PROJECT NAME

SUPPLIER SUSTAINABILITY IMPROVEMENT

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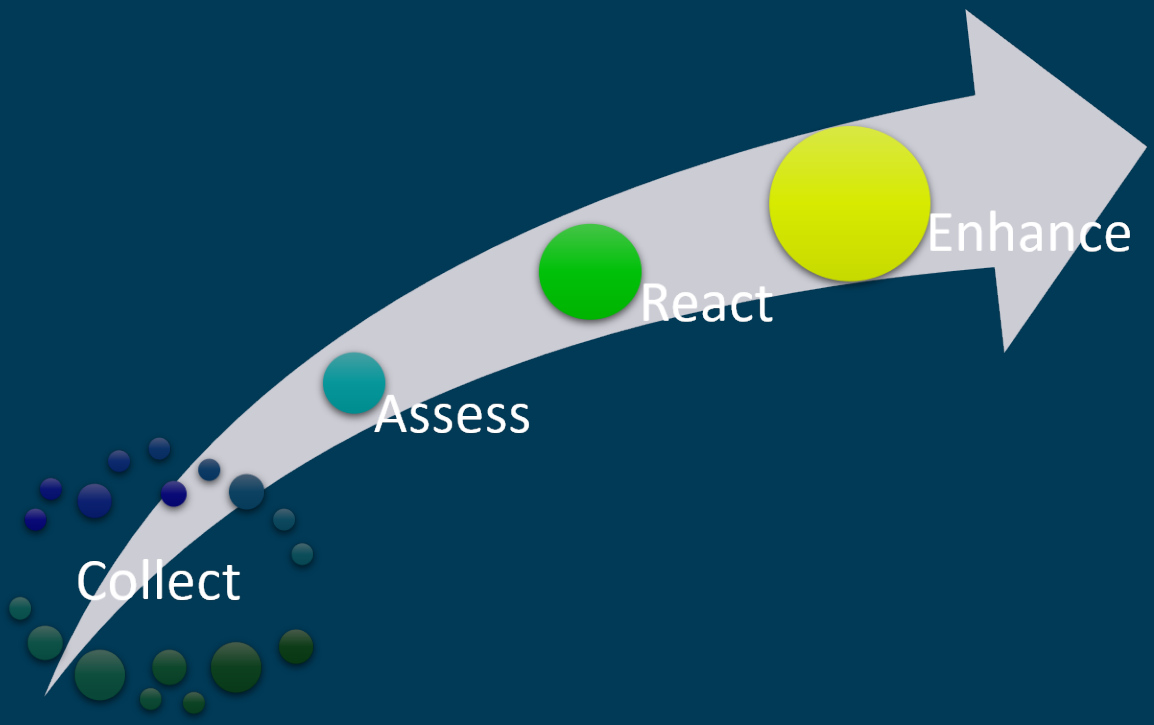


TKI DINALOG
Dutch Institute for Advanced Logistics

SUMMARY

Traditional auditing has been common practice for multinational companies to monitor their suppliers against sustainability violations and enforce them to comply with their code-of-conduct. However, supplier assessments driven by third-party auditors are often biased due to conflict of interests between the auditors and suppliers. With our Supplier Sustainability Improvement project, we offer a paradigm shift from traditional monitoring-based auditing to a proactive improvement-based supplier assessment where collaborative relationships and supplier improvement is prioritized rather than merely policing and eliminating suppliers. We advocate for supplier self-assessments -possibly combined with on-site visits conducted by the buyer- and propose a conceptual framework that we call as CARE, consisting of Collect, Assess, React, and Enhance phases. This framework unifies assessment of current sustainability levels of suppliers, prediction of the future levels, and their improvement, all based on suppliers' characteristics, such that supplier-specific sustainability improvement plans can be generated, taking into account available resources of both the buyer and the supplier. With this project, we contribute to the data-driven research on sustainability practices, particularly in developing countries. We also develop a cross-sector methodology to achieve structural sustainable improvement through a well-controlled change management process. Our framework has been applied at our project partner Philips in full. Supplier assessment data collected by Philips over the past years is analyzed by our generic framework making use of machine learning techniques. Our results show that the buyer's assessment frequency, quality certification of suppliers, and the facilities existing at the supplier site turn out to be the most influential variables on suppliers' sustainability levels. The buyer's involvement in sustainability activities of the suppliers is also shown to be a game changer to escalate sustainability improvement. Philips reports that the overall 2020 year-on-year improvement in sustainability performance has been 36% for suppliers that entered the program in 2019. Our project paves the way to transform traditional auditing towards a self-assessment-based unified supplier sustainability assessment and improvement framework in supply chains. Our future vision is to extend this framework to lower-tier suppliers in the supply chain, which typically have more significant sustainability issues while the multinational enterprises often do not have enough influence to directly prompt sustainability improvement actions. Therefore, a different set of incentives and information-sharing mechanisms need to be developed in order to lead the lower-tier suppliers towards sustainable operations.

