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Clothing, textile, and fashion industry sustainability impact measurement and management

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ABSTRACT
Data from the Kering Group's 2018 Environmental Profit and Loss (EP&L) statement were examined for their capacity to meet the demand for meaningful and manageable sustainability metrics. Significant resources were invested in creating the data reported in this EP&L statement, as Kering's operations in 104 countries were evaluated in ways separable into almost 1,500 different indicators. The data system was not, however, designed as a measurement system. That is, it was not set up as specifically positing the possibility of estimating separable parameters for comparing company location performances across sustainability challenges. Of particular importance is the lack of information in the EP&L on the overall consistency of the data reported, on the uncertainties associated with the metrics given, and on the meaningfulness of comparisons across environmental impacts, processes, and materials. The results reported here showing far from perfect data consistency and large uncertainties comprise an effort at constructing meaningful measurements that offers important lessons for the redesign of the data and reporting system.

Section: RESEARCH PAPER

Keywords: sustainability; clothing industry; measurement science; climate change; data quality

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1. INTRODUCTION

Clothing serves essential functions ranging from basic protection against the elements to symbolic expressions of social status and individual creativity. To create its products, the clothing, textile, and fashion industry taps into a wide range of resources, from agriculture (cotton, wool, leather, etc.) to petroleum (synthetics) to mining (metals for buckles, zippers, rivets, etc.) and water. The industry employs hundreds of millions of people globally, and has recently begun to recognize that it is a major polluter, with new efforts focusing on enhanced long-term sustainability.

Following the lead of the report entitled, *Fixing Fashion: Clothing Consumption and Sustainability* [1], and in the spirit of being the change we want to see happen in the world, we propose a seven-point program:

1. The development of comprehensive measurements of sustainable practices for water, low carbon emissions, and other factors in support of operational, transparent, and credible standards informing green investment bonds.
2. Consensus processes for industry-wide alignments of global impact measurement standards, creating an ecosystem of collaborating industries, governments, financiers, tax authorities, and legal regulations.
3. Creating an easy-to-use IT digital tool that will help guide bond issuers, investors, and firms toward substantively effective sustainability projects.
4. Custom made intervention program planning and implementation for sustainability R&D and innovation, addressing most urgent climate action global challenges in common metrics across regions and sectors.
5. Contribute to growing public awareness and consciousness as to opportunities and need for environmental and social impact innovation.
6. Developing impact investing market products and efficiency such as a sustainability risk index for investors, new funding models, cross-sector comparability metrics, etc.
7. Transparent data collection general ledgers on secure public networks for multi-stakeholder account

management and communications throughout the whole supply chain.

These seven points apply in the fashion industry a new ecologizing approach to sustainability impact measures [2]-[8]. The world urgently needs a clear and revolutionary solution to increasingly catastrophic problems of human suffering, social injustice, and environmental degradation. The universal presence, visibility, and appeal of clothing and fashion could make it a leading driver of innovation in advancing the cause of sustainable impact measurement, management, and investing.

2. MODELS AND METHODS

The crux of the matter is the opposition between today's dominant modern concepts, methods, and institutions, and the ecologizing concepts, methods, and institutions we need [9], [10]. Where modern ideas assume an outside-in, top-down, command-and-control approach to measuring and managing sustainability, ecologizing ideas enact an inside-out, bottom-up, emergent and self-organizing, go-with-the-flow approach that circularly informs top-down administrative processes with authentic and meaningful policies and practices. Measurement is ecologized by distributing instruments calibrated to a unit standard explained by theory [11] and reported at individual levels revealing individual variation in the context of a shared language [12].

Measurement models of this kind [13]-[19] provide well-established, scientifically proven, and practical ways of coordinating the sustainability policies and procedures of all participants in the fashion industry. The capacity to think together in a shared language via metrologically traceable, quality assured metric standards is of vital importance [20]-[27].

The unstated assumption in the Kering EP&L, as in the vast majority of other presentations of sustainability metrics, is that people as individuals, organizations, and communities have the abilities needed to succeed in managing the challenges posed by activities impacting environmental quality. The implicit requirement for meaningful and actionable measurement of this relationship is that it must embody an invariant structural ideal.

That is, the challenges of sustainable operations must be addressed consistently no matter who the particular people involved are, and the abilities of the people involved must consistently succeed and fail no matter which challenges are taken up. In short, the probability of success must be a function only of the differences between the abilities of the people involved and the difficulties of the sustainability challenges they face.

No data ever perfectly fit a model of this kind; in the same way, measured precisely enough, the lengths of the sides of right triangles do not satisfy the Pythagorean Theorem. The point is not whether the data fit the model perfectly; the point is whether the approximation can be made useful [16], [18]. Contrary to popular opinion, measurement is not performed for the purpose of discovering laws; rather, the ability to measure is a function of the laws already embedded within instruments [28].

