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## **Sustainability strategies of manufacturing companies on corporate, business and operational level**

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**Abstract:** Throughout society sustainability has gained great awareness and consumers expect producing companies to act sustainably. Research has shown that companies are starting to develop and communicate their sustainability agenda, but leaving the customer wondering if and how sustainability is really executed down the line. Therefore, this paper investigates sustainability strategies in manufacturing and their communication by first defining a research methodology and then applying it to a case study. Sustainability goals and strategies are studied on corporate, business and operational level. They are rated on their conveyance and correlation. These results are visualized in a matrix. A case study with the web-based information of 100 companies revealed that energy, waste, and diversity are the most named sustainability goals. Support of charity programs, smarter programming, reuse of waste heat, efficient lighting systems and childcare/ work time models were the most cited sustainability strategies.

**Keywords:** Sustainability; strategy; marketing; awareness; green manufacturing; research methodology

**Reference** to this paper should be made as follows:

**Biographical Notes:** Daniella Van der Spiegel received her bachelor's degree in mechanical engineering and business administration at the RWTH Aachen University, Germany in 2012. During her bachelor studies she studied at the Universidad Politécnica de Madrid, Spain for 6 months and worked at a trading company for secondary raw materials for another 3 months. In her master studies Daniella specialized in production engineering at RWTH Aachen University and was enrolled in environmental economics classes at UC Davis for a quarter. Currently she is finishing up her master's degree by researching with Dr. Barbara Linke at her Sustainable Manufacturing Technologies Laboratory at UC Davis.

Barbara Linke got her diploma and doctorate in mechanical engineering at the RWTH Aachen University, Germany. She worked with Prof. Fritz Klocke at the Laboratory for Machine Tools and Production Engineering WZL from 2002 – 2010. She then was a research fellow at the University of California Berkeley at Prof. David Dornfeld's lab with a research grant from the German Research Foundation (DFG). Since November 2012, Barbara has been an assistant professor at the University of California Davis. Barbara received the F.W. Taylor Medal of the CIRP in 2009 and the Outstanding Young Manufacturing Engineer award of the SME in 2013.

Jens Stauder studied mechanical engineering and business administration in the bachelor and master program at RWTH Aachen University, Germany. During his studies he worked as a student worker at Fraunhofer IPT Aachen in the department of high performance cutting and at the Laboratory for Machine Tools and Production Engineering WZL at RWTH Aachen in the working group technology planning. Since April 2013 he is employed at the WZL as a scientific researcher also in the working group technology planning. His research interests are ramp-up management and manufacturing technology design.

Steffen Buchholz studied mechanical engineering at RWTH Aachen University, Germany. From 2007 until the beginning of 2008 he wrote his master thesis on cutting edge preparation using spark erosion at McMaster University Hamilton, Canada. Since 2008 he works as a research associate in the working group technology planning at the Laboratory for Machine Tools and Production Engineering WZL at RWTH Aachen University. In 2011 he completed his MBA and assumed the direction of the group for technology planning. His research fields are technology assessment and the design of production sequences.

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## **1 Introduction and Motivation**

The industrial sector does not only have a grave impact on environmental factors but also the economy and society are shaped by it (Lankoski, 2005). Governments, producers, and consumers are becoming aware of their actions and influence on future generations (Barber, 2005). Given the abundance of products and choices it has to be clarified what their environmental, social and economic consequences are, not only for the safety of the consumer but also for the overall environmental health. The key term of this discussion is *sustainability*.

Research has shown that sustainability awareness has increased and many major industrial companies are acting on current social expectations (Kolk, 2004). Sustainable development has also gained importance in the academic field. Markard et al. (2012) shows that the number of citations in journals mentioning sustainable transitions has risen by 50% from 2009-2011. Various companies advertise their sustainability efforts and make profits out of their proactive approach (Sharma et al., 2010). But one should ask - what are other motivational factors to act more sustainably?

Besides drivers from legislature, public pressure and competitiveness, companies, for example, in Germany are mostly motivated by the cost saving factor in green manufacturing (Mittal et al., 2013) and one can suspect that this is similarly important in all other countries.

