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A reference model for a sustainable commitment to sustainability in packaging development

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Abstract

Packaging is regarded as a major contributor to the environmental impact of products and supply chains. This is largely infused by the role of packaging in the use and post-use stages of a life cycle, which leads to packaging being regarded as superfluous or excessive. Simultaneously, within the current (product-packaging) development landscape, an erosion of the connotation of ‘sustainable development’ is discerned, combatting the inherent complexities of product-packaging development. In addition, there is a mismatch between sustainability desires (the strategic level) and materializations of it (the operational level) in industry, and a lack of academic or legislative solutions to this. These issues lead to product-packaging development processes in which sustainability-related considerations are subordinate to other decision-making criteria, and which therefore yield suboptimal solutions.

The main contribution of this article is the proposition of a reference model as an instrument aiming at streamlining the integration of sustainability-related considerations in decision-making in product-packaging development. This model aims for the tenable integration of such considerations by recognizing the complexity of sustainable development and multiple levels of sustainability. With this, the reference model simultaneously aims to address key characteristics of packaging development cycles in daily practice and the intertwinement of life cycles of product and packaging in the design and engineering domain.

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1. Introduction

When considering the environmental sustainability of products and their supply chains, packaging is often believed to be a major negative influencer. Despite the essential facilitating role packaging plays in a supply chain [1, 2], packaging is often regarded as superfluous or excessive – a result of a disproportionate focus on the role of packaging in the (post-)use stages of a product’s life cycle. Simultaneously, the major stakeholders influencing the development of product-packaging combinations (which include brand owners, packaging developing industries, and regulatory institutions) aim to increase a focus on ‘sustainability’ [3-5]. However, when considering the scope in which product

development and innovation materialize, the implementation of sustainability-related considerations as development-directing or decision-making criteria remains limited [6-8].

Moreover, current industry practice and legislation approves of solutions in which sustainable development is subordinate to other decision-making criteria [9]. The dilution of the meaning and connotation of ‘sustainable development’, and the decoupling of ‘sustainable development’ and ‘sustainability’ [10, 11] creates challenges within the inherent complexities of product-packaging development. Added to a mismatch between a sustainability desire (strategic level) and its materialization (operational level), product-packaging development generally undershoots the integration of sustainability-related considerations [12].

In this article, the innovation materializes in the form of a reference model that provides a structured basis for integrating sustainability in product-packaging development. This model recognizes the necessity, potential complexity, and all-encompassing scope of sustainable development at strategic and operational level. Additionally, it characterizes product-packaging combinations as an artefact in life cycle engineering. The reference model provides an illustration of, and focus on, the relations between sustainability-related entities, which is an essential element of solution-building: the seamless integration of sustainability into development practice [13]. The reference model adds to the current knowledge on tools and models aimed at integrating complex decision-making criteria in product-packaging design engineering processes [12, 14, 15]. It does not intend to add yet another discourse on ‘sustainable development’. Rather, the main contribution is to capture, determine, and describe the various views from a product-packaging life cycle perspective, when synthesizing sustainability-related considerations in development processes.

The following sections present the foundations of the reference model: an interpretation of sustainability in the context of development processes, a framework of levels of sustainability, and a life cycle perspective on product-packaging combinations in the design and engineering domain.

2. Contextual interpretation of sustainability

Ever since the establishment of ‘sustainable development’ as a political paradigm to address the deeply rooted systemic errors in resource depletion and inequality [16], ‘sustainability’ as a term has developed from a theoretical construct to an archetypical decision-making criterion. The establishment of ‘sustainability’ as a development identifier has taken off strongly after the publication of the UN report ‘Our Common Future’ [17]. Since then, the term has been established in the international policy discourse [18] and is inseparably connected to environmental impact, even though the ‘Brundtland definition’ of sustainable development does not mention an isolated focus on ecosystems only, yet rather concentrates on societal needs in the broadest sense. What initially started as the desire for societal systems in which development can be sustained with a lasting balance in social equity, economic prosperity, and environmental replenishment – the triple bottom line [19] – has now become a free-for-all attribute of everything remotely environmentally conscious (with many synonyms and derivatives [12, 20]), while economic systems are still hampered by a deeply rooted systemic error: profitability banking on resource depletion.

