Progress in IS

Volker Wohlgemuth
Frank Fuchs-Kittowski
Jochen Wittmann *Editors*

Advances and New Trends in Environmental Informatics

Stability, Continuity, Innovation

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EnviroInfo 2016

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Preface

This book covers the main research results of the 30th edition of the long-standing and established international and interdisciplinary conference series on leading environmental information and communication technologies (EnviroInfo 2016). The conference was held on 14–16 September 2016 at the Hochschule für Technik und Wirtschaft Berlin (HTW Berlin), University of Applied Sciences. The EnviroInfo conference series under the patronage of the Technical Committee on Environmental Informatics of the German Informatics Society looks back on a history of 30 conferences. Thus, one important thread in Berlin was a retrospective on the experiences made and the lessons learned in the field of environmental informatics during the last years. Basic topics that were covered under the central focus *Environmental Informatics—Current trends and future perspectives based on 30 years of history* were applications of geographical information systems, environmental modelling and simulation, risk management, material and energy flow management, climate change, tools and database applications and other aspects with regard to the main topic ICT and the environment.

Due to the interdisciplinary character of environmental informatics, one important goal of this conference was to bring experts from industry, research and education together to exchange ideas and proposals for solution of urgent problems and needs in the field on environmental protection and its IT support.

The editors would like to thank all contributors to the conference and these conference proceedings. Special thanks also go to the members of the programme and organizing committee. Especially, we want to thank all "helping hands" and students of the HTW Berlin. Last, but not least, a warm thank you to our sponsors and to the HTW Berlin for being the host of this year's conference.

Berlin, Germany
June 2016

Volker Wohlgemuth
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Part I
Design, Sustainability and ICT

Analysis of Product Lifecycle Data to Determine the Environmental Impact of the Apple iPhone

Hans-Knud Arndt and Chris Ewe

Abstract The increasing awareness of environmental protection, e.g. in the course of climate change, also affects products of the information and communication technology industry along their lifecycle. Companies have to consider how their processes and products can be designed correspondingly the expectations of their stakeholders as well as the public. Therefore they have to measure and analyze environmentally concerning data to improve their service provision. Using the Apple iPhone as an example this paper will execute such an analysis to evaluate its environmental impact. The data investigation is performed by reconditioning, analyzing and interpreting the data as well as giving potential causes and correlations with other datasets. Basing on the performed analysis a generalized model for the assessment of the environmental impact of ICT products can be enabled.

Keywords Environmental protection · Sustainability · Product lifecycle · Design · Data analysis · Data visualization · Reporting

1 Sustainability, Environment and Design in the ICT Industry

The Nature Conservancy states on their website that it's crucial for humanity to raise the awareness for environmental protection as one of the central parts of sustainability (The Nature Conservancy 2016). Major impacts of an inadequate further procedure would be the greenhouse gas caused consequences of the climate change. They state: "With rapid climate change, one-fourth of Earth's species could be headed for extinction by 2050" (The Nature Conservancy 2016). Direct impacts,

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which threaten animal's as well as human's life's are: higher temperature, rising seas, stronger storms, increased risk of drought, fire and floods or the increase of head related diseases (The Nature Conservancy 2016).

Especially companies have a strong impact on effects like air pollution or the consumption of resources. Therefore, they have to design their products and processes to leave a preferably small footprint. This also applies to products of the information and communication technology (ICT) throughout their entire lifecycle. From procurement to production, usage and disposal, ICT products and their processes should be designed to have a minimal environmental impact in order to meet climate goals (Arndt 2013).

Smartphones, as a continuously growing part of the ICT, also have to meet these requirements (Statista 2015). Along their lifecycles they have to consider, which materials in which amounts should be used, which services should be offered or how the hardware can be disposed at the end of use. Manufacturers have to think about how the user interacts with the product to e.g. save material while using less hardware. Accurately analyzing this sustainability data will help companies to decide better how to influence their footprints. One company who already gathers data along the lifecycle of their smartphone is Apple. Collecting, preparing, analyzing and interpreting this data as well as examining possible causes is subject of the following chapters.