As soon as the management of a company has decided to implement sustainable strategies there is again a number of drivers and barriers influencing the implementation process (Bey et al., 2013). Consultants often help through the process of developing a sustainable vision and integrating sustainability into the corporate strategy. What happens though on the business and factory level, where many daily decisions are made that should execute the sustainable vision of the top management? In order to know if a suitable decision was made, it is necessary to have the full scope of information on the company's motives, goals, and strategies. Since the industry has figured out the power of marketing and especially marketing of sustainability, it is important to include this aspect into the observation of sustainability strategies (Bridges and Wilhelm, 2008). Preliminary web studies have identified lack of available in-depth information about the execution of sustainable strategies and how they are communicated to the public. Consequently, there is a need for research on how the top management's sustainability strategies are executed and publicised on the business and operational level. This study describes a research methodology to structurally attain such a pool of information. In

order to understand the background and current sustainability trends it is important to answer the following research questions:

1. Do manufacturing companies act sustainably, if yes, how?
2. How intensively is sustainability communicated to consumers?

Here, the term ‘manufacturing company’ describes a producing company that uses mechanical power and machinery. At times this term also refers to non-mechanical producing companies. The questions mentioned above have been chosen after studying academic literature and conducting expert interviews. It is evident that marketing strategies in sustainability are little explored by researchers (Kumar et al., 2012). Sharma et al. (2010) stress the need for empirical research on the links between sustainability and firm performance which is tackled with this paper.

Section 2 gives a brief overview on sustainability in manufacturing. Then the concept of sustainability strategies is defined in section 3. Section 4 explains the research methodology to analyse company strategies on corporate, business and operational level and evaluate their communication and correlation. In section 5 qualitative results of a small scale study with 100 companies are presented. The paper closes with an outlook.

## **2 Sustainability in Manufacturing**

The World Commission on Environment and Development, also known as the Brundtland Commission defined sustainable development as the “[...] development which meets the needs of current generations without compromising the ability of future generations to meet their own needs“ (Brundtland, 1987). The World Commission’s main concern is the revival of healthy growth which means that environmental and social factors have to be included in technological and economic progress. This train of thought was continued by United Nations (United Nations, 1992) in their Agenda21 with the introduction of the Three Pillars of Sustainability: society, economy, and environment. For manufacturing, Yuan et al. (2012) and Linke et al. (2013) stress the need to consider technology as a fourth dimension to sustainability besides economy, environment, and society. This fourth dimension will be added to the scope of sustainability in this study.

Manufacturing plays a critical role within modern socio-economic systems and poses a burden on the environment (Haapala et al., 2013; Jayal et al., 2010). For example, the industrial sector is responsible for a substantial part of today’s energy consumption. The U.S. Energy

Information Administration (2013) reported that 24.0 quadrillion Btu were consumed in the industrial sector in 2011, which is approximately one-third of total U.S. delivered energy. Hence, manufacturing processes and manufactured products have to become more efficient and socially friendly to preserve future generations' wealth. Allen et al. (2002) formulated the long term dilemma for manufacturing: "how to achieve economic growth while protecting the environment".

In addition, legislative frameworks pressure manufacturers to address sustainability, for example the European Sustainability Strategy, Clean Air Act, Global Warming Solutions Act (European Union, 2005; Air Resources Board, 2006; EPA, 2013). Producers are becoming more responsible for their products, for example through the Waste Electrical and Electronic Equipment (WEEE) Directive by the European Union (2012). Many different standards and methodologies exist to evaluate impacts of products, processes and manufacturing systems as listed by Singh et al. (2012). The most commonly used method for environmental sustainability is Life Cycle Assessment (LCA), including its variants process LCA, Economic Input-Output LCA and hybrid LCA (Reich-Weiser et al., 2010).

Social Life Cycle Assessments are still in development (Hauschild et al., 2008). The Committee on Sustainable Development of the United Nations (2007) has a large set of indicators with a strong focus on social sustainability and countries. Sustainability indicators evaluate the overall performance in all dimensions (Krajnc and Glavic, 2003; Joung C.B. et al., 2012; Singh R.K. et al., 2012; Linke et al., 2013). Social indicators include for example poverty, governance, health, education, but remain very general. Hutchins et al. (2010) focus on social sustainability in manufacturing and define employees, stockholders, suppliers, customers, community, and the public as most important stakeholders. Once a firm is motivated to address sustainability in one or more of the discussed dimensions, it needs to develop a strategy to address all relevant issues and build an effective program of action (Allen et al., 2002).

