THE DEVELOPMENT OF A NOVEL STANDARDISATION-CUSTOMISATION CONTINUUM

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ABSTRACT

Published work on product-oriented customisation lacks clarity in establishing how it is characterised, how it is bounded, and how one would define increasing levels of customisation. This paper describes the development of a standardisation-customisation (S-C) continuum which consists of 13 distinct intervals, starting with “standardisation”, or absence of customisation and ending with “evolution customisation”, or absence of standardisation. Each interval is defined using nine characteristics that collectively define the boundaries of the intervals within the continuum. Analysis using a randomly selected sample of products from a range of industries has demonstrated the continuum’s capability for distinguishing the associated level of S-C. Furthermore, no industry investigated develops products at each level of S-C, however, when combined all industries do. The number of possible levels of S-C tends to depend on the product’s complexity and number of components. The continuum framework clarifies the concept of customisation, provides a scale for determining the product’s customisation and supports the analysis of markets and industries against S-C.

1 INTRODUCTION

This paper highlights the development of a new standardisation-customisation (S-C) continuum defining thirteen levels based on product development factors. These levels are required to improve the understanding and consensus referring to a customisation within design, manufacture and marketing communities.

High levels of manufacturing competition lead companies to create and offer more attractive products to customers for increasing sales, customer numbers and loyalty. The keys to success and loyalty are the reliability of a product or brand, quality, trust, and the possibility of maintenance through spare parts; being traditionally achieved through standardisation (Ding and Keh 2016, Wang *et al.* 2016). Standardisation allows the production of the same product based on general customer needs despite varying locations, times and manufacturers (Ding and Keh 2016, Wang *et al.* 2016). As a result, standardisation has been the key to the manufacturing industry since its introduction. However, the manufacturing industry has evolved to become more complex, specialised, flexible and competitive, typically due to technological advances. These advances have circumvented a lot of these limitations and provide the ability to create unique customised products by designing and analysing extremely complex and unique adapted solutions (Miceli *et al.* 2013). Furthermore, the market demands more responsiveness and adaptability to a customer’s needs rather than to the general needs of the market (Jitpaiboon *et al.* 2013, Wang *et al.* 2016).

The choice of standardisation or customisation a basic product or component is obvious. However, the same selection for a complex product consisting of numerous components is not as simple because product customisation could imply the inclusion of some or all standard components (Wang *et al.* 2016). This situation is likely due to interchanging and sharing componentry across products that provide benefits in the development, manufacturing, maintenance, recycling and disposal phases (Wang *et al.* 2016). The use of standard componentry is due for example to reliability, inventory control, and the advantages this provides for mass production. Accordingly, product families are developed with a standardised core and customised interface between the customer and the product (Hu and Cunha 2013, Wang *et al.* 2013). As a result, the customisation perception varies amongst authors depending on a product's analysis depth, suggesting different levels of S-C.

This lack of clear definition for product customisation, levels of customisation and main customisation areas leads to the need of a continuum determining a complete range of levels of S-C, starting with full standardisation and ending on full customisation. The continuum must consider manufacturing environment, customer involvement, parts of the product and stages of product development affected by the customisation, and cost, among other product development factors.

2 STATE OF ART

The state of art has been determined by means of a literature review. This primarily investigated the definitions of standardisation and customisation, the evolution of S-C related manufacturing paradigms and S-C continuums. In addition, related keywords such as "mass customisation" or "standard production" were also searched. The outcome represents papers that focus on definitions for standardisation and customisation, and S-C related manufacturing paradigms, but few focus on S-C continuums.

2.1 Standardisation and customisation definitions

Both the concept of standardisation and that of customisation have been discussed by numerous authors. The definition of standardisation regarding either product or manufacturing has been very clear since Henry Ford started the production of the model Ford-T (Alizon *et al.* 2009), but customisation definitions are vague and lack consensus. There is, therefore, a need to agree on definitions for clarifying concepts and increasing general understanding, allowing new strategies for product manufacturing development.