2 Apple, iPhone and Report Data

2.1 Apple Environmental Politics and the iPhone

According to Apple, a preferably low environmental product impact is one of the key factors in their lifecycle design (Apple Inc. 2015a). They state: "We don't want to debate climate change. We want to stop it" (Apple Inc. 2015a). To comprehend this, the company provides data in form of reports, which demonstrate the product impact on the environment (Apple Inc. 2015b). Apple was chosen as an example, because they provide lifecycle data for their products, which can be used for such an analysis. The iPhone as the product example was chosen because of its relevance for the company's success, its broad range of models with many data to analysis as well as its popularity as a smartphone (Börsen-Zeitung 2015). For the analysis all iPhone models with an environmental report have been chosen, which are: 3G (2008), 3GS (2009), 4 (2010), 4s (2011), 5 (2012), 5c (2013), 5s (2013), 6 (2014), 6+ (2014), 6S (2015), 6S+ (2015), SE (2016) (Apple Inc. 2015b; Spiegel 2013). The structure of the iPhone reports and the definition of Apple's understanding of the dataset are subject of the following section.

2.2 Environmental Reports—Product Lifecycle Data

The core of the reports is formed by criteria that enable the quantification of the environmental awareness. For our analysis we focus on the greenhouse gas emissions (GGE), which are one key factor to ensure environmental protection. "A greenhouse gas is any gaseous compound in the atmosphere that is capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere. By increasing the heat in the atmosphere, greenhouse gases are responsible for the greenhouse effect, which ultimately leads to global warming." (Livescience.com 2015) All other given values are considered as influential factors, which could lead to possible explanations for the GGE development.

Apple's reports show the total amount of GGE as well as the share of each phase of the lifecycle in kg of carbon dioxide equivalents (CO_2e) (Apple Inc. 2015b). The company's understanding of the product lifecycle slightly differs between different models. In the following we show exemplary the definitions for the model 3G (Apple Inc. 2015b):

- **Production**: Extraction, production and transportation of raw materials and the manufacturing, transport and assembly of all parts and product packaging.
- **Transport**: Air and sea transportation of the finished product and its packaging from the manufacturer of the product to the distribution center. The transport of the product from the distribution center to the end customer is not included.
- **Customer use**: For the power consumption of the user, a three-year period is assumed. Use scenarios were modeled based on data that reflects intensive daily use of the product. Geographic differences in the power grid need to be considered on a continental scale.
- **Recycling**: Transport from the collection to the recycling centers as well as the energy that is used for mechanical sorting and for shredding of the components.

3 Environmental Impact Analysis of the Apple iPhone

3.1 Course of Analysis

1. **Collection and Cleaning of the Data**: The data have to be prepared to enable an access of analysis tools. Therefore we collect all data in Microsoft Excel.
2. **Analyzing the Data**: We use Microsoft Power BI to upload the Microsoft Excel sheets and analyze them by visualizing the datasets in different comprehensive ways (Microsoft Inc. 2016).
3. **Interpretation of Findings and possible Explanations**: We show the facts that have been provided by the visualizations and also give answers to explain the results. Possible explanations are given by comparing the emission data with other given data like the product weight.

3.2 Greenhouse Gas Emissions

The reports illustrate the total GGE as well as the single lifecycle stage GGE. While the total is given in kg CO_2e, the shares of the single phases are displayed as percentage from the total. To analyze the given data we implemented a Microsoft Excel sheet, which contains the total GGE as well as the converted values for each stage. The resulting is shown in Table 1.

In the next step the spreadsheet had been uploaded to the analysis tool. Therewith, it was possible to create a variety of visualizations, which show the development in the course of time. A visualization in form of a line chart can be seen in Fig. 1.

The ordinate shows the single models ordered by their release data from left to right. The abscissa shows the GGE in kg CO_2e. In the following the graphs will be interpreted:

(1) **Total Emissions**

Starting with 55 kg CO_2e of model 3G the emissions vary only by ±10 kg CO_2e until model 4S. Model 5 shows the first stronger increase by 20 %. From model 5s to 5c a decrease is shown, while the 5c has even less emissions than the first iPhone. With the release of iPhone 6 and 6+, these values strongly increased to 95 kg CO_2e and 110 kg CO_2e. It can be seen that iPhone 6+ causes twice as much emissions compared to 3G. The models 6S and 6S+ decrease these values in each case by 15 kg CO_2e. The latest model SE is with 75 kg CO_2e slightly above the median which lies at 71.25 kg CO_2e.