### **3 Sustainability Strategy**

Whether companies are acting sustainably can be assessed by studying their strategies as mentioned in corporate reporting. For Chandler (1997), "strategy can be defined as the determination of the basic long term goals and objectives of an enterprise, and the adoption of course of action and the allocation of resources necessary for carrying out those goals".

Furthermore, this broad term can be defined according to its hierarchy level: corporate, business, and operational.

A company's **corporate strategy** is focused on the overall mission and scope of the business while satisfying stakeholder's interests. It gives guidelines to make high level decisions strategically (Andrews, 1997). When a particular market or product line is regarded the **business strategy** has to be fulfilled. In order to comply with the company's corporate orientation, strategic decisions about choice of products, competitive advantages, customer satisfaction, and new developments have to be made (Barney, 1997). Consequently the **operational strategy** is focused on the orientation and structure of resources, processes, and people to fulfil the corporate and business level strategic direction.

Therefore, a sustainability strategy is a roadmap/route to pursue each of the sustainability pillar's goals concurrently and in a coherent way. In a more abstract sense it can also be described as an optimization problem with a high number of interrelations. Veshagh et al. (2012) showed that there is a high interest within companies to act sustainably but companies face barriers such as lack of expertise and high implementation costs. Therefore more research is needed to specify more clearly the underlying motivations and strategies. As mentioned earlier there are legislative factors that pressure companies to fulfil certain environmental and social standards (Barber, 2005). The two other motivational factors are an intrinsic corporate motivation or economic advantages (Epstein and Roy, 2001). For example, the **corporate motivation** can come from the company owner. However, economic advantages can always motivate companies and is explained in more detailed for this research. **Economic advantages** can be achieved in various ways. One possibility is that the stakeholders and investors administrate top-down pressure which can be motivated by asset development, competitiveness or foresight. The company is economically pressured because of its dependency on the stakeholders and they are motivated by possibly higher profits. The other possibility is the customer pull. If the consumer demands higher sustainability efforts then the fulfilment could lead to higher returns. The last option is that the company simply improves its productivity, reduces its costs or improves its products by integrating environmentally and socially friendly actions. (Parris and Kates, 2003; Bey et al., 2013)

In an attempt to answer the research questions *Do manufacturing companies act sustainably, if yes, how?* and *How intensively is sustainability communicated to consumers?* the following methodology has been developed.

## 4 Research Methodology

The proposed method helps to analyse and correlate available data on sustainability strategies, which is then visualized in a matrix. The methodology is shown in Figure 1 and consists of five steps with subtasks (a), (b), (c). Step 1 collects and analyses information on corporate strategies, Step 2 focuses on business and operational strategies. Step 3 connects these strategies with common sustainability goals. In Step 4 the results from the previous steps from several companies are assembled in a final matrix. In Step 5 the results from the final matrix are evaluated and conclusions from the various interwoven factors can be made. In the following sections each step is explained in more detail.

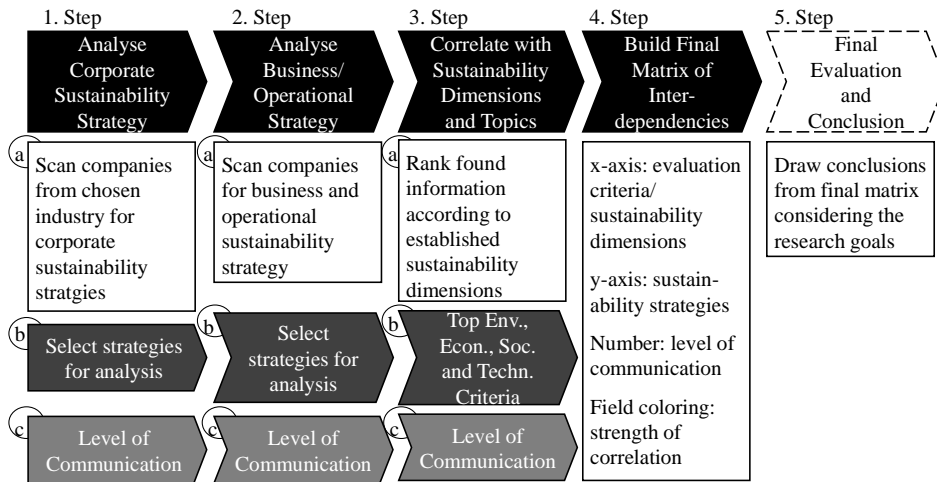


Figure 1: Research Methodology

### 4.1 Step 1: Analyse Corporate Sustainability Strategy

The first step of the applied research methodology is dedicated to corporate sustainability strategies. Corporate data is collected through expert interviews, websites, sustainability reports, brochures, etc. In the first subtask (1a) this data is scanned regarding statements on sustainability strategies. Part of this filtering step is the reply of the following questions:

1. Is sustainability part of the company's vision?
2. How is sustainability defined?
3. What are the main sustainability factors that are considered?

