NordDesign 2014
August 27 – 29, 2014
Espoo, Finland / Melbourne, Australia

Measurement and visualisation of evolutionary changes in product shape for justification of styling decisions in design.

Charlie Ranscombe[1], Janneke Blijlevens[2]

[1]*Dept. Interior Architecture & Industrial Design, Swinburne University Of Technology*
cranscombe@swin.edu.au
[2]*Centre for Design Innovation, Swinburne University Of Technology*
jannekeblijlevens@swin.edu.au

Abstract
Ample literature shows consumers have a general preference for product designs that are novel or different, but still recognizable. However, there exists little guidance or objective methods to establish the degree of difference that the appearance of a new product should have in comparison to competitors or its predecessors. Therefore, it is difficult for designers to justify the appearance of a design. To address this we explore the use of shape comparison software to measure and visualize differences in shape through a case study of the evolution of an iconic beer bottle design. Results show the potential of the method to provide objective measures for change in shape and visualization of the nature of change. Practical implications of gathering shape change data are in being able to make more specific design briefs and map to other data to investigate the market success of previous styling decisions.

Keywords: *Measurement and Visualisation Method, Product Shape Evolution, Justification of Styling Decisions*

1 Introduction

It is well researched that product appearance plays a substantial role in product perception and subsequent product success on the market [1-3]. This gives rise to the concept of strategic styling where a company/brand sets out to achieve certain strategic goals through the manipulation of product appearance [3-5]. Thus product appearance becomes inherently tied with potential market success, but also risks associated with products being unsuccessful. The result of this link is the requirement for designers to justify appearance with respect to the strategic goals of a given product strategy.

Styling decisions in general can be difficult to justify and communicate across design teams primarily due to their multifaceted nature; appearance is not considered in isolation, it must be reasoned alongside costs, market success, product performance, materials and manufacture [6-8]. Many of these criteria that influence styling decisions can be reasoned and justified objectively; for example, through quantifiable costs of a product or the strength of materials used in the product. While companies prefer objective bases for justification of decisions, matters of appearance are usually justified through reasoning relating to a designer's experience and design intuition and are therefore far more subjective [8]. Hence, objective and quantifiable measures that can be used to justify product appearance changes in styling strategy are currently lacking. Therefore, the research reported here sets out to address this issue of subjectivity in justification of product appearance, through providing a method for objective and quantifiable measurement of differences in appearance, which can then be used to justify styling decisions.

2 Background

The background is now discussed in terms of styling strategy and approaches for objective measurement and comparison of appearance.

2.1 Strategic styling decisions.

Person, Snelders [5], provided a framework outlining strategic decision making during the styling process, thereby elaborating on previous work [1, 3, 9] and emphasizing the important role product appearances play in the success of the product. They describe a generic set of factors that influence styling decisions, and provide a framework for justifying logic behind styling decisions. More specifically, this framework employs three dimensions of product context that provide guidance on how similar or different the future product designs should be from other products in these dimensions: current portfolio, succession of products and competing products.

When the current portfolio is concerned two strategies can be followed. Either a company can choose to style new products similar to existing products so that they are easily recognized as belonging to a certain brand or they decide to have a multitude of styles within the portfolio in order to reach as many segments of the market as possible. When it concerns the succession of products, companies can choose to keep high similarity in successive product designs, because this helps communicate a clear symbolic meaning that can, for example, have a clear historical connation. On the other hand, differentiation may be preferred by companies to adapt to current trends and if repositioning is needed. Lastly, when competition is concerned, similarity to a dominant competitor can be beneficial when wanting to clearly communicate what the product is and can do. Differentiation, however, is often preferred to ensure uniqueness of the product compared to other products on the market.

Clearly, Person, Snelders [5] contributed significantly by providing generic guidelines for styling products and justifying their appearance in terms of similarity/difference to other products. However, in providing generic guidelines, the guidance remains abstract and does not provide exact guidance on the degree to which a product in a specific context should be made similar or different in order to adhere to a strategy. Moreover, what is considered as very different in one product category, may be considered quite similar in another. Hence, designers do not know the magnitude in which a product design should differ from the product designs within the current portfolio, within the specific product line or compared to competing products. Therefore, in this paper we introduce a method that provides insights into the styling strategy that a company generally follows as identified through retrospective quantitative data-analyses of changes in product appearance changes. That way, designers have insights in the magnitudes and directions of differences of product designs that a product has been through. These insights can consequently be used as guidance for what magnitude of appearance change a future product should adhere to given the styling strategy of a company.