Health & Safety Violations at Suppliers

CONTENT

IN ORDER TO MAKE A TRUE DIFFERENCE IN SUSTAINABILITY, FIRMS NEED TO LOOK ALSO OUTSIDE THEIR OWN ORGANIZATIONAL BOUNDARIES.

TARKAN TAN
ASSOC. PROF. DR.

BACKGROUND

Empowered with social media and rapid disperse of information, today's society is more conscious of environmental and social issues than hitherto, amid growing concerns about sustainability. This increases the pressure on businesses to act on sustainability. While an increasing number of firms disclose and exert effort to improve their “own” sustainability impacts to a certain extent, multinational companies (MNCs) are also being held responsible for the sustainability impact of their suppliers' activities, by external stakeholders such as NGOs, media, customers, communities, and governments. This is mostly because the MNCs have gone through a complete globalization of their supply chains in the past few decades and have heavily been sourcing from suppliers in developing countries that have many social and environmental problems. Leaving the suppliers out of the sustainability problem for global corporations clearly means leaving out the heart of the matter. Firms, especially the MNCs, need to be more preemptive in mitigating the sustainability violations in their supply chains, not just for philanthropic reasons, but also for the sake of their reputation, brand well-being, and financial risks.

Environmental Sustainability Violations

CHALLENGE

Assessing and improving sustainability in the supply chains is an onerous challenge, requiring a holistic framework. Most MNCs make use of structured sustainability audits as a tool to monitor their suppliers, followed by incentives and penalties to divert suppliers towards sustainability compliance. The auditing activities are typically outsourced to third parties and financed by suppliers themselves. This conflict of interest encourages biased evaluations by the auditors. Recent studies and the practical experience of our industry partners point out that audit results are far from reliable. Furthermore, audits are based on a pass/fail mentality to check supplier compliance, instead of focusing on addressing the root problems and building up continuous improvement plans. Consequently, more proactive actions are needed to make an impact on sustainability. While academic literature and the practice are becoming more and more aware that audit system does not work well, there is a huge gap in literature as to what does -or would- work and how. This project is meant to fill in this gap by developing an interdisciplinary framework that simultaneously addresses many aspects of the problem. The goals of the project are as follows: 1) Create a predictive model addressing the sustainability performance of the suppliers, based on existing audit results, self-assessment data, and predefined requirements, 2) Develop decision support for supplier selection and improvement, trading-off cost, service, lead-time, quality, and sustainability, 3) Develop a cross-sector methodology to achieve structural sustainable improvement through a well-controlled change management process, 4) Uncover the differences between multinational companies and SMEs in implementing sustainability within the own organization and the supply chain.

PROJECT DESIGN

Logistics is one of the top sectors in the Netherlands and the Dutch government wants to remain competitive in this domain. To be able to take on this role, it has been becoming ever more crucial that sustainability is taken into account in supplier assessment process, which is a key logistics decision in supply chain management. The aim of our project has been to improve the sustainability of the whole supply chain by supporting the transition from supplier selection to supplier engagement and development by providing decision support and by supporting the implementation process. Our focus has therefore been on the whole supply chain rather than the organizational boundaries of a focal firm.

Even though the scientific understanding of many aspects of sustainability is advancing faster than ever before, there is still a gigantic gap in research that simultaneously addresses interacting critical building blocks towards paving the path for sustainable supply chains. Our project has taken a step in filling this gap by studying these problems directly in the field. Including one of the leading organizations in the sustainability field like Philips in the consortium has provided us with the opportunity to study how to address the sustainability issue within MNCs. In particular, we have analyzed the sustainability-related data of Philips's suppliers by using machine learning techniques to identify which characteristics and features yield higher sustainability levels and improvement potential, resulting in developing supplier-specific sustainability improvement plans taking into account available resources of both the buyer and the supplier. We have made use of self-assessment questionnaires (SAQs) and evidence pieces provided by the suppliers as a basis of this analysis. This approach enables MNCs to assess and improve their suppliers' sustainability performance without having to conduct costly and unreliable audits. Our project has also been is unique in approaching sustainability as not only an operational but also an organizational change issue that involves both the focal company and her suppliers.

We have combined the knowledge of various fields of expertise, operations management and organizational psychology, and our industry partners. Specifically, we have built on the knowledge of 1) designing sustainable supply chains, 2) using (big) data to develop predictive models of factors predicting suppliers' sustainability performance and improvement potential, 3) factors affecting organizational change, and 4) insights from the field of work and organizational psychology. These diverse backgrounds allowed us to create and develop new tools, algorithms, and organizational practices that also take the human factor into account when enhancing companies' sustainability. The partner organizations also facilitated the translation of scientific insight into specific organizational practices as well as the dissemination of the results.

