and Yuthas also provide sample measures of each impact that are associated with a range of possible outcomes that may be experienced within a particular community (see Figure 21, p. 162). In addition to their measures related to the natural environment, their sample measures of health include, among other things, life expectancy, infant mortality, number of people suffering illness or death, and number of visits to clinics per year. The sample measures of community and economy consist of the same measures and involve perceptions of safety, crime rate, number of community meetings attended, and number of people with access to transportation and latrines.

A recent handbook by Fontes et al. (2016) provides a useful and detailed account about how to conduct social impact assessment. The handbook identifies the relevant stakeholders that must be considered when assessing social impacts as consumers, workers who manufacture the products and participate in the supply chain, and local communities. Fontes et al. (2016) also identify social topics to be assessed for each stakeholder and measures related to each topic. Social topics related to workers include a variety of items, but examples include health and safety, discrimination, and work-life balance. For consumers, topics are limited to health and safety, and well-being. For the last stakeholders, communities, examples consist of health and safety, access to tangible resources, and community engagement.

The Technology Assessment literature provides another framework that addresses the economic, environmental, and social sustainability of technology. This interdisciplinary field seeks to understand and minimize potential damage that can arise from uncritical application of technologies, incorporating various methodologies in pursuit of that goal. Such

popular methodologies that consider social impact include Constructive Technology Assessment (CTA), which frames technology within a larger societal context, often shaping technology design in order to improve social outcomes (Van Den Ende et al. 1998). CTA achieves this through focusing on incorporating more stakeholders into the design process. Another noteworthy Technology Assessment methodology is the Social Shaping of Technology (Williams and Edge 1996), which examines the social conditions and context under which technology and innovation come about. From these and various methodologies, a significant contribution of the field of Technology Assessment is the increased awareness in promoting positive social, economic, and environmental impacts while minimizing future damages in designing and distributing technology.

However, the scope of social impact consideration historically has remained limited within this field (Russell et al. 2010). An emerging framework, Technology Assessment in a Social Context, addresses these limitations by utilizing the work of Vanclay (2002) in SIA to incorporate a greater understanding of social impacts and processes (Russell et al. 2010).

These frameworks are exceedingly valuable for those interested in understanding a range of social phenomena affected by products and technology; however, they provide little-to-no empirical support as a basis for justifying the categories they identify as social impacts. These frameworks often provide intuitive concepts based on authors' perceptions or described in 'ethnocentric terms' (Vanclay 2002, p. 188), but lack a systematic investigation that generates a cumulative trajectory of work based on previous empirical research. Accordingly, these frameworks that are provided list multiple categories of social impacts and, consequently, a 'high degree of inconsistency between such lists' exists (Vanclay 2002, p. 184).

To be clear, we are not challenging the lists of social impacts generated by previous researchers. But, there is an empirically rich set of studies in a variety of social science and engineering disciplines that are relevant to those interested in the topic of social impacts that remain insufficiently utilized when generating these lists. Myriad studies in social science and engineering disciplines have documented instances of individuals' everyday lives that have been affected by the adoption or diffusion of new technologies, but no efforts of which we are aware have been made to integrate these literatures. Our review paper represents an effort to integrate these studies into coherent categories and, as a by-product, produce an additional list of social impacts that incidentally is informed by empirical studies conducted in the social science and engineering literatures. Table 1 listed the results of our literature search and the columns in the table correspond with each section of the paper outlined below. Not all of the items identified in Table 1 are discussed in the text below and not all of the studies

cited below are included in Table 1; exemplary studies are listed in Table 1 for illustrative purposes.

In Table 1 and our subsequent descriptions of products that affect the day-to-day lives of individuals, we follow Vanclay (2002) who distinguishes between *social impacts* and *processes*. For Vanclay a social impact influences 'an actual experience of an individual or community' (p. 188).³ This expression of a social impact is similar to Burdge's (2004) cited above. Vanclay portrays a process as a characteristic of the host community. A process is really a social change or intervening or mediating factor that influences 'whether the community is likely to experience impacts' (p. 188). Vanclay continues, for example, 'Local government and other formal organisations, as well as informal organisations such as community groups may experience impacts, but the actual presence of these organisations is not the impact' (p. 188). We distinguish between process and impact, but we discuss both in our paper because they are closely related; both are often highly salient for social impact assessment. In fact, Vanclay explains, both should be considered together (within the SIA framework) to ensure that the necessary social change processes generate acceptable impacts.