2.2 Objective measurement of change in appearance

Ranscombe, Hicks [7] have explored a range of methods to measure and compare product appearances. The analyses used in these methods consider the proportion and orientation of features with respect to other features as well as change in the shape within individual features. Analysis of proportion is based on measuring and comparing basic dimensions of features such as overall height and width. Orientation analysis measures and compares the relative position of features based on their centre, and extrema. Analysis for shape is based on plotting the relative distance of points on the outline of a feature to the features centre of area. This allows for comparison of a wide range of shapes and measurement of the location and magnitude of differences in the shape of feature outline.

The methods set out by Ranscombe et al. are based on 2D representations of products and focus on product feature comparison rather than the overall appearance. Hence, these methods provide abstracted and limited insights in overall appearance change of products and are, therefore, less suitable for identifying styling strategy of a company. Moreover, the presentation of measures for differences is presented purely in graph form. As such, results require a high degree of interpretation to relate values for degree of difference back to the appearance/overall shape being analysed. We believe that the lack of visualisation poses a barrier in being able to communicate the relationship between measures of difference and the appearance of a product and thus also a barrier for designers justifying styling decisions. Accordingly, the current research sets out to overcome the above mentioned limitations through adapting the method for measuring shape change differences within features to measuring shape change differences in overall appearance. As such, 3D models form the basis for comparison rather than 2D representations. In addition, the visualisation properties of the current method are adapted to provide more ease in translating the quantitative data about shape change back to the overall appearance. The resulting approach aims to provide the context specific and explicit information needed for styling strategy justification that the framework proposed by Person et. al. can not provide.

3 Aims and Objective

The overall aim of this research is to address the need for objectivity in the process of making styling decisions through the provision of measurement data of change in shape. Provision of this data gives the potential to allow designers to more objectively justify claims of similarity and difference and hence the adherence to various strategy guidelines set out by Person et al.

The primary objective of the research reported here, and the 1st step in achieving the overall aim, is in exploring the use of surface comparison software as a means to provide measurements (objective data) for change in shape and visualise measurements.

4 Method

Measurement of change in shape is undertaken by investigating the change in shape from one model/product to the model/product's successor. This is then repeated through the full evolution of a given product. The outcome is a succession of data/measurements for magnitude of change between each 3D model and a visualisation of this on the 3D model's surface. These measures are then compared over the total evolution to establish trends in the magnitude of change, which may be used to benchmark the degree of difference in future designs. Visualisation contextualises these values for change with respect to the product's form.

4.1 Measurement of difference in shape

For the purposes of this study the measurements of difference are made using 3D digital models as the basis. It is contended that the use of 3D digital model is most ideal when investigating a company/brand's product history as such data is usually readily available to designers and can be considered the most realistic version of the product shape compared with using product images as in [7].

3D digital model surface data is then converted to a point cloud. A point cloud is a representation of the surface by points or coordinates located on and covering the surface of the shape. A cloud consisting of 90,000 – 100,000 points was used. This cloud density was selected as it was believed to represent the surface in suitable detail while not using so many points as to become a burden on software processing power.

The approach taken to calculate differences in shape is referred to as the Hausdorff difference calculation primarily used to compare surface accuracy of mesh representations to the original digital models [10]. This approach calculates the distance between a point on the successor model point cloud and the nearest point/intersection with the previous model. This is then repeated for each point that makes up the point cloud representation of the new and successor model. The magnitude of difference the direction is also calculated (positive or negative) where positive reflects an increase and negative reflects a decrease in size. Each measurement of difference is output as a data file. It is then possible to perform analyses on the data. A histogram is used to show the distribution of difference in shape for each model.

In calculating difference in shape, alignment of models becomes critical. For this study models were aligned based on the orientation they are typical viewed by the consumer. Thus models are aligned about their central axis and placed on surface (shelf). It is possible to select other approaches/rationale for aligning models such as the centre of volume, top etc.

4.2 Visualisation of difference in shape

As the intention of the use of this tool is to inform decisions relating to appearance, it is essential that measurement data can be related back to appearance. Thus, there is requirement for the outputted data to be made relevant to the visual impression of the shape. Simply put, the designer must be able to "see" and show which elements or areas of the product's surface are different from the previous version.