(2) **Lifecycle Phase Emissions**

It indicates e.g., that model 3G caused 24.75 kg CO_2e during the production process, which corresponds to 45 % of the total. The values illustrate that, except

Table 1 Total GGE and single lifecycle phase GGE of iPhone models

Mod.	Total	Production	Transport	Customer use	Recycling
3G	55	24.75	26.95	2.75	0.55
3GS	55	24.75	26.95	2.75	0.55
4	45	25.65	15.30	3.60	0.45
4S	55	33.00	17.05	3.85	1.10
5	75	57.00	13.50	3.00	1.50
5c	50	36.50	10.50	2.00	1.00
5s	65	52.00	9.10	3.25	0.65
6	95	80.75	10.45	2.85	0.95
6+	110	89.10	15.40	4.40	1.10
6S	80	67.20	8.00	4.00	0.80
6S+	95	79.80	10.45	3.80	0.95
SE	75	61.50	10.50	2.25	0.75

Source According to Apple Inc. (2015b)

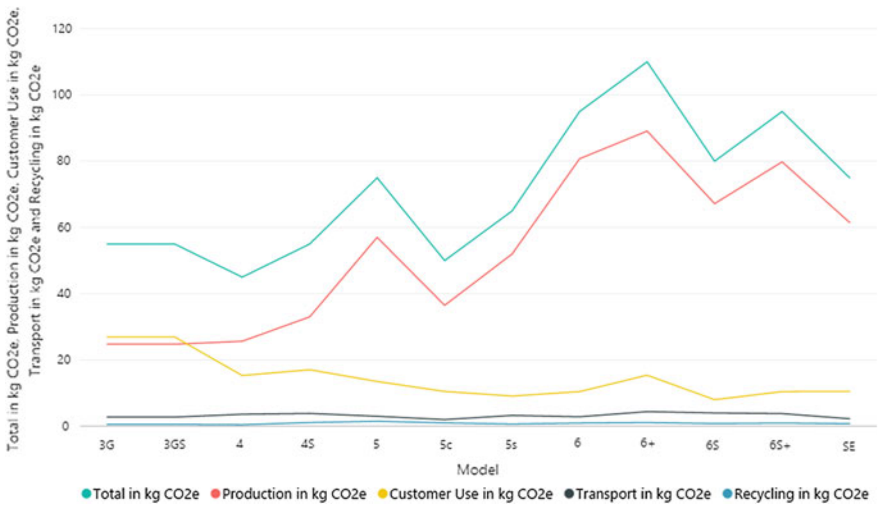

Fig. 1 Emissions in kg CO_2e—total and single lifecycle phases. *Source* According to Apple Inc. (2015b)

the first two models, the largest emission causer is the production phase followed by customer use, which is the largest for 3G and 3GS. However, the course demonstrates that the customer use emissions had been reduced in total over time with only slightly peaks in between. On the contrary, the production GGE show an increase over time. Transport and recycling show a continuously low impact and can therefore be considered as the areas with the lowest improvement potential.

(3) **Total Emissions compared to Production and Customer Use**

Figure 1 illustrates that the total GGE and the production GGE graph are running almost simultaneously. As an example the model 5s can be used. While total and production emissions increase from the predecessor model, the customer use emissions decrease. For that reason we identified the production phase as the most critical lifecycle stage to perform improvements, which will be conducive to a progressive environmental politic at Apple. At the first models the customer use had been in this role. Since we have no access to evaluate why the production of model 6 emits 80.75 kg CO_2e, more than 30 times as much as the production of model 4, future studies should access even better data for a deeper investigation.

3.3 Possible Causes of the Shown Developments

The illustrated development depends on different factors. For example, the internal processes could have changed or some new findings in production processes could effect to the emissions. Also the replacement of materials could contribute to a change. Since models 5 (except 5c), aluminum was used (Apple Inc. 2015b).

This material is highly recyclable, but could possibly cause more emissions during another phase (Pehnt 2010). Another example is the change of size and weight of the models, which is in turn also connected to the used materials. In the following, some of the presumptions shall be exemplary verified.

(1) **Influence of Product Weight on Total Emissions**

(a) **Weight Development**

Table 2 shows the weight of each model in gram. The weight is the sum of all materials, which are shown as product parts in the reports.

The individual changes from one model to the next are depicted in Table 3. Here, the gram numbers were taken, since they can be better compared to the emissions.

The table is read from left to right. For example, the weight from 3G to 3GS has increased by 2 g. If the weight has decreased the number is written in red. The upper right from the diagonal shows the timely development seen from early to later. Below the diagonal the opposite view is shown with inversion results.

(b) **Greenhouse Gas Emission Development**

In Table 4 the GGE changes are shown in the same way we worked out the weight changes in Table 3.

Table 3 e.g. shows that the GGE from 3G to 4 have changed by −10 kg CO_2e.

