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An integrated tool to support sustainable toy design and manufacture

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ABSTRACT

Whilst the importance of considering the positive societal benefits of a product, in addition to other social, economic and environmental factors, has received wider recognition, its definition, concept, and integration into product design are not so well developed and studied. A literature review on sustainable design identified the potential of Social Life-Cycle Assessment as a tool to measure societal benefits of products; however further analysis of sustainable assessment methods highlighted the lack of a coherent definition and method for achieving this. This paper presents a framework for including societal benefits within a product portfolio management process and a prototype tool which aims to support the implementation of the framework within the toy industry, specifically on the societal benefit assessment of the products during the first stage. Finally a simulated case study of three toys is used to exemplify the intended application of this tool and to support the concluding discussions.

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SLCA; sustainable design; product development; toy manufacturing; societal benefit

1. Introduction

With growing material scarcity, future scenarios suggest that as competition for access to these resources increases, alternative economic models will be required if a fair and equitable society is to be maintained (Rahimifard, Sheldrick, Woolley, Colwill, & Sachidananda, 2013). Specifically it is suggested that other factors such environmental performance and the value of the company's outputs to society (societal benefits) (Shin, Colwill, & Young, 2015), will have a significant influence on future manufacturing sustainability. The framework providing a systematic approach to undertaking this 'Societal Value Assessment' at various levels within the organisation; was presented in a previous paper and is summarised in Section 2 (Shin et al., 2015). Further research identified the need for a specific assessment methodology tailored to the company's industry sector, which is further summarised in Section 3 (Shin & Colwill, 2016). This paper presents the design for a decision support tool to assist in the implementation of the framework and assessment methodology within the Toy industry. This industry was selected as it provides a good example of a sector where

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the products differ in terms of their societal benefits and where they are targeted at specific age groups.

2. Methodology

This research aims to provide a systematic approach for manufacturers to incorporate societal benefit considerations into their broader sustainable product management and design practices. In order to achieve this aim the following five objectives were established; to identify existing methods for assessing a products positive societal benefits through a review of relevant literature, to establish the limitations of these current approaches and identify areas for improvement, to develop a framework for including societal benefit assessment within existing sustainable manufacturing methods, to develop a methodology for assessing the positive societal benefits of a specific product category, and to present a design of a decision support tool for the implementation of the framework and methodology.

A literature review of current 'sustainable' product assessment methodologies was conducted to identify where the positive societal benefits of a product were being included. A number of concepts and frameworks were identified, such as Corporate Social Responsibility (CSR); however Social Life Cycle Assessment (SLCA) was the most advanced in considering a product's impact throughout its life cycle. An in depth review of SLCA was conducted and three main approaches for measuring positive impacts were summarised and scrutinised.

Following this review a framework was developed to incorporate positive societal benefit considerations into sustainable product management and design (Shin et al., 2015). The assessment phase of the framework identified the need for developing product category specific assessment method for measuring societal benefits. The framework and methodology are based on the widely-accepted ISO14040 LCA standards, but include some significant additions and modifications.

From this a tool was developed to support the implementation of the framework within a specific product category. The tool brought together a compilation of assessments and methodologies to follow the steps set out by the framework. A case study was carried out in order to test and validate the tool. Both the assessment methodology and the tool were developed to be used by the toy industry. Toys were selected for the case study as the benefits of toys are ambiguous, and yet most researchers in early development would point out the importance of play. Three toy products were chosen for this case study to demonstrate the application of both the societal benefit assessment methodology and the decision support tool.

3. Literature review

3.1. Sustainability

The concept of sustainability began to emerge as environmental issues were first brought to the public's consciousness by the release of 'Silent Spring' (Carson, 1962). Heightened public awareness led to a wave of greenwashing by companies who tried to capitalise on these consumer concerns with dubious claims rather than substantive improvements. Increased public pressure also put pressure on governments to respond which further highlighted the lack of understanding as new policies and legislation failed to deliver the required benefits (Chitnis,

Sorrell, Druckman, Firth, & Jackson, 2014). This knowledge gap was soon embraced by the academic community as a growing number of researches aimed to better understand the ecological factors and effects. In 1987, the UN Environment Commission Report set the tone for sustainability efforts to follow. More commonly known as the Bruntland report, it defined sustainable development as '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*' (World Commission on Environment & Development, 1987). The fundamental principle of sustainability is development that considers economic, environment, and social issues, which is often referred as the three pillars of sustainability (Elkington, 1997; Hansmann, Mieg, & Frischknecht, 2012; Kajikawa, 2008; Schoolman, Guest, Bush, & Bell, 2012). These principles have been adopted into product design practices to various degrees over the past decades and design for sustainability theories and practices are thus developed.