To achieve this visualisation a colour map is employed. The colour map is a gradient between colours where each colour represents a value and the various hues created by the gradient represent the continuum of values between those defined as extremes. The hue that reflects the value of difference is then applied to each point in the cloud. The result is a skin covering the surface of the current model, coloured to reflect the areas and magnitudes of change from the previous model.

4.3 Case study: Crown Lager

The subject of the case study used to demonstrate the approach is the beer bottle of the brand Crown Lager. Beer (or its bottle packaging) as a product it can be said to be in a mature phase hence there is little competition in terms of functionality or technology. Thus there is increased emphasis on values such as brand and appearance to differentiate in the market. Furthermore the shape of Crown's bottles is viewed by the brand as being particularly iconic. Finally the Crown Lager bottle has a relatively long history of product models (9 to date) offering numerous evolutions to compare.

As per the method each model is compared with the previous model. For each comparison the difference in shape is output in the form of a histogram and data is visualised using a colour ramp on the surface of the "successor model". The colour ramp was defined from -3mm to 3mm. This was based on the maximum difference seen across the difference measurements discounting anomalies from point cloud creation.

5 Results

Following the application of the approach prosed in section 4 to the Crown Lager case study, the evolution is illustrated showing the bottle designs and the mapped difference in Figure 1. Figure 2 shows measurement data with mapped difference alongside. Results are discussed first in terms of the degree/magnitude of difference seen in changes (primarily represented through histograms). Data for direction of difference is then discussed in the context of the product shape referring to the visualisation of difference using the colour ramp/map.

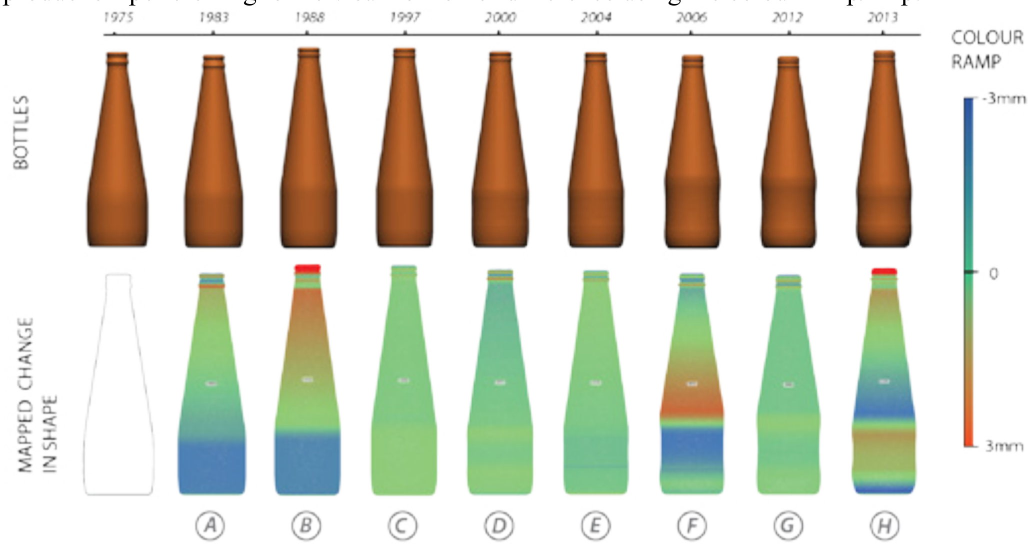


Figure 1. Evolution of bottle designs. Note change in shape mapped using the colour ramp (right) on each successive bottle design.

5.1 Degree of change

The first observation from looking at the degree of difference data is that there are two kinds of change in shape. Major changes are embodied by greater deviation with the majority of points deviate within the range – and + 2mm from 0. These changes are characterised in histograms by a wider distribution in shape changes around 0, where frequency is distributed more evenly across the degrees of difference (See Figure 2 Plots A, B, F and H). The second type of change, minor changes are embodied where degree of difference in the majority of points is of + or – 0.5mm with the majority of points deviating within – and + 1mm. This minor change in shape is characterised by the histograms that show difference "spiked" around 0 (See Figure 2 Plots C, D, E and G).

