

INDIVIDUALS' SUSTAINABLE BEHAVIOUR ALONG THE LIFE CYCLE OF IT

Research paper

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Abstract

Information Technology (IT) is both, a cause as well as a solution to environmental degradation. This research paper aims to investigate factors influencing individuals' behaviour along the different stages within the life cycle of IT. We differentiate between three stages, namely "Manufacturing / Buy", "Use" and "Disposal" of IT. The research model builds upon the Theory of Planned Behaviour and extends it through the addition of environmental factors. Further, the research model is applied as a multi group model to all three life cycle stages. We conduct two survey-based empirical studies and find that environmental factors significantly influence an individual's intention to show sustainable behaviour across all three life cycle stages of IT.

Keywords: Green Information Technology, Sustainability, Life Cycle of IT, Technology Acceptance, Theory of Planned Behaviour.

1 Introduction

Climate change, waste generation, air pollution, and natural disasters are factors contributing to the worldwide change of the environment and leading to its degradation (Bonini and Oppenheim, 2008). Evidence suggests that environmental problems are mostly human-induced. Accordingly, individual actions need to be adjusted to decrease their environmental impact, as the Intergovernmental Panel on Climate Change states: "Environmental degradation due to human activities continues to occur at an increasing rate with annual emissions of carbon dioxide having increased by 70 percent between 1970 and 2004" (IPCC 2007, p. 5).

Information technology (IT) is historically seen as a contributor to environmental deterioration, since it consumes energy resources and produces both, emissions and waste. Nowadays however, IT is also regarded as an enabler of sustainable processes, services, and products, supporting behavioural adjustments of individuals towards sustainability (Melville, 2010; Watson et al., 2010; vom Brocke et al., 2013). Gartner Inc. (2007) supports this notion by outlining that IT is responsible for about two per cent of global greenhouse gases but, at the same time, has the potential to address reducing the remaining 98 per cent.

Considering this ambiguous role of IT, this research paper is situated on the intersection between IT and sustainability research. We investigate the influence of *environmental factors (EN)* on individuals' behaviour towards sustainability along the life cycle of IT. Thereby, we focus on the environmental aspect of sustainability, which is an urgent challenge to address (Watson et al., 2010). By building upon the Theory of Planned Behaviour, combining it with a Life Cycle Assessment (LCA), and extending it by *EN* along three life cycle stages, we postulate the following research question:

What factors influence individuals to behave in an environmentally sustainable manner across the different life cycle stages of information technology?

With the knowledge about individuals' perceived importance of sustainability within the different life cycle stages, IT's potential to decrease environmental damages can be further utilized. As our findings show, IT companies can derive managerial implications in terms of sustainability for their product design, manufacturing, and marketing processes.

To address our research question, we build upon a life cycle of IT consisting of three life cycle stages, namely "Manufacturing / Buy", "Use", and "Disposal" of IT. The proposed research model integrates LCA since research has shown that this assessment helps to point out important issues from an environmental perspective (Andrae and Andersen, 2010). Thereby, the multi group model allows an in-depth analysis, assessing individuals' sustainable behaviour across different IT life cycle stages. Individuals' sustainable behaviour within the different stages can be described as follows: Within the first stage, individuals pay attention to the way IT is produced. Within the second stage, individuals apply IT to enhance sustainability. The last stage concerns individuals' behaviour when faced with different options of IT disposal.

The research paper unfolds as follows: In Section 2, we introduce the theoretical background this research builds upon. In Section 3, we develop our research model by conducting a structured literature review. In this section, we also develop hypotheses, which we assess in a two-step approach aka "Study 1" and "Study 2" in the following parts. In Section 4, we apply an explorative factor analysis to analyse *EN*, which we add to the theoretical model. This study ("Study 1") results in a supplementary independent variable as well as two moderating factors. In Section 5, we use a structural equation model to validate the proposed research model ("Study 2"). We conclude the research paper with a discussion of the theoretical and managerial implications in Section 6.

2 Theoretical Framework

2.1 Life Cycle of IT

To demonstrate the role of IT in the context of sustainability, we use a framework called Life Cycle Assessment (LCA). LCA is defined as a comprehensive recognition of the environmental performance of small and distinct product systems considering all aspects of natural environment, human health, as well as resources (Andrae and Andersen, 2010; ISO 14040; Menzies et al., 2007). LCA provides a quantitative evaluation of the environmental impact of products over their entire lifetime (Burgess and Brennan, 2001).

Building upon the LCA framework, there are multiple definitions of a "life cycle" within the literature which share varying degrees of similarity. For example: According to Duan et al. (2009) a life cycle consists of the four stages "manufacturing, distribution, use, and end-of-life treatment". Park et al. (2006) use a similar life cycle definition only differing in the first and last stage, calling it "raw material acquisition" and "disposal". Socolof et al. (2005) introduced a life cycle consisting of only three stages, "cradle-to-grave, use, and disposal". In this model, the stage "cradle-to-grave" includes an upstream and manufacturing process. Additionally, ISO 14040 or SETAC developed another variation of the life cycle definition. Azapagic (1999) presents an enlarged life cycle model which includes eight stages, namely "extraction of raw material, manufacturing, transport, use, reuse, maintenance, recycling, and disposal".