3. DATA AND MODEL

The Kering Group's 2018 Environmental Profit and Loss statement (https://kering-group.opendatasoft.com/pages/report/) includes data on assessments of environmental impacts in six groups (air emissions, greenhouse gases, land use, waste, water consumption, and water pollution) resulting from the application of 20 process areas (abattoir, animal rearing, crop farming, extraction, ginning, spinning, weaving, dyeing, tanning, washing, etc.) to 15 material groups (animal fibers, cellulose fibers, synthetic fibers, fur, leather, metal, rubber, stones, wood, etc.) involving a total of 102 different materials.

Not all process areas are relevant to all materials, and not all processes affect all six environmental impact groups; of the potential 2,040 (20 * 102) indicators, 1,446 were observed, for both the material and monetary values. Of the potential 150,384 (1,446 * 104) observations, 88.3% (132,742) were missing for both sets of values. Material impacts are given in the original data in the following units:

- Air pollution: kg air pollutants (NOx, SOx, VOCs, PM…)
- Greenhouse Gas: kg CO2
- Land use: Ha
- Waste: kg
- Water consumption: m^3
- Water pollution: Kg water pollutants (heavy metals, chemical compounds, nitrogen, phosphorus…)

The Kering report focuses on overall volumes of environmental impacts, their cost, and their effects on local populations. No mention is made of how to make impacts comparable across locations varying in production volumes. The monetary values of the material volumes are given in Euros. Substantive environmental and social outcomes are discussed in the report at length but are not measured.

The measurement of environmental impacts is not the same as measuring mass, volume, or monetary value. These physical and financial values are being interpreted and applied as though they are measurements of a higher order, more complex, construct. That overarching construct, environmental impact, has not, however, been explicitly defined, modelled, or estimated.

The material and monetary values reported in the Kering Group's EP&L statement are given with no statement of the overarching model, no evaluation of the consistency of the observations, no uncertainty estimates (standard errors), and no calibration of a standard unit in which communications can be assured of references to a shared object. Individual mass, volume, and monetary values are provided for each combination of processes and materials in an unmanageably cumbersome array of numbers all assumed to be perfectly precise.

Monetary values are provided as a way of making the material volume and mass impacts comparable, but the same problems obtain as to the volume of data, and its interpretability, consistency, and precision. The purpose here is to provide an introduction to the technical processes involved in addressing these matters of estimation, model fit, reliability, precision, calibration, and unit definition.

3.1. Model statement

In this data set, people's abilities are represented at the level of the Kering operations in various countries. The environmental impact challenges are represented by the detailed array of physical masses and volumes, and monetary values, associated with production processes applied to materials of various kinds. The implied measurement model can be stated as:

$$\ln[P_{ni} \,/\, (1 - P_{ni})] = B_n - D_i, \tag{1}$$

which in the Kering data context states the formal expectation that the log of the odds of success is a function of the difference between the ability B of country n and the difficulty D indicator i poses as a barrier to successful sustainability.

3.2. Scoring algorithm

The distributions of values for each of the material impacts and the values in Euros were divided into six equipercentile groups and were scored from 1 to 6, with low impact volumes corresponding to 1 and high volumes with 6. Lower measures then indicate less impact. This conversion of the physical measurement and monetary values enables an evaluation of the consistency of the observed data across countries and indicators.

3.3. Data preparation

Material volumes and Euro value ratings were generated for 1,446 combinations of environmental impacts, production processes, and materials assessed on companies and divisions in 104 countries. Of the total 2,892 material and value indicators, the vast majority (2,344) are rated on operations in fewer than 20 countries, and well over half (1,664) are rated on fewer than 10.

Given the formulaic relationship between variation and the uncertainty associated with the number of available observations [29], an initial investigation of the potential for identifying structural invariances in the data excluded the 2,344 indicators with 19 or fewer ratings. The remaining two sets of 274 indicators' data were then fit to rating scale models using Winsteps [30].

4. RESULTS

Separate analyses of the material mass/volume and Euro value ratings of the six groups of environmental impacts resulted in several country measurement separation reliabilities over 0.90, but indicator separation reliabilities were 0.00. Analyses proceeded then with the intention of identifying subsets of indicators calibrating in reliably distinguished and meaningful ranges. Summary statistics from four of these analyses are shown in Table 1.

4.1. Environmental impact masses and volumes

Principal components analyses (PCA) of the standardized residuals for the mass/volume ratings revealed indicator clustering by material, process, and impact group. The large proportions of unexplained variance captured in the contrasts suggest that very different constructs are measured across indicator groups [31].

Selecting out only animal, plant, and synthetic fibers for examination in a new PCA, for instance, isolated the single code for spinning, weaving, and dyeing processes in a cluster separate from all other processes. This strong consistency of the variance shared among indicators falling into the same process code suggests a capacity for meaningfully measuring a common construct.

Further PCAs of the material mass and volume ratings then showed the six environmental impacts with strongly contrasting residual variance loadings. In the analysis of spinning, weaving, and dyeing processes for fibers, for instance, the two water impacts (consumption and pollution) were initially clearly distinguished from the other four environmental impacts.

A subsequent analysis then showed water consumption separated into its own contrast of 15 process-material indicators with loadings from 0.31 to 0.88, while water pollution was separated into its own distinct contrast of 15 items with loadings from 0.22 to 0.85. The same sharp definitions were produced in each of the other PCAs of the four environmental impacts for the same spinning, weaving, and dyeing processes applied to fibrous materials.