Population change

Population change includes in- and out-migration, transiency of the population (Rolfe et al. 2007; Esteves 2008; Lockie et al. 2009; Petkova et al. 2009; Forsey 2011; Hajkowicz et al. 2011), relocation of families (Brouwer and van Ek 2004), presence of a seasonal leisure population, influx of temporary or permanent workers, and changes to the age structure of the community (Burdge 2004; Epstein and Yuthas 2014). Advances in transportation technology, in particular, increase access to new places and may affect these population dynamics. The first transcontinental railroad in the United States, finished in 1869, provides an illustration. Labor opportunity initially drew in primarily men from both within and outside of the United States (such as Chinese immigrants) to help with its construction (Pfeffer 1983; Holland 2007). Populations of the surrounding communities were in flux as the railroad building took place (Hudson 1982; Walters 2001). Once built, there was a greater flow of migrants to the Western United States, which greatly aided in the expansion of western cities (Pfeffer 1983; Hafen 1997; Mayda 2011). Other studies have shown that improved roads within a community reduce permanent out-migration (Gachassin 2013) and rural cities are likely to grow with the introduction of new roads if they are proximate to urban centers (Rudel and Richards 1990).

When discussing some of the social changes that stem from new mining operations in rural parts of Australia, Petrova and Marinova (2015) report population change as one of the first social processes to appear. Rural Australian mining communities often lack the necessary

Table 1. Social impacts of products by community or individual level change.

Stratification	Employment	Health & well-being	Human rights
(Impacts/Processes)	(Impacts/Processes)	(Impacts)	(Impacts)
Inequality between communities (Burdge 2004; Okeagu et al. 2006)	Change in job opportunities (Nimkoff 1950; Berman et al. 1998)	Secure/safe living conditions (Brouwer and van Ek 2004)	Homeless rights (Cox 1998)
Inequality within community (Okeagu et al. 2006)	Work environment/ideology (Cowan 1976; Chesley et al. 2013)	Safety and security (real/perceived) (Weingaertner and Moberg 2014; Cuthbertson et al. 2016)	Disabled rights (Breed and Ibler 1982; Pierce 1998)
Introduction of new classes or sub-communities (ex: gangs) (Burdge 2004)	Change in employment status (Guyatt 2001)	Activity/exercise (Quigg et al. 2012)	Indigenous rights (Strickland 1986)
Social status indicators; prestige (Solomon 1983; Veblen 2005)	Industrial diversification/change of economic focus (Okeagu et al. 2006)	Mental health (Breed and Ibler 1982; Cuthbertson et al. 2016)	Gender rights (Garton and Wellman 1993; Muir 2006)
Social mixing (Garton and Wellman 1993; Petrova and Marinova 2015)		Physical health; mortality (Islam et al. 2000)	Other human rights (Burdge 2004; Weingaertner and Moberg 2014)
		Life/health improvement from product (Guyatt 2001)	Democracy or decision-making participation (Larry Diamond 2010)
		Lingering feelings from usage (frustration, positivity, etc.) (Jordan 1998)	
		Perceived future opportunities/goals (Okeagu et al. 2006)	
		Diet (Cowan 1976)	
Networks & Communication	Experience of conflict & crime	Cultural identity/Heritage	
(Impacts/Processes)	(Impacts)	(Impacts)	
Networks (relations between actors) (Hudson 1982; Hampton and Wellman 2003)	Potential conflicts (Garton and Wellman 1993)	Weakening and strengthening of values (Hafen 1997)	
Relationships between community stakeholders (Burdge 2004; Benoît et al. 2010)	Homicide and violent crimes (Okeagu et al. 2006; Hoffmann 2011)	Cultural/ethnic/religious ideas and beliefs (Wheatley 1997; Hafen 1997)	
Impaired or improved personal relationships (Neustaedter and Greenberg 2011)	Non-violent crime (Ratcliffe et al. 2009)	Cultural intolerance (Faler 1974; Hafen 1997)	
How communication is carried out (Garton and Wellman 1993)	Corruption (Okeagu et al. 2006)	Cultural/religious rites and practices (Wheatley 1997; Vanclay 2002)	
Reliance on participation in the decision-making process (Dietz-Uhler and Bishop-Clark 2001)	Deviance from informal regulations/norms (Garton and Wellman 1993)	Cultural/religious artifacts and places (Vanclay 2002; Yastikli 2007)	
Social capital (Hampton and Wellman 2003; Weingaertner and Moberg 2014)	Increased or decreased substance abuse (Wheatley 1997)	Religious demographics (Hafen 1997)	
		Individual identity reliant on cultural identity (Wheatley 1997)	
		Understanding of the universe and the role one plays in it (Faler 1974; Wheatley 1997)	