3.2. Sustainable product design tools

Sustainable product design has three distinctive phase over the years; Green design, Eco-design, and Sustainable design (Argument, Lettice, & Bhamra, 1998; Bhamra & Lofthouse, 2007; Keitsch, 2012). Green design takes into account the impact of the product on the environment whilst Eco-design aims to minimise environmental impacts while meeting cost, quality, and performances goals. As a result eco-design has been more broadly accepted and adopted by industry as it recognises the commercial environment that companies must operate in. Sustainable design aims to take this one step further by balancing the environmental and economic concerns of eco-design with social considerations (the triple bottom line). As these phases evolved so a range of product design tools were developed to support the implementation of these new considerations within the design process, with social considerations being a recent addition. Currently these design tools can be grouped into six categories; frameworks, analytical tools, checklists and guidelines, rating and ranking tools, software and expert systems, and organising tools. A recent review of 108 product design tools that considered at least one of the three 'pillars' identified that only 59 considered social issues, compared to 92 with economic and 69 with environmental considerations (Shin et al., 2015). Based on these numbers alone one might assume that social considerations in product design are close to reaching parity with environmental ones, however further investigation shows that this is not the case. A report by the OECD (2012) states that social sustainability is largely considered in terms of the social implication of environmental policies instead of an equally integral component of sustainability. These findings were substantiated by the review which found that of the 59 design tools that included social considerations only 18 did so with equal emphasis to environmental. In fact the majority of tools reviewed tended to be specific to one 'pillar' for example Life Cycle Assessment (LCA) only considers the environmental impacts whilst economic considerations are well advanced with tools such as life cycle costing, sustainable supply chain practices, and lean production practices (Chiarini, 2014b, 2014a; Finkbeiner, Inaba, Tan, Christiansen, & Klüppel, 2006; ISO, 2006a, 2006b; Mostafa, Dumrak, & Soltan, 2013; Womack, Jones, & Roos, 1990). This is to be expected with financial sustainability being the main driver in commercial enterprises.

Although the need for social considerations in sustainable assessment is slowly growing, it is widely acknowledged that the three pillars of sustainability have received differing degrees of attention in sustainable product design tools (Colantonio, 2007; Drakakis-Smith,

1995; Hussain, Ahmad, & Case, 2015; Marghescu, 2005). One of the reasons for this is that economic and environmental aspects can be quantified more accurately and with a higher degree of objectivity. Social aspects on the other hand can be highly subjective and difficult to quantify often having directly opposing benefits or impacts (Neugebauer et al., 2014). Furthermore, many of the social impacts associated with a product occur during its use phase which can be highly variable and complex making it difficult to assess accurately. However, the majority of the benefits to the user and society are generated during the products use; these benefits can be regarded as the positive social impacts. Current sustainable design tools offers little consideration for positive impacts and only a handful of tools that identify and quantify the positive impacts of products (Shin et al., 2015).

3.3. Positive impacts in sustainable assessment

A key assertion of this paper is the need to assess the positive impacts of products throughout their life cycles. However, there is little consensus on the definition of positive impacts and on methods that incorporate them into impact assessments (Shin et al., 2015). To a certain extent, the development in SLCA embodies the evaluation of positive impacts. The assessment boundary of SLCA is set in relation to an Area of Protection, which is inferred to be human well-being. According to the SLCA guideline, human well-being is described as the state of an individual's life situation (Benoit & Mazijn, 2009). SLCA can be carried out on two different levels: generic product chain on a general level and/or actual product chain of specific product. Generic assessments are often carried out to identify social hot-spots. The results are used to highlight potential risks of significant negative social impacts and risks to brand reputation instead of the positive benefits that the products brings about (Benoit-Norris, Cavan, & Norris, 2012).

In comparison to its environmental life cycle assessment (ELCA) predecessor, which largely considers only negative impacts, SLCA also includes positive impacts relating to social factors (Ekener, Hansson, & Gustavsson, 2016). However, these positive impacts are sometimes simply the absence of a negative one. For example, a factory's strategy of not using child labour is considered to be a positive impact, whereas in reality, the elimination or reduction of child labour is really only achieving a neutral or reduced negative impact. While the concept of positive impacts has arisen in recent years, there is still no shared definition of positive social impacts (Sala, Vasta, Mancini, Dewulf, & Rosenbaum, 2015).

SLCA guideline defines positive impact as impacts that go beyond compliance specified by laws, international agreements and certification standards. This indicates that social benefits/ social security issues are only considered positive only under the assumption that they provide additional benefits to the stakeholders. To be precise, this means benefits above the level expected and already given in society. Therefore, positive impacts should cause a 'net gain' in human well-being. Furthermore, similar to ELCA, which SLCA inherited, majority of the researches in SLCA so far mainly focuses on negative impacts or generic hotspot assessment on potential negative impacts. Thence, there are no consensus, well-developed, clear definition of positive impacts and methods that truly incorporate these into impact assessment.

Various ways of addressing positive impacts are identified from reviews of literature. Ekener-Petersen and Finnveden (2013) inverted the issue by measuring the lack of/ low level of positive aspects as negative impacts. However, this approach has limitation in identifying

positive impacts. Benoît and Mazijn (2009) expanded this approach by setting performance target points that the impacts are assessed against, thus positive and negative impacts can be determined from the performance target points. Ramirez, Petti, Brones, and Ugaya (2014) also adopted this approach, however positive and negative impacts were not distinguished.

A second approach is use by Ciroth and Franze (2011), where negative and positive impacts are rated by assigning values from 1 to 6, (1 for positive and 6 for very negative impacts). This approach is easy to use; however there are arguable elements such as assessing the lack of forced labour as a positive aspect, whilst this merely put it back to neutral impacts at best. Another approach to address positive impacts is the theory of hand printing, proposed by Norris (2013). Hand printing attempts to measure the positive impacts in terms of avoided negative environment impacts that would have contributed to the environment footprint. While the activities discussed in hand printing involves interactions between individuals and social groups, the fundamental theory is still environmentally linked.