For this research paper, we use an abstracted life cycle model for IT, rooted in a consumer context. Thus, we research literature for detailed sub-stages of product life cycles (e.g., Khasreen et al., 2009, Menzies et al., 2007) which we then aggregate to overarching stages. By aggregation, we mean the combination of detailed sub-stages (i.e., Pre-Manufacturing, Production, and Distribution) to a stage, where consumers can play a key role by showing sustainable behavioural intentions in the context of IT. For the purpose of this study, we define behavioural intention as an individual's conscious decision to behave sustainably, therefore to increase or at least consider the state of their natural environment, within the different stages of IT's life cycle. As a result, we find three main stages, namely "Manufacturing", "Use", and "Disposal" (Figure 1), in each of which individuals can behave in a sustainable manner. Thereby, we understand "Manufacturing" as a consumer's attention to the production of IT, which can be considered within the IT purchase process. Hence, the stage captures an individual's behavioural intention to

buy sustainably manufactured IT. In alignment with the outlined context and definition, we rename the first life cycle stage “Manufacturing” to “Manufacturing / Buy”. The second stage concerns an individual’s behavioural intention to use IT with the aim of increasing sustainability. An increased sustainability can either be due to adjusting energy-saving settings of IT or to buying “Green-IT”. The third stage focuses on the way IT is disposed, the investigated intention is thereby described as the behavioural intention to dispose IT sustainably.

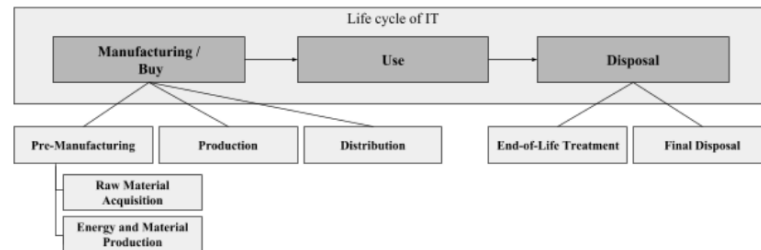


Figure 1. Proposed life cycle of IT

2.2 Theory of Planned Behaviour

To analyse an individual’s behaviour regarding IT, we build upon the Theory of Planned Behaviour (TPB). The theory originates from the field of psychology and links an individual’s beliefs to an individual’s behaviour. Specifically, TPB proposes that people act or behave in accordance with their intentions (Ajzen, 1985; Ajzen and Fishbein, 1980). Figure 2 shows the factors that impact behavioural intention, according to TPB.

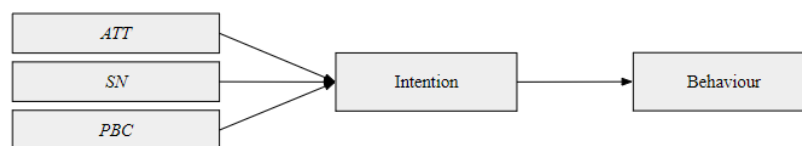


Figure 2. The Theory of Planned Behaviour (Ajzen, 1985)

Note: ATT: Attitude, SN: Subjective Norms, PBC: Perceived Behavioural Control

The factor *Attitude (ATT)* is defined as the degree to which a person evaluates or appraises the behaviour in question favourably or unfavourably. The factor *Subjective Norms (SN)* is defined as the perceived social pressure to behave in a certain manner. Finally, the factor *Perceived Behavioural Control (PBC)* is defined as the individual’s perceived ease or difficulty of behaving in accordance with his or her intentions. *PBC* is assumed to reflect past experiences as well as anticipated impediments and obstacles. Accordingly, an individual’s intention to behave in a certain way is positively correlated with an individual’s *ATT*, *SN* and *PBC* regarding the behaviour in question. Knowing this, we focus on investigating intention within this research study as it is an acknowledged predictor for an individual’s future behaviour (Armitage and Conner, 2001).

The original TPB does not only consistently exhibits high explanatory power and predictive validity in terms of the percentage of variance explained (see Godin and Kok, 1996 and Sutton, 1998 for meta-analytic reviews), but has also been applied in manifold application contexts. More specifically, TPB as a research model does not lose explanatory viability when explaining behaviour in both fields of research, sustainability and technology. Previous research has shown, that TPB is applicable to a sustainable IT context. The theory is used to explain sustainability use cases such as recycling (e.g., Boldero, 1995; Cheung et al., 1999; Taylor and Todd, 1995b), and composting (Taylor and Todd, 1995b). Also technology-related issues such as the usage of mobile applications is explained by applying the theory (e.g., Yang, 2003). Moreover, TPB can also be applied to analyse behavioural intentions at the intersection of sustainability and technology related research. As such TPB is employed to explain behaviour regarding energy conservation (Harland et al., 1999), consumer adoption of cleaner vehicles (Lane and Potter, 2007), and smart meters (Guerreiro et al., 2015).

Ajzen (1991) describes the model as open to further extension if additional important proximal determinants are identified and they increase its explanatory power significantly (Conner et al., 1998). Therefore, we aim to add *EN* to the original model to tailor it to the increasingly relevant context of behavioural intentions regarding environmentally sustainable or green behaviour (Chen and Tung, 2014; Ek and Söderholm, 2010; Samuelson, 1990).