(c) **Comparison of the Developments**

The comparison reveals the relation between weight and emission changes over several generations or even from predecessor to successor model. Exemplary all four cases are shown for changes over several generations (colored in the tables):

Table 2 Weight of iPhone models

Mod.	3G	3GS	4	4S	5	5c	5s	6	6+	6S	6S+	SE
Weight (g)	133	135	135	140	112	132	112	129	172	143	192	113

Source Apple Inc. (2015b)

Table 3 iPhone weight changes in gram*Source* According to Apple Inc. (2015b)

Mod.	3G	3GS	4	4S	5	5c	5s	6	6+	6S	6S+	SE
3G	-	+2	+2	+7	-21	-1	-21	-4	+39	+10	+59	-20
3GS	-2	-	0	+5	-23	-3	-23	-6	+37	+7	+57	-22
4	-2	0	-	+5	-23	-3	-23	-6	+37	+8	+57	+26
4S	-7	-5	-5	-	-28	-8	-28	-11	+32	+3	+52	-27
5	+21	+23	+23	+28	-	+20	0	+17	+60	+31	+80	+1
5c	+1	+3	+3	+8	-20	-	-20	-3	+40	+11	+60	-19
5s	+21	+23	+23	+28	0	+20	-	+17	+60	+31	+80	+1
6	+4	+6	+6	+11	-17	+3	-17	-	+43	+14	+63	-16
6+	-39	-37	-37	-32	-60	-40	-60	-43	-	-29	+20	-59
6S	-10	-7	-8	-3	-31	-11	-31	-14	+29	-	+49	-30
6S+	-59	-57	-57	-52	-80	-60	-80	-63	-20	-49	-	-79
SE	+20	+22	-26	+27	-1	+19	-1	+16	+59	+30	+79	-

Table 4 iPhone GGE changes in kg CO_2e*Source* According to Apple Inc. (2015b)

Mod.	3G	3GS	4	4S	5	5c	5s	6	6+	6S	6S+	SE
3G	-	0	-10	0	+20	-5	+10	+40	+55	+35	+40	+25
3GS	0	-	-10	0	+20	-5	+10	+40	+55	+25	+40	+25
4	+10	+10	-	+10	+30	+5	+20	+50	+65	+35	+50	+30
4S	0	0	-10	-	+10	-5	+10	+40	+55	+25	+40	+20
5	-20	-20	-30	-10	-	-15	-10	+20	+35	+5	+20	0
5c	+5	+5	-5	+5	+15	-	+15	+45	+60	+30	+45	+25
5s	-10	-10	-20	-10	+10	-15	-	+30	+45	+15	+30	+10
6	-40	-40	-50	-40	-20	-45	-30	-	+15	-15	0	-20
6+	-55	-55	-65	-55	-35	-60	-45	-15	-	-30	-15	-35
6S	-35	-25	-35	-25	-5	-30	-15	+15	+30	-	+15	-5
6S+	-40	-40	-50	-40	-20	-45	-30	0	+15	-15	-	-20
SE	-25	-25	-30	-20	0	-25	-10	+20	+35	+5	+20	-

1. Weight increased and GGE decreased—e.g. 3G to 4 (marked blue)
2. Weight decreased and GGE decreased—e.g. 3G to 5c (market green)
3. Weight decreased and GGE increased—e.g. 4 to 5s (marked yellow)
4. Weight increased and GGE increased—e.g. 5s to 6+ (marked red)

The comparison of the values show that there is no explicit correlation between weight and GGE. This result clarifies that the consideration of individual factors can be insufficient for such a complex problem. On the one hand, a higher weight would also explain a higher material consumption and hence e.g. a higher demand for fossil fuels. On the other hand, the change of materials also requires considering their emissions and potentially adopted production processes, which could have a lower environmental impact than before. A heavier smartphone with improved processes can thus cause fewer emissions.

(2) **Influence of Used Materials on the Emissions**

Since the used materials affect the resulting emissions by the product itself as well as the emissions in the manufacturing process, it's important to research how different materials could have an impact on total and single lifecycle emissions. With the set of data we can try to answer questions, like:

1. Does the use of aluminum positively influence the GGE in the recycling stage?
2. Is there a material, which has a significantly high impact on the total GGE?
3. Does the use of polycarbonate significantly impair the environmental balance?
4. Does the 3G with 14 % plastic has higher GGE than the 4S which 2 % plastic?

Following we exemplary research the first two questions:

According to Apple, aluminum is used because it is almost indefinitely recyclable and has therefore a strong impact on this phase (Apple Inc. 2016; Hall et al. 2015). However, looking at the recycling phase the graph reveals that there is no clear relationship between the use of aluminium and a significantly decrease of recycling emissions. For some models the emissions are higher than looking at most models who hasn't used the material, like 3G or 3GS. Figure 2 shows these findings and marks the aluminium models with red cycles.