Focusing on the distributions skew toward positive or negative change, it can be seen that minor changes (Plots C, D, E and G) represent a subtle shrinking in overall shape. Furthermore the accompanying visualisations show that this shrinking occurs uniformly over the shape. Oppositely visualisations show that major changes do not occur uniformly over the bottle but are embodied in more substantial changes to certain areas of the bottle shape.

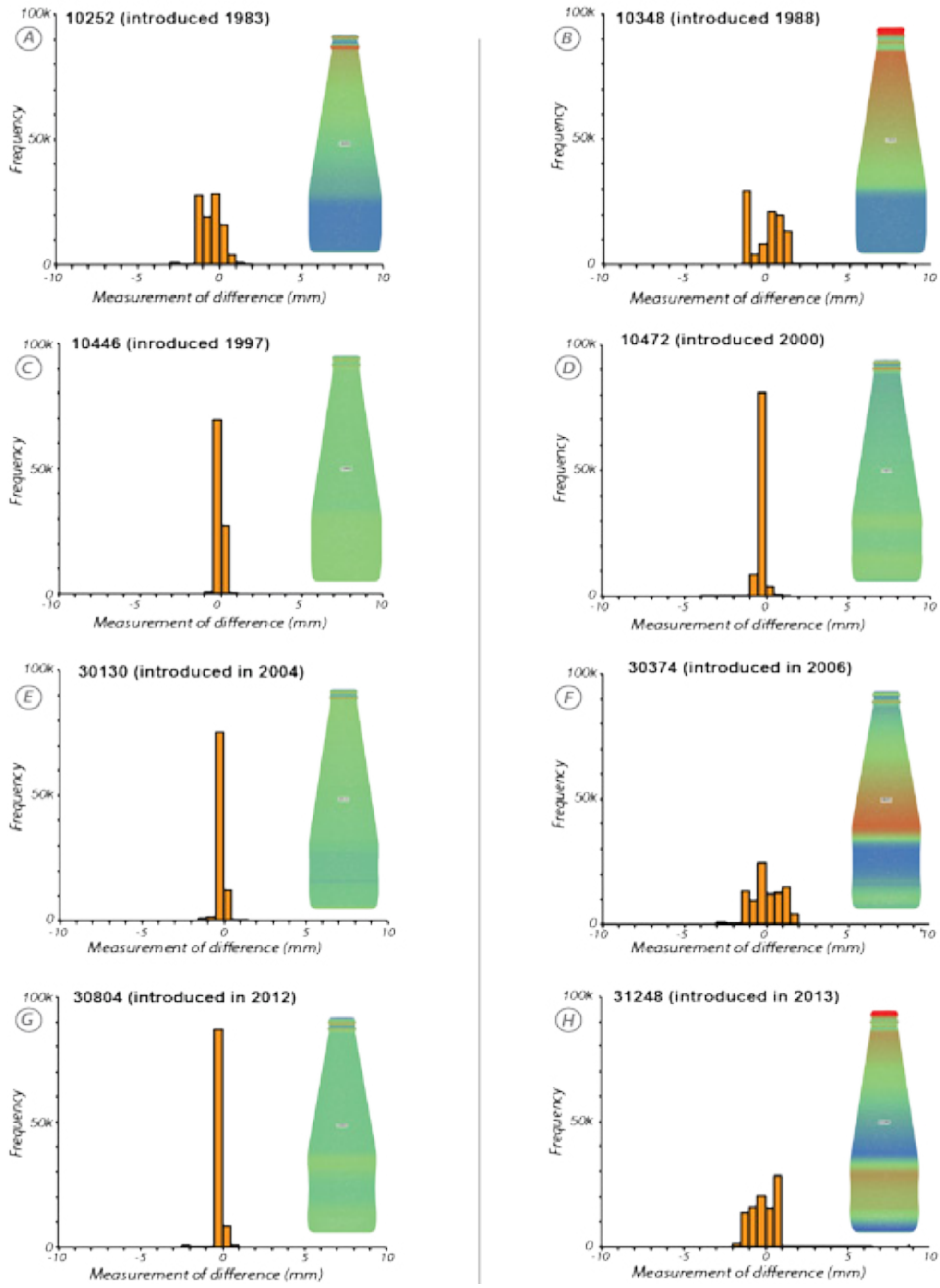


Figure 2 Resulting measurement data for incremental changes in bottle shape. Histograms show the distribution of degree of difference of surface comparison. Data is also visualised on the bottle surface using a colour ramp that accompanies each plot.