3 Development of Research Model

Following Ajzen's (1991) call for further extensions, this research study aims to investigate individuals' perceived importance of environmental sustainability regarding IT. Therefore, we adapt the original TPB model to the sustainability context by combining it with the LCA, resulting in a combined research model. We integrate LCA since research has shown that this assessment helps to point out important issues from an environmental perspective (Andrae and Andersen, 2010). Thereby, our proposed research model allows an in-depth analysis, assessing individuals' sustainable behaviour across different IT life cycle stages. Based on this multi group model, we develop hypotheses before assessing them in the following parts.

3.1 Existing Adaptation of TPB in the Environmental Context

For investigating an individual's intention to exhibit sustainable behaviour within all three life cycle stages of IT, we extend the TPB by *EN*. With this extension, we follow Tate et al. (2015) definition to specialise the original TPB model. To identify *EN*, we conduct an exhaustive literature review in scientific libraries (e.g., Web of Science) focusing on papers that primarily investigate sustainability as well as technology. The citation search results in 1,135 papers from the sustainability and 1,963 papers from the technological research area.

To ensure the relevance of the results, we apply three selection criteria: First, we include only research studies building upon both research fields, sustainability and technology. Second, specific results are required to provide an environmental extension of the original TPB model. An extension contains the introduction of one or more independent variables or a replacement of a TPB variable. Third, results must contain either an explicit or an implicit definition of the novel factors. The definition could also be in the form of examples or comparably helpful constructs. After eliminating all duplicates, the selection process results in a total number of 19 unique *EN* from a total of 18 papers.

When looking at the overview of the 19 *EN* in Appendix B (Supplementary Material A, Table 1), one recognizes that the most often added factors are "Environmental Awareness" (EA), "Environmental Concern" (EC), and "Environmental Knowledge" (EK). However, within the literature, the difference between the factors EA and EC is not clear. Best and Mayerl (2013) state, for example, that EA and EC cannot be differentiated whereas Chan et al. (2015) distinguish both factors and show how they are individually significant. What makes this even more complicated is the fact that there is a panoply of definitions of each factor. Table 1 gives an exemplary overview of this circumstance. Finally, also the way *EN* is embedded within models differs between multiple authors. Shi et al. (2017) positions EC as pre-factor whereas Tan et al. (2017) uses it as additional direct variable.

Therefore, we conduct an exploratory factor analysis (EFA) with data from 18 papers outlining 19 *EN* in Section 4 (Study 1). Based on the results of the EFA we decide on the number and composition of the *EN* that we consider in this paper.

Applied Definition	Source
“Environmental Awareness” is the degree to which people are concerned about environmental issues and how easy daily habits can affect the environment.	Wang et al., 2016
“Environmental Awareness” is for example an individual’s concern about the environment, environmental pollution, and about water and pollution.	Engelken et al., 2016
“Environmental Concern” is defined as the degree to which people are aware of problems regarding the environment and support activities aimed to solve them or even engage personally in such activities.	Prete et al., 2017
“Environmental Concern” denotes an individual’s general orientation toward the environment.	Shi et al., 2017

Table 1. Exemplary definitions for “Environmental Awareness” and “Environment Concern”

3.2 Development of Hypotheses

To develop our hypotheses, we build upon existing literature. Thereby, we transfer proven assumptions to our proposed life cycle approach investigating their significances across the three stages. Former research indicates that *Attitude* is a relevant predictor of green and ecological behavioural intentions (e.g., Greaves et al., 2013; López-Mosquera et al., 2014; Olsen et al., 2010; Wang et al., 2014). More specifically, various studies show a positive influence of *Attitude* on behavioural intention in the context of technology (e.g., Adnan et al., 2017; Corral, 2013; Engelken et al., 2016; Lane and Potter, 2006). Similarly, we expect that *Attitude* positively influences behavioural intentions regarding sustainable behaviour in the context of IT. Accordingly, we claim:

H1. *Attitude* toward sustainable behaviour is positively related to the intention of environmentally sustainable behaviour across the life cycle of IT.

Ha and Janda (2012), Hori et al. (2013), Petschnig et al. (2014), or Wang et al. (2014), amongst others, show that *Subjective Norms* is strongly linked to sustainable behaviour, as well. Such behavioural intentions, for example, are expressed as energy-saving behaviour, adoption of alternative fuel vehicles, or the purchase of energy-efficient appliances. We expect that *Subjective Norms* positively influences intended sustainable behaviour and develop the following hypothesis:

H2. *Subjective Norms* is positively related to the intention of environmentally sustainable behaviour across the life cycle of IT.

Specifically, in the field of green behaviour, *Perceived Behavioural Control* has been studied and confirmed as a significant determinant of behavioural intention (e.g., Albayrak et al., 2013; Chen and Tung, 2014; López-Mosquera et al., 2014). Likewise, we expect that *Perceived Behavioural Control* positively influences sustainable behavioural intentions in the context of IT and develop the following hypothesis:

H3. *Perceived Behavioural Control* is positively related to the intention of environmentally sustainable behaviour across the life cycle of IT.