Our project not only fits to the "Human Capital" action theme of the TKI-Toeslag 2017 call (within which it is granted), but also to all three current innovation themes of TKI Dinalog in an organic way, namely Sustainable Logistics, Data-driven Logistics, and Chain Management. The project can be categorized as an industrial research project that included scientific research by
Two postdoctoral research fellows: Dr. Hakan Akyüz and Dr. Keri Pekaar,
Two faculty members at TU Eindhoven: Dr. Tarkan Tan at the Operations, Planning, Accounting, and Control (OPAC) capacity group and Prof. Evangelia Demerouti at the Human Performance Management (HPM) capacity group,
A Post-Master Professional Doctorate in Engineering (PDEng) student: Santiago Ruiz Zapata,
Seven master's students: Roel Smouter, Tom Scholte, Len Wismeyer, Bengisu Urlu, Isabelle Linders, Mert Kayhan, and Jochem Kamst.
The research has been conducted in partnership with the project's industrial partners: Philips (Marco Baren, Dylan McNeill, Marcel Jacobs), Friesland Campina (Walter Vermeer, Hubert Verweij, Jeannette Rusticus), and Fairphone (Remco Kouwenhoven, Laura Gerritsen). We followed a Concept – Develop – Execute approach, each step formulated as a work package, as detailed below.

1

WORK PACKAGE 1: CONCEPT

This work package has five phases: 1. Detailed activity based project plan, 2. Develop methodology to execute analysis of available data sets, 3. Data Analysis, 4. Achieving effective awareness, and 5. Change management. The goals, followed approach, and the targetted results/deliverables per phase were as follows:

Phase 1.1: Detailed activity based project plan.
Finalize a detailed PMP (Project Management Plan), including detailed project plan, roles and responsibilities, communication plan, stakeholder mapping, risk criteria, targets and objectives.

Phase 1.2: Develop methodology to execute analysis of available data sets.
Analyze existing supplier sustainability data sets at industry partners, with the purpose of translating data sets and data requirements in a methodology to conduct data analysis when comparing different sources and definitions (data integrity, respect privacy, manipulation, description, standardization, benchmarking, and classification). Identify which factors pose the greatest sustainability risks for the supplier and accordingly also business risks for the buyer, and how these various measures can be unified into a “sustainability score”.

Phase 1.3: Data Analysis.
Project partners have data concerning supplier sustainability, e.g. obtained through self-declaration. We define which data parts are the most reflective and descriptive for sustainability assessment and to what extent. This enables manipulating (parts of) existing supplier sustainability data in an effort to make it easier to organize, understand, interpret, and compare. Following data manipulation and standardization, we conduct statistical analysis. Accordingly, we develop a supplier sustainability classification scheme based on existing data.

Phase 1.4: Achieving effective awareness.
Identify and describe how to achieve effective awareness at SMEs and other relevant stakeholders based on existing available training materials. Talk to different supply and account managers to recognize which key players are involved in sustainability-related activities within the organization and the supply chain. Understand the sustainability bottlenecks within the extended supply chain and how the research team can help with those bottlenecks.

Phase 1.5: Change management.
Specify the participants of the suggested trainings. Define a methodology to achieve structural sustainable improvement through well controlled change management process. Interviews with potential participants of the trainings are to be conducted in order to recognize the current situation of the manager/employee in order to tailor the training.

WORK PACKAGE 2: DEVELOP

This work package has four phases: 1. Predict organizational sustainability capabilities and needs as input for structural improvement, 2. Measure sustainability impact using an updated SSP concept, 3. Decision Support, and 4. Updated improvement training approach based on specific organizational capabilities and needs. The goals, followed approach, and the targetted results/deliverables per phase were as follows:

Phase 2.1: Predict organizational sustainability capabilities and needs as input for structural improvement.
The major problem sustainability data obtained through audits is the reliability. It is well documented that audits usually do not reflect the “true” sustainability state of the suppliers, as many of them turn back to business-as-usual state after the audit. Self-declarations are meant to resolve this problem, but there is no mechanism to guarantee truthful declaration.
Conduct careful analysis of not only the audit and self-assessment data, but also the procurement history in order to identify the factors that might be indicators of sustainability violations. Identify the common variables / elements among verified sustainability violations and use those variables to predict violations in other cases. Test the hypotheses that such variables are indicators of violation, using statistical analysis. Make use of machine learning techniques to predict violations.

Phase 2.2: Measure sustainability impact using an updated SSP concept.
Update/amend self-assessment survey that are geared towards efficient assessment of supplier sustainability levels. Develop a framework based upon the new designed predictive model. Investigate how the representability (truthfulness) of the declarations can be increased.

Phase 2.3: Decision Support.
Develop mathematical models utilizing the best trade-off between cost, service, quality, and sustainability, which help making decisions to determine the necessary actions concerning supplier selection and improvement. Mathematical programming models are to be utilized to make supplier selection and development decisions, which also depend on the associated cost or effort in supplier development.

Phase 2.4: Updated improvement training approach based on specific organizational capabilities and needs.
The purpose of this phase is to develop a training that stimulates empowering leadership and employee crafting behavior to embrace sustainability to daily practices. In order to uncover the impact of trainings, we assess attitudes towards sustainability and actual use of sustainability criteria during decision making before and after the training. Review existing training materials as currently available at project partners and publicly available ones, develop a questionnaire in order to measure the attitudes and behaviors relevant to sustainability before and after the training, and develop a training workshop in order to teach and exercise empowering leadership and job crafting behavior.