labor force required to support the mines, which leads to large numbers of workers migrating to these communities. Typically in such circumstances, the workers fly in from other areas, work for a designated amount of time, and then fly back to their homes. This practice leads to increased numbers of outsiders, especially young males, migrating to mining communities (Rolfe et al. 2007; Lockie et al. 2009; Forsey 2011; Hajkowicz et al. 2011). Increases in mining activity that is accompanied by in-migration also introduces new diseases and decreased education quality (Rolfe et al. 2007; Esteves 2008; Forsey 2011; Hajkowicz et al. 2011). As a result, young families have been observed leaving these communities in search of better living conditions (Lockie et al. 2009). Overall, an increase in mining operations can lead to an atypical demographic structure characterized by a surge in younger, male, transient residents who

may come to outnumber permanent residents (Petkova et al. 2009).

Family

Perceptions of the family's role in society vary by culture; nevertheless, new product adoption can affect the roles the family plays in society, the roles individuals play within the family, and the stressors that result in strained family relationships. Certain work-related technologies can change the levels of stress or strain experienced within the family. The long absences of family members, predominantly men, engaged in work on offshore oil and gas installations can put strain on both the worker as well as those left behind. While spouses and partners are affected by such a schedule, young children may be particularly susceptible to the

strain these situations cause (Mauthner et al. 2000; Parkes et al. 2005).

One way products that are used in the home can change family members' roles are by changing the way work is distributed or perceived. Products can affect the roles family members are expected to fill or lead to new obligations members are expected to meet within the home. For example, with the introduction of so many labor-saving household products in the early 20th century such as washing machines, electric irons, gas-powered ovens, and refrigerators, the need for maids or nurses in middle class homes disappeared. As a result, parents in these homes were expected to fill the roles previously taken by nursemaids, including emotional closeness with children not previously observed (Cowan 1976). Others have pointed out that technological advances can reinforce existing family roles, maintain inequality between family members, and thus have negative impacts on family relations. Thrall (1982, p. 194) suggests that 'when families have an item of equipment which is used for a particular task, they are likely to be more traditional in their division of labor for that task than are families that do not have the equipment.' His study of 99 families living in a Boston suburb shows that husbands are less likely to help with the dishes in families who own a dishwasher. Another study of women's time-use diaries examined for various years beginning in 1925 and ending in 2011 indicates that time-saving home equipment seems to have led to a decline in time women spend doing housework over this period. But these gains were offset by increases in time spent in paid work, childcare, and shopping (Gershuny and Harms 2016).

Communication technologies have been shown to influence social interaction positively and negatively within the family. Weisskirch's (2011) study demonstrates that parents report greater social support from phone calls initiated by children and vice versa, but children report greater conflict when parents call to monitor behavior. Group video chat apps were also found to improve family relationships despite long distances, bringing extended family members such as grandparents into closer relationships with their grandchildren (Ames et al. 2010). In a study conducted in Jamaica, parents who lived abroad were more closely involved with their children's lives despite the great distances, and children reported waiting with anticipation for their parent's weekly phone call (Horst 2006). The increased interaction brought about by phones and video chat products may lessen the strain felt by families where one or more members may be away for extended periods of time. In a study of cell phones and work-related communication in Rwanda, researchers found that roughly two thirds of phone usage consisted of interactions with family and friends (Donner 2007). Even when cell phones are purchased for work-related reasons, they are often used for strengthening family relationships (Wei and Lo 2006; Donner 2009).