As second subtask (1b) corporate sustainability strategies that are going to be examined further are selected, e.g. Corporate Citizenship or



Sustainable Products. This selection can be made with a software-based evaluation according to a predefined scope of research (Freundlieb and Teuteberg, 2012). As third subtask (1c) the collected data is assessed regarding forms of communication and conveyance. Communication can be understood here as the way how frequent and demonstrative sustainability efforts are mentioned on the companies' websites or presentation materials. The following questions can be used as evaluation guidelines:

1. How easily can the information be obtained?
2. How strong is the overall appearance of sustainability in the company representation?

Freundlieb (2012) proposes a multi-method approach for the quality evaluation of sustainability reports. First a catalogue of quality criteria is iteratively developed. Research methods are literature reviews, empirical surveys, or expert opinions. Then the data is captured and reported with a database management system such as Access. Finally different stakeholder groups, such as customers, suppliers and investors should be involved into the evaluation process. This can be done with questionnaires.

In this paper the selection and evaluation process was simplified in order to proof the concept. The intensity of advertisement of selected strategies was ranked from 1 – 3, with 1 being the lowest and 3 the highest intensity of conveyance. If a company's sustainability measures are well conveyed to the public and results are clearly explained then the level of communication is 3. However, sometimes companies might stress sustainability as a main marketing strategy but not as a focus point in their corporate strategy. For example, a company may advertise strongly that it is a newly awarded Energy Star partner because all its products are Energy Star certified but the term "Energy Star" does not even appear in the company's sustainability report. If sustainability has a high importance on the corporate level it means that sustainability is considered in every major strategic decision. Personal interviews with industry contacts have led to the theory that the execution is more likely if these factors are introduced top down (Parris and Kates, 2003).

#### **4.2 Step 2: Analyse Business/Operational Sustainability Strategy**

In the second step of this research methodology, the companies' sustainability efforts are observed in more detail. As explained earlier, the business strategy is concerned with a certain customer market, location or product line. A company's operational strategy is one step further in the level of detail and occupied with the production processes, employees and

resources. Here, business and operational sustainability strategies are considered at the same time because this study showed that companies disclose only sparse information on these levels. Figure 1 shows collecting data regarding applied sustainability efforts as the first subtask (2a).

The central questions for Step 2 are the following:

1. What sustainability initiatives are introduced regarding line of products?
2. Is sustainability introduced more strongly at certain locations and if yes, how?
3. Are factories operated more sustainably and if yes, how?

These questions can be answered by comparing metrics, e.g. BMW has a production plant which converts methane from a near landfill into power and hot water. This covers 50% of the plant's total energy consumption (BMW, 2013) and makes it more energy friendly than other BMW plants.

Similar to task (1b), in task (2b) business and operational strategies are pre-selected by a quantitative tool, e.g. frequency analysis of keywords. To further reduce the selection it is proposed to execute a paired comparison. A paired comparison is a useful tool to evaluate a number of different options and rank them according to importance (Mind Tools, 2013). The first step is to create a generalized profile for the observed companies. It includes their preferences, corporate goals, scope of action, and resources. In the second step the preselected business and operational strategies are confronted with each other. Then each strategy is compared and ranked, always considering the companies' profile. Those strategies that were preferred/higher ranked most frequently are the final selection (Mind Tools, 2013).

As third subtask (2c) the degree of communication of the chosen sustainability strategies is assessed following the methodology mentioned in task (1c).

