Abstract. The triple bottom line principle of sustainability is an important philosophy which leads to the reduction of environmental and economic impacts and risks. Its application in new product development helps to achieve an excellent brand image, thereby improving the competitive advantage in similar type of products. This paper proposes a tool that incorporates the sustainability dimensions along with the balanced scorecard perspectives for the new product development. The proposed tool, Sustainability Balanced Score card matrix is tested by applying it in a small scale industry. The successful usage of the tool in the development of a product, demonstrate its potential for the development of a customer satisfying, profitable and sustainable product.

1. Introduction
The need for implementing sustainable development concept is gaining more and more relevance in all areas of the society, especially in industries. Focusing on consumption and production in general, the 2002 World Summit on Sustainable Development (WSSD) highlighted the current patterns of consumption and production as unsustainable, as they are resulted adverse environmental and social impacts [1]. These impacts include climate change, waste generation, pollutant emissions to air and water, biodiversity loss and depletion of natural resources [1-5]. They affect various stages of the product life cycle namely raw material acquisition, production, distribution, use and end of life reuse, recycling, treatment or disposal. Apart from these, they can cause adverse ethical and social issues such as child labour, discrimination, inequitable distribution of resources and inequitable trading policies [6-8].

Environmental policy considerations at the early stages of the product development are extremely important for reducing the adverse environmental impacts of the products. A new approach on the design and development of eco-friendly and sustainable products is gaining momentum recently [9]. In this, environment friendly production practices are considered either equal to or more important than the cost, quality and time to market.

Sustainable product development requires to address all the three dimensions of sustainability namely environment, social and economic impacts, at the very initial stage of product development. A model for new product development that integrates the principles of balanced score card (BSC) and the three dimensions of sustainability is proposed in this paper.
2. Literature review

BSC is a strategic planning and management system that is used extensively in business and industry, government, and nonprofit organizations worldwide to align business activities to the vision and strategy of the organization, improve internal and external communications, and monitor organization performance against strategic goals [10]. It was originated by Dr. Robert Kaplan (Harvard Business School) and Dr. David Norton as a performance measurement framework that added strategic non-financial performance measures to traditional financial metrics to give managers and executives a more 'balanced' view of organizational performance.

BSC is a management system (not only a measurement system) that enables organizations to clarify their vision and strategy and translate them into action. It provides feedback around both the internal business processes and external outcomes in order to continuously improve strategic performance and results [10]. When fully deployed, BSC transforms strategic planning from an academic exercise into the nerve centre of an enterprise. Kaplan and Norton describe the innovation of BSC as follows: "The balanced scorecard retains traditional financial measures. But financial measures tell the story of past events, an adequate story for industrial age companies for which investments are in long-term capabilities and customer relationships were not critical for success. These financial measures are inadequate, however, for guiding and evaluating the journey that information age companies must make to create future value through investment in customers, suppliers, employees, processes, technology, and innovation"[11]. BSC suggests that the organization is viewed from four perspectives namely the Learning and growth, Business process, Customer and the financial perspectives and which ultimately lead to financial success through cause-and-effect chains. Following are the features of a good BSC.

1. The Learning & Growth Perspective: This perspective includes employee training and corporate cultural attitudes related to both individual and corporate self-improvement. In a knowledge-worker organization, people the only repository of knowledge are the main resource.
2. The Business Process Perspective: This perspective refers to internal business processes. Metrics based on this perspective allow the managers to know how well their business is running, and whether its products and services conform to customer requirements.
3. The Customer Perspective: Recent management philosophy has shown an increasing realization of the importance of customer focus and customer satisfaction in any business. These are leading indicators: if customers are not satisfied, they will eventually find other suppliers that will meet their needs.
4. The Financial Perspective: Kaplan and Norton do not disregard the traditional need for financial data. Timely and accurate funding data will always be a priority, and managers will do whatever necessary to provide it. In fact, often there is more than enough handling and processing of financial data. With the implementation of a corporate database, it is hoped that more of the processing can be centralized and automated. But the point is that the current emphasis on financials leads to the "unbalanced" situation with regard to other perspectives.