Standardisation is defined as the ability to develop a product or component based on the general needs of the population (Lehrer and Behnam 2009, Ding and Keh 2016). Standardisation allows products with the same characteristics, requirements, material and architecture (hardware and software) (Hu and Cunha 2013); being possible to interconnect or interchange them, assembling and working perfectly due to tolerance and shared platforms applied when manufacturing them (Wang *et al.* 2016). Standardisation allows product reproducibility irrespective of the manufacturer (Wang *et al.* 2016).

Authors have a consensus on a very basic definition of product customisation: the action of making or modifying a product according to specific needs of a customer (Ding and Keh 2016, Wang *et al.* 2016). However, there is not a clear understanding of how deeply a product has to be customised. This includes which aspects of it need to be customised, the extent of customer involvement within product development, or even if a product has to be produced and/or modified to consider it as customised. In addition, authors (Alford *et al.* 2000, Poulin and Montreuil 2013, Wang *et al.* 2016) have defined mass customisation, but rely on standardisation within product development when defining customisation. The fundamental principle of customisation relates to product development that focuses on a specific customer's needs (Tu *et al.* 2004, Ma *et al.* 2007). It suggests that customisation involves numerous product aspects (i.e. aesthetics, usability, technically, etc.), leading to the situation where if any of these product aspects is customised, the product itself is considered customised because the product accomplishes the required principle (Hu and Cunha 2013). For example, Hu and Cunha (2013) defined customisation through modularity where standard components and structure allow to assemble a product based on a particular customer needs. Therefore, different types or levels of customisation can be achieved, identified and defined.

2.2 Manufacturing paradigms in relation to standardisation and customisation

The manufacturing industry endeavours to deliver the best possible products considering customer needs, product cost, technical capabilities, logistics and customer demand. This results in different manufacturing paradigms. Accordingly, products result in different levels of customisation depending on the selected manufacturing paradigm. Manufacturing paradigms have modified, evolved and adapted the methodology and principles through time in order to satisfy market requirements or improve productivity and competitive advantage. Manufacturing paradigms are dependent on existing, developing or future technologies (Wang *et al.* 2013). Handcraft manufacturing production (Hu and Cunha 2013), reflected a lack of interface, upgrading, substitution or repeatability within the product. Mass production or the production of a high volume of reliable product at low cost obtained standardised products by standardised assembly along a production line (Hu and Cunha 2013). Lean production is a variation of mass production, sharing the same core principles but producing the same product with different variations such as size and colours, allowing customer choice. Mass customisation is the production of a "low-cost, large-volume delivery of individually customised products"(Tu *et al.* 2004). Finally, personalisation is the production of "products individually tailored for/and by each consumer, satisfying consumers' needs while maintaining high production efficiency" (Wang *et al.* 2013). These different paradigms suggest that the manufacturing industry has focused on satisfying customers' needs either by standardisation for general needs or customisation satisfying specific needs that are required or desired by a customer.

2.3 S-C Continuums

The need for and feasibility of a continuum for defining and determining different levels of S-C was previously considered and proved. Lampel (1996) developed a continuum with five different levels depending on the stage of the development process where customisation first takes place. The mentioned stages are design, fabrication, assembly and distribution. Consequently, Spring & Dalrymple (2000) compared Lampel's continuum (1996) with other authors' S-C criteria. Neither of the continuums considers the characteristics of customisation such as the customer, the customer's role, applied Manufacturing Process , the depth of product customisation, the product's cost per unit, or legal and safety (L&S) aspect. Biao et al. (2004) updated Lampel's continuum (1996) by correlating levels of S-C, Manufacturing Environment (ME), levels of globalisation, the agility of the production and the levels of postponement. The correlation is based on which manufacturing stages the customer engages with and includes packaging and distribution. This continuum also does not consider the depth of product customisation, does not define levels of customisation, and the added stages are both not part of a product development and linked to previous stages. Similarly, Hu and Cunha (2013) highlight three different levels of S-C by defining the key differences between "mass production", "mass customisation" and personalised production. In that case, customer role, production goal, desired product characteristics or production systems are considered and correlated to the three manufacturing paradigms. Therefore, the different continuums' perspectives for a similar goal suggest the need for a new continuum considering more customisation related factors. And so, the concepts are clarified to the community, allowing future studies to focus and compare research knowing the particular S-C level rather than mistaking different levels. Customisation within the manufacturing industry can subsequently be developed rather than product selection industry.