5.2 Direction of change: Visualising where change occurs

From inspection of the colour mapped models it can be seen that minor changes appear more or less uniformly over the product surface aside from changes relating to height that are manifested in the cap/top area of the bottle. Inspecting the visualised changes for the major changes, it can be seen that much of the difference is associated with the "shoulder" of the bottle (shoulder defined as the area where the more cylindrical base begins to taper toward the cap). In major changes from the first to second bottle introduced (figure 4 A and B) we see the shoulder moving upwards towards the cap and the diameter of the cylindrical section reducing. In the 3rd and 4th major changes it can be seen that the cylindrical section becomes wasted (Figure 4F) but subsequently returns to the more traditional forms seen in early versions/models of the bottles (Figure 4H). These visualisations demonstrate the overall trend that the bottles have gradually evolved from the original form to an extreme (Figure 4F) and that the final major change (Figure 4H) shows a return to the more traditional forms.

6 Discussion

With respect to the function of the approach, results show the method is capable of measuring and visualising changes in shape. The fundamental contribution of this is in achieving a quantitative overview of shape change, and thus ascertain trends over the total evolution. With respect to the case study, this means being able to identify and quantify major and minor changes.

Results of our method show trends in the magnitude of differences between product shapes. Hence, considering Person's model [5], for each dimension we are given guidance for making designs similar or different to others. The key contribution of our research is in giving an explicit magnitude for the degree of difference that has been used in the succession of product generations. It is possible for designers to use these values as benchmark when justifying to what extent a future design should be different from the previous ones when wanting to adhere to a certain strategy. In other words where the strategy dictates less change there is a typical magnitude for this. Similarly, if a strategy dictates a more major change there is a benchmark for the extent to which this has occurred.

Measurements for magnitude of difference alone have use in individual instances in answering "how different is this design". However in instances where appearance has evolved over a number models (as in the case study), it is far more useful to understand whether a difference is deviating further from a brand style or returning to a brand style. It is in this secondary question of direction where the visualisation component of the approach makes a contribution (to justification). Hence with respect to Person's guideline for appearance differentiation/similarity within the line of successors of a product design [5], visualisation allows designers to communicate whether change of a given magnitude is a change towards reinforcing symbolic meaning or oppositely towards repositioning styling.

While human vision is adept at perceiving minor changes in shape, it is contended that it would not be possible through observation only to compare and synthesise the degree of change in shape of nine successive models (eight comparisons) that is made possible through measurement. Hence, a further contribution of the approach is in such synthesis of a large number of comparisons

6.1 Limitations and further research

The current case study presents an instance where changes in shape are relatively minor. The subsequent question raised is in the efficacy of the approach in scenarios with large degree of change in shape. One area for further research is in the strength of the approach in scenarios where product shape changes fundamentally, such as a product form having a significant feature removed or added. For example if a bottle were to have a handle added. Such scenarios become much more likely when considering the approach's use in comparisons in the present product portfolio and competing products dimensions of Person's model [5]. In these dimensions it is anticipated that changes in shape are likely to be greater to account for the different functionalities that are offered across a company's current product range or across competing products. Thus there may be need for research establishing an upper limit for the degree of change after which there is little use in providing measurement for change. It is contended that there may still be validity in assessing such fundamental changes (changes obvious from inspection alone). This is because objective measures for change in shape can provide benchmarks that may be referred to for any further fundamental changes in future designs.

Currently the surface comparison software makes comparisons from one product (surface) to another. Considering the further dimensions of importance in styling strategy (brand portfolio and competition), a further area for research is in synthesising shape change data for an entire range of products in any of Person's dimensions. The advantage in doing so over making individual comparisons (as done in this research) is being able to establish a bounding range to represent the total diversity in shape of a product in a given range/dimension. It follows that it is then also possible to investigate average shape and variance in shape.

The purpose of the visualisation approach is in complementing the measurement data by providing an opportunity for the designer to reference measurements of change in shape when discussing the design direction. It is not the intention of the visualisation approach to be a means of showing designers differences that may or may not be perceived when comparing digital models without colour mapping.

The specification of the colour ramp/map (maximum positive and negative values associated with colours) may impact on what might be argued as significant or insignificant differences. It is contended that setting the limits larger than the maximum change seen through an entire product evolution, and keeping limits consistent across the study in question easily remedy this.