The existing product development tools target on the traditional cost/profit models to achieve high quality and high profit at reduced cost [12]. However, during last two decades, efforts have been taken to incorporate environmental consideration also into product development. The integration of environmental considerations in product development has been dealt by researchers using different strategies. Instead of considering three dimensions of sustainability, many of the recent research works focus on one or two dimensions of sustainability [13]. Assessing sustainability requirements along with customer requirements, causes sustainability requirements get weighed very low and their importance in the design gets reduced [14]. Also, all stages of product development cycle need to be assessed for sustainability [15]. In addition, implementation of an organization policy on level of fulfilment of sustainability and customer requirements is also required in sustainable new product development [16].
2.1. Sustainability balanced scorecard (SBSC)
A strategy-based BSC system aligned with principles of the Triple Bottom Line (TBL) is aimed at accomplishing social and environmental goals while integrating them with financial performance and competitive advantage [17]. The concept of SBSC is derived from conventional BSC with both environmental and social issues as essential pillars of a sustainable development of the business [18].

By integrating BSC perspectives along with the three pillars of sustainability, SBSC helps to overcome the limitations in environmental and social management systems. SBSC not only helps detecting important strategic environmental and/or social objectives of the company but also enhances the transparency of value-added potentials emerging from social and/or ecological aspects and prepares the implementation process of the strategy [19]. For integrating the TBL factors into conventional BSC first, the environmental and social issues can be incorporated into the existing perspectives of conventional BSC [20]. Or otherwise the number of perspectives can be increased by including a fifth non-market perspective. The concept of a SBSC offers the possibility for companies for translating sustainability visions and strategies into action. SBSC provides the potential for the integration of environmental and social aspects and objectives into the core management of companies. Thus the Sustainability Balanced Scorecard provides a strong tool for an integrated and value based sustainability management. It helps to overcome the shortcomings of the often parallel approaches of environmental and social management systems implemented in the past.

3. Conceptual Model Development
Three dimensions of sustainability namely Economic, Environmental and Social and four dimensions BSC namely Financial, Customer, Internal Business Process and Learning & Growth are considered here. Among them only Economic / Financial perspective is shared in both the sustainability and BSC perspectives. Thus the SBSC matrix categorizes six dimensions as shown in the Figure 1.

The SBSC model for product development has two stages. In the first stage the attributes of six dimensions namely Customer, Financial, Environmental, Social, Internal Business Process and Learning & Growth for the Product Development cycle (PDC) stages are identified. The four stages of PDC considered are the Design (DE), Material Selection (MS), Manufacturing Process (MP), Distribution & Usage (DU) and Disposal (DI) stages. Accordingly, weightage matrices are to be developed for individual stages of PDC by separately considering the six dimensions of SBSC. SBSC matrix is to be developed subsequently in the second stage.

The process adopted for constructing the weight matrix of the Design Stage of the PDC is described in this section. Table 1 shows the customer requirement (CR) weightage matrix for the SBSC model in the Design stage of the PDC. The SBSC model considers $z$ different design options. There are $n$ customer requirements that are identified by the design team. The level of fulfilment of the customer requirement $CR_i$ will be different for different design options. A ranking is carried out by expert team based on the level of fulfilment of $CR_i$ for the design option $k$. These ranks are converted
to weights using multi-criteria decision making (MCDM) methods. The values of $a_{ki}$ indicate the weights of the Customer Requirement $CR_i$ for the different design options $k$. The total weight of $k^{th}$ design option on fulfillment of customer requirement (CRTW), $A_k$, is arrived at using the equation (1).

$$A_k = \sum_{i=1}^{n} a_{ki}$$

(1)

Where $a_k$ is the total weight of $k^{th}$ design option on CR.