3 METHODOLOGY

A continuum or sequence of levels identifying product development on a S-C range has been developed within this paper. The continuum was developed to address the lack of accurate definitions and levels of S-C.

The development of the continuum is based on a literature review which considered customer acquisition behaviour, technological capabilities, product complexity, logistics, ME and L&S aspects. The first stage was to analyse the relationship between standardisation and customisation. Secondly, General Morphology Analysis (GMA) is applied to identify and evaluate factors affecting the product development in relation to the decision-making process, customer, product componentry, technical capabilities, cost per value, L&S aspects, i.e. the motivation for the product level of uniqueness, customer trust, focused market or customer communication with manufacturers (Ritchey 2006, de Fátima Teles and de Sousa 2016, Duczynski 2017). In addition, the parts of the product (aesthetic, components, structure) or product development stages (modification, assembly, manufacture, design, process design) are analysed in order to identify the depth of customisation within the product. Each identified factor is divided based on GMA technique and considering each factor's influence on the product development (Ritchey 2006, de Fátima Teles and de Sousa 2016, Duczynski 2017). Finally, the factors are pairwise being the pairing condition "yes (or more convenience)", "possible (it could be convenience)" and "no (or less convenience)" (Ritchey 2006, de Fátima Teles and de Sousa 2016, Duczynski 2017).

The continuum starts from superficial or basic customisation (aesthetic) to the deepest customisation (product and developing process design). Different grades or levels of information are identified based on the information analysed within previous steps and correlated with the different factors. Thus, the difference of each level's correlation with the factors defines, delimits and allows sequentially organising the levels to produce a continuum.

4 S-C CONTINUUM

The S-C levels development started by determining how deep the product is affected by customisation. The most superficial layer is the product's aesthetic, only the finishing of the product is affected. The next layer is component related; one or some of the components of the product can be affected but not the structure, limiting so the component's customisation referring for example to connectivity or interaction. Finally, the structure is customised affecting all parts of the product because the structure drives the components' interconnection or even the component's internal features. All of the synthesised characteristics which define the levels of S-C are described below and further visualised in Table 1defining the levels of S-C and described below. Figure 1 reflects a graphical illustration of the characteristics defined within Table 1, and illustrates each of the levels in the continuum.