### **4.3 Step 3: Correlating Sustainability Dimensions and Topics**

In Step 3 common sustainability dimensions and topics are correlated to the strategies. As subtask (3a) the previously found data is investigated according to the different sustainability pillars. The goal is to figure out what the most important sustainability topics (energy consumption, water consumption, etc.) within the broad sustainability dimensions (environment, economy, technology, society, see section 2) are and which are addressed most frequently. In subtask (3b) the top two topics for each dimension are defined. To clarify, a sustainability dimension is 'environment' and a topic within this dimension could be 'water

reduction'. This selection can also be done by frequency analysis (Morhardt, 2009). For most manufacturing companies the main interest lies in environment, economy and technology but nevertheless society is an important component of sustainability and only if all factors are observed the overall sustainability strategy can be evaluated (Park et al., 2009; Kolk, 2003).

Same as in Step 1 and 2, the third subtask (3c) assigns a level of communication. In this case it is rated how well the different topics are communicated. This means that if a possible customer researches a company's sustainability guidelines, how easily are the top sustainability criteria recognized. The grade of communication at this level can also be determined by the aforementioned multi-method approach. Marketing and the perception of web presences is indeed a very subjective matter and multiple investigators and formalized rules help to overcome this problem.

#### **4.4 Step 4: Build Final Matrix of Interdependencies**

The next step of the hereby presented methodology is the consolidation of the results acquired in the first three steps. To visualize not only the results but also the interdependencies, a matrix is set up. On the y-axis in Figure 2 the main sustainability strategies are arranged for corporate, business and operational level. Each business and operational strategy is labelled with the determined communication level 1 - 3. The most frequently stated sustainability topics are arranged on the x-axis and similarly described by their communication level. The centre of the matrix is then filled with the level of correlation and resulting level of communication.

The **level of correlation** or **interdependency** is visualized by the shade of colouring. The correlation level can be derived from companies' published reports and the frequency of citing sustainability with its relation to sustainability topics. The darker the shade is, the stronger the correlation between the two aspects. This way it can be observed at first glance which strategies have a strong impact on which criterion. Unfortunately, this information is difficult to obtain quantitatively, therefore paired comparison and logical conclusions are other options. For example, Operational Strategy 3.1 (reuse of waste heat) and Environmental Topic 1 (energy consumption) might have a strong correlation (darkened field E1) or Operational Strategy 1.1 (sustainability workshop) and Environmental Topic 1 (energy consumption) might be weakly connected, but mentioned together (light-grey coloured field A1) (Figure 3). If strategies are not advertised at all in connection with a

specific sustainability topic, no correlation is indicated and the field is left white.