The connotative meaning of ‘sustainability’ appears to have been separated from the evolutionary nature of ‘sustainable development’ [10, 21]. The theoretical paradigm addresses a “process of change” [17], while contradictory, the common denominator of ‘sustainability’ in policy-making and industry is a non-defined platitude. Dependent on context, background, and level of ambition, the aim of ‘being sustainable’ often merely covers efficiency gains in already existing processes – an aim on “being less bad” [22, 23] in

environmental terms. This leads to a conflicting manifestation: the indefensible way in which the technical domain of our economic system relies on resources stemming from the ecosystem without fully adhering to its non-negotiable limits. While ‘sustainable development’ paints a picture of a lasting balance in which business and society respect future needs, ‘sustainability’ as a development criterion does not achieve that in the current manner of application (see also section 3).

In addition to this, sustainability-related considerations rarely shape a front-end criterion to base a development process on [9]. This limited integration derives from the confusing or conflicting nature of many paradigms and theories in sustainability-related realms, an inadequate focus on a continuous improvement context, a limited applicability of available tools and methods, unclear decision-making processes within development teams, and a lacking systemization of sustainability-related considerations in relation to other decision-making criteria [6, 8]. This leads to trade-offs biased towards non-sustainable considerations. Despite strategic aims and operational efforts, sustainability inclusions often remain a suboptimal or late-stage differentiator in development processes [9, 24, 25].

To scope the playing field, the ecosystem’s resource limitations are considered as the unconditional societal boundaries within which environmentally safe, sustainable development can take place: the planetary boundaries [26]. This framework came up primarily as a policy-making instrument, and more recently as the scope-setting indicator for environmental management and assessment, the quantification of human activity [27, 28]. For sustainability-related considerations to establish a core position in development processes, the economic arena is shaped and limited by the societal implications, which in turn is a subset of the playing field defined by the planetary boundaries [29].

In practice, sustainability integration shows business-related criteria prevailing in trade-off situations [9], possibly resulting from development strategies primarily focusing on economic objectives, whilst ignoring the relative importance of the triple bottom line in fundamental conceptualization publications [12, 18]. Therefore, in this article, the planetary boundaries are not applied as a benchmarking or assessment context, but as the unconditional limitation of the operating space for human activity – and with that, product development. Following, the planetary boundaries shape the overarching level of a sustainability focus: absolute sustainability [27, 30]. Building upon efforts quantifying the planetary boundaries as a foundation for product development [27, 31], the abstract level itself is addressed, by means of a revisitation of the way in which it can be applied as a non-negotiable differentiator in product development. With this elaboration of currently available research of both a similar nature and critically different, this research introduces a foundation for the contextual interpretation of sustainability.

3. Levels of sustainability

Within the realm of academic literature on sustainable development, a practically inexhaustible number of

taxonomies and categorizations on theories, methods, and tools can be identified, e.g., [6, 13, 20]. These range from goal-setting directives and guidelines (e.g., the UN Sustainable Development Goals) to end-of-pipe impact assessments (e.g., eco costing), and resource-focused theories (e.g., Circular Economy and Cradle to Cradle). Many of these tools and methods in fact consider sub-level means as targets. This happens in operational paradigms (e.g., recycled material quantities as the key target for ‘circularity’), in legislation (e.g., climate agreements based solely on CO₂ emission figures), and in commercial practice (e.g., material quantity reductions as key sustainability argumentation).

While targets address the required or desired outcome of development efforts, the means act as the tools required to realize these targets. The state of means becoming targets leads to development processes which demonstrate a mismatch between a company’s sustainability desire and its materialization [9]. As a result, development processes yield suboptimal solutions, potentially leading to systemic inefficiency. This premise leads to the necessity for an extension of the position of sustainability-related considerations in development processes. ‘Sustainability’ cannot just be included in some decisions or phases, but must be central in all design decisions, regardless the project aim, perspective, development phase, or level of detail.

The perspective in this article stems from three company-centric sustainability levels: desired, perceived and achieved sustainability. These levels reflect both the strategic and the operational levels of sustainable development. The strategic level refers to a company’s mission, vision, and strategy. The operational level refers to the activities of multidisciplinary development teams, which leads to the materialization of concepts and products. The strategic and operational level represent the interface levels between the planetary domain and the design and engineering domain, the key levels of interaction and intervention in the context of this research. Therefore, the tactical level is not explicitly addressed.