Aung and Arias (2006), Chan et al. (2015), Chen et al. (2016), Peattie (2010), and Rokicka (2002) amongst others, confirm that there is a positive relationship between an environmental factor and sustainable behaviour. For instance, a meta-analysis presented by Chen et al. (2016) indicates that general environmental knowledge and specific knowledge about environmental problems are important indirect determinants (through the activation of responsibility, social norms, and guilt) of pro-environmental intention. For example, Chan et al. (2015) show that consumers with broader environmental knowledge better understand the harm to the environment and are more willing to pay higher prices for environmentally friendly products as compared to less environmentally friendly ones. According to Aung and Arias (2006), “Environmental Knowledge” is a significant factor influencing individual intentions to engage in environmentally friendly behaviours. These findings are consistent with Peattie (2010). Additionally, Rokicka (2002) confirmed the positive influence of “Environmental Knowledge” on consumers’ eco-friendly purchase intention.

Studies, by Abrahamse and Steg (2009), Gärling et al. (2003), Stern et al. (1995), Peters et al. (2014), and Wan et al. (2017) show the positive influence of “Environmental Awareness” on behavioural intentions. Wan et al. (2017) indicates that awareness of environmental consequences has a significant influence on individual’s recycling intention. This finding is consistent with Stern et al. (1995) and Gärling et al. (2003) who also showed a positive contribution of “Environmental Awareness” to pro-environmental behavioural intentions. Additionally, Peters et al. (2014) confirm that “Environmental Awareness”, as the awareness of problems such as climate change or dependence on fossil fuels, exerts an influence on the purchase of a fuel-efficient vehicles. Consistent with Abrahamse and Steg (2009), people believing energy use has negative environmental consequences and feeling personally responsible for these problems have a higher “Environmental Awareness”. These people will feel a stronger obligation to help solving environmental problems and are more likely to reduce their energy use.

Lastly, other researchers show the positive relationship between “Environmental Concern” and behavioural intention (Hallin, 1995; Hopper and Nielsen, 1991; Newell et al., 1998; Paladino and Ng, 2013). In their study, Paladino and Ng (2013) provide a literature review supporting that “Environmental Concern” has a positive direct impact on green purchase intentions (Keesling and Kaynama, 2003; Roberts and Bacon, 1997). Additionally, Hopper and Nielsen (1991) confirm that consumers with higher environmental concern are more likely to purchase from socially responsible entities. Consistent with Newell et al. (1998), consumers buy eco-friendly substitutes to express their environmental concern. Moreover, Hallin (1995) concludes that “Environmental Concern” is a reliable factor in predicting an individual’s shift toward more environmentally friendly behaviour.

Taken together, we are confident that *environmental factors* are driving environmentally sustainable behaviour and, therefore, develop the following hypothesis:

H4. *Environmental factors* are positively related to the intention of environmentally sustainable behaviour across the life cycle of IT.

4 Study 1 – Model Development

The aim of Study 1 is the development of the measurement model for *EN* as a construct. To this end we apply principal axis factoring (PAF) as a form of exploratory factor analysis on literature items. From the resulting items, we develop a questionnaire. Based on the questionnaire’s results we validate *EN* in the context of TPB, as explanatory factors for environmentally sustainable behaviour across the life cycle of IT.

4.1 Method

The literature review (see Section 3.1) resulted in 55 items reflecting *EN*. Using content validity assessment we checked if items exhausted their respective domains (Churchill, 1979). Through excluding, renaming, and repositioning procedures the number of items was reduced from 55 to 51¹, as stated in Appendix B (Supplementary Material B, Table 2). To be used in the questionnaire, some of the items’ contexts were changed to fit the general context of IT (e.g., items such as “I am concerned about the environment” were adapted to “In the context of technologies, I am concerned about the environment”).

From the identified items, measured on a five-point Likert scale anchoring on “strongly disagree” and “strongly agree”, we constructed a survey. An independent pre-test with 20 participants was not included in the main survey results (Summers, 2001). Participants were recruited via Amazon Mechanical Turk leading to 302 respondents. With an item to response ratio higher than 1:4 (Hinkin, 1998) and a suggested sample size falling between 100 to 500 (MacKenzie et al., 2011), the sample is sufficiently large for an exploratory factor analysis. There was no evidence of any systematic bias in the survey that could have caused premature abandonment.

¹All remaining items, although having similar formulations, investigate to some extent different angles of sustainable behaviour. Therefore, we considered the second item and third item (Table 2), since the second item refers to specific issues concerning the environment whereas the third item asks for the individual’s general concern about the entire environment.

4.2 Results

In the PAF, we applied parallel analysis to determine the number of significant factors (Wood et al., 1996; Zwick and Velicer, 1982, 1986). An oblique rotation criterion referenced underlying primary studies where *EN* factors were correlated. The PAF suggested three factors which accounted for 48% of the total variance in the data.

All items with a major loading lower than the conventionally accepted threshold of 0.7 were eliminated (Urbach and Ahlemann, 2010; Venkatesh et al., 2003). We limit the maximum number of items to four per factor, referencing the TPB model, selecting the items with the highest loadings. Table 2 and Figure 3 show the resulting model consisting of 11 items indicating the 3 factors. Table 2 states the loadings, cross-loadings, eigenvalues, percentage of explained and cumulative variance. Appendix B (Supplementary Material B, Table 2) contains further details of all original 51 items.