- Goal of the customer. There are three main goals: utilitarian, hedonic and 'major force'. The utilitarian goal or practical purpose and low need of uniqueness requires reliability, efficacy, functionality, delivery speed, maintenance options and cost reduction, leading to standardisation due to cost reduction, the predictability of product performance and risk perception (Ding and Keh 2016, Viardot *et al.* 2016). The hedonic goal requires high uniqueness, self-expression, expectations, aesthetic tendencies and particular needs, leading to the acceptance of higher prices as far as psychological and monetary cost do not outweigh the product benefits (Li *et al.* 2014, Ding and Keh 2016). The 'major force' goal is required to satisfy a particular customer need as the main purpose, otherwise, the product would be useless for example dental prostheses (Kruth *et al.* 2005, Deselnicu *et al.* 2016a).
- Focus of customer's decision. A high level of uniqueness implies more decisions for determining product suitability to customer needs and so the product customisation depth (Alford *et al.* 2000). The customer can decide about the purchase, the selection, adapted product, post-purchase configuration, configuration, aesthetic, components, architecture or the engineering of the product, in that order. 'Purchase' implies the moment, price, quality and type of product's acquisition (Fujimoto 2014). 'Selection' implies a range of product to choose from and the moment (Poulin and Montreuil 2013, Wang *et al.* 2016). 'Adaptation' is a 'selection' that focuses on smaller group based on for particular requirement. 'Post-purchase configuration' allows the customer to vary the product at any time from a range of forecasted possibilities within the final product (Lehrer and Behnam 2009, Wang *et al.* 2016). 'Configuration' is the choice of components (Hu and Cunha 2013). 'Aesthetic' decides the finishing of the components (Ma *et al.* 2007, Miceli *et al.* 2013, Sansoni 2015, Ding and Keh 2016). 'Component' requirements are defined without affect the structure (Brem *et al.* 2016, Wang *et al.* 2016). 'Structure' decision affects the entire product defining the product basics (Hu and Cunha 2013, Wang *et al.* 2016).
- The customer engagement point is the stage of the product Manufacturing Process (MP) chain where the customer gets involved in (Olhager 2003, Olhager and Prajogo 2012, Willner *et al.* 2014). The customer 'Purchase' engagement influences future productions and design as a customer satisfaction data (Alford *et al.* 2000, Li *et al.* 2014). 'Modification' implies the customer upgrading or updating the product along or after the purchase being a core standard product (Alford *et al.* 2000). 'Assemble' results from customer defining the components configuration from standard components based on modularity (Olhager 2003, Tu *et al.* 2004, Jewkes and Alfa 2009, Wang *et al.* 2016). 'Production' point is the manufacturing of a customer order that is selected from standard designs (Lampel , Brière-Côté *et al.* 2010). 'Design' implies the customer's involvement within the start of the product's development and affecting the whole manufacturing supply chain (Ma *et al.* 2007, Gosling and Naim 2009, Brière-Côté *et al.* 2010, Willner *et al.* 2014). 'Evolution' is a future concept that involves the development of the product and the drivers, i.e. devices that diagnose and treat when required (Onoshima *et al.* 2015).
- Cost per unit. Types of cost per unit were defined as convenience, shopping, specialty and unsought (Simpson and Matthew , Simpson and Mathew 2001, Jee *et al.* 2013). Convenience "goods are purchased frequently with little planning or shopping effort, low-priced and widely available". Shopping "goods are purchased less frequently and are compared on the basis of suitability, quality, price and style". Specialty "goods are purchased with special effort, little brand comparisons and low price sensitivity". Unsought "goods that the consumer does not know about or knows about but does not normally think of buying".

- Reliability. L&S reliability avoids unsafe situations and ensures that the product is worth the payment. Customer foresight reliability on both certifications and previous experiences with the product, componentry or brand (Zhang *et al.* 2009, Li *et al.* 2014, Featherston *et al.* 2016). Certifications are based on tested and statistically analysed product's series sample, and its reproducibility, relying on standardisation (Blind and Knut 2011 , Ding and Keh 2016, Featherston *et al.* 2016). Therefore, a customised product's reliability is dependent on the standardisation.

Table 1: S-C's levels definitions

	Characteristics								
Levels	Customer goal	Customer's decision focus	Customer engages at	Cost per unit	L&S Reliability	Main purchase motivation	Customer group	MP	ME
Standardisation	Utilitarian	Purchase	Purchase	Low	Product & performance	Standardisation	Mass market	Traditional	MTS
Standardisation selection	Utilitarian	**Selection**	Purchase	**Convenience**	Product & performance	**Mass market**	Mass market	Traditional	MTS
Adaptation	Utilitarian	**Adapted product**	Purchase	Convenience	Product & performance	Mass market	Mass market	Traditional	MTS
Product configuration	Utilitarian	**Post-purchase configuration**	**Purchase**	**Shopping**	Product & performance	Mass market	Mass market	Traditional	MTS
Modification, upgrade/update customisation	**Hedonic**	**Configuration / aesthetic**	**Modification**	Shopping	**Product (perf. Depends on variations)**	**Value per money**	**Particular customer**	Traditional	**ATO**
Assembly customisation	Hedonic	Configuration/ aesthetic	**Assembly**	**Special**	Product (perf. Depends on variations)	Value per money	Particular customer	Traditional	ATO
Aesthetics customisation	Hedonic	**Aesthetic**	**Production**	Special	Product (perf. Depends on variations)	Value per money	Particular customer	Traditional	**MTO**
Order customisation	Hedonic	**Components**	Production	Special	Product (perf. Depends on variations)	**Special requirement**	Particular customer	Traditional	MTO
Components customisation	Hedonic	Components	**Design**	**Unsought**	**Process, materials & companies**	Special requirement	Particular customer	**Non-traditional**	**ETO**
Architecture customisation	Hedonic	**Architecture**	Design	Unsought	Process, materials & companies	Special requirement	Particular customer	Non-traditional	ETO
Customisation	**Hedonic/ Force**	**Engineering**	Design	Unsought	Process, materials & companies	**Customisation**	Particular customer	Non-traditional	ETO
Personalisation	Hedonic/ Force	Engineering	Design	Unsought	Process, materials & companies	Customisation	**Customer-user**	Non-traditional	ETO
Evolving customisation	Hedonic/ Force	Engineering	**Evolution decision**	Unsought	Process, materials & companies	Customer-user	Customer-user	Non-traditional	ETO