With the contextual interpretation of sustainability in the previous section in mind, this framework can be extended with three levels in both the planetary and public domain: absolute sustainability, compulsory sustainability, and communicated sustainability. In these extended levels of sustainability, absolute sustainability covers the unconditional limitation of the operating space. Compulsory sustainability is the level in which regulations, legislation, and governmental directives materialize. Communicated sustainability addresses a company’s efforts to disseminate desired, perceived, and achieved sustainability aims and performance. Both at and between levels, many mismatch risks exist; this article exemplifies five of those risks (see Table 1):

- Mismatches 1 and 2 relate to the issues disconnecting the planetary domain from the public domain and a company’s strategic level, respectively:
 - The first relates to inadequate or fragmentary legislation, where a limited number of indicators aims to represent absolute sustainability;
 - The second mismatch relates to a company’s strategic sustainability desires not being in line with absolute sustainability, or being merely a weakened version of it;

- The third mismatch risk covers a company’s operational daily practice not being in line with the strategic level;
- The fourth mismatch indicates a knowledge gap within a company’s operational level, between perceived and achieved sustainability [9];
- The fifth potential mismatch covers greenwashing, where communicated sustainability is not aligned to desired, perceived, or achieved sustainability.

Ideally, the public and company levels of sustainability align with absolute sustainability, avoiding suboptimal solutions resulting from a diluted planetary focus.

The sustainability levels shape the first foundation element of the reference model aimed at overcoming the identified mismatches in sustainability-related decision making.

Table 1 | Mismatch risks between levels of sustainability

Domain	Sustainability level	Mismatch risks
Planetary	Absolute	← (1) (2)
Public	Compulsory	
Company	Strategic	← (3) (4) (5)
	Operational	
	Operational	
Public	Communicated	

4. Packaging as an artefact in life cycle engineering

In this article, the dominant focus is on product-packaging development as a subdomain of ‘generic’ product development [14]. When considering packaging as an artefact, two typologies are key: (1) the role of packaging as a facilitating add-on to a product, and (2) the essential functions packaging fulfils [12, 32, 33]. Combined, this shapes the commensalistic interaction between product and packaging: a product-packaging combination, which acts as the main artefact in a multidisciplinary network of actors forming a life cycle [1, 2, 12]. As a consequence of this role of packaging, any definition of ‘sustainable packaging’ is speculative. It is crucial to regard packaging as a set of functions and artefacts providing added value for the commensalistic system rather than a separate entity. Consequently, the ‘(un)sustainability’ of a packaging can merely be assessed in the context of its content – a product-packaging combination can only act as the subject of study in life cycle engineering when regarded as one integrated entity.

Many different disciplines (e.g., packaging development, marketing, R&D, quality assurance, and procurement [34]) are involved in adequate product-packaging development, each contributing to specific aspects of a product-packaging combination. Each discipline has a certain perspective on specific packaging functions, and a field of expertise with corresponding standards, working methods, and jargon. Typically, within companies that market product-packaging combinations (e.g., brand owners), these disciplines join forces in multidisciplinary development teams, although they may have different, potentially contradicting, interpretations of, and directives on sustainability [9].

Consequently, the development cycle leads to a definition of the product-packaging combination as an artefact. Within

packaging development cycles, not the physical package itself but its definition is the central outcome [34]: the collection of information that defines the artefact as a set of functionalities embodied in the specification of e.g., geometry, material, performance, and appearance. With this, endless instantiations of this definition can be produced, (re-)used, and disposed of.

Any design decision regarding the artefact also has significant influence on the corresponding life cycle. As such, developing this artefact largely determines the corresponding and intertwined life cycles of both the product and the packaging. These life cycle depictions can be a deliberate outcome of (re-)design and development processes, a logical consequence of it, or an implicit side-effect. In any case, this inevitable life cycle defines the sustainability-related impact of any product-packaging combination. As such, the product-packaging definition and its corresponding life cycles shape the second foundation element for the reference model.

5. Reference model

The deconstruction of the notion of sustainability for product-packaging combinations, combined with the framework of sustainability levels and the corresponding life cycles of product and packaging in the design and engineering domain, provide the groundwork for a reference model. The focus of this model is to facilitate overcoming the issues that spawn the current integrational limitations, and to provide a framework for a revision of the way in which sustainability-related considerations are implemented in product-packaging development processes. It provides a relevant tool to sustain strategic and operational commitments to sustainability in product-packaging development. The model does not deliver a ‘sustainable’ methodology for packaging development, simply because there is not one definitive strategy or answer to the complex issues that need to be addressed in relation to absolute sustainability boundaries.

The reference model addresses the operational design and engineering domain, in which the activities of multidisciplinary development teams transpire. The focus on development teams and the context of artefact development leads to the design and engineering domain as the dominant level of aggregation in the reference model – this outset links the daily development practice with the various levels of sustainability and the planetary and public domains. This aligns to empirical research into the integration of sustainability-related considerations in product-packaging development [9], which acts as input for the reference model.