When analysing the main-loadings in Table 2, the resulting factors can be interpreted as follows. The first factor consists of technology-related items originally derived from the factors “Environmental Awareness” (EA) as well as “Environmental Concern” (EC). Due to their similar definitions, we introduce a combined factor *EA/EC*. The second factor builds upon “Environmental Knowledge” (EK) items referring to an individual’s common understanding of environmental related issues (see items 5-8, Table 2). We call this factor *General EK*. On contrary, *Personal EK* as a third factor focuses on specifically personal environmental understanding (see items 9-11, Table 2). It is also derived from former *EK* items. The two *EK* factors (*General EK*, *Personal EK*) address an individual’s knowledge concerning the environment and are not limited to understanding the impact of IT. Therefore, we propose both as moderators of *EA/EC*. Both moderators are not adjusted specifically to the IT context.

Items	<i>EA/EC</i>	<i>General EK</i>	<i>Personal EK</i>
When I think of the consequences of IT on the climate, I am very worried.	.92	-.13	-.03
In the context of IT, I am often concerned about environmental issues.	.91	-.11	.03
In the context of IT, I am concerned about the environment.	.89	-.10	.01
When I think about how IT influence our oil supplies, I am very worried.	.89	-.34	.08
Melting of the polar ice caps may result in a flooding of shores and islands.	-.04	.76	.01
Fossil fuels (e.g., gas, oil) produce carbon dioxide (CO ₂) in the atmosphere when burned.	-.12	.74	.03
I have heard the terms, “sustainable technologies”, “renewable energy”, “green power” or “green electricity” before today.	-.17	.76	.03
A reduced number of species may interrupt the food chain, affecting one subsequent species in the food chain.	-.19	.85	-.02
I know much about sustainability (e.g., energy-saving) tips of daily life.	.04	-.04	.84
I know sustainable methods (e.g., for energy-saving) well.	-.04	.06	.73
I know the meaning of the labels affixed on the sustainable technologies (e.g., energy-efficient devices).	-.06	.04	.71
Eigenvalues	14.81	6.60	3.30
Variance explained	.29	.13	.06
Cumulative variance	.29	.42	.48

Table 2. Loadings and cross-loadings in exploratory factor analysis

The model resulting from the PAF is conceptualised as a multi group model referencing the respective stages of IT's life cycle. Hence, the resulting model is tested for each life cycle stage as illustrated in Figure 3.

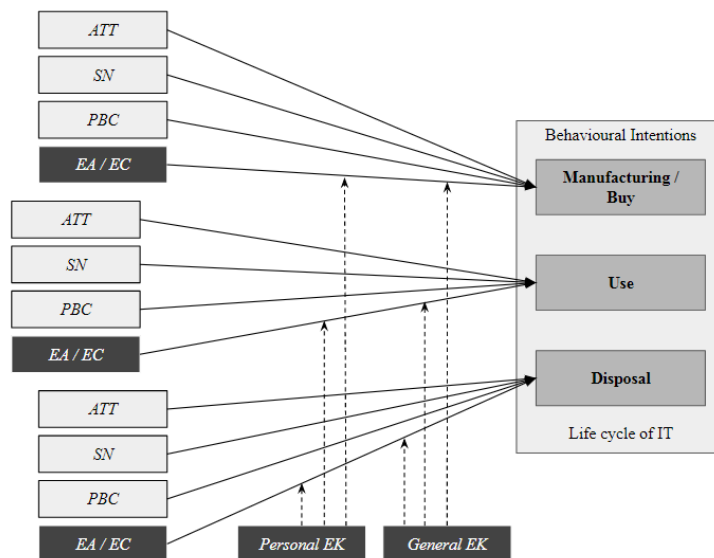


Figure 3. Research model derived from exploratory factor analysis

Notes:

- ATT: Attitude, SN: Subjective Norms, PBC: Perceived Behavioural Control, EA/EC: Environmental Awareness/Concern, EK: Environmental Knowledge.
- Dashed lines illustrate moderating factors.
- As a multi group model, the model is applied to every stage within IT's life cycle.

5 Study 2 – Model Validation

Study 2 aims at validating research model shown in Figure 3. Based on new empirical data, structural equation modelling (SEM) is applied to investigate individuals' intention to behave sustainably within the different life cycle stages. We focus on investigating individuals' intention within this research study as it is an acknowledged predictor for an individual's future behaviour (Armitage and Conner, 2001).

5.1 Method

The original TPB model was measured as proposed by Taylor and Todd (1995a). The variables *EA/EC*, *General EK* and *Personal EK* were measured with new items derived from Table 2. The dependent variable *Behavioural Intention* was measured with three items, also derived from Taylor and Todd (1995a). All items, except the moderating factors (*General EK* and *Personal EK*), refer to the specific life cycle stage. Appendix A (Tables 5 and 6) states items used in the first stage of our three life cycle stages (i.e., "Manufacturing / Buy"). Appendix B (Supplementary Material C, Table 3) lists the items for the other two life cycle stages (i.e., "Use" and "Disposal").

In order to collect data, we developed a questionnaire. The pre-data collection procedure and item measurement were equal to the respective parts of Study 1. The participants answered the questions in the context of the three different stages of the IT life cycle. The order of the stages was randomized to decrease possible bias.

There were 313 respondents. Based on a marker question, fifteen of them did not answer the survey conscientiously and were therefore excluded from our analysis. Hence, the final sample consists of 298

valid responses. The sample size is sufficiently large for the application SEM (Barclay et al., 1995; Cohen, 1992; Hair et al., 2013).