3

WORK PACKAGE 3: EXECUTE

This work package has five phases: 1. New test case execution, 2. Progress and performance measurement, 3. Training execution, 4. Update the supplier sustainability improvement method and prepare mass deployment, and 5. Valorization of project insights through our industry partners and in collaboration with Responsible Business Alliance (RBA). The goals, followed approach, and the targetted results/deliverables per phase were as follows:

Phase 3.1: New test case execution.
Execute test cases of the supplier sustainability improvement project based upon the developed predictive methodology.

Phase 3.2: Progress and performance measurement.
Define KPIs to measure supplier sustainability improvement, define and set targets and objectives.

Phase 3.3: Training execution.
Develop a tailored employee/operator training for sustainability consisting of an instruction part, weekly small job crafting assignments for 3 consecutive working weeks, and a final reflection workshop. The training is to be tested by comparing measures of managers' self-perceptions as well as employees' perceptions of sustainability management between the experimental and the control group prior and posterior to the intervention.

Phase 3.4: Update the supplier sustainability improvement method and prepare mass deployment.
Update approach, tools, and communication materials, and deploy to internal and external stakeholders.

Phase 3.5: Valorization of project insights through our industry partners and in collaboration with RBA.
Provide feedback of learnings to cross industry (RBA) members.

RESULTS

The project has been succesful in developing a framework that facilitates a paradigm shift in sustainable supply chain management, moving away from traditional monitoring-based third-party sustainability auditing towards a generic quantitative multiple-phase machine-learning-based collaborative methodology to monitor, assess, predict, and improve supplier sustainability. We advocate for supplier self-assessments -possibly combined with on-site visits conducted by the buyer- and propose a conceptual framework that we call as CARE, consisting of four phases. The first phase is to Collect relevant supplier data via means such as SAQs, on-site visits, and publicly available data. At the Assess phase, supplier sustainability profiles are constructed by (i) evaluating the sustainability levels for the suppliers with sufficient data, and (ii) predicting sustainability levels of the other suppliers using machine-learning algorithms based on supplier characteristics. Future sustainability levels of suppliers are predicted in the React phase -also making use of machine learning- to enable further actions depending on the prospect drawn for the supplier, so that the buyer can identify the suggestions and improvement actions that have the potential to make the highest impact. Finally, at the Enhance phase, tailor-made sustainability improvement plans for suppliers are crafted, taking into account available resources of both the buyer and suppliers.

In our implementation at Philips, the buyer's assessment frequency, quality certification of the suppliers, the activities/processes of the suppliers, the workforce structure of the suppliers, and the facilities existing at the supplier sites turned out to be the most influential variables that define suppliers' sustainability levels. We also show that the buyer's involvement in sustainability activities of the suppliers can be a game changer to escalate sustainability improvement. Philips reports that the overall 2020 year-on-year improvement in sustainability performance has been 36% for suppliers that entered the program in 2019. We demonstrate that this could potentially be even further proliferated with buyer investment by making use of the mathematical programming model that we propose, particularly for small-scale suppliers.

With our project, we contribute to the data-driven research on sustainability practices in global supply chains. The proposed CARE framework is scalable, as the assessment and prediction of sustainability levels and the identification of the actions that would result in the biggest improvement are all automated via machine learning based on data collected by SAQs. The framework is also generic and flexible, as it does not rely on a particular SAQ or a particular scoring mechanism and it can be adopted partially, i.e. firms can choose to implement only one or a few steps of it, calibrate it according to their needs and capabilities, and deploy different techniques for implementation. Even a complete step of the framework such as future sustainability level predictions can be left out for a partial implementation, or existing sustainability audit results can be employed to feed data to the framework concerning supplier characteristics such as company size, workforce distribution, existing quality certificates, etc.

We also find out in our project that change management in the sustainability domain is highly dependent on human factors such as individual motivation and proactivity. Job crafting (optimizing demands) helps employees to enact their sustainability intentions in daily work. Furthermore, (e-)training interventions (face-to-face or self-trainings) are promising avenues to increase people’s motivation toward sustainability and to train them the proactive skills that are needed to implement sustainability in daily work.

Some detailed results and the developed managerial insights per work package are as follows:

Work Package 1:

- A sustainability measure is developed to determine the sustainability levels of the suppliers, making use of SAQs and other data. Data analysis is based on predictive models in order to identify the characteristics that correlate most significantly with the sustainability levels of the suppliers.
- Companies need to set clear business incentives that enforce suppliers to invest in sustainable development and provide the tools and the knowledge that enable them to actually engage in sustainable development.
- Employees need the motivation to contribute to sustainability improvement, a supporting context , and the tools and skills to translate these motivations into action. This process may be supported using motivational interventions that target proactive behaviors such as job crafting, network crafting, and self-nudging.