Figure 1 represents the reference model. It incorporates the planetary, public, and company domains, in a fashion similar to the well-established nested circles representation of the triple bottom line [18, 29]. Additionally, it consolidates the pivotal position of the design and engineering domain. Within this domain, the development of the product-packaging definition shapes the deliberate outcome of the development process, mirroring the corresponding life cycles as the consequential by-product – this relation is represented by a dotted line. The addressed six levels of sustainability are positioned in their respective locations within the planetary, public, and company domain context. Between these levels of

sustainability, arrows introduce the relations and dependencies, being directional rather than sequential or time-dependent indications. Direct links are distinguished from indirect links (visualized as dotted arrows).

Viewing the reference model from the planetary domain, absolute sustainability can be regarded as the starting point. This level feeds into both compulsory sustainability and desired sustainability – the latter as a direct resultant, or via compulsory sustainability as a mediating factor. Concurrently, desired sustainability acts as input for the product-packaging development process within the design and engineering domain, as dictated by the planetary boundaries. Perceived sustainability materializes in three reciprocal instances in relation to the design and engineering domain. Dominantly, a multidisciplinary development team regards the outcomes of the decision-making process in terms of the product-packaging definition and the corresponding life cycles as its resultant. An indirect perceived sustainability manifestation in the context of the design and engineering domain is the interface between the product-packaging definition and the corresponding life cycles. These life cycles are a potentially latent result and thus represent an indirect connection to perceived sustainability; therefore, this link is visualized as a dotted arrow.

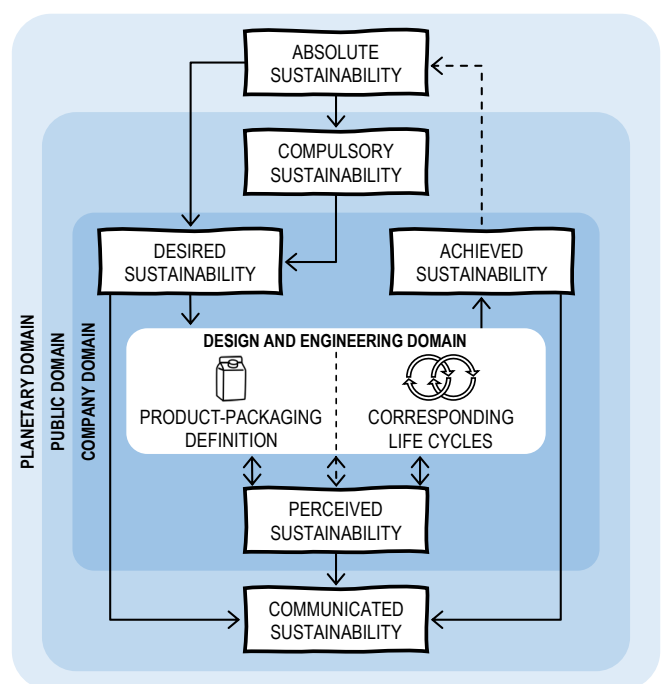


Figure 1 | Reference model for sustainability in packaging development

Within the company domain, no direct relations between the desired, perceived, and achieved levels of sustainability are identified. These levels revolve around the design and engineering domain which, in this context, acts as a mediating link. Where desired and perceived sustainability directly connect to the development of the product-packaging definition, achieved sustainability – as the output of the design and engineering domain – primarily builds upon the quantifiable environmental impact as a feature of the product and packaging life cycles. This quantified product-packaging sustainability-related assessment must act as input for the

consideration of revisions of a company's sustainability desire. For this, absolute sustainability acts as a mediating sanity check – visualized as a dotted arrow in the reference model. Finally, the level of communicated sustainability builds on input from all three sustainability levels within the company domain.

6. Valuation

To enable the reference model to support the integration of sustainability-related considerations in decision-making, a number of characteristics must be underlined. Firstly, it is key to emphasize the composition of the reference model as a set of entities relating to the multi-level sustainability framework, and the relations in between. This set-up bridges the gap between the all-encompassing long-term span of sustainable development and the short-term vision of a development project. This aligns to findings in empirical cases on current product-packaging development [9], in which the elements of the reference model were identified as gaps. The reference model provides support in balancing trade-offs in development processes and simultaneously enables the definition and tailoring of scope and targets within the design and engineering domain, adhering to the safe operation space dictated by the planetary boundaries.