| Design options | Customer Requirements | CRTC | CRTW |
|-----------------|-----------------------|------|------|
| Design 1        | $a_{11}$ $a_{12}$    | --   | $a_{1n}$ | $A_1$ |
| Design k        | $a_{ki}$ $a_{kj}$    | --   | $a_{kn}$ | $A_k$ |
| Design z        | $a_{zi}$ $a_{zj}$    | --   | $a_{zn}$ | $A_z$ |

The weight matrices of the remaining five dimensions of SBSC model are also to be developed similarly. The total weight of $k^{th}$ design option $B_k$, $C_k$, $D_k$, $E_k$ and $F_k$ on fulfillment of Financial Requirement (FR), Environmental Requirement (ER), Social Requirement (SR), Business Process Requirement (BPR), and Learning and Growth Requirements (LGR) respectively also are to be calculated using formula 2 to 6.

$$B_k = \sum_{i=1}^{n} b_{ki}$$

(2)

$$C_k = \sum_{i=1}^{n} c_{ki}$$

(3)

$$D_k = \sum_{i=1}^{n} d_{ki}$$

(4)

$$E_k = \sum_{i=1}^{n} e_{ki}$$

(5)

$$F_k = \sum_{i=1}^{n} f_{ki}$$

(6)

Where $B_k$ is the Total Weight of $k^{th}$ design option on FR, $C_k$ is the Total Weight of $k^{th}$ design option on ER, $D_k$ is the Total Weight of $k^{th}$ design option on SR, $E_k$ is the Total Weight of $k^{th}$ design option on BPR, $F_k$ is the Total Weight of $k^{th}$ design option on LGR, $k$ is the design option number, $n$ is the total number of FRs, ERs, SRs, BPRs and LGRs in the respective matrices. $b_{ki}$ is the weight of the $FR_i$ for the design option $k$, $c_{ki}$ is the weight of the $ER_i$ for the design option $k$, $d_{ki}$ is the weight of the $SR_i$ for the design option $k$, $e_{ki}$ is the weight of the $BPR_i$ for the design option $k$, $f_{ki}$ is the weight of the $LGR_i$ for the design option $k$.

The SBSC score of the individual design options has to be calculated as shown in the Table 2. The weights obtained from the six dimensions of SBSC are consolidated in this table. The Policy Weight $P_1$ to $P_6$ are also considered in the SBSC matrix. The top management can assign weight to all the six dimensions as a policy of the organization. These weights can be equal, if top management does not want to give priority to any of the six dimensions. The values in the SBSC matrix are arrived at using equations 7 to 13.
Table 2. SBSC Matrix for the Design Stage

| Design options | Weight | Customer | Financial | Environmental | Social | Internal Business Process | Learning & Growth | SBSC Score |
|----------------|--------|----------|-----------|---------------|--------|---------------------------|-------------------|------------|
| TW A1          | CRD1   | B1       | FRD1      | ERD1          | SRD1   | PRD1                      | GRD1             | SBD1       |
| PW P1          |        |          | P2        | P3            | P4     | P5                        | P6               |            |

\[ SBD_k = CRD_k + FRD_k + ERD_k + SRD_k + PRD_k + GRD_k \]  \hspace{1cm} (7)

where \( SBD_k \) is the SBSC Score for the Design stage

\[ CRD_k = A_k \times P_1, \]  \hspace{1cm} (8)

where \( CRD_k \) is the CR score of \( k \)th design option

\[ FRD_k = B_k \times P_2, \]  \hspace{1cm} (9)

where \( FRD_k \) is the FR score of \( k \)th design option

\[ ERD_k = C_k \times P_3, \]  \hspace{1cm} (10)

where \( ERD_k \) is the ER score of \( k \)th design option

\[ SRD_k = D_k \times P_4, \]  \hspace{1cm} (11)

where \( SRD_k \) is the SR score of \( k \)th design option

\[ PRD_k = E_k \times P_5, \]  \hspace{1cm} (12)

where \( PRD_k \) is the BPR score of \( k \)th design option

\[ GRD_k = F_k \times P_6, \]  \hspace{1cm} (13)

where \( GRD_k \) is the LGR score of \( k \)th design option

\( P_1, P_2, P_3, P_4, P_5 \) and \( P_6 \) are Policy weights

The similar process is followed for the other stages of PDC to arrive at the SBSC score of the alternatives in these stages. The total score of the paths, which are compatible and their SBSC score are to be identified from the SBSC matrices. The path that has maximum SBSC score will be the most sustainable PDC option.