5.2 Results

Building upon Venkatesh et al. (2003, 2012), we applied PLS-SEM by using the software SmartPLS (Ringle et al., 2015). To address common method variance, we used a priori remedies and post hoc detection methods. A priori remedies guarantee anonymity during the data collection process, assuring participants that there are no true or false answers, asking participants for honest answers, and careful wording and scaling the developed items (Podsakoff et al., 2003). For post hoc detection methods, we applied the correlational marker technique (Lindell and Whitney, 2001) and the CFA marker technique (Richardson et al., 2009). For the correlational marker technique, we chose the smallest and second-smallest positive correlation between variables as a post hoc selected marker. For the CFA marker technique, one theoretically irrelevant marker question concerned with medical treatment was subject to the survey. Both assessments indicate the absence of common method variance in our sample.

To address multicollinearity, we examined the correlation table of latent constructs. Table 3 shows the correlation matrix for the second stage, "Use", within IT's life cycle. Data for both other stages are to be found within Appendix B (Supplementary Material D, Table 4 and Table 5). Based on the correlations, no significant correlations between *EA/EC* and other latent constructs were found. To further test for multicollinearity, the variance inflation factor values of the latent constructs were inspected. We found them to be around 2.37 with a maximum of 4.47 and, thus, for all independent variables below the critical threshold of 5, suggesting that multicollinearity was not present in the surveyed sample (Gefen et al., 2000). Additionally, the internal consistency reliabilities (ICRs) of the multi-item scales are 0.70 or higher (Gefen et al., 2000) for all factors within all stages of the IT life cycle. Since the AVE values are above 0.50 and higher than the square of the correlations, convergent and discriminant validity are supported (Fornell and Larcker, 1981; Urbach and Ahlemann, 2010). Finally, the Cronbach's Alpha values are higher than 0.8 for all factors which indicate an excellent level of internal consistency within all three stages.

	"Use"									
	ICR	Mean	SD	ATT	SN	PBC	EA/EC	Personal EK	General EK	Intention
ATT	.909	.200	.064	.715						
SN	.946	.067	.196	.508	.897					
PBC	.875	.281	.067	.484	.402	.699				
EA/EC	.939	.219	.102	.037	.228	-.012	.795			
Personal EK	NA	.008	.090	.156	.126	.060	.067	NA		
General EK	NA	-.090	.106	-.192	-.170	-.047	-.050	-.164	NA	
Intention	.945	-	-	.475	.497	.469	.303	.211	-.231	.852

Table 3 Descriptive statistics – correlations and AVEs – in the IT life cycle stage "Use"

Notes:

- ATT: Attitude, SN: Subjective Norms, PBC: Perceived Behavioural Control, EA/EC: Environmental Awareness/Concern, EK: Environmental Knowledge.
- ICR: Internal Consistency Reliability; SD: Standard Deviation.
- Diagonal elements represent AVEs and off diagonal elements correlations.

The analysis of significant path coefficients is based on their respective p-values. Results are shown in Table 4. Hereby, "D only" indicates that no interaction terms were included in the model, whereas "D+I" describes the model with interaction terms included. The indices R^2 and Adjusted R^2 indicate the model fit in every life cycle stage.

	“Manufacturing / Buy”		“Use”		“Disposal”	
	D only	D + I	D only	D + I	D only	D + I
<i>ATT</i>	.083	.059	.221***	.192**	.297***	.290***
<i>SN</i>	-.180	-.219	.216	.189	-.360	-.336
<i>PBC</i>	.482***	.438***	.278***	.290***	.187**	.192**
<i>EA/EC</i>	.121*	.136**	.249*	.243*	.223***	.222***
<i>EA/EC x Personal EK</i>		-.063		.094		.046
<i>EA/EC x General EK</i>		-.222		-.112		-.046
R²	.414	.506	.419	.473	.506	.550
Adjusted R²	.406	.493	.411	.459	.499	.537

Table 4. Results of the structural model

Notes:

- *ATT*: Attitude, *SN*: Subjective Norms, *PBC*: Perceived Behavioural Control, *EA/EC*: Environmental Awareness/Concern, *EK*: Environmental Knowledge.
- * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The support of the hypotheses varies across the different stages of the life cycle of IT: Within the first stage, “Manufacturing / Buy”, H3 and H4 were supported. *PBC* and *EA/EC* significantly and positively impact an individual’s intention to buy environmentally sustainably manufactured IT. H1 and H2 are not supported. In total, the research model explains 50.6% of the variance in the intention to buy sustainably manufactured IT. In the second stage of IT’s life cycle, “Use”, H1, H3, and H4 were supported. Hence, *ATT*, *PBC*, and *EA/EC* influence the intention to use IT in an environmentally sustainable way. Only hypothesis H2 is not supported. Overall, the research model explained 47.3% of the variance within this stage. Similarly, H1, H3 and H4 are supported within the last stage, “Disposal”. However, the significance levels slightly differed for *ATT*, *PBC*, and *EA/EC*. Again, only hypothesis H2 is not supported. In total, 55.0% of all variance regarding the intention to dispose IT in a sustainable way is explained by the proposed research model. Overall, results show that *EA/EC* as well as *PBC* are significant across every life cycle stage, whereas *SN* has no significant influence on an individual’s intention to behave in an environmentally sustainable manner.

6 Contribution

6.1 Discussion

This research paper is located at the intersection of sustainability and IT research. By adding *environmental factors* to the TPB model and evaluating the new research model along all stages of the life cycle of IT, we adapt the scope of existent TPB application areas.