Ekener et al. (2016) divides the subcategories in the SLCA guidelines into positive and negative impacts, and suggested tentative indicators for the 12 positive social impacts that were identified. However, there is no proposed way to identify, measure, and assess the beneficial user values. While life cycle approach should assess the entire life cycle of products, it can be argued that societal benefits (user values) are the most important social impacts as they characterise the products and fulfil the needs of products. To put it simply, all the other positive or negative impacts should not be made if the products are not fulfilling a need, thus should not be manufactured in first place. Therefore, it is important to assess the benefits of products in particularly during their use phase. The next section outlines a framework of societal benefits assessment.

4. Framework for incorporating societal benefits into sustainable product design

The framework as shown in Figure 1 provides an overview of a systematic approach to incorporating societal benefits into manufactured products. The sustainable toy design framework consists of three stages: assessment & target setting (strategic positioning), trajectory correcting & prioritisation (tactical plans) and design. The aim of the strategic framework is to facilitate the translation and communication of the strategic goals into design and manufacturing of toys. The main focus of this research falls primarily within the first and second stages of this framework, specifically the development of a novel social benefit assessment methodology (SBA), incorporating the SBA results with the product's environmental performance and integrating this within the company's product portfolio management review process. It is intended that this framework can be implemented within the company's existing management and design processes. Thus stage three is primarily concerned with how the outputs from the earlier stages can be incorporated into the company's existing design process.

4.1. Societal benefits assessment

Firstly, this assessment is developed to measure the societal benefits of products. It is called 'societal' as it intends to measure the benefits of products for the greater society instead of individual social issues. For the assessment method, it is necessary to define the terms

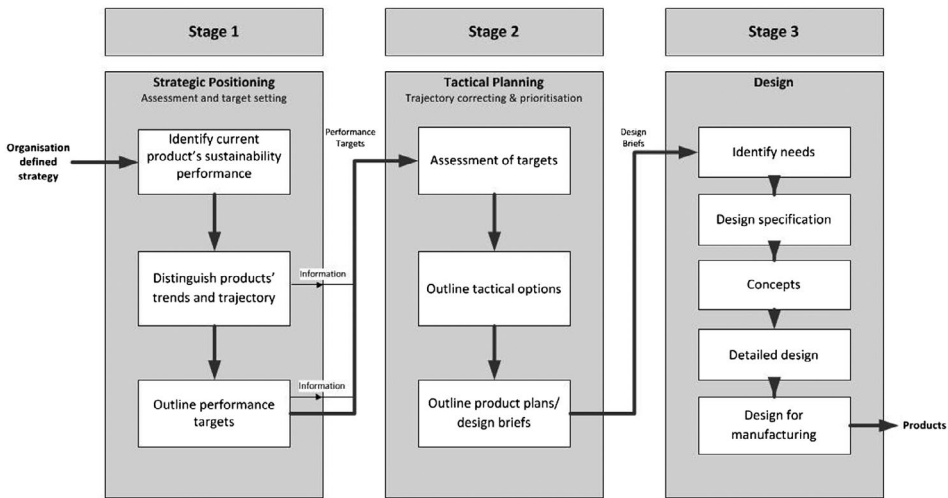


Figure 1. Framework for incorporating societal benefits into sustainable product design.

'play values' and 'play benefits'. 'Play' is defined as the quality of mind during enjoyable, captivating, intrinsically motivated and process focused activities. Hence 'play value' is the affordance of play and the higher its value the more effective the toy is in benefiting child's development. This definition of play value means that it focuses mainly on the action or activity of play and the affordance of an enjoyable, captivating, and intrinsically motivated play from the toys, whilst 'play benefits' focus on the skills and growth that are developed through playing i.e. the effects that are created after play (Kudrowitz & Wallace, 2010). Therefore play value and play benefits, whilst closely related, are not the same.

The structure of the SBA methodology, as illustrated in Figure 2, is based on the similar approach to that used within the ISO14040 standard for LCA (ISO, 2006a, 2006b). In place of inventory impacts, the SBA substitutes play types, and for mid points the SBA equivalent is play benefits. The individual steps undertaken during an assessment are similar to that of an LCA with the initial scoping and definition of the societal group, aggregation and allocation of the play types, and classification and characterization into play benefits, with an optional final stage of weighting and grouping into a single score.

For the purposes of demonstrating the SBA methodology a case study of three 2–3 years old toys have been chosen for assessment and comparison; an interactive singing and dancing soft toy, a pull-along toy with small parts inside, and some wooden sensory blocks with colourful panels were assessed. It should be noted that the age range within the societal group chosen represents a key stage of child sensory-motor and preoperational development, according to the Piaget's stages of development (Bee & Boyd, 2012).