4. Case Study

A case study on the implementation of the SBSC Matrix was conducted in a plastic products manufacturing firm, M/s Ibis Industries Private Limited (IIPL) located at Thrissur District of Kerala State, India. The Design department of IIPL was explained about SBSC Matrix and sought their involvement in conducting the case study. An expert team comprising of Owner, Manager, Design Engineer, Production and planning Supervisor and Sales Executive was constituted by the top management to use the SBSC Matrix for NPD. After the consultation, the product, Plastic Bucket was
selected for conducting the case study. Design Selection, Material Selection, Manufacturing Process and Distribution stages are the PDC stages of Plastic Bucket in IIPL.

The four possible design options identified are shown in Table 3. The expert team collected CRs from the history of various enquiries, company standards and market survey on design. The combination of 'metallic and plastic handles' and 'body with and without ribs' are already being produced by the company. The requirements from customers and the designs of competitors were the inputs for arriving at these models.

Table 3. Design Options of the Plastic Bucket

| Sl. No. | Design options                      |
|---------|-------------------------------------|
| 1       | Plain body with metal handle       |
| 2       | Plain body with plastic handle     |
| 3       | Body with ribs and plastic handle  |
| 4       | Body with ribs and metal handle    |

Table 4. SBSC Dimensions and the attributes for the product

| SBSC Matrix Dimensions | Customer Requirements | Financial Requirements | Environmental Requirements | Social Requirement | Internal Business Process Requirements | Learning and growth Requirements |
|------------------------|-----------------------|------------------------|----------------------------|--------------------|----------------------------------------|---------------------------------|
| Attributes             | Better appearance (BA)| More Asset utilization (MAU) | Minimum Product Waste (MPW) | More employee satisfaction (MES) | Low energy consumption (LEC) | Less employee education (LEE) |
|                        | Better Comfort (BC)   | More Sale profitability (MSP) | Max. waste recovery & reuse (MRR) | More Customer satisfaction (MCS) | Increased speed to market (ISM) | More research and development (MRD) |
|                        | Low price (LP)        | More Cash flow (MCF)    | Low content of Additives (LA) | New Customer Acquisition (NCA) | Improved efficiency (EI)     | More employee knowledge sharing (MRD) |
|                        | More Durable (MD)     | Low Financial risk (LFR) | Less Harmful to environment (LHE) | More employment opportunities (MEO) | More ability to respond to emergencies (MAE) | More sustainable consciousness of top management (STM) |
|                        | Low weight (LW)       | More Profit (MP)        | --                         | --                 | --                                     | More change in business strategy (MCBS) |

As the sustainability requirements are product centric, it will be different for different products and were identified by experts through discussions, whereas, the BSC perspectives requirements were identified from literature and agreed among experts. The possible SBSC dimensions and their attributes for the design selection stage opted are listed and tabulated in the Table 4.
The ranking of individual attributes with respect to the design options have performed for all the dimensions of SBSC at Design selection stage. This activity was carried out by the expert team. Ranking were carried out based on the capability of the design options in fulfilling the attributes. In the case study, Rank Order Centroid Weightage (ROCW) method is used to assign weights to each combination of design options and attributes. The Ranking of the design options with respect to the different attributes of Customer Requirement is shown in Table 5. Similar ranking is done for all other SBSC dimensions.