Work Package 2:

- Machine learning tools are devised to predict supplier sustainability levels automatically based on general supplier information. Our supplier sustainability predictions based on general information conform with the verified supplier sustainability levels with an accuracy of up to 94%.
- Sustainability improvement of suppliers over time is tracked to predict future sustainability level of suppliers, also using machine learning. We developed resource-constrained mathematical

models to optimize the effort for supplier sustainability improvement. Another mathematical model to select and plan on-site visits is also developed for efficient assessment of important suppliers.
- Several trainings have been developed (face-to-face training, self-training, e-learning) based on motivational principles in which employees (e.g., buyers, supply chain managers) are trained to engage in proactive behaviors such as job crafting and self-nudging to stimulate the implementation of sustainability in daily work.

Work Package 3:
- Additional datasets are tested at the final stage of the project, through which we improve the suggested predictive models by incorporating their learning behaviour.
- The training is effective in improving (aspects of) sustainability performance, but this effect is more pronounced for specific sustainability behaviors than overall sustainability measures.
- Optimizing demands seems to be the most promising job crafting strategy to improve sustainability performance.

An issue we had with executing trainings in companies was the Covid-19 pandemic, resulting in different priorities at some firms, small samples, and changing to online format.

Philips has been one of the sustainability front-runners in the industry and does not limit the sustainability scope with its own boundaries. Indeed, the CARE framework is implemented at Philips, which has around 15000 first-tier suppliers many of which are located in China, resulting in unprecedented improvements in identifying and addressing sustainability issues in its supply chain, in comparison to the audit-based approach they used to follow. Philips reports in its 2020 annual report that the overall 2020 year-on-year improvement in sustainability performance has been 36% for suppliers that entered the program in 2019, and for the 302,000 workers at suppliers participating in the program, labor conditions improved, the risk of serious injury reduced, and the negative environmental impact of suppliers was brought down. It is also stated in the same annual report that Philips's suppliers undertook projects in 2020 that resulted in savings on carbon emissions amounting to 17 million metric tonnes CO2. Internally, it is estimated that 40% of supplier sustainability improvements can be attributed to our joint SSI project, resulting in estimated CO2 savings around 6.8 Million metric tonnes. Furthermore, Philips estimates that 12-15% of its 10 Billion Euro brand value is due to its sustainability activities, which consists of three pillars including Supply Chain Management. The contribution of our joint SSI project to this additional turnover for Philips is estimated by Philips as 96 Million Euros. It is also expected that significant cost savings have occurred at suppliers, but these are not directly reflected to our project partners.

SOCIETAL RESULTS	
CO2 reduction	6.8 Million metric tonnes
Sustainability level improvement at suppliers that entered the program in 2019 (as measured by our methodology)	36%
Employees that saw improvements in the health & safety and labor conditions at work	302,000

SECTOR RESULTS	
Additional turnover of project partners	€ 96,000,000
Number of new business start-ups as spin-off	1
Bereikte bedrijven	All RBA members
Number of researchers/students from the project that have found new employment in companies	5

SCIENTIFIC OUTPUT	
Master theses	6
PostDocs	2
Scientific Working Papers	5
Scientific seminars, workshops, lectures, presentations etc.	16

There has been one new business start-up as spin-off of the SSI project named CIRCL8, founded by our project partner at Philips, Marcel Jacobs. The process of rolling out our project for wider use is in progress via Responsible Business Alliance, which is a non-profit coalition comprised of electronics, retail, auto and toy companies to support continual improvement in the social, environmental and ethical responsibility of their members' supply chains. RBA now offers an online tool for suppliers to complete an SAQ and share it with multiple customers. We also collaborated with the "Fourth Sector Group" and KPMG for the widespread dissemination of our framework.

The project has also resulted in 1) maturity-based engagement of suppliers on sustainability, 2) better understanding of ways to drive change, and 3) collaboration activities between Philips and FrieslandCampina in the domain of supply chain sustainability. Our dissemination activities included presentation at prestigeous conferences such as INFORMS, invited seminars at universities such as the University of Zurich and the Middle East Technical University, a dedicated workshop at European Supply Chain Forum entitled “Supply Chain Sustainability”, a workshop at Philips on our project for a delegate from Arizona State University, three guest lectures at the OML MSc program of TU/e, three guest lectures at the Executive MOS program of TIAS School for Business and Society, two sustainability training pilots, among others. Our main industrial partner, Philips, is awarded Dutch ‘Crystal Prize’ as a result of its efforts in engaging its suppliers in structural improvement of their sustainability, which is the central theme of our project. Philips was also awarded the Supplier Engagement Award by the Sustainable Purchasing Leadership Council.