4.1.1. Inventory stage

In traditional LCA, inventories are selected before being quantified as there is an extensive list of environmental inventories. Conversely, SBA for toys has a limited amount of play types, which is the equivalent of inventories in this case. The data collection phase consists of the scoring of all the play types of the toys. The play types are adopted from previous work on the play pyramid, in which a list of play types were summarised from previous

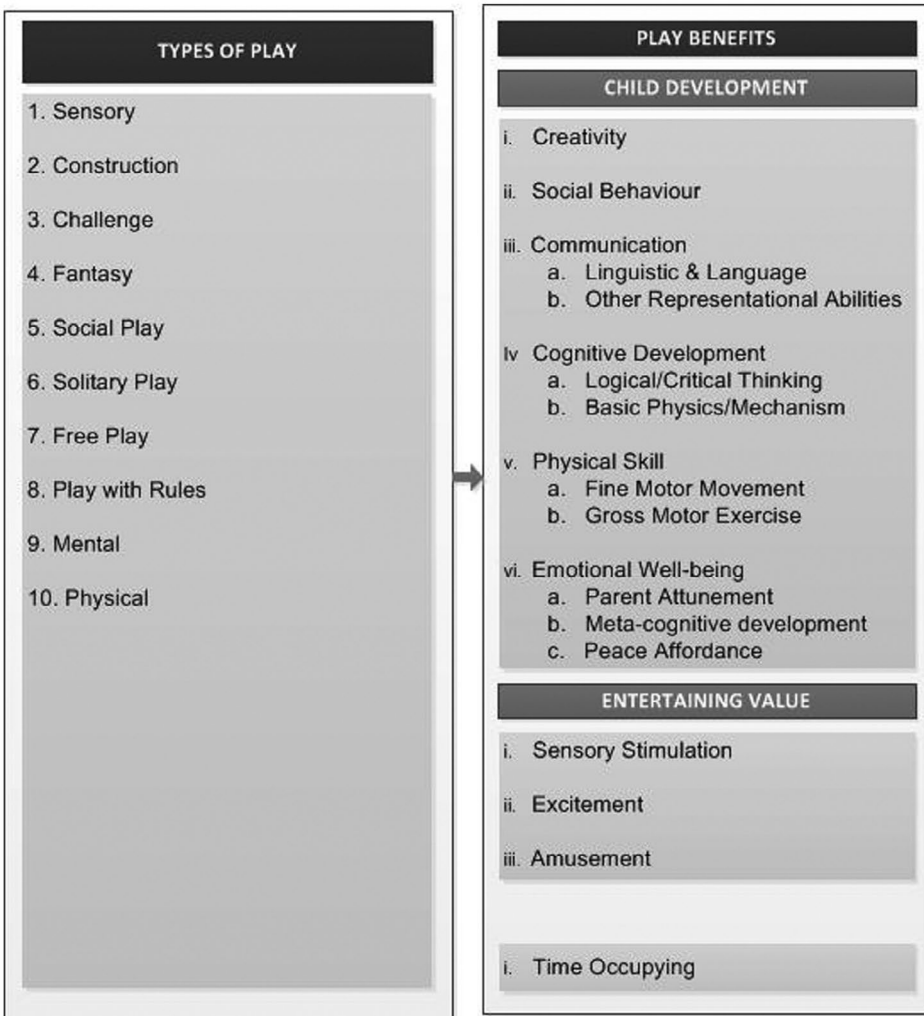


Figure 2. Societal benefit assessment methodology.

researches (Kudrowitz & Wallace, 2010). The play types defined and used in this case study are: sensory play, construction play, challenge, fantasy, social play, solitary play, free play, play with rules, mental play and physical play.

Sensory play refers to how the toys and play feels, looks, smells, tastes and sounds. Fantasy play refers to the ability of the toy to put the player into a world or state of mind that is outside of the ordinary. Construction play refers to toys and play that allows users to create. Challenge play refers to play that tests one's abilities against others or oneself.

The rest of the play types can be referred to play characteristics, they refer to the atmosphere or the setup for which the toys are played in. for example social play and solitary play refers to whether the toys enable children to play together or alone. One toy can be played both socially and solitarily, and may bring different benefits from different play. This is the same case for free play vs. play with rules, and mental vs. physical play. All the play types are scored from 0 to 10, where 0 means the toy being assessed does not afford that type of play

and 10 means it fully affords that type of play. The scores are modified objectively to relate to the societal scope, this process is similar to relating inventory data to the functional unit in LCA. The scores are weighted to their importance to that specific age. The importance weighting will be calculated with the use of analytical hierarchy process (AHP) (Saaty, 2008). AHP generates the weightings objectively through pairwise comparisons of each play types.

AHP is a one of the more recognised approaches for multi-criteria decision-making. It is normally used to establish a hierarchy of importance for alternative options selection, such as selecting manufacturing strategies for multiple customer requirements (Hofmann & Knébel, 2013). Within the process, a priority weight is determined for each option. It is this process that was adopted into the societal benefit assessment methodology.

The priority weights are calculated following the Saaty approximation method. This method involves comparing the importance of each pair of play types. The number of pairwise comparisons required follows a $n(n - 1)/2$ relationship, in this case, there are ten play types, and therefore 45 comparisons are needed. A judgment matrix is generated with 10 rows and 10 columns. A normalised matrix is obtained from the judgement matrix by dividing each entry in each column by the total of that column. The average of each row is obtained by adding the values in each row of the normalised matrix and dividing the sum by the number of entries in each row. The result is the priority weight of the alternative. A consistency test is performed to ensure that the pairwise comparisons are consistent.

The score on the play types will be multiplied by the priority weighting for further classification and characterisation into play benefits. An example of the scoring chart is illustrated in Figure 3.

4.1.2. Assessment stage

Table 1 below shows how the play types are classified into play benefits. The play types are given classification score of 0–5 where 0 means that particular play type does not contribute to that benefit and 5 means it strongly contributes to that play benefit. The list of play benefits are summarised from a number of literatures that focuses on the relationship between playing and child development (Goldstein, 2012; Whitebread et al., 2012). Play benefits can be grouped into two categories: child development and entertainment value. Child development entails physical development, cognitive development, emotional well-being, etc. entertainment value entails sensory stimulation, excitement, and amusement.