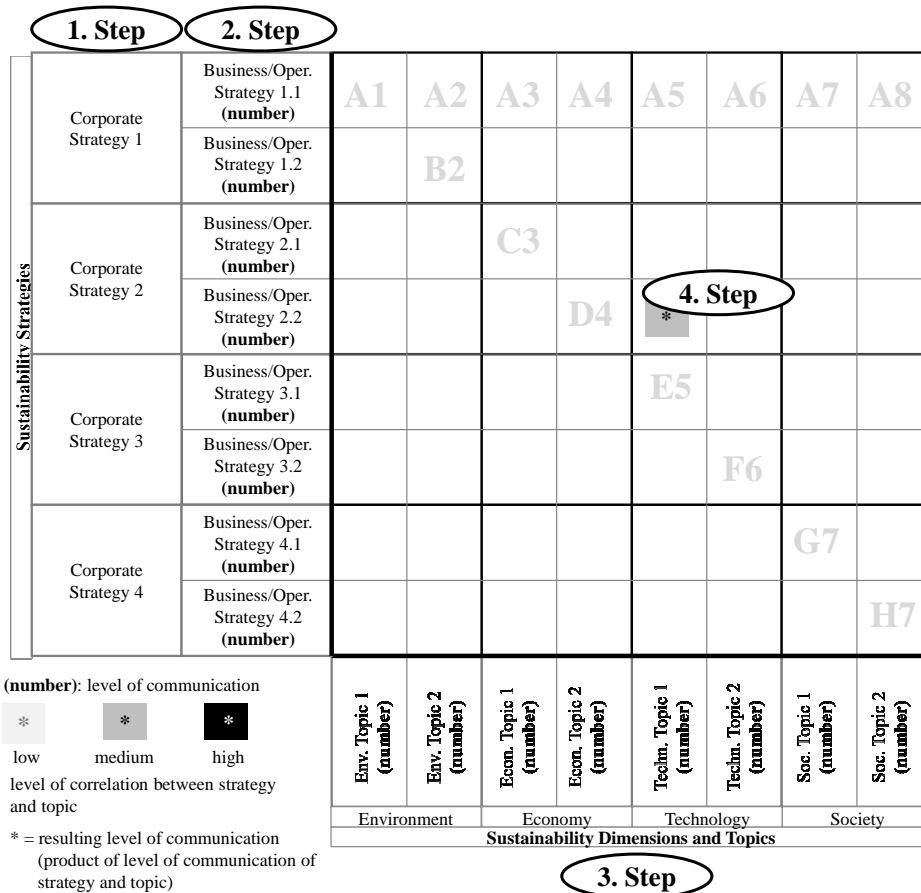


Figure 2: Matrix of Interdependencies

In addition, the **resulting level of communication** is calculated by multiplying the communication levels of strategies and the correlating sustainability topics. For example, Operational Strategy 1.1 is concerned with Environmental Topic 2. The total communication level is the product of communication level of Operational Strategy 1.1 and Environmental Topic 2 and marked in field A2. The resulting level of communication is applied, because most sustainability topics and strategies are communicated with a different intensity. This gives the guideline to answer the second research question: *How intensively is sustainability communicated to consumers?*

#### **4.5 Step 5: Final Evaluation and Conclusion**

The final evaluation will show which sustainability strategies are described most frequently and which sustainability topics they address. The same can be identified the other way around. For each pillar of sustainability, i.e. sustainability dimension, the most commonly addressed topics are listed and it is presented how they are integrated into companies' strategies.

Furthermore, by integrating the level of communication it is noticeable at first sight which topics are most and least addressed. At the same time, the level of relevance of a sustainability topic to a company can only be assumed. It has to be differentiated between communication and importance. Using advertisement for greener products does not necessarily mean that the whole corporate strategy is oriented to greener products. It might only be part of the marketing strategy. On the other hand, companies might have vast operational strategies to reduce energy and resource consumption in their technology chain, but do not advertise this.

### **5 Results and Discussion**

#### **5.1 Scope of Case Study**

A total number of 100 manufacturing companies from various industries have been observed and data regarding their sustainability efforts have been collected, mostly from their websites. These company's sizes range from 3.000 – 450.000 employees and the selected group is divided as follows between the industries: machine tool (25), health (15), semiconductor (21), transportation (7), and conglomerates (32). It is assumed that the information on the website is representative of any other company materials. The monitored companies range from multinational engineering companies to smaller machine tool producers.

Each step of the methodology in Figure 1 has been applied and the results have been accumulated to the final matrix of interdependencies (Figure 3). The level of communication, which was determined in tasks (1c), (2c) and (3c) of the research methodology (Figure 1) is noted in parenthesis after each business and operational strategy and after every sustainability topic (Figure 3).

It has to be noted that there are many synonyms for sustainability and sustainability strategies. Research showed that the most popular terms besides Sustainability were Corporate Social Responsibility (CSR), Corporate Citizenship, Corporate Governance, Environment, Energy Efficiency and Environmental Health & Safety (EHS). This has to be

factored into the selection process of sustainability topics and strategies. Analytical tools would have to be especially designed to recognize all the various synonyms.

Whilst it is proposed to apply the presented research methodology for diversified and large research studies, this case study focused on a small scale project with data of 100 companies. For proof-of-concept the computer based frequency analyses were simulated by manual rankings. The goal was to give qualitative answers to the research questions listed in section 1.

## **5.2 Analysis of Corporate, Business and Operational Strategies and Correlation with Sustainability Topics (Step 1 – 3)**

Collecting and filtering data has shown that companies are concerned with a high number of environmental topics. Besides **energy consumption** and **waste production**, water usage and CO<sub>2</sub> emissions are of high concern. Many companies point out their efforts in reducing CO<sub>2</sub> emissions by switching to greener energy, reducing energy, and waste in their manufacturing processes, improving their technology chain, and more but these changes are costly and therefore introduced cautiously.

In this study only economic factors that are related to the other sustainability pillars are considered, not economic strategies that only increase the company revenue. This focus was chosen to show possible motivational factors for companies to act more sustainably. Neither **investment costs** nor **variable costs** of operational strategies for sustainability are presented on websites aside from popular figures such as energy savings or savings from carbon footprint reduction. The figures that are mentioned are often percentages without reference or concrete comparative values, e.g. “reduction of CO<sub>2</sub> emissions by 20% by 2020”.