Model fit for each of the six sets of environmental mass and volume impacts for the spinning, weaving, and dyeing processes on fibrous materials was satisfactory. All country measurement and indicator separation reliabilities were 0.88 or higher, and all PCA correlations of the measurements implied by contrasted indicator loadings were over 0.90.

The meaningfulness of the dimensions defined by the hierarchies in the subsets of processes and materials within each environmental impact group remains to be determined.

4.2. Environmental impact monetary values

The monetary value ratings cohered more broadly across processes, materials, and environmental impacts. This preliminary investigation then returned to the full data set for closer examination.

With 221 to 247 value indicators within each environmental impact group, the average number of indicators per country was about 29, with standard deviations of about 30 and ranges of 2 to 180.

Measurement separation reliabilities were consistently well over 0.90, except for the greenhouse gases environmental impact group, which was at about 0.73 to 0.81 (depending on how error is estimated and whether extreme values are included). Country measurement model fit statistics for the monetary values tended to slightly over fit, but some showed strong under fit in negative point-measure correlations and root mean square errors peaking well over 4.00 (1.00 is the expected value).

Monetary value indicators were rated on about 12 countries across the six environmental impacts, on average, with a standard deviation of 12 and range from 1 to 57. Indicator separation reliabilities spanned a broad range, from 0.08 to 0.94, with all but two below 0.80. Model fit was also problematic for some indicators, with root mean square error values ranging to highs above 4.00. PCA results generally supported the unidimensionality of these within-environmental impact group monetary value scales, with ratios of explained to unexplained variance exceeding 6/1; the majority of measurements implied by the separate indicator contrasts correlating 0.90 and higher.

5. DISCUSSION

These results show that a great deal of analytic work will have to be done to identify and evaluate the combinations of processes and materials cohering together well enough to define rigorous and meaningful measurements for each of the six environmental impacts. Even more conceptual and investigative work needs to be done to shift the focus away from the relatively

Table 1. Summary statistics for four examples from the Kering Group's 2018 EP&L data.

Construct	Number of Countries	Number of Indicators Total / Mean	Reliability	Mn Sq OutFit Mean / SD
Leather waste	66	18/7	0.88-0.91	0.94/0.6
Plant fiber waste	56	9/4	0.88-0.94	0.94/2.1
Animal fiber spinning, weaving, dyeing	33	36/31	0.95-0.96	1.01/0.6
Waste across materials & processes	85	18/6	0.86-0.87	0.83/0.7

easily measured physical constructs of material environmental impacts and their monetary valuations, toward the more conceptually and operationally difficult social and environmental outcome constructs. Implementing these measurements will necessitate yet another investment of resources.

The results produced in this project are inconclusive but suggest positive opportunities for:

- Reduced data volume with no loss of information
- Managing what is measured in adaptive terms
- Support for lean thinking and quality improvement
- Comparability across materials, processes, and locations
- Systematic measurement of environmental impacts
- Revealing previously unestimated uncertainty, reliability, and consistency values

We see an opportunity for the fashion industry to position itself as a global leader in sustainability impact measurement, management, and innovation. We highlight the fact that measurement systems and knowledge infrastructures must inform both (a) on-the-ground day-to-day management and (b) investment accountability, with eventual development of various scientific, metrological, legal, financial, accounting, regulatory, and other standards [2]-[9], [23], [32]-[38].

Most importantly, measurements must be designed to resiliently and agilely adapt to changing circumstances without compromising communications standards [14]. This requires a framework for impact criteria aligned to global standards for measurement and metrology, such as an ecologized version of the United Nations' Sustainable Development Goals [5], [6], [8]. Analytics accuracy and uniformity require the development of quality assured systems supporting efficient data collection, instrument calibration, and results reporting [23].

Estimating impacts in this way quantifies market externalities by lowering transaction costs and facilitating efficient communications [39]. We intend to create efficient markets for trading sustainability impacts. Our goal is to make it possible to compete on sustainability: to organize markets so that returns on investments in human, social, and natural capital pay returns in terms of both authentic quality of life and money in the bank. Our motto is, "Sustainability for Fun and Profit!"

Based on selected impact audit criteria, periodic impact measurements for sustainability monitoring and management can be achieved. New kinds of report formats, such as Measured Impact Profit & Loss, impact budgets, and risk management evaluations will support end user decision processes. By having common languages for engaging in distributed sustainable impact management, decisions and behaviours will be coordinated and communicated in new more effective ways.

6. CONCLUSIONS

As shown in the analysis of the Kering Group's EP&L statement data, today's mainstream sustainability measurements suffer from a number of fatal design flaws. Longstanding, proven alternative approaches to impact measurements have marked practical advantages that are essential if industries, governments, investors, and financial institutions are to be able to succeed in meeting the demand for viable, feasible, and desirable solutions to the urgently pressing problems humanity faces in the world today.

Systematically researched and proven models and methods stand ready to contribute to the realization of the United Nations' Sustainable Development Goals and Agenda 2030 [5], [6], [8]. The global fashion industry stands to be a key leader in this work.

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