A societal benefit value is calculated by multiplying the inventory score by the classification score. The societal benefit values for all benefits are averaged and converted into a societal benefit potential by dividing it by a theoretical maximum benefit value. The individual play benefits values were consistent with similar qualitative assessments carried out by toy and children development experts such as the ones that are evaluated by The Good Toy Guide (Fundamentally Children, 2017). The overall societal benefits potentials of the singing and dancing soft toy, the pull along toy, and the sensory blocks are 50, 58 and 53% respectively.

There are two concerns with the assessment methodology:

- (1) The scoring classifications should be reviewed and refined, as the results can have a bigger differentiation. The overall scores do show the difference between products, however some results in the individual benefit potentials are not consistent with

Product Name	Score	Adj Scores
Fullplay Colourful Sound Sensory Blocks		
Sensory	9	9.00
Construction	6	3.04
Challenge	3	0.64
Fantasy	0	0.00
Social Play	2	0.10
Solitary Play	7	0.86
Free Play	10	3.15
Play with Rules	5	0.45
Mental	4	1.56
Physical	4	2.94
Product Description		
It consists of a few colourful boxes filled with coloured beads and balls. It allows children to sort them, stack them and making different sounds and noise with them. The hollow boxes allow children to look through and see a world with different colours. These blocks should engage the children and develop basic ideas like shapes, colour and sound recognition. They would encourage fine motor skill development and creativities. This toy is assessed through the tool along with other identified competitors'.		
Intended age	12 months to 2 yrs	

Figure 3. Play type scoring chart for wooden sensory blocks.

real life expert opinions. More expert inputs would be preferable in classifying play type into playing benefits.

- (2) The setup of the assessment lean towards favouring toys with multiple features, which can explain the pull-along toy scores in which the toy provides good features for both gross and fine motor developments. This causes potential concern with toys being overrated by the assessment. This problem is similar to ELCA, where detailed results should be reviewed for critical judgements before making key decisions. The assessment methodology provides clear transparent steps to be retraced, and in some respect, it is more important than a definitive score in subjective decision-making.

4.2. Cost benefit matrix

Cost Benefit Matric (CBM) is the integration and presentation of the results from LCA and SBA. CBM essentially plots each product’s environmental and social performances onto a



Table 1. Play benefits classification.

	Child development										Emotional well-being				Entertainment			
	Communication			Cognitive development			Physical skill				Parent attunement			Meta-cognitive development	Peace affordance	Sensory stimulation	Excitement	Amusement
	Social behaviour	Linguistic & language	Other representational abilities	Logical/critical thinking	Basic physics/mechanism	Fine motor movement	Gross motor exercise	Parent attunement	Meta-cognitive development	Peace affordance	Sensory stimulation	Excitement	Amusement					
Sensory	0	0	1	3	5	3	3	1	0	4	5	4	3					
Construction	5	0	1	3	5	4	2	2	1	4	0	2	3					
Challenge	3	4	3	5	1	0	0	1	4	1	0	3	2					
Fantasy	5	2	3	3	0	0	0	2	4	5	0	3	3					
Social play	3	5	3	2	0	0	0	1	3	1	0	3	4					
Solitary play	3	0	0	3	0	0	0	0	3	5	0	1	1					
Free play	5	0	0	1	0	0	0	0	5	2	0	4	4					
Play with rules	1	0	2	2	0	0	0	0	1	0	0	2	1					
Mental	4	0	0	5	3	0	0	1	5	2	0	0	0					
Physical	0	0	1	0	1	5	5	0	0	0	4	0	0					

graph. As shown in Figure 4, the y axis represents the environmental impact scores from environmental assessment in the form of single points. This can be calculated by software such as SimaPro or the Eco-indicator 99 worksheet which utilises key information from Eco-indication 99 database or Streamlined assessment like Environmentally Responsible Product Assessment (ERPA) (Hochschorner, 2003; Pré Consultants, 2000; SimaPro UK, 2016). The x axis represents the societal benefits factor, which is determined from applying SBA. The products' performances are plotted onto a graph, this visualises the performances and makes it more straightforward to compare performances. A matrix can be set up by setting benchmark performances for both environmental and societal performances; illustrated as dash lines in Figure 4. These targets are set by the practitioners who are carrying out the assessment. In the case of a toy company, these will be the predetermined strategic goals in the form of environmental and societal benchmark performances.

5. An integrated tool for incorporating of societal benefits in sustainable design

A tool is developed based on the same structure of the framework proposed in the previous section. The overall inputs and outputs are illustrated by an IDef0 diagram as illustrated in Figure 5. It clearly highlights the requirements and corresponding mechanisms for each process box as well as the input and output. Requirements are represented by arrows going into the boxes from the top (e.g. Legal Requirements). Mechanisms are represented by arrows going into the boxes from the bottom (e.g. the corresponding officers in charge of finishing the task of that stage and methods required for the task). Thus, the data required and information feeding out of each process are clearly defined and indicated.