With Study 1, we apply an explorative factor analysis of environmental factors derived from existing literature, combining both areas of research, sustainability and IT. With the results of the EFA, we show that *Environmental Awareness* and *Environmental Concern* should be combined into one independent variable which we name *Environmental Awareness/Concern*. Moreover, we show that two additional environmental factors, *Personal Environmental Knowledge* and *General Environmental Knowledge*, serve as moderating variables of *Environmental Awareness/Concern*. Together with the original independent TPB variables (*Attitude*, *Subjective Norms*, and *Perceived Behavioural Control*), we derive our research model.

In Study 2, we analyse the structural relationships between the three adapted independent TPB variables combined with our additional variable *Environmental Awareness/Concern*. Further, we include the two moderators to elicit their combined impact on individuals’ intentions to behave sustainably within the three life cycles stages, “Manufacturing / Buy”, “Use”, and “Disposal” of IT. We thereby show the

significant, positive influence of *Environmental Awareness/Concern* and *Perceived Behavioural Control* within every life cycle stage (H3 and H4). The significant influence of *Environmental Awareness/Concern* could indicate growing awareness and concern about environmental issues within society. IT could receive more focus as it can be seen as both, a cause as well as a possible solution to many environmental problems. It is conceivable, that an increased level of IT adoption leads to more experience with energy-efficient IT. This may be the basis for explaining *PBC*'s significant impact in the model. The difficulty to behave more sustainable along the life cycle of IT decreases, with environmentally friendly technologies becoming ubiquitous. *Attitude* shows a positive relationship toward sustainable behaviour in the context of IT across two out of three life cycle stages (H1). *Attitude* does not significantly influence intention to behave in an environmentally sustainable manner the first stage "Manufacturing / Buy". This lack of significance can possibly be explained by individuals' lacking insights and understanding of sustainable production processes of IT. Arguably, the Manufacturing / Buy stage is the most unintuitive one for an everyday user. Therefore, individuals do either not develop an *Attitude* toward buying sustainably produced IT or at least it is not important enough to them. Interestingly, *Subjective Norms* never showed a significant influence on sustainable behaviour in the context of IT (H2). A possible explanation could be that the perceived social pressure in the context of buying, using, and disposing IT is rather limited in a sustainability context.

Considering the potential explanations, more research is required to understand the relationship between independent variables and sustainable behavioural intentions along the life cycle of IT.

6.2 Theoretical and Managerial Implications

6.2.1 Theoretical Implications

This paper offers two major theoretical contributions. First, the underlying work contributes theoretically by providing an overview of existing extension factors of the TPB model within a sustainability and technology context. More specifically, our research paper adapts the TPB by environmental influence factors regarding the life cycle IT. Based on 18 studies which already added parts of *environmental factors* before, we conducted an exploratory factor analysis showing that *environmental factors* consist out of two moderating factors, *Personal Environmental Knowledge* and *General Environmental Knowledge*, as well as one additional independent variable, *Environmental Awareness/Concern*. We therefore provide a novel measurement model for *environmental factors*, which we showed was significant for sustainable behaviour in the context of IT. Second, our research paper extends the TPB model by applying it to three life cycle stages of IT. To the best of the authors' knowledge, this research paper is the first one combining LCA and the TPB model and therefore provides further insights into people's intention to behave in an environmentally sustainable manner in the context of IT's life cycle stages. Thereby we show that *Perceived Behavioural Control* and *Environmental Awareness/Concern* significantly impact individuals' intentions to behave sustainably along the entire life cycle of IT. Our research paper reveals that the significance of influencing factors varies across the three life cycle stages of IT.

6.2.2 Managerial Implications

Our empirical findings on sustainability generate two managerial implications. First, Study 2 shows the significant influence of the environmental factors on sustainable behaviour within all three stages of IT's life cycle. This has three implications: First, we find that individuals prefer to buy IT which is sustainably produced. Therefore, IT producers should focus on both, a sustainable manufacturing process and sufficient marketing campaigns that ensure its publicity. Second, by finding individuals' intentions to adopt environmentally sustainable behaviour with the help of IT, products, for example by design, should facilitate this desire. Third, we find that individuals pay attention to the disposal of IT. Therefore, IT should be designed to offer people a simple and convenient way of sustainable recycling. In total, these findings imply that people are finally aware of their responsibility regarding environmental issues within all stages of IT's life cycle. As a second implication, this research paper contributes by increasing the awareness of *Attitude* as an influencing factor along the life cycle stages. With revealing its significances in the stages "Use" and "Disposal", professionals should aim at convincing individuals

to increase their sustainability within these two stages. Hence, marketing strategies designed to influence individuals to develop a favourable evaluation of using IT to increase their sustainability as well as disposing IT in a sustainable way should be implemented.