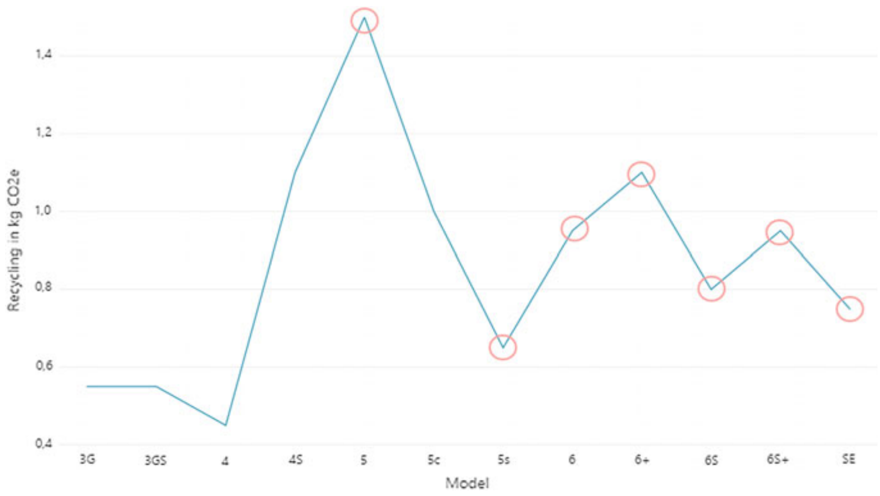

Fig. 2 Recycling GGE with aluminium containing models marked. *Source* According to Apple Inc. (2015b)

Again, the complexity of the problem is shown since a basically solid assumption that aluminium would be always conductive to emissions at least in the stage of recycling had to be refuted. One explanation approach could be, that the emission causing factors in the lifecycle phase of recycling are based on other indicators like machine emissions or similar.

The second question searches for materials, which have a significantly high impact on the total GGE. We would consider this as true for a material, which whenever weight increases the total emissions also increase. To answer this we have a look at the GGE developments as well as the development of the single components. What we are looking for are two graphs, one from the emission figure one from the material figure, which always go in the same direction. This finding would indicate a significant impression of the component on the emission graph and therefore reveal a possible connection of them both.

The comparison corresponds to a two dimensional table with changing values from one model to another. Doing so we found that the graphs of aluminium and emissions seem quite similar. Figure 6 illustrates both graphs as single and overlap-ping. The developments in the overlapping graph are given without an outline scale since the lines have different standards. The total emission graph starts at 40 kg CO_2e and the aluminum graph starts at 0 g since there are models without this material (Fig. 3).

Since aluminum was not part of the first four models we start to research the graphically development by having a look on the change from 4S to 5. Table 5 shows the changes of the consecutive models, so e.g. from 5s to 6 the change is +5 since model 5 has 21 g and model 6 has 26 g of aluminum.

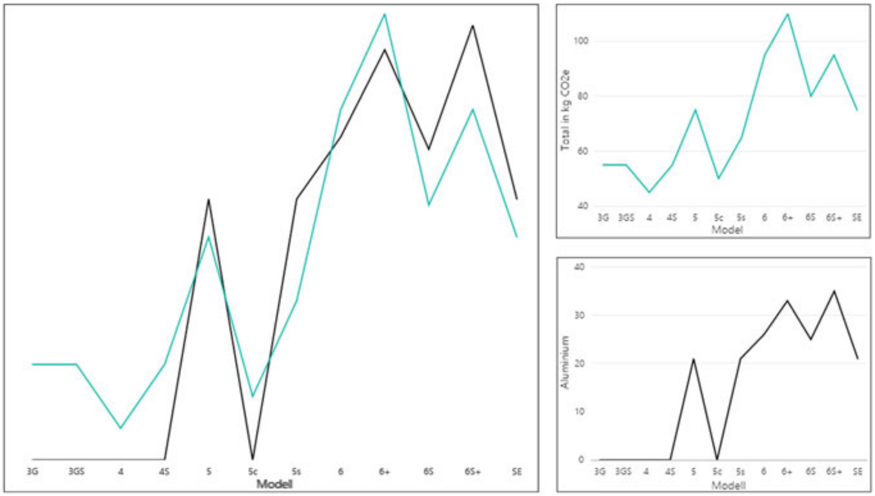

Fig. 3 Comparison of total emissions and the material aluminum. *Source* According to Apple Inc. (2015b)

Table 5 Aluminium and GGE changes of consecutive models

Mod.	Changes of aluminium in g	Changes of emissions in kg CO_2e
4S	0	+10
5	+21	+20
5c	-21	-25
5s	+21	+15
6	+5	+30
6+	+7	+15
6S	-8	-30
6S+	+10	+15
SE	-14	-20

Source According to Apple Inc. (2015b)

It can be seen that whenever the used aluminium increases or decreases the emission graph is going in the same direction. According to our findings it seems that aluminium causes a lot of emissions in total. Aluminium is a very good example to again show the complexity of this topic. For models 5 and 5s the same amount of aluminium is used, but the emissions do not increase by the same value. This shows that more factors must be taken into account than just one by one, because from this perspective it seems that using aluminium to produce a smartphone is not as useful as desired.