The appropriateness and robustness of the reference model in the wider academic and practical discourse is primarily indicated by the consolidation of its multi-level constituents and relations as the outcome of a design rationale, stemming from theory and empirical practice. Yet, the introduction of a reference model as a support facilitator creates a situation in which assumptions exist [35]. Therefore, the valuation of the reference model is extended with a conjunction to current multidisciplinary product-packaging development research.

The reference model acts as a steppingstone for the construction of case-specific crystallized alignment frameworks. Following, the model can act as both the foundation for a roadmap towards a more structured integration of sustainability-related considerations in product-packaging development processes, or as part of the infrastructure by means of which this integration can be assessed. Dependent on the application context of the reference model, its facilitating support functionalities provide input for optimization advice. These opportunities stem from the demystification of the link between the development of product-packaging definitions and the corresponding, intertwined, life cycles of both the product and the packaging as a primary characteristic of the reference model.

In the context of a novel transdisciplinary packaging sustainability community, consisting of active representatives from industry, academia, education, and governmental bodies [36], the value of the reference model has been evaluated by means of a theoretical case. In this evaluation, critical responses have emerged. Where this circle of packaging innovation champions denoted the conceptual characteristics of the reference model as valuable, two key considerations surfaced in the feedback. Both considerations relate to the single-company focus as represented in the reference model. Since the model explicitly targets the levels of sustainability

as relations between the planetary, public and company domain, inter-company connections are not represented. After scrutinizing the quintessence of those relations, a subsequent formulation of the reference model can incorporate them by reshaping connections to additional actors in the product-packaging chain as well as by aligning the sustainability-related relations. Correspondingly, the significance of value chains in the context of the reference model was identified as a potential addition to address. Where the reference model revolves around the product and packaging life cycles as a resultant of the development of product-packaging definitions within the design and engineering domain, value chains can be regarded as cross-company materializations of product-packaging development, for which the mentioned inter-company connections as addition to the reference model can provide solutions. The final point of discussion regarded the connections between the company domain and compulsory sustainability. The connection of operational packaging innovation knowledge to legislative developments can be identified, albeit via a weak link. That underlines the omission of that link in the reference model.

7. Concluding remarks

With a dominant impression of packaging as a critical factor influencing the environmental sustainability of products and supply chains, in combination with a legislative and industrial focus on packaging as an isolated entity, interventions focusing on optimizations of 'just' packaging definitions will not be sufficient to advance the solid alignment of product-packaging combinations and the corresponding product and packaging life cycles with absolute sustainability. Such interventions will yield local efficiency gains at most, which are finite. Instead, a more rigorous path for improvement can be found in the relations between the design and engineering domain, and the planetary, public, and company-focused levels of sustainability. This research suggests a more structurally sound integration of these levels in development approaches by means of a reference model, addressing both the set of entities that constitute the multi-level alignment scope and the relations between these entities. Explicating the planetary boundaries as the non-negotiable constraint for development shapes the added value of the reference model: linking the intertwined nature of product-packaging definitions and their corresponding life cycles to the levels of sustainability.

Currently, the reference model exists as a theoretical construct. To further evaluate the efficacy of the model, and to validate the foundations on which it is built, follow-up practice-based assessments are essential as a steppingstone for advancement. Such assessment with increased practical rigor will provide valuation beyond the initial rhetorical and conceptual valuation as addressed in the previous section.

Three lines of future research are proposed. The first covers a substantiation of the levels of sustainability and the relations between them, in the planetary, public, and company domains. Previous research, which acts as a source of input for the definition of levels of sustainability definition [9], predominantly covers the relations within the design and

engineering domain. This can be enhanced with an empirical study covering all three domains. Secondly, research on the relative positions and orientations of the elements of the reference model and the relations in between is relevant. This can be executed by case studies, targeting comparative analyses with the reference model implementation as an independent variable. In addition, the value of product-packaging development experience as an influencing factor on the efficacy of the use of the reference model can be measured, by comparing the model as an intervention in both a practical and an educational context. Finally, the cross-company influences on the reference model (as addressed in the previous section) define a relevant research area.

In the wider academic discourse, these assessments of the reference model can provide a backdrop for further discussions on the pivotal position of ‘sustainability’ in development processes. Following, this leads to an open invitation to the academic community at large. The reference model pursues the alignment of sustainability levels with (product-packaging) development practice. This calls for critical responses to its constituents, value, and application within and beyond product-packaging development processes.

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