Figure 1 shows the expanded system of the overall product level tool. It clearly demonstrates the three stages of the tool: Strategic positioning, Tactical planning and operational design/redesign. The strategic directions are fed in as input into this tool from the brand level management. It feeds into the strategic planning stage, a LCA and SBA are carried out

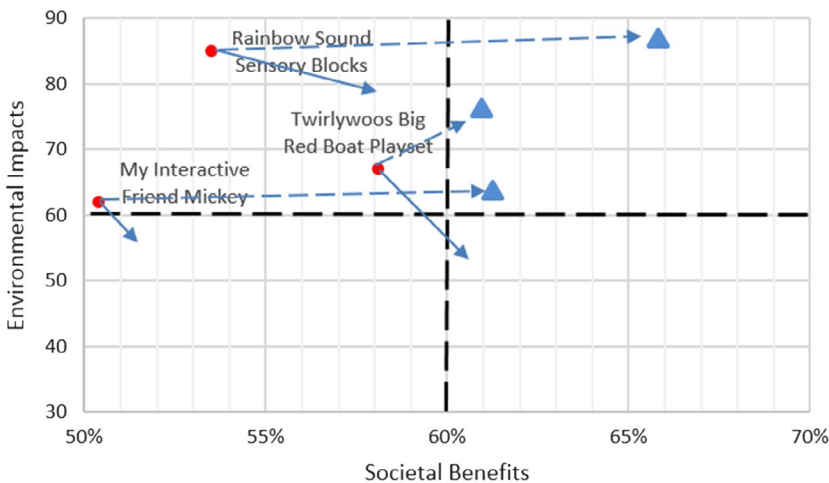


Figure 4. Cost benefit matrix.

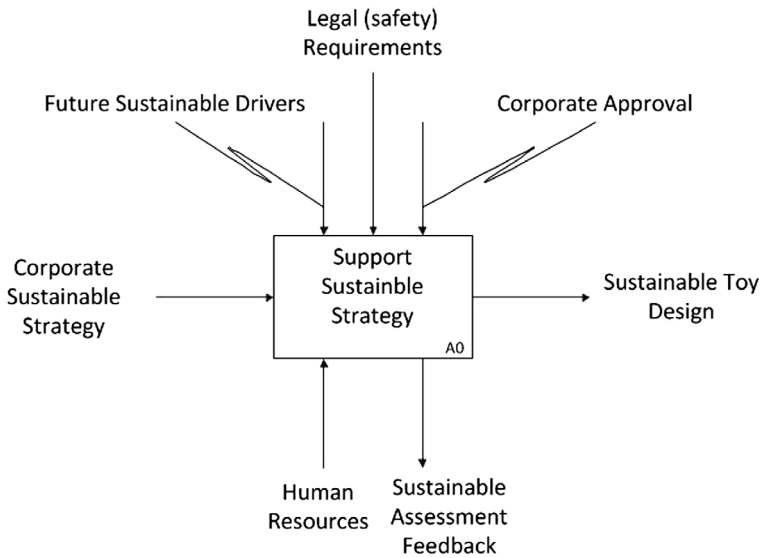


Figure 5. Overall view of the integrated tool for incorporating of societal benefits in sustainable design.

and the results are combined in CBM matrix. The presentation and the use of CBM will be discussed in more details in later section.

5.1. Stage one – strategic positioning

This tool aims to answer three strategic questions about the product(s). The results will aid the determination of the targets that will set the directions for the entire manufacturing company. The three questions are: ‘How is/are the product(s) performing in terms of the social and environmental sustainability?’, ‘What is the products’ future performance?’ and ‘How should the products be doing in the future?’

The three steps in the tool are set up to answer these questions and aid to develop a clear set of targets and goals for the tactical planning stage. The three steps in the strategic planning are Current Products’ Performance Assessment, Products’ Trends & Trajectory Analysis, and Performance Targets Formulation. Figure 6 shows the steps with the corresponding methodologies and requirement in an IDef0 format.

5.1.1. Current products’ performance assessment

This step determines the sustainable performance of the product/products, both environmentally and socially. Two methodologies are adopted for this step; ERPA is used for assessing the environmental performance while SBA is applied for the social performances. Results from both the SBA and ERPA are combined into the cost benefit matrix, Figure 4. The results show that all toys have acceptable performances. However, it is important to strive to improve. Just having more than 50% for societal benefit potential is not enough. Therefore, it is important to set the targets to be higher than 60% for any improvements in design. Environmentally, the wooden sensory blocks are performing well and does not necessarily require any major changes. Whereas, the two toys that required batteries and

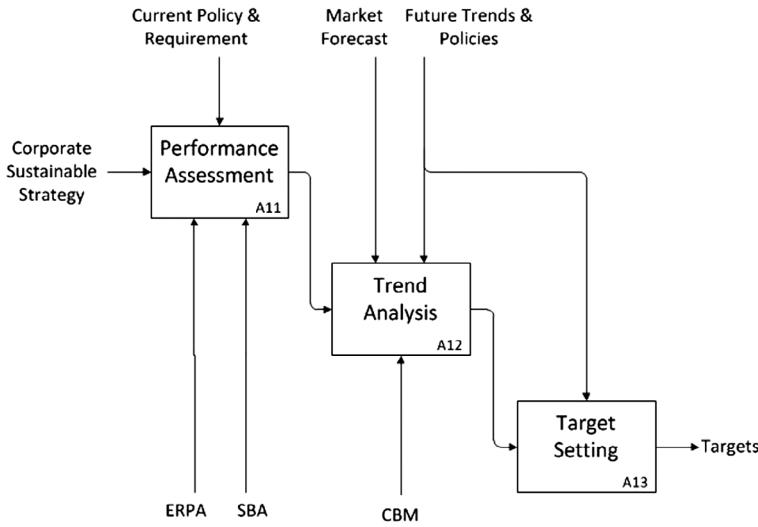


Figure 6. Strategic positioning tool.

international shipment would require improvements in both the design and the supply network system.