The choice of the most commonly cited social aspect, however, has been unambiguous. The **employee’s safety and health** is stressed by most companies. This has various reasons. Firstly, the employee’s well-being results in higher productivity, fewer sick days and stronger loyalty. Secondly, companies are motivated due to improvements in their insurance rates (interview with W. Haberstock, EMS Representative at Advantest America, Inc., 26 September 2013). The second social topic is **diversity**. This choice was not clear cut because companies are faced with different social challenges according to their location and background. The term diversity includes a number of social aspects, such as the rate of female associates, international employees and the support of low income families. The choice of technical sustainability topics was strongly influenced by the Overall Equipment Effectiveness (OEE) metric system

and expertise opinions (Helu et al., 2011). The OEE is based on four metrics: Loading, Availability, Performance, and Quality. Within the scope of this research several experts have been interviewed to determine the two most fundamental metrics. The biggest concerns for producing companies are **performance** and **quality**, regarding not only their own production sites but also their products. It is still broadly assumed that environmental friendly machines may not deliver the same performance and quality levels.

### 5.3 Resulting Matrix of Interdependencies (Step 4)

All research results have been assembled into the final matrix (Figure 3). It needs to be pointed out that communication and correlation level can be different. This is best explained by means of an example. The correlation between “smaller products/fewer parts” and “investment costs” is ranked as a medium (grey) interdependency, since there are essential costs involved to redesign the product, possibly buy new machines etc. The degree of conveyance is ranked relatively low with 2 (maximum is 9). This means that it is not well reported how much the introduction of this strategy costs or how much is saved. Often times the level of communication and interdependency is very similar since usually only existing correlation are published. The aforementioned example shows though that there are exceptions.

Consequentially another dimension of conclusions can be drawn from these differences. In the matrix it can be observed that investment costs themselves are marketed not per se (communication level of 1), but the strategies they are used for are advertised with communication levels of 1 – 3. This makes sense, considering that companies use environmental and social efforts as marketing strategies. Figure 3 shows 10 black fields with white numbers which represent strategies that correlate strongly to the confronted sustainability topic. For example, reuse of waste heat impacts energy consumption and waste consumption strongly and therefore the field is coloured black. The resulting level of communication for each factor individually is multiplied with the correlating one and results in level 9 for energy consumption and waste production. That means that it is well advertised that reuse of waste heat improves energy usage and reduces waste reduction. Most strategies have high numbers indicating that companies communicate both well, the strategy and the sustainability goal. Two strategies, however, have low numbers. The charity programs are advertised (level 3), but the investment is not communicated well as sustainability criteria (level 1). In contrast, resuscitation and First Aid

classes are seldom addressed (level 1), but contribute strongly to the well-advertised goal of employee safety and health (level 3). The five strategies with numbers in grey on light grey background are communicated within a certain sustainability dimension, but the dependency is rather weak. Sustainability workshops are mentioned rarely (level 1), but affect many categories, such as energy consumption, waste production, investment costs, variable costs, employee safety and health, and diversity. Smaller products/fewer parts or childcare/work time models have several sustainability goals to which they contribute strongly, but are also cited for performance or employee safety and health respectively which is not immanent. Companies seem to sometimes advertise sustainability strategies for unfitting goals (such as childcare for the goal of employee safety).

Corporate Level	Bus./Oper. Level								
Corporate Citizenship	Sustainability Workshop (1)	3	3	1	2			3	2
	Charity Programs (3)			3					6
Sustainable Products	Smarter programming (2)	6	6	2	4	4		6	
	Smaller products/fewer parts (2)	6	6	2	4	4	6		
Sustainable Factory & Offices	Reuse of Waste Heat (3)	9	9	3	6				
	Efficient Lighting systems (2)	6		2	4			6	
Corporate Social Responsibility	Resuscitation & First Aid classes (1)			1	2			3	
	Childcare/Work time models (3)			3	6	6		9	6
		Energy Consumption (3)	Waste Production (3)	Investment Costs (1)	Variable Costs (2)	Performance (2)	Quality (3)	Employee Safety & Health (3)	Diversity (2)
		Environment		Economy		Technology		Society	
Sustainability Dimensions and Topics									

(number): level of communication  
 \* low    \* medium    \* high  
 level of correlation between strategy and topic  
 \* = resulting level of communication (product of level of communication of strategy and topic)

Figure 3: Matrix of Interdependencies in the case study



#### **5.4 Discussion and Evaluation of Results (Step 5)**

This research methodology only captures part of the information companies publicise. It is not only important to observe the company's direct operational sustainability strategies but also the mentality that is exemplified by the corporate leadership (van Marrewijk, 2003). Additionally, it also has to be considered how regularly these sustainability efforts are enforced and audited.