RESULTS TO BE PROUD OF:

1. A FRAMEWORK THAT FACILITATES A PARADIGM SHIFT IN SUSTAINABLE SUPPLY CHAIN MANAGEMENT.
2. A COLLABORATIVE METHODOLOGY TO MONITOR, ASSESS, PREDICT, AND IMPROVE SUPPLIER SUSTAINABILITY.
3. CUTTING-EDGE QUANTITATIVE MULTIPLE-PHASE MACHINE-LEARNING-BASED EVALUATION TECHNIQUES.
4. ENGAGING BUYERS IN SUSTAINABILITY ACTIVITIES OF THE SUPPLIERS.
5. PROVEN PERFORMANCE THAT RESULTED IN 36% IMPROVEMENT IN SUSTAINABILITY PERFORMANCE.
6. 6.8 MILLION METRIC TONNES REDUCTION IN CO2 EMISSIONS AND 302,000 WORKERS WITH IMPROVED WORKING CONDITIONS.
7. ROLLING OUT FOR WIDER USE VIA RESPONSIBLE BUSINESS ALLIANCE.
8. MULTI-DISCIPLINARY APPROACH INCORPORATING HUMAN FACTORS SUCH AS INDIVIDUAL MOTIVATION & PROACTIVITY.
9. DEVELOPING TRAINING INTERVENTIONS TO INCREASE MOTIVATION & PROACTIVITY TOWARDS SUSTAINABILITY.
10. PRIZES AWARDED TO OUR MAIN INDUSTRIAL PARTNER PHILIPS FOR ENGAGING IN SUPPLIER SUSTAINABILITY.

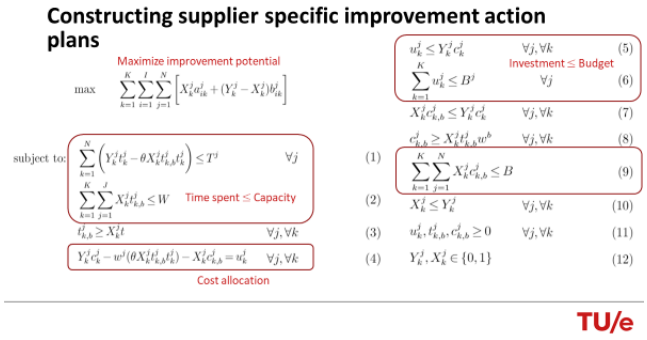
PREDICTING SUSTAINABILITY PERFORMANCE OF SUPPLIERS

This tool evaluates current sustainability levels and predicts the future sustainability levels of the suppliers using as little information as possible. First a set of suppliers (training data) are carefully assessed concerning their sustainability in Environment, Health & Safety, Business Ethics, and
Human Capital topics, using data sources such as SAQs with evidence pieces and site visits. The training data is then used to train a machine learning model for predicting the sustainability level of suppliers who did not complete an SAQ. Then, sustainability prediction is performed using general supplier information when a new supplier (test data) is to be assessed. Such an approach achieves scalability, e.g. when the number of suppliers to be assessed is excessive, which typically is the case for MNCs.

Sustainability Profile Dashboard

CONSTRUCTING SUPPLIER SPECIFIC IMPROVEMENT ACTION PLANS

This tool generates Improvement Action Plans (IAPs) to improve the sustainability levels of the supplliers. Suppliers have different improvement potentials depending on their characteristics, therefore supplier custom-made IAPs are generated by solving an optimization problem which considers restrictions on available resources as well as the improvement potential of the suppliers. Collaboration positively impacts supplier improvement, so that buyer's involvement in supplier's improvement efforts such as financial help, providing guidance and/or training,
donation of equipments improve the sustainability improvement potential of a supplier. Accordingly, the objective of the tool is to select supplier specific improvement actions that would maximize potential sustainability improvement of the suppliers under budget and capacity constraints while deciding on which suppliers to help and to what extent.



Mathematical model for maximizing sustainability improvement

EXPERIENCES

In many aspects, the project worked even better than originally anticipated. In particular the collaboration between Philips and TU Eindhoven has been very fruitful. Philips hosted five master's students and one PDEng for their graduation projects within the framework of our Supplier Sustainability Improvement project. Our collaboration is still contunuing with two follow-up projects. FrieslandCampina also hosted one master's student. On the other hand, some managerial changes and the Covid-19 pandemic prevented us from fully materializing some of the planned activities, particularly related to training interventions concerning change management aspect of the project.