5.1.2. Distinguish product’s trends & trajectory

Forecasting methodologies can be applied to determine the future social and environmental performances of the products. The performance trends and targets are plotted onto CBA in Figure 4. The performance trends indicate that current existing development in design will bring the toys down in terms of environmental impacts. For the sensory blocks, it is the possibility of incorporating flashing electronic lights. The two battery operated toys are going to add new sophisticated features that required more battery powers and capacitors; features such as a voice recording and processing element.

5.1.3. Outline performance targets

New targets are set for future products (re)development. These targets are set based on information of future legislative requirements and expectations for social and environmental improvements. The targets are set with the urgency and priority in mind. In this case, all toys are performing relatively well environmentally, therefore their targets mostly aim to improve the societal benefits. For the two battery-operated toys, the efforts required to improve the environmental scores are accounted for, hence the shorter targets for improvements in societal benefits.

5.2. Stage two – tactical planning

The tactical stage aims to translate newly set targets into a clear design brief for product development. It consists of three steps that will utilise the CBM. Firstly, the targets are to be examined in order to determine priorities and time scale for any actions. Secondly, suitable tactical options are listed and chosen for achieving the targets. The options should be chosen in the light of the information of timescale and priorities determined in the previous step.

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Lastly, a design brief should be generated for the design team. This brief should embody the tactical options that were chosen. The overall processes are illustrated in Figure 7.

5.2.1. Analysing the targets and outlining tactical options

The targets set in the strategic planning stage provides an objective or a goal to be achieved, however there are no indications of timing and priorities when multiple products are involved in the decision-making process. There are multiple products and product lines in even SMEs, and it is essential to determine priorities and time scale along with the targets for sustainability performances. This is because of the fast and unpredictable nature of the industry and its market trends. In order to determine time scale and priorities, CBM and a Boston matrix are used for visualising and comparing the products on both matrices (Boston Consulting Group, 1970).

With high market share and slow or stagnating market growth, the singing and dancing soft toy is in its second year of sales. This makes it a 'cash cow' in a Boston matrix. Considering that sales are likely to decrease slowly in the following years, it is sensible to reduce the batches or stop sales all together instead of committing valuable time and resources to improve a finishing product. The pull along toy is a relatively new product on the market, with spectacular market growth and share, this means that it would be better to improve the design for better societal benefits. However, the environmental impacts also need to be addressed as it is very near the benchmark line for environmental impacts. The sensory blocks have low market share due to its niche market, but it has shown a good and steady market growth from increasing awareness from parenting websites and general mindfulness for environmentally friendly toys. It would be sensible to improve its design for societal benefits.

5.2.2. Outlining design brief

For redesigning options, a design brief should be generated for designers and manufacturing engineers to follow. The brief should be a clear statement that is instructive for achieving

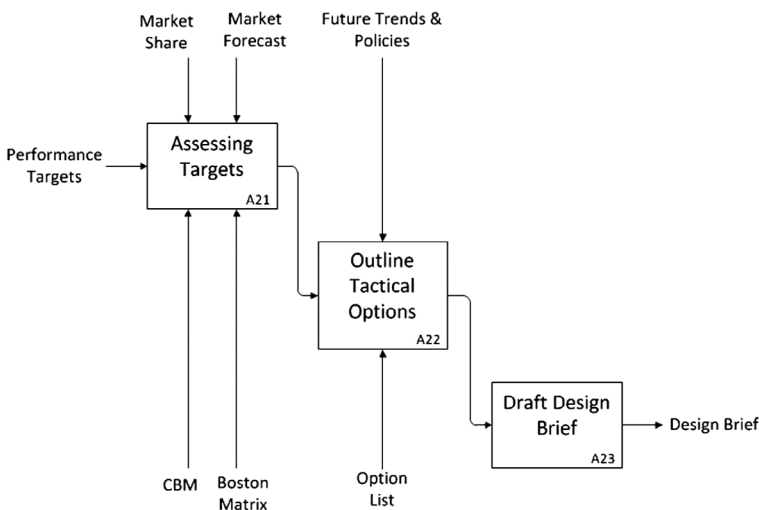


Figure 7. Tactical planning tool.

targets; however, it should not be specific so that there is room for creativity and innovation. The design brief should embody the targets that were set in strategic phase and should give clear indication of what to achieve. For both the sensory blocks and pull along toys, societal beneficial features need to be added or enhanced. This would mean aims for the toys. The pairwise comparisons results can be used as a guide. And that means improving the designs in the sensory and physical play types mostly and features that would provide a constructive play opportunities.