- Main purchase motivation. The market holder is a factor that leads to the product use and consumption. 'Standardisation' is required for interaction, trust or legal value (Viardot *et al.* 2016). 'Mass market' reduces the product's development cost to a price that does not overwhelm the product's performance (Blind and Knut 2011 , Wang *et al.* 2016). 'Value per money' overcomes mass produced product's benefits in relation to the extra cost (Ma *et al.* 2007, Li *et al.* 2014). 'Special requirements' drive the purchase overcoming the product price (Deselnicu *et al.* 2016a). 'Customisation' is indispensable to satisfy the product purpose; otherwise, the product will be useless (Hu and Cunha 2013, Wang *et al.* 2013, Deselnicu *et al.* 2016b).

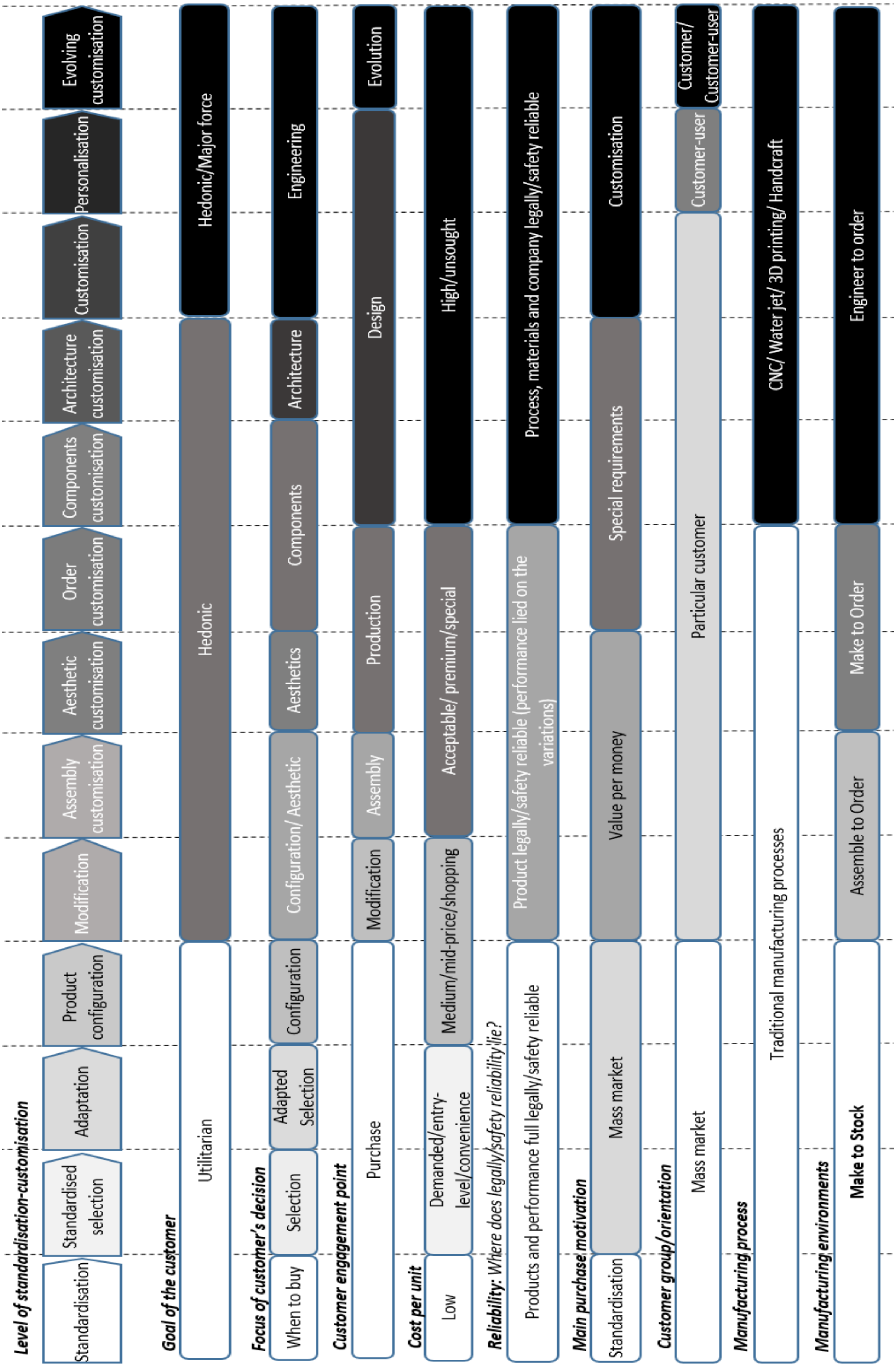

Figure 1: S-C continuum.

- Customer group/orientations are distinguished as mass market, particular customer and customer-user, increasing the level of uniqueness in correlation to the focus group. Mass marker considers a large group of consumer and global requirement (Wang *et al.* 2016). Both particular customer and customer-user consider just one or few consumers for defining the particular requirements (Hu *et al.* 2011, Wang *et al.* 2013).
- Manufacturing processes (MP) are grouped as 'traditional' (forming, machining, cast or moulding) and 'non-traditional' (Additive manufacturing, CNC machining, etc). 'Traditional' MP are small scale high cost per unit but cheap for large and non-stop productions due to the economics of scales on tools, set-up, planning, workforce, etc (Hu and Cunha 2013, Wang *et al.* 2016). 'Non-traditional' has the ability to produce complex shapes and fix production cost per unit that is cheap on a small scale but high for large production (Hu and Cunha 2013, Conner *et al.* 2014).