4 Conclusion and Implications for Future Research

Taking environmental protection actions like the reduction of greenhouse gas emissions, is an important challenge for the ICT industry. Companies have to figure out solutions to emit as little emissions as possible along the lifecycle of their products. Therefore, it's important to measure and analyze environmental data to make decisions on a reasonable base. On the example of the Apple iPhone this paper analyzed the sustainability related data given by Apple. For our analysis we concentrated on the GGE. Other data had been used as an explanation for the development of them.

As could be revealed, the production phase is the decisive factor with the highest potential for improvement. The curves of total and production emissions run nearly parallel. We also found that the product weight has no mandatory influence on the GGE. Afterwards we took the material share dataset to research two exemplary questions. First, we found that the models, which used aluminum caused in some cases more emissions in the lifecycle phase of recycling than most of the models, which haven't used this material. This finding was unexpected since aluminum promises to be highly recyclable and maybe still is because other, at this time, unknown factors caused this growth. The second question was, if at least one of the used materials has a significant impact on the total GGE. We found that the aluminum graph seemed very similar to the emission graph and analyzed the changes between the consecutive models. By contrasting this changes to the emission changes we proved that the graphs run always in the same direction. This proved that aluminum seems to have a profound impact on the total emissions. Another finding was that the impact of using an equal amount of aluminum did not result in an equal emission change. This showed that there has to be taken more into account than a single material to explain the total emission changes.

Due to the complexity of the topic as well as the relations between the data, further research should be conducted to answer even deeper questions. Also, already answered question could be modified so that e.g. the question of material influence could be extent to combinations of two or more materials. Further papers could also include more environmental data for explanations of the emission development like the products energy consumption. Another critical point of our analysis is the given dataset, which comes directly from Apple. Since Apple is the producer of the iPhone, independent measurements would be desirable but not feasible. Furthermore the product lifecycle defections have to be standardized since different models have slightly different views on some stages. Ultimately the performed analysis could lead to an environmental data dashboard which would enable the real time monitoring of environmental data. This dashboard could also be used for benchmarking purposes e.g. between the iPhone and another smartphone, which could be another implication for further research approaches.

However, the paper has shown that sustainability in the context of environmental protection is a crucial topic nowadays. Customers become more and more aware of these aspects. Their recognition of achievements in this field will also create competitive advantages, so that technology companies have to be even more aware of this challenge. To make progress companies have to measure, analyze and report those data. The performed analysis can be one way to investigate the datasets and give deeper insights. The development over time reveals facets one can't see by the first view so e.g. materials, which seem to be conductive must be questioned to get products and processes with a preferably low environmental impact.

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Sustainable Software Design for Very Small Organizations

Stefanie Lehmann and Hans-Knud Arndt

Abstract Very small organizations rarely use software to organize their business processes, because there are comparatively few known solutions for their particular problems. On the one hand, these software solutions are often associated with high costs and on the other hand, particularly very small organizations do not have enough resources to find suitable solutions. These organizations miss a lot of opportunities: Through the use of the Information and Communication Technique (ICT) business processes can be processed not only resource-efficient due to reduced paper consumption. The ICT also helps to make business processes more efficient. To find such a sustainable software solution for very small organizations, requirements are identified. To determine a structure for such software to document business processes, it is important to apply design aspects for the implementation of the software. A definition of such design aspects can be achieved by the properties of a sheet of paper, which help to organize business processes in very small organizations. By analogy of the dominant metaphor of paper we specify requirements of sustainable software design for very small organizations.

Keywords Sustainability · Software design · Very small organization · Business process

1 Motivation

Very small organizations such as start-ups, associations or even societies are characterized by few employees and limited financial and time resources. Typically, the information transfer in these organizations is focused on handwritten notes on a sheet of paper. However, it is obvious that very small organizations should be able

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to easily transfer information from handwritten notes into an Information and Communication Technique (ICT)-based system. To do so, on the one hand reduces risks and losses of knowledge of business processes, such as caused by non-readable handwritings. On the other hand, based on ICT the exchange of knowledge can be done more efficiently. The limited resources of small organizations must be considered for such changes. In this paper, we discuss how sustainability of software design can support very small organizations during their day-to-day operations. This helps to improve the business processes especially in organizations, e.g., against the background of frequent change of personnel. One of our goals is that staff members can quickly see the important facts of the business processes. Today, most very small organizations fulfill their documentation of business processes in their own way, which may change over time. The consequences are uncertainties due to the documentation of business processes, which might hinder the sustainable operation when business processes need to be rethought or errors occur due to incorrect documentation. Therefore, staff members of very small organizations should be encouraged to handle information in a more uniform style by the use of a structured form and only one system.