In this study we set out to describe a method that can provide designers with objective data on product appearance changes compared to its predecessors or competition. We argue that designers can use the information gathered from this data to guide future design decisions. However, designers should note that the consumers of the products may perceive 'minor' versus 'major' changes differently than what is suggested by the objective measures and visualisations. Perception of appearances' typicality/novelty by consumers can be affected by all kinds of contextual factors [11]. Hence, it is advised that the objective measures are used merely as guidelines and not as strict advice. Because there may be a difference between what consumers perceive as similar/different and what the objective measures may suggest as similar/different, in future research we aim to validate our objective measures with subjective measures of product appearance change.

7 Conclusions

This paper explores the measurement and visualisation of evolutionary changes in in product shape for the justification of styling decisions. Surface comparison software was adopted to measure incremental change in shape between 3D digital models of a succession of iconic beer bottles. For each evolution the change in surface shape was recorded and the magnitude visualised on the model's surface.

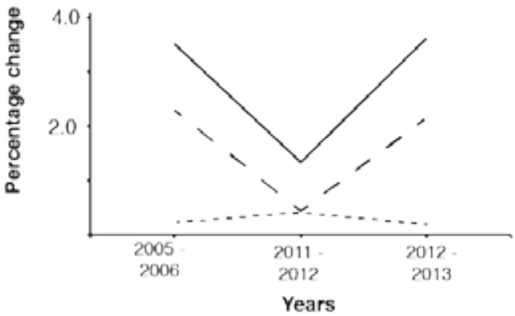
The primary conclusion drawn from the study is that the approach successfully provides a quantitative assessment for change in shape and thus change in styling. This in itself is of value in terms of justification as such measures, (particularly in the 3D format) are not available to designers. Thus the approach provides a quantitative basis to justify the degree of difference of a proposed design with respect to guidelines given in Person's framework for styling strategies.

7.1 Practical implication

The implication of this for design practice is in that application of this approach would alleviate some of the issues experienced across design teams during decision making with respect to styling. This is because the mode of justification for styling decisions can move from being visual and subjective to objective in terms of magnitude of degree of difference. From a strategic perspective such measurement and visualisation of shape change provides an option to make more precise briefs for new designs in being able to specify the desired degree of shape change. Finally the approach also gives the first step toward being able to test the effectiveness of styling strategy in that measures for change in shape can be correlated to metrics for success.

7.2 Example of application of measures

The current method contributes because of the ability to map the quantitative data on shape changes to other quantitative data that form the criteria for styling decisions (cost, market success, product performance). Such correlations present an opportunity to provide an explanation for why a certain styling strategy was followed by a company providing additional modes for justification of magnitude and direction of shape change for future bottle designs. For example, focusing on the shape changes that occur from 2006 onwards, there are three changes made, two major and one minor. The magnitude of these changes (the average change in shape) are compared with statistics for total revenue for the Australian beer market and the proportion of revenue accounted for by imported beers. Data for this comparison is summarised in Figure 5. The comparison of data shows a significant positive correlation between shape change and total revenue change: when total revenue increase was small (0.44 %) a minor incremental shape change took place, while when the total revenue increase was greater (2.30 %), a major change in shape is implemented ($r = .99$, $p < 0.01$)). At the same time the data shows a negative correlation between shape change and proportion of revenue of imported beer change: when the proportion of revenue accounted for by imported beer, was greater (0.41%), a minor shape change took place, while when the increase in percentage of revenue accounted for by imported beers was smaller (0.24% and 0.19%), more drastic shape changes took place ($r = -.98$, $p < 0.01$). These correlations can provide an explanation for why certain style strategies were chosen in the past: when revenue for beer is high, and a lesser amount of revenue is accounted for by imported beers, there is money to spend on restyling of the bottle (defining the magnitude). Because of the lingering threat of imported beers, the direction of change is to regress back to the more symbolic and historical meaning of the first bottle.



Metric \ Year	2005 - 2006	2011 - 2012	2012 - 2013
% Change in bottle shape	3.52	1.32	3.63
% Change in revenue for the Australian beer market	2.30	0.44	2.19
% change in proportion of total revenue accounted for by imported beer	0.24	0.41	0.19

Figure 5. Percentages of shape change, import as proportion of total revenue change, and total revenue change in the years 2005-2006, 2011-2012 and 2012-2013.

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