Gender

Technological advances can impact gender norms and expectations. Or, gender norms can be reproduced through these technologies. Online social media can be used to reproduce or express gender identity (Boonmongkon et al. 2013). Moreover, as mentioned, labor-saving household devices may be used to reinforce gender roles, though time spent doing different household tasks has increased (Cowan 1976; Thrall 1982; Gershuny and Harms 2016). Gender roles outside of the home can change as well. The adoption of email in the workplace has allowed women to overcome the norms of face-to-face conversation that typically put them at a disadvantage. In this way, email and other online forums may increasingly allow women's voices to be heard (Garton and Wellman 1993; Turco 2016).

The availability of contraception and assisted reproductive technologies (ART) such as *in vitro* fertilization (IVF), donor eggs, and egg-freezing have had a tremendous impact on women in particular. In addition to women's increasing participation in the labor force and higher education that have also played important roles (Wu and MacNeill 2002), contraception and ARTs have given women more control over the timing of childbirth, and ARTs have expanded opportunities to conceive and bear children at older ages (Friese et al. 2008). In the United States, the average age of first-time mothers has increased from 21.4 years in 1970 to 25.0 years in 2006 (Mathews and Hamilton 2009) while the first birth rates for women ages 35 through 39 has increased from 1.7 percent 1973 to 11.0 percent in 2012 (Mathews and Hamilton 2014). Of course, control over the timing of child birth provide women with more flexibility regarding the pursuit of educational and employment opportunities, but it also can affect their identity. Interviews conducted with 79 couples who had a child born from a donor egg and who were typically older than many other parents, indicate that women often adopted the identity of an 'older mother.' These women often experienced a negative stigma associated with being an older mother, which commonly occurred through social interactions with others in public places like playgrounds and schools. These negative stigmas center on others' assumptions or expectations about the mother's infertility, her dependency on a donor egg to get pregnant, being the child's grandmother rather than the mother, or being less physically capable than younger parents (Friese et al. 2008).

Education

Education can come from a variety of sources, such as formal in-school learning or informal skill acquisition. Products and technology can influence educational opportunities by enhancing the delivery of information, providing increased access to education (e.g. online

courses), or informally through using the product itself (i.e. learning to use and operate a product). An iPad provides an illustration of a product that can be used in an educational setting. Shah (2011) observed that iPad applications helped special education students to interact and communicate better. Applications on the iPad were better suited to children with poor motor skills than a desktop computer and was easier to use for those with vision problems. Another example of a product used for improving education is the use of virtual reality for medical students in teaching surgical procedures. Haluck and Krummel (2000) discuss the tremendous potential of surgical simulations to help medical students prepare for surgery by learning and refining their surgical skills in virtual settings without the risk of harming live patients.

Using other products also promotes informal educational opportunities as users are required to receive training to properly operate the product. Such is the case for the Village Drill, a human powered drill intended to bore holes for wells in developing countries. The setup and operation of the drill, as well as the installation of the accompanying pump, all require knowledge of the equipment to be successful. Customers who purchase the drill are also trained in its use (Mattson et al. 2017). As well as learning how to operate the drill itself, customers are trained in how to locate water sources and trouble shoot problems that may arise such as the drill getting stuck. Lastly, another product that generates informal learning is Family Story Play, a product that includes reading materials and video feeds for children (Raffle et al. 2010). Family Story Play encourages families living apart to engage in activities specifically designed to help young children learn and develop reading skills.

Paid work

Products and technologies have been observed in a number of instances to promote better employment opportunities (Nimkoff 1950; Faler 1974; Bray 1978; Cudahy 2006; Donner 2009). Many new jobs may become available to those living in a community as a result of the adoption or widespread use of a product. Or, employment may be negatively impacted by the production and use of other products. van der Voort and Vanclay (2015) report that earthquakes in the Netherlands resulting from natural gas extraction has caused property damage, and consequently, lost revenues for businesses. Individuals who are affected may need to miss time at work as they repair property damage. Okeagu et al. (2006) observe that the natural gas and petroleum industries in Nigeria benefited from the global oil crisis in the 1970s. However, pollution caused by natural gas and petroleum production also displaced many farmers and rural residents, forcing them to migrate to cities to find work.