OPEN INNOVATION

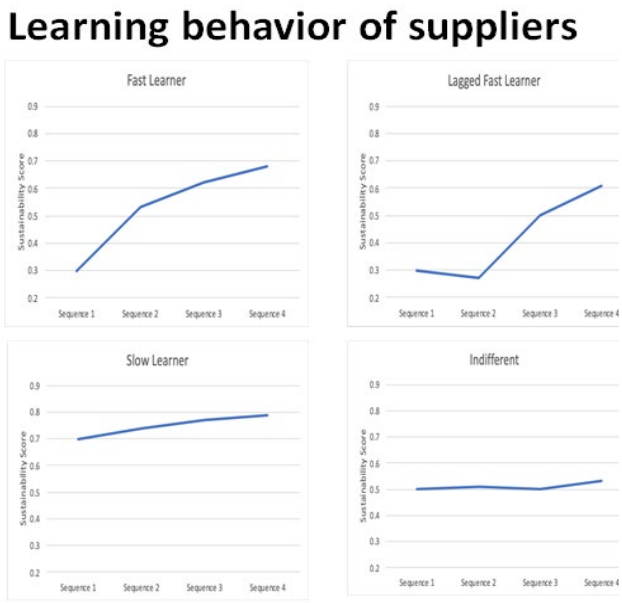
There have been frequent collaboration activities among all of our project partners in the domain of supply chain sustainability, facilitated and monitored through plenary project meetings. Philips, FrieslandCampina, and Fairphone shared their own supply chain sustainability experiences with each other, next to the communications towards sharing project findings and insights with the consortium members. Elevate was originally among the consortium members but dropped afterwards, as their involvement in supplier auditing services contradicted with the basic project idea of shifting from monitoring-based auditing to a proactive and collaborative improvement based on supplier self assessments. On the other hand, FrieslandCampina was not among the original consortium members but joined during the execution of the project due to their dedication and interst in supply chain sustainability. Their experience and expertise in sustainability in a completely different industry was a very welcome addition to the consortium that provided many valuable insights. Fairphone has been an invaluable project partner, considering that their whole business model relies on sustainability, as Fairphone is a social enterprise company which develops smartphones that are designed and produced with a lower environmental and social impact. Last but certainly not least, Philips has been the driving power in facilitating and implementing our project. They have provided the project researchers and students with the opportunity to benefit from their expertise and work on their data. Philips also openly facilitates know-how transfer on supplier sustainability not only through means like workshops and guest lectures, but also through its ivolvement in making the SAQ-based approach a cross-industry standard of RBA.

DINALOG AND TOPSECTOR LOGISTICS

We gratefully acknowledge the support of TKI Dinalog, without which this project would not have taken place. We believe that the project constibuted significantly to TKI Dinalog's and Logistics Topsector's goals and ambitions by developing framework to assess and improve supplier sustainability in an efficient manner. In particular, the project constributes to 1) Sustainable Logistics innovation theme as it addresses sustainability in supplier assessment process, which is a key logistics decision, 2) Data-driven Logistics, as it develops a generic framework making use machine learning techniques based on actual data of Philips's many suppliers, and 3) Chain Management, as it considers the whole supply chain rather than the organizational boundaries of a focal firm.

ANALYSIS OF SUPPLIERS' SUSTAINABILITY LEARNING BEHAVIOR – TU/E

In this MSc thesis, Mert Kayhan considered the problem of (i) understanding the suppliers' sustainability learning behavior which means evolution of supplier's sustainability levels throughout the time, and their relationship to supplier characteristics, (ii) modeling suppliers' learning process by using learning curve theory and construct predictive models for parameters of the learning curves and (iii) increasing the effectiveness of supplier sustainability improvement process by considering suppliers' learning capabilities and several buyer involvement strategies. A complex machine learning model (XGBoost) is used to understand the relationship between the learning behavior of suppliers and supplier characteristics by using SHAP model. Results show that, starting score of the suppliers, activities that are performed by suppliers, facilities located at suppliers' sites, worker distribution variables and certificates have a relationship with the learning behavior of suppliers. In order to structure the sustainability improvement process, several optimization models are constructed. The results show that the learning capabilities of suppliers can be included in the models to increase effectiveness of action plans. It is found that sustainability levels compared to initial sustainability levels of suppliers can be increased up to 30% by optimizing the buyer involvement strategies.



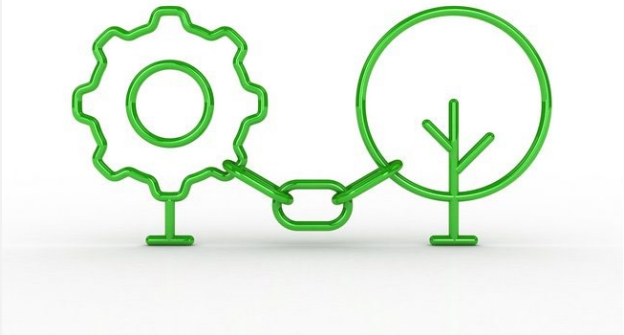
Observed sustainability learning behaviors of suppliers

CASE ON SUPPLY CHAIN SUSTAINABILITY - PHILIPS MEASUREMENT AND IMPROVEMENT

Based on Philips's own supply network and experiences with our project, we developed a case study that introduces a hypothetical firm called "Arya Phones". The firm has had a good sustainability reputation, but is well aware that there are environmental, social, and economical issues at its suppliers in developing parts of the world, despite the audits not being able to detect any significant sustainability violations that are referred to as "zero tolerances" (i.e. fake or falsied records, child and/or forced labor, immediate threats to the environment, immediate threats to worker health and safety, failure to comply with regulatory and/or Arya's requirements, workers' monthly income failing to meet regulatory requirements). The case asks the participants to devise a plan to detect sustainability violations and improve sustainability in Arya's supplier base consiting of 15,000 suppliers mostly in Asia, in the most efficient way. Participants work in groups of 3-4 people for 30 minutes and present their plan to the others and discuss. The case has been used in several occasions including a workshop at European Supply Chain Forum, in a master's course at the OML program of TU/e, and at the Executive MOS program of TIAS School for Business and Society. While the participants usually come up with good ideas, the scalable machine-learning based framework that we present in the end is an eye-opener for most and receives high praise and acclaim.