5.3. Stage three – operational design

The operational design stage only applies where design or redesigning was selected as the tactical option. The processes involved are depicted in Figure 8 along with the methods, tools and information that are required for each stage. The design process follows a well-established, widely used methodology of design; it starts with identifying needs and formulating a specification for the design where the needs are fulfilled. In this case, societal benefits will be highlighted as one of the more important needs. CBM can be used to quickly assess the specification to see whether the product described in the specification is going to perform to the brief drafted in the tactical stage and the targets set in the strategic stage. Design concepts are generated in accordance to the specification, where detailed design and prototypes are made. Quality function deployment methodology can be applied to ensure that the specification answers all the needs listed. Once again, the concepts, detailed design and prototypes can all be measured in CBM to ensure the social and environmental elements are properly and thoroughly considered. The final design put forward for manufacturing can be evaluated with performance data and put into CBM for a detailed assessment to confirm whether the final products are performing to the targets set in the strategic stage.

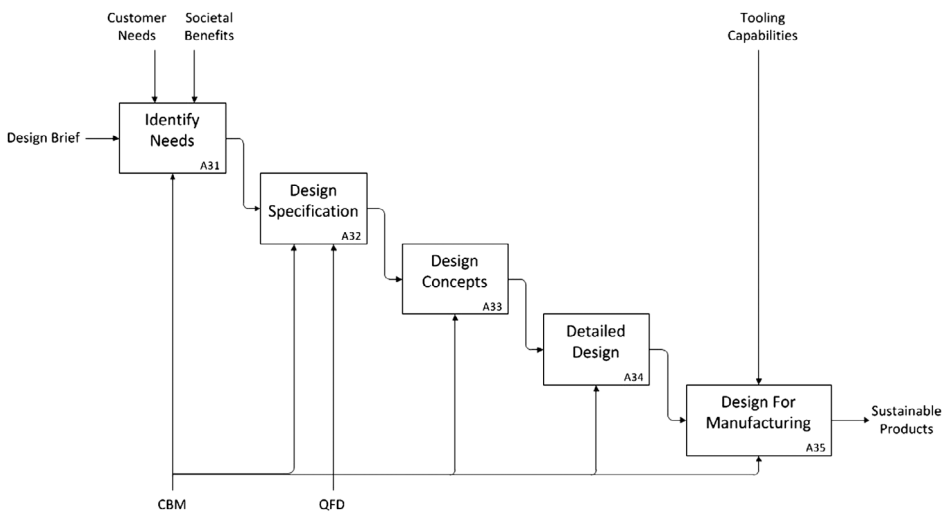


Figure 8. Operational design tool.

6. Discussion and conclusion

Current sustainability LCA methods primarily consider the negative impacts, and to a lesser degree the positive impacts, of a product over its life cycle. However these impacts are associated with the resources used in delivering these functions rather than the benefits derived from the functions themselves. How well a function is delivered and the benefit of that function are not generally considered in sustainable product assessment. It is proposed that in a resource constrained future, choices will have to be made as to which products are manufactured based on their value/benefit to society. This assertion led to an investigation of existing product assessment methods which identified a lack of capability in defining and quantifying positive societal impacts both a product and business level. Prior methods accounted positive impacts by avoiding or reducing negative impacts, instead of creating and enhancing positive social values. Based on the findings of this review a framework for incorporating societal benefits into sustainable product design was developed. This framework provides a systematic approach to encompassing societal benefit considerations into a company's product portfolio management process and ultimately its products.

A key activity in the first stage of the framework is the need to conduct a societal benefit assessment of individual products. The initial methodology for achieving this was developed within the framework however it became clear that a 'product category' assessment method would need to be developed to support this process. An assessment method was developed for toys aimed at 2–3 year olds that helps managers to quantify their products' positive impacts on this societal group. Whilst the initial method provides a quantitative result, the inputs used to achieve this have been determined through a largely qualitative process; its accuracy and objectivity have been enhanced through the use of AHP and other statistical methods. It is clear that whilst the initial findings and results are encouraging more work, including comparing the repeatability of the assessments, is needed to validate this approach.

The tool developed to support decision-making and strategic target settings for toy manufacturing and design helps to ensure a successful translation of the strategies from initial design brief to final product. Data obtained from the environmental and societal benefit assessments are compared and graphically presented within the tool to provide a simple and effective representation of the company's current position and trajectory that enables future sustainability targets, objectives and actions to be realistically set. The accuracy and effectiveness of the tool is dependent on the quality of the data input however the transparent application of this data would allow anomalies to be easily identified and investigated. Also whilst the tool supports the decision-making process it does not replace it and the final business outcomes will be dependent on the decisions taken.

The case study presented in the paper provides a clear demonstration of how the framework, method and tool are applied in a specific scenario. However it does not validate or measure the effectiveness of the tool and accuracy of the result. Due to the qualitative approach used to obtain the assessment metrics, weightings and scores, further case studies will need to be conducted in order to achieve a reliable measure of the tools success.

6.1. Limitations of research

As identified within the previous section, one of the biggest limitations of this approach is the ability to assess the societal benefits of product accurately. The accuracy of results

from the assessment method and the decision support tool depends on the appropriateness of scoring, measuring metrics, and weighting methods. These determine the ability to convert subjective data into quantitative and objective outcomes. Attempts have been made to address this limitation by combining expertise (in early child development and child psychology) with statistical processes to mitigate bias in the assessment. However, the effectiveness of these measures can only be determined through multiple case studies and the consistency of the results.

6.2. Further work

- More expert comments and opinions are required for AHP importance.
- Experts opinions in classification of play types scores into play benefits. This will address the assessment bias to toys with multiple features.
- The SBA results should be formally scrutinised against other results for verification of SBA.
- A detail case study is currently being carried out for validation of the tools for supporting design improvements for managers.

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