6.3 Limitations and Further Research

Our research study is not without limitations. The first limitation concerns the generalizability of our empirical results. Availability of technology between respondent groups is necessary to assure comparable results. Our research was conducted in the U.S., an industrialized country. Accordingly, IT is widely available. Results may differ compared to countries exhibiting different economic conditions. Additionally, the age of the participants in our sample is not representative of the population as a whole with a mean age of 28 in Study 1 and 29 in Study 2. Therefore, the findings may not apply to a significantly older group of people. Future research can build upon this paper by testing our research model in different geographical areas and cultures, employing a sample with different demographic attributes. Second, the purposes of the surveys were openly introduced in the introduction for Studies 1 and 2. Therefore, sustainable behaviour was described and openly named. Our results may be influenced by this description, and a social desirability bias may have influenced the results. However, we included a control question as well as a marker question to identify and exclude participants who did not answer the survey conscientiously. The third limitation addresses the underlying theory our research model builds upon. We used the origin TPB as a framework which we adapted to a sustainable context, since it has been proven mature and well-suited for research questions at the intersection of sustainability and IT. However, we note that Ajzen and Fishbein have continued updating the origin TPB model (Reasoned Action Approach; Ajzen and Fishbein, 2010). Further research could build upon this updated research model, examining whether this new model adds explanatory power to answer our research question. The last limitation pertains the scope of our research model in two ways: Firstly, for this research study we focused on *environmental factors* as additional independent variable to adapt the TPB. A yet to be answered research question would be to examine a research model not limited to *environmental factors*, but embracing all additional factors introduced within sustainability and technological research and analyse their different significances across the life cycle of IT. Secondly, within this study we focused on investigating the influence on individuals' intention along IT's life cycle as a dependent variable. Future research could apply the research model within different contexts to further broaden the area of application. Additionally, another yet to be answered question relates to the level of detail within the life cycle of IT. Since our study aims to identify the differences of the individuals' perceived importance of sustainability, we use an aggregated, three-staged life cycle of IT to present the major consumers' touchpoints to IT. Building upon our results, further research could use this life cycle approach to investigate differences between the stages of a more detailed life cycle. Figure 1 illustrates an example of a more detailed life cycle referring to Khasreen et al. (2009), Menzies et al. (2007), and Azapagic (1999) amongst others.

7 Conclusion

To the best of our knowledge, up to now, neither *environmental factors* as a comprehensive construct nor their significant impact on individuals' behavioural intentions to behave in an environmentally sustainable manner across IT's life cycle have appeared in prior research. We show that *environmental factors* can be modelled as *Environmental Awareness/Concern* as a direct variable. This variable is moderated by *General Environmental Knowledge* and *Personal Environmental Knowledge*. Furthermore, by analysing the individuals' behavioural intentions to be more sustainable along IT's life cycle, we show that *Environmental Awareness/Concern* has a significantly positive impact within every stage across the life cycle of IT. Overall, we are confident that the results of this research paper open the door to further research opportunities on the intersection of IT and sustainability with broad potential among its manifold facets.

Appendix A

Items of Study 2 (SEM)

	Items within the Stage “Manufacturing / Buy”	Authors
ATT	Buying sustainably manufactured IT is a good idea.	Taylor and Todd, 1995
	Buying sustainably manufactured IT is a wise idea.	
	I like the idea of buying sustainably manufactured IT.	
	Buying sustainably manufactured IT would be pleasant.	
SN	People who influence my behaviour would think that I should buy sustainably manufactured IT.	
	People who are important to me would think that I should buy sustainably manufactured IT.	
PBC	I would be able to buy sustainably manufactured IT.	
	Buying sustainably manufactured IT is entirely within my control.	
	I have the resources and the knowledge and the ability to buy sustainably manufactured IT.	
Intention	I intend to buy sustainably manufactured IT this year.	
	I intend to buy sustainably manufactured IT within my daily life.	
	I intend to buy sustainably manufactured IT frequently.	
EA/EC	When I think about the manufacturing of IT, I am often concerned about environmental issues.	
	When I think about the manufacturing of IT, I am concerned about the environment.	Engelken et al., 2016
	When I think of the consequences of the manufacturing of IT on the climate, I am very worried.	Peters et al., 2014
	When I think about how IT manufactures deal with our oil supplies, I am very worried.	

Table 5. Items for independent variables included in SEM (Study 2), stage “Manufacturing/Buy”

Notes:

- ATT: Attitude, SN: Subjective Norms, PBC: Perceived Behavioural Control, EA/EC: Environmental Awareness/Concern, EK: Environmental Knowledge.

	Items	Authors
Personal EK	I know the meaning of the labels affixed on the sustainable IT (e.g., energy-efficient devices).	Wang et al., 2014
	I know sustainable methods (e.g., for energy-saving) well.	
	I know much about sustainability (e.g., energy-saving) tips of daily life.	
General EK	Melting of the polar ice caps may result in a flooding of shores and islands.	Tan et al., 2017
	Fossil fuels (e.g., gas, oil) produce carbon dioxide (CO ₂) in the atmosphere when burned.	
	A reduced number of species may interrupt the food chain, affecting one subsequent species in the food chain.	Chan et al., 2015
I have heard the terms “sustainable IT”, “renewable energy”, “green power” or “green electricity” before today.		

Table 6. Items for Moderating Factors included in SEM (Study 2)

Note:

- EK: Environmental Knowledge.

Appendix B

For the Supplementary Material, such as the full list of the extended EN with their definition in literature (A), an overview about all items used for EFA (Study 1, B), the results of all EFA items (Study 1, C), and the correlations within the stages “Use” and “Disposal” (D), please see <https://www.dropbox.com/s/g0ls681pmsxu1y0/Supplementary%20Material.pdf?dl=0>

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