The nature of employment has changed for many employees with the widespread adoption of information and communication technologies (ICTs), which have generated both positive and negative impacts. Chesley et al. (2013) suggest that the use of information technologies has blurred the boundaries between work and home by making it difficult for employees to escape from workplace tasks and responsibilities when they are at home. In another study, Chesley and Johnson (2015) demonstrate that ICT use improves an employee's ability to do her job. However, ICT use also increases the amount of stress experienced on the job – stress that is likely due to blurred boundaries between work and home or negative spillover from work to family life.

Products designed to complement or replace human labor, such as factory automation, change the nature of employment at those factories, particularly for unskilled to specialized labor (Milkman and Pullman 1991; Berman et al. 1998; Brynjolfsson and McAfee 2014). Manufacturing, printing, and publishing industries in particular are affected by microprocessors and other technological advancements (Berman et al. 1998). Or, products can improve an individual's employment prospects. Such is the case with respect to lightweight prosthetic limbs, which allowed military veterans to complete a full day's work and gain better employment (Guyatt 2001).

Stratification

Social stratification, or the system by which the society ranks groups of people in a hierarchy according to their characteristics (e.g. economic, racial, religious, etc.) (Grusky and Weisshaar 2014) is also affected by the adoption of new products and technology. Advances in technology can impact employment prospects for people who have certain job-related skills (Nimkoff 1950; Cowan 1976; Bray 1978; Parikh and Thorbecke 1996; Wheatley 1997; Cudahy 2006; Okeagu et al. 2006; Carrera and Mack 2010; Petrova and Marinova 2015), but they can also affect inequality in a community (Bray 1978; Cuthill 2010; Weingaertner and Moberg 2014) or the unequal distribution of revenue or other sources of income (Okeagu et al. 2006).

Consuming particular products may also contribute to stratification by signaling a certain social standing or status to others (Veblen 2005). A product that is manufactured from expensive materials may only be available to those who occupy the highest socio-economic status. Furniture, clothing, and automobiles can be examples of such products (Solomon 1983), and the form or design can greatly influence this perception. Though he was writing some time ago, Fussell (1983) argues that upper-class Americans prefer British designs, which are deemed a symbol of classic style.

Health and safety

The World Health Organization defines health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (Grad 2002, p. 981). Fontes et al. (2016) explain that companies need to consider how their products may affect the health, well-being, and safety of a number of stakeholders including employees, consumers, and local communities. Weingaertner and Moberg (2014) note that health impacts are among the core impacts that should be considered by any company. Health can be impacted by the pollution that is caused by petroleum production (Okeagu et al. 2006). Because of flooding risks Brouwer and van Ek (2004) explain that in the Netherlands one of the government's primary policy concerns has always been building dikes so that residents of surrounding areas have safe and secure living conditions.

To be sure, one of the primary considerations of product impact is user and community safety. Streetlamps are often installed to prevent crime, protecting pedestrians from potential harm (Haans and de Kort 2012). The Spider Boot, a product designed to increase the distance between one's feet and landmines, is intended for the prevention of physical harm (Islam et al. 2000). Cell phone (or smart phone) texting and driving has become a major safety concern that was not foreseen, but it has had a major unintentional negative impact on driver and pedestrian safety (Johnston 2001; Strayer and Strayer et al. 2003; Lesch and Hancock 2004; Beede and Kass 2006; Strayer et al. 2006; Fitch et al. 2013).

Products can also increase social and emotional well-being. Motorized wheelchairs increase intellectual and emotional development by allowing users to engage more fully with their community and surroundings (Breed and Ibler 1982). On the other hand, products also have the potential to worsen emotional well-being. One study found that electronic handheld devices could make users feel positive emotions such as excitement, satisfaction, and nostalgia. But when these products were difficult to use, the users were more likely to feel negative emotions such as frustration, annoyance, or disappointment, and these negative emotions lasted even after the users had stopped using the handheld device (Jordan 1998).