Thinking of such an ICT-based solution, one idea might be to create something completely new (e.g., programmed by students during an internship). Instead, characteristics of a sustainable software design should be determined to identify existing sustainable software solutions (e.g., open source) especially for very small organizations.

2 Paper as the Most Important Information Carrier

Even in today's information age, especially very small organizations benefit from paper as the most important information carrier. Only occasionally ICT has prevailed over paper to transfer information in small organizations.

An established example to provide information with the help of technology instead of paper is shown by the step from a letter to an email (Hoffschulte 2011). There are similarities and differences between letter and email as a medium for providing information.

Similarities or parallels between letter and email are that, e.g., both present a structure by which the information for transmission is being performed. A significant difference between them lies in the technological implementation of the email: using technology information can be faster or even immediately distributed. In addition, digitalized information like emails can easily be reproduced. Furthermore, information can be transmitted more environmentally friendly by reducing paper consumption through emails.

Like in letters and emails, information is exchanged in business processes. Consequently, the general rule is that for business processes an ICT support is suitable for more efficiency and effectiveness in contrast to the use of paper, even in very small organizations. The use of ICT enables an improvement of business processes. But in particular an ICT solution for very small organizations must be as paper-like as possible. On the other hand, many current pen-based methods of ICT (e.g., like the Apple Pencil for iPad Pro Apple Inc. 2016) serve the dominant metaphor of paper very well. Especially very small organizations have a need for long-lasting, sustainable software and in consequence also hardware solutions. Therefore, pen-based methods might be too modern and show little progress in the context to improve business processes of very small organizations. So this argument might guide them to a more conservative strategy.

Against this background the question about the best paper-orientated software design for very small organizations arises. In order to find an approach, design aspects can help here. In the past, it has been shown that the Ten Principles for Good Design stated by Dieter Rams (Vitsoe Ltd. 2016) can be used to evaluate the design of software (Arndt 2013).

3 Requirements of Sustainable Software Design for Very Small Organizations

To represent knowledge-intensive business processes by a technology, the Ten Principles for Good Design by Dieter Rams could be helpful. In this step, the advantageous properties of paper-based information should be transferred into digitalized ICT-based information. Sustainable design requirements on ICT are described for the technological representation of typical paper-based information of very small organizations by using the various aspects of the Ten Principles of Good Design.

These principles provide a framework of requirements for good design of products, but are also suitable for the design software (Arndt 2014). In the following, the description of the principles is used to show analogies to the properties of paper-based information for ICT-based information in the context of very small organizations. Each principle is considered in detail. Consequently, there will be a derivation of requirements for ICT to represent information and, therefore, also business processes which can be described by such information.

3.1 Good Design Is Innovative

This principle implies that a technological development could optimize the utility value of a product. This innovative design is always produced in association with innovative technology. From the transmission of these statements to the support of business processes follows that with a modern ICT-based method instead of a

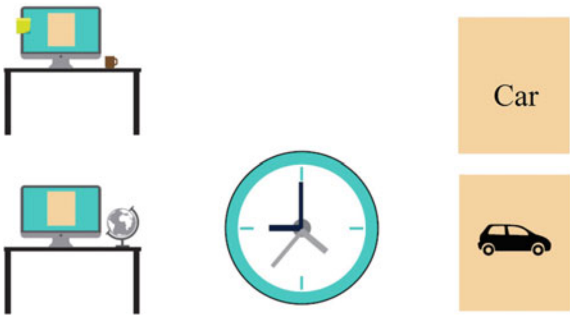

Fig. 1 Visualization of requirements based on the principle “good design is innovative”. *Source* According to Vector Open Stock (2015a, b)

paper-based method the business processes can be improved: The working times and places of work can be made more flexible, because the staff members are not tied to a single sheet of paper on which the information is stored. Moreover, thanks to modern technology, a flexible design of business processes is possible: Like on a sheet of paper there should no precise work instructions needed how knowledge has to be left. In addition, information cannot only be saved in the form of texts, but also, e.g., with the help of graphics.

Figure 1 outlines the requirements on an ICT to be innovative to support the business processes: Like a sheet of paper the information could be used at different workstations, at different times and the business processes could be designed according to the users’ needs, if the information is made available by ICT.