The set-up of the final matrix of interdependencies (Figure 3) has shown difficulties in the correlation between sustainability strategy and sustainability topics. The high number of grey fields in the investment and variable costs shows the lack of clarity. As pointed out earlier, companies do not mention specifically how much each sustainability implementation costs and which outcomes they expect. Often times companies are not even aware how much they save and what consequences their actions might have further down the line. In order to accurately measure improvements the previous conditions have to be recorded first (presentation by W. Haberstock, Advantest America Inc. at Pacific Coast Machine Tool Expo, 26 September 2013). For example, companies have introduced new design approaches to integrate environmental aspects into the product designing process. This way a product may consist of fewer parts and be smaller in order to reduce the need of raw materials, to facilitate recycling or to decrease fuel consumption for delivery. This product development process has almost contradictory consequences. It may increase the manufacturer's energy usage to produce the new part but simultaneously it might decrease the energy consumption of the final product in its use phase. Dornfeld describes this effect as leveraging (Dornfeld 2011). This clarifies the problem of defining the intensity of interdependencies in the matrix. Additionally, the determination and final combination of levels of communication have been challenging. The theoretical results in the matrix do not necessarily correlate with main marketing efforts. For example, it is rarely advertised how childcare or work time models improve performance, let alone quantitative data is offered but according to the matrix this interdependency is strongly communicated through websites and reports (level 6). Therefore, one can even assume that companies' web presences are designed and determined by marketing strategies and possibly independently of the developers of the sustainability strategies. Further research on the design of marketing strategies for sustainability is needed.

## **6 Conclusion and Outlook**

In this paper the term *sustainability strategy* has been defined and a research methodology was developed to systematically evaluate manufacturing companies' according to their sustainability efforts. This research methodology is supposed to give a guideline for structured and effective research, including the visualization of the results. It can also be extended to bigger scale research projects. Since this study was focused on defining the sustainability strategies and giving a proof-of-concept example, the communication (subtasks c) was evaluated by rather subjective standards. The definition of 'marketing' is vague - its message is perceived differently by different people. For future projects it is recommended to do surveys or multi-user assessments to rank the level of communication.

In a case study a multitude of sustainability strategies on corporate, business and operational level collected from 100 manufacturing companies have been reviewed. Whereas corporate strategies were easy to obtain, business and operational strategies such as changes in production processes or in production chains are often not disclosed. Besides overall changes in the product design process and consequently changes in the production or small changes such as smart programming (e.g. programming a machine to go into standby mode faster), it is not communicated how different production technologies might be used or process chains rearranged. The reason lies likely within not wanting to give away a competitive advantage. This shows that there is a need for further research to quantify sustainability in actual manufacturing processes on a non-competitive basis. This project also considered the conveyance of aforementioned sustainability strategies. It was shown qualitatively that certain environmental topics are communicated strongly. More research needs to quantify this.

Strong marketing was found for sustainability goals on energy, waste, and diversity. The strategy of supporting charity programs was pointed out most by companies, followed by smarter programming, reuse of waste heat, efficient lighting systems, and childcare/ work time models.

One of the main challenges for research in this field of study is setting the centre of attention. When speaking of sustainability efforts, it has to be questioned if sustainable products or a sustainable production are examined. One's product is part of the other one's production. On the one hand it is important to define the regarded scope but on the other hand this brings forward how complex and interwoven this topic is. Sustainability is

a global, widespread and open-minded topic and its analysis has to be the same way.

This research has raised many questions and shown that there lies a lot of potential in further developing this research methodology. It is recommended to expand the scope and cooperate with programming specialists to professionally apply analytical tools and report collected information. Furthermore the multi-method approach should be executed in the scope of a larger study. Questionnaires and surveys for stakeholders and a consideration of corresponding marketing strategies could be applied.

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