Human rights

A product's impact on human rights includes the protection and promotion of rights that are presumed to apply to everyone. Human rights that have been identified by the Office of the United Nations High Commissioner for Human Rights (OHCHR) include

civil and political rights, such as the right to life, equality before the law and freedom of expression; economic, social and cultural rights, such as the rights to work, social security and education, or collective rights,

such as the rights to development and self-determination, are indivisible, interrelated and interdependent.⁴

Human rights issues come into question for Weingaertner and Moberg (2014) in the context of labor – specifically, forced labor and child labor.

Products may present opportunities or barriers for disadvantaged groups. Products may be designed to improve accessibility for those with physical disabilities. Motorized wheelchairs, prosthetic limbs, and curb ramps enable those with disabilities to interact with their community, pursue employment, and pursue many opportunities for mobility afforded to those without disabilities (Breed and Ibler 1982; Pierce 1998; Guyatt 2001; Meyers et al. 2002; Rimmer et al. 2004; Bennett et al. 2009; Zidarov et al. 2009). Or, the Transcontinental Railroad in the United States provides an example of how a product or technology can infringe on human rights. When railroad lines were built, they often crossed onto Native American territory. This westward expansion illustrates a disregard for land rights of Native American and led to forced displacement and the formation of reservations. But it also had deleterious effects on their lifestyle, and was accompanied by 'little sympathy for the preservation of a way of life that left farmlands unturned, coal unmined, and timber uncut' (Strickland 1986, p. 722).

Social networks and communication

New products may impact social ties between individuals in a number of ways, such as the formation of new relationships (Garton and Wellman 1993) or increasing or decreasing the strength of the relationship. Donner (2009) suggests the use of cellphones has allowed families to maintain strong relationships when members are living apart or when one moves away for work, which helps keep individuals and communities united (Wheatley 1997). Advances in transportation technology and travel opportunities can foster more social connections between different geographical areas (Hudson 1982). Or, communities with influx or outflow of residents may lead to the disruption of established relationships (Petkova et al. 2009; Petrova and Marinova 2015).

Technologies have greatly enhanced communication and interaction with others over long distances. ICTs such as email, social networking sites, and instant messaging and video apps prove invaluable for maintaining connections to geographically dispersed friends, family, and acquaintances. Hampton and Wellman's (2003) study of a neighborhood in a Toronto suburb demonstrates that residents with high-speed internet access either maintained or increased contact with distant friends while contact decreased for residents with no internet connection. Studies that have been discussed above show that increased mobile phone use in developing countries allows for family members to remain connected over long distances (Donner 2009), and increased use

of email in the workplace reduces face-to-face communication between coworkers (Garton and Wellman 1993). Research suggests that products themselves can change how communication is carried out. Experiments with online communication show that those who use internet chat and discussion boards express higher confidence and comfort in expressing ideas, which facilitates the expression of different ideas (Dietz-Uhler and Bishop-Clark 2001). Applications that allow face-to-face communication over long distances, such as video chat, can also influence the quality of communication. Video chat has been found to create a greater sense of emotional closeness between couples living long distances apart compared to audio-only forms of communication (Neustaedter and Greenberg 2011).

Conflict and crime

Conflict includes activities that go against formal and informal rules within the community as well as conflicts between individuals (Goode 1997; Schmallegger 2005; Fontes et al. 2016). Okeagu et al. (2006) indicate that conflict in the Niger Delta is common as oil and gas companies actively seek to impose their will on local communities, using violence in some instances. As a result, local citizens may resort to violence as a way to get back at the companies. More modest forms of conflict may also result. Garton and Wellman (1993) report that with increased use of email in the workplace, coworkers tend to be more conflictual in their communication. Groups communicating via email tend to be more polarized and take longer to reach consensus. Nevertheless, the email conversations gave voice to more diverse opinions that may lead to better decisions overall.