3.2 Good Design Makes a Product Useful

In addition to the primary functions, also psychological and aesthetic features of a product must be observed. Such a product is also ICT. Compared to paper-based information, all information can be detained for a business process to document it and to protect it against information overload. The data must always be up to date, which helps in distributing information. Furthermore, the data must be manageable: A sheet of paper has no restrictions in this sense, because its contents can be monitored at a glance. When a page is full, another sheet for additional information could be added. Transferring to ICT, restrictions have to be avoided for mapping information: either by a character limit or by the dimensions of the screen.

Figure 2 depicts the requirements of ICT to be useful for supporting the business processes: Like with a sheet of paper there is no limitation, data can be sorted and searched, and information can not only be taken from each user, but the user can also add or delete data when the data are updated.

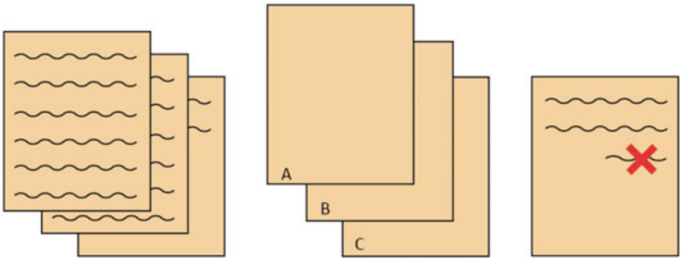

Fig. 2 Visualization of requirements based on the principle “good design makes a product useful”

3.3 Good Design Is Aesthetic

Devices that are used every day characterize the environment and affect the well-being. Consequently, in managing business processes with ICT, the operation should be as effective as or even better than by using a piece of paper. Just as the use of paper has prevailed in the daily office, also the use of a technological solution for information should be accepted and change the business processes positively. Thus, the business processes can be improved and thereby working time could be abridged.

Figure 3 visualizes the requirements of ICT to realize the aesthetic aspect for supporting the business processes: The procedures and processes can be improved, so that working hours can be reduced, and the user feels comfortable at his workplace, e.g., because there is less paper chaos.

3.4 Good Design Makes a Product Understandable

Following this principle, the structure of ICT has to be illustrated in a reasonable manner and without explanations. To organize information, it is established that the use of the data structure of lists is generally understandable. By analogy with a sheet or stack of paper the structure of the data is recognizable: A stack of paper can be sorted without many explanations. Expanding on the complete, global ICT, also its other functions should be as self-explanatory as possible. Limited on the natural language the use of the mother tongue within the system provides to understand this.

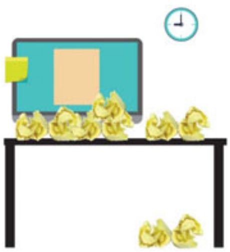

Fig. 3 Visualization of requirements based on the principle “good design is aesthetic”. *Source* According to Freepik (2011), Vector Open Stock (2015b)

Fig. 4 Visualization of requirements based on the principle "good design makes a product understandable". *Source* According to Vector Open Stock (2015b)

Figure 4 depicts the requirements of ICT to make it understandable for supporting the business processes: The use of lists illustrates a sorting of the data. The execution of the functions should be understandable to the user; the functions of ICT should be understood through the use of the mother tongue.

3.5 Good Design Is Unobtrusive

Products, which serve a purpose, have an instrumental character and should therefore have a neutral style. If the purpose is to manage business processes in a group, the focus is on the information contained in these business processes and the system itself moves into the background. If the design is as flat as possible, this corresponds to the design of a simple white paper where the notes are left on. Even if a system defines a certain structure, the user should be allowed a self-realization. So he/she can leave the notes in their own way. E.g., similar to a sheet of paper, the background color of information could be changed for communicating and sending various signals.

If the system acts as a tool, it should be apparent what kind of information is put in and is put out, is being processed. For this representation of business processes a simple Kanban Board can be useful, as outlined in Fig. 5.

3.6 Good Design Is Honest

A product has an honest design, if it does not break with the expectations of the users. Hence, also a knowledge management system should not promise more than that it collects information and distributes it for reuse. All other guaranteed

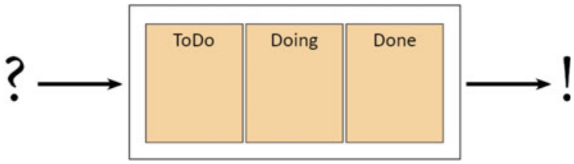

Fig. 5 Visualization of requirements based on the principle "good design is unobtrusive"