The phone made by the imaginary "Arya Phones" company

VISION OF THE FUTURE



With this project, we hope to have paved the way of a new venue for research and practice in getting closer to sustainable supply chains, by showing how to make supplier sustainability improvement process more structured, scalable, objective, and long-lasting. As the implementation at Philips demonstrates, unprecedented improvements in identifying and addressing sustainability issues in the supply
chain is possible with this approach, in comparison to the traditional audit-based approach. The next step is to make this approach the standard cross-sectional approach, as already initated by RBA which offers an online tool for suppliers to complete a self-assessment questionnaire and share it with multiple customers.

Our project also demonstrates that suppliers potentially improve more when the buyer not only uses/shares know-how but also is willing to allocate some budget -albeit very limited- to financially support some suppliers in sustainability improvement actions, based on the improvement potential of the supplier. Firms often avoid expenses that are not expected to provide monetary return and hesitate to directly invest in suppliers. We acknowledge that there is also the risk of losing a supplier to another buyer after investing in it. Nevertheless, investing in suppliers will likely go a very long way in establishing a trust-based long-term cooperative relationship with them. Naturally, some contractual agreements such as purchase and/or price guarantees can also be considered to safeguard return on sustainability investment. In any case, besides the corporate responsibility aspect and all the benefits associated with improved sustainability in a firm's supply chain, investing pro-actively in suppliers' sustainability improvement can be seen a paltry expense for a large firm in comparison to the potential costs associated with the aftermath of a social or environmental disaster at a supplier's site.

FOLLOW UP ACTIVITIES

Recent pandemic conditions have shown us that global problems can only be solved by participation and collaboration of all parties involved. Arguably being the biggest global problem of all, sustainability requires continuous efforts of different stakeholders such as firms, NGOs, governments, customers, and communities. Capability of buyers is limited, e.g. with legal boundaries imposed by regulations. Nevertheless, our project demonstrates how the limited capacity of a buyer can be efficiently utilized to improve the sustainability level in its supply chain. A natural but non-trivial next step is to extend our framework to lower-tier suppliers in the supply chain, which typically have more significant sustainability issues while the multinational enterprises often do not have enough influence to directly prompt sustainability improvement actions. Therefore, a different set of incentives and information-sharing mechanisms need to be developed in order to lead the lower-tier suppliers towards sustainable operations.

> ARGUABLY BEING THE BIGGEST GLOBAL PROBLEM OF ALL, SUSTAINABILITY REQUIRES CONTINUOUS EFFORTS OF DIFFERENT STAKEHOLDERS SUCH AS FIRMS, NGOS, GOVERNMENTS, CUSTOMERS, AND COMMUNITIES.
>
> **TARKAN TAN**

PROJECT PARTNERS

PUBLIC PARTNERS

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Eindhoven University of Technology (TU/e) is a research-led university specialising in engineering science & technology. Education, research and knowledge valorisation contribute to science for society, industry, and science. TU/e is training future engineers to face formidable sustainability challenges. Moreover, all departments of TU/e conduct research contributing to the transition to a more sustainable society. Project participants: Dr. Tarkan Tan, Prof. Evangelia Demerouti, Dr. Hakan Akyüz, Dr. Keri Pekaar, Santiago Ruiz Zapata, Roel Smouter, Tom Scholte, Len Wismeyer, Bengisu Urlu, Isabelle Linders, Mert Kayhan, and Jochem Kamst.

PRIVATE PARTNERS

FRIESLANDCAMPINA

Royal FrieslandCampina N.V. is a public limited liability company that supplies consumer products, such as milk, yogurt, cheese, infant nutrition and desserts, products for the professional market, such as cream and butter products, ingredients and semi-finished products for producers of infant nutrition, the food industry and the pharmaceutical sector. FrieslandCampina shared its own experience and expertise in sustainability with the project partners, hosted a plenary meeting and a master's student. Project participants: Walter Vermeer, Hubert Verweij, and Jeannette Rusticus.

FAIRPHONE

Fairphone is a social enterprise company which develops smartphones that are designed and produced with a lower environmental and social impact. Fairphone shared its own experience and expertise in supply chain sustainability with the project partners and hosted a plenary meeting. Project participants: Remco Kouwenhoven and Laura Gerritsen.

PHILIPS

Philips is a technology company that has the purpose of improving people's health and well-being through meaningful innovation. Philips is an industry expert, working with thousands of suppliers, initiator of the supplier sustainability performance program, and board member of Responsible Business Alliance. Philips has facilitated empirical research, data analysis, implementation, and valorization of this project. Furthermore, Philips hosted some plenary meetings, five master's students and one PDEng for their graduation projects within the framework of our project. Project participants: Marco Baren, Dylan McNeill, and Marcel Jacobs.

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