Engineered products also have the potential to reduce crime. In reviewing crime deterrence principles and their applications, Hoffmann (2011) explains that the Los Angeles Police Department installed physical barriers in a number of through-streets to make getaways following drive-by shootings more difficult. The installation of these barriers was meant to increase the perceived cost associated with engaging in this behavior. Indeed, shootings in these areas drastically decreased. Research also demonstrates that Closed Circuit Television (CCTV) cameras used for monitoring activity in public spaces is associated with a moderate reduction in some type of crime such as robberies (Casteel and Peek-Asa 2000; Welsh and Farrington 2004; Cozens et al. 2005; Welsh and Farrington 2009). Ratcliffe et al. (2009) evaluated the use of CCTV cameras in high crime areas in Philadelphia and determined that their use was largely responsible for a 13% reduction in observed crime. Improved lighting in public spaces through streetlamps, for instance, has been shown to reduce both crime and the fear of crime (Herbert and Davidson 1994; Painter 1996; Farrington and Welsh 2002).

Cultural heritage and identity

Cultural heritage is the expression of the 'ways of living developed by a community and passed on from generation to generation, including customs, practices, places, objects, artistic expressions and values' (Nzeadibe et al. 2015, p. 80). This represents an emerging theme in the social impact assessment scholarship (e.g. Dixon et al. 2009; Petrova and Marinova 2015) in which products are typically viewed as having negative impacts. Culture can be negatively impacted through, for instance, loss of language, defilement of culturally sacred sites, or violation of cultural taboos (Vanclay 2002).

Cultural heritage takes many years to develop, but it can be disrupted in a relatively short period of time (Gramling and Freudenburg 1992). An example comes from Wheatley (1997) who reports that mercury pollution negatively impacted Aboriginal communities in Canada in the 1970s. Residents on native reservations were forced to decrease their fishing activities and fish consumption significantly. Fishing, however, was 'part of their cultural identity ... in which everyone had a role and where traditional skills were passed on' (p. 87). Wheatley reports that a host of other negative outcomes accompanied the disruption of the traditional way of life in these communities including increased crime, violence, and suicides. Similarly, the transcontinental railroad challenged the Native American way of life by seeking to exterminate bison herds that local indigenous populations hunted and relied on. As part of the railroad expansion westward the US Army often sponsored hunting expeditions for private hunting parties to kill buffalo (Smits 1994).

Transportation technologies may bring new or temporary residents that may not hold the same cultural values as the local residents, or their presence may strengthen the way local residents perceive or portray themselves. The transcontinental railroad changed the culture of Salt Lake City, Utah, during the latter half of the 1800s (Hafen 1997). The expansion of the railroad brought new settlers and tourists to this city, which was previously intended to be a religious haven for Mormon pioneers who settled there to escape persecution experienced elsewhere in the Eastern and Midwestern United States. As outsiders came to Salt Lake City, the culture of the city began to change. Instead of trying to remain isolated and insulated from outside influences, over time the original settlers sought to present themselves as educated and civilized. And as they did, Mormons 'ultimately affected the way they conceived themselves' (p. 376). Instead of trying to maintain a separate existence and identity, they came to exemplify some of the same social, educational, and economic values shared by 'the elite classes of American Society' (p. 376).

Products may also serve to preserve cultural heritage by preserving the memory and physical spaces of sacred sites or by making such places more accessible

to community members. ICTs including digital photogrammetry, laser scanning, and other digitization technologies can assist in the creation of materials that preserve visual displays of cultural sites, photographs, or language. Specifically, digital photogrammetry products have improved the recording of cultural heritage sites (Yastikli 2007). Additionally, R  ther et al. (2009) explain, the use of laser scanning can provide a permanent record of a cultural artifact or site to be preserved for future generations to observe.