**Table 5.** SBSC Ranking of Design options based on attributed of Customer Requirements

| Design options                        | Customer requirements |
|---------------------------------------|-----------------------|
|                                       | BA       | BC    | LP    | MD    | LW    |
| Plain body with metal handle          | 4        | 4     | 3     | 2     | 4     |
| Plain body with plastic handle        | 2        | 2     | 4     | 1     | 3     |
| Body with ribs and plastic handle     | 1        | 1     | 2     | 3     | 1     |
| Body with ribs and metal handle       | 3        | 3     | 1     | 4     | 2     |

According to the ROCW (Ahn, 2011), the ranks are converted to weights using equation (14) given below.

\[
wt_i = \left(1/n\right)
\]

\[
w_i = \frac{1}{1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}}/n
\]

\[
w_t = \left(\frac{1}{n}\right)/n
\]

Where \( wt_i \) represents the weight of \( i \)th rank and ‘\( n \)’ represents the total number of attributes that are ranked.

Six weightage matrices were developed by calculating the Customer Requirement weights using ROCW method for Design Selection stage. That is shown in Table 6.

**Table 6.** Weights of Design options based on attributed of Customer Requirements

| Design options                        | Customer requirement Weights | Total Weight |
|---------------------------------------|------------------------------|--------------|
|                                       | BA   | BC   | LP   | MD   | LW   |             |
| Plain body with metal handle          | 0.063| 0.063| 0.146| 0.271| 0.063| 0.604       |
| Plain body with plastic handle        | 0.271| 0.271| 0.063| 0.521| 0.146| 1.271       |
| Body with ribs and plastic handle     | 0.521| 0.521| 0.271| 0.146| 0.521| 1.979       |
| Body with ribs and metal handle       | 0.146| 0.146| 0.521| 0.063| 0.271| 1.146       |

Top management decided to give equal preferences to all dimensions of SBSC Matrix. Hence, Policy weighs (PW) to each dimension was given same weight of 0.167. Calculation of CR, FR, ER,
SR, PR and GR scores were carried out using the formulae 8 to 13. The SBSC score was calculated for each design options using formula 7. The SBSC matrix developed is shown in Table 7.

From Table 7, the option, Body with ribs and plastic handle is having highest SBSC score (1.378). Hence, this design option is selected as the most customer satisfying, profitable and sustainable design.

Table 7. SBSC matrix for Design options

| Design options                          | Types of Weight | Customer | Financial | Environmental | Social | Internal Business Process | Learning & Growth | SBSC Score |
|-----------------------------------------|-----------------|----------|-----------|---------------|--------|--------------------------|------------------|------------|
| Plain body with metal handle            | TW 0.604        | 2.146    | 1.708     | 0.542         | 1.25   | 0.771                    |                  |            |
|                                          | PW 0.167        | 0.171    | 0.338     | 0.285         | 0.09   | 0.208                    | 0.128            | 1.17       |
| Plain body with plastic handle          | TW 1.271        | 0.896    | 0.875     | 1.458         | 0.333  | 0.979                    |                  |            |
|                                          | PW 0.167        | 0.172    | 0.149     | 0.243         | 0.056  | 0.163                    | 0.969            |            |
| Body with ribs and plastic handle       | TW 1.979        | 1.063    | 0.542     | 1.458         | 1.083  | 2.146                    |                  |            |
|                                          | PW 0.167        | 0.177    | 0.090     | 0.243         | 0.181  | 0.358                    | 1.378            |            |
| Body with ribs and metal handle         | TW 1.146        | 0.896    | 0.875     | 0.542         | 1.333  | 1.104                    |                  |            |
|                                          | PW 0.167        | 0.149    | 0.146     | 0.090         | 0.222  | 0.184                    | 0.983            |            |

5. Conclusion
A model for sustainable product development is presented in this paper by incorporating sustainability principles with the balanced scorecard perspectives. The Rank Order Centroid Weightage technique is used to assign weights to the different options of design. The SBSC Matrix tool proposed for product development is demonstrated here by conducting a case study in a small scale industry. The Design selection stage of the product development cycles of a typical product is considered for the case study. The most customer satisfying, profitable and sustainable design is identified using this tool.

This tool can be applied to all product development cycle stages and thus, the most sustainable options can be identified for developing sustainable products. This tool can also be used by managers and researchers for sustainable product development combined with other MCDM techniques.

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