Conclusion

The purpose of this paper is to review and integrate research from a wide range of social science and engineering disciplines to provide a more informed inventory of social impacts compared with past work that includes lists of social impacts that are derived from authors' ps or intuition. We believe this is an important step toward building a cumulative trajectory of work in this area. We also call for more work in this area to validate which social impacts are most relevant and under what conditions. A fruitful avenue for empirical research should, then, leverage experimental methods or examine product adoption in a number of settings to develop a more complete picture of whether certain consequences are broadly applicable or context-specific. To date, scholarship largely consists of case studies that identify product consequences, but insufficiently considers whether adoption may yield similar results in other settings. While instructive, this research typically 'selects on the dependent variable' by making few, if any, attempts to compare different elements of the social environment or different social environments that are affected by products and their features. Additionally, leveraging experimental methods will help researchers in distinguishing between the social phenomena that influence the antecedents of adoption compared with the outcomes or impacts that result from product use. Gender roles may not only be impacted by products, but they may influence who is likely to use a product in the first place.

In this paper, we follow other scholars who have attempted to integrate impact assessment categories in one place (Vanclay 2004; Kirkpatrick and Lee 1999). While such integration is often beneficial, recent studies of impact assessment suggest that the inclusion of too many factors presents challenges. Integrated frameworks may present too much complexity and in fact overburden or even weaken assessment efforts. Or, integrated approaches may exacerbate tensions that exist between balancing social, environmental, and economic considerations such that one of those considerations comes to the fore while the others fade into the background. Similarly, the addition of new social impact categories to assessment efforts may draw attention away from existing categories

or a methodology's intended emphasis on a specific impact (Kidd and Fischer 2007; Tajima and Fischer 2013). Integration has been most successful when it is balanced enough to benefit the project without adding unnecessary complexity (Tajima and Fischer 2013). In considering the summary of social impacts and processes we have provided, we encourage researchers to thoughtfully and appropriately weigh each of the various measures into their own efforts.

A limitation of our paper, in particular, is the incomplete list of potential social impacts and processes we have identified. We could imagine a number of additional social phenomena that are shaped by product use. Religious practice and spirituality could be directly impacted by technology that enhances communication between believers or indirectly impacted by providing competing demands on believers' time and attention. Social justice could be impacted by ICTs that spread empowering knowledge and ideals, analogous to when the invention of the printing press delivered the Bible to the masses. Domestic violence can be addressed by users of technologies like the smart phone application *Aspire*, which is disguised as a news app but allows users to send a covert message to a trusted friend or contact. Technology could also affect communities' ability to respond to tragedy as well as community efforts to rebuild and move past such tragedies. No doubt there are other significant impacts for products that we did not identify in our paper. Discovering additional relevant impacts and social change processes constitutes another promising avenue for future research, considering that new technologies are increasingly introduced into the global marketplace. Therefore, the categories identified in our paper necessarily should be revised and improved for future use.

Of course, research on social impacts has many practical implications. The primary goal of this strand of research is to generate products that improve individuals' everyday lives, especially products for groups who are disadvantaged or in need of help. To this end, we believe that engineers can use the categories we have identified in this paper, as well as lists that have been generated in prior research (c.f. Epstein and Yuthas 2014; Fontes et al. 2016; Vanclay 2002), to design products with the end-user in mind as a way to gain a better understanding of the social benefits of their products. These categories could be used to inform a variety of methods for discovering and assessing the social impacts of an engineered product, such as Life Cycle Assessment or IDEO's Human Centered Design. As shown in our paper, design of seemingly innocuous features that accompany the use of common, everyday products, represents a significant need and can have a significant effect. But until these social impacts are named and evaluated, a greater awareness by researchers, designers, and users of these products will remain out of reach.

Notes

1. *Code of Ethics of Engineers*. 2009. American Society of Mechanical Engineers. See https://www.asme.org/getmedia/9EB36017-FA98-477E-8A73-77B04B36D410/P157_Ethics.aspx; accessed April 14, 2017.
2. *Code of Ethics*. 2001. Society of Manufacturing Engineers. See <http://ethics.iit.edu/ecodes/node/3296>; accessed April 14, 2017.
3. Elsewhere, Burdge and Vanclay (1996, p. 32) define social impacts as
all social and cultural consequences to human populations of any public or private actions that alter the ways in which people live, work, play, relate to one another, organize to meet their needs, and generally cope as members of society.
4. See <http://www.ohchr.org/EN/Issues/Pages/WhatareHumanRights.aspx>; accessed June 5, 2017.

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