- Manufacturing environments (ME) are defined based on the manufacturing value chain stage where the customer engages (Olhager 2003, Willner *et al.* 2014). "Make to Stock" ME (MTS) produces a product with predefined specifications (Willner *et al.* 2014) before the customer makes the order, and inventory risk (Olhager 2003, Jewkes and Alfa 2009), being adequate to high-volume of standardised products (Olhager 2010). "Assembly to order" ME (ATO) assemblies a configuration of standard components according to a customer's specifications (Gosling and Naim 2009, Jewkes and Alfa 2009, Brière-Côté *et al.* 2010). "Make to order" (MTO) produces product from standard designs after receiving customer order (Brière-Côté *et al.* 2010, Willner *et al.* 2014), leading to low inventory risk (Jewkes and Alfa) and allowing to acquired old design products (Olhager 2003, Olhager and Prajogo 2012). "Engineering to order" (ETO) designs and develops the product based on customer's specifications, obtaining high uniqueness (Gosling and Naim 2009, Brière-Côté *et al.* 2010).

5 DISCUSSION AND ANALYSIS OF THE S-C CONTINUUM

The continuum is analysed by placing a random selection of products for industry groups and at each level of S-C within the group. The continuum capability for determining the level of S-C is tested. Also, an overview of the current situation of the manufacturing industry with regards to S-C is shown, resulting in the identification of the S-C levels that the industry provides the most.

5.1 Analysis of the continuum capability

The continuum should be capable of containing any possible product's level of S-C. Otherwise, the validity of the continuum would be rejected. The analysis has been conducted by placing a selection of products within the continuum. Each product was correlated with a level of S-C based on the level's characteristics that are identified within the continuum. In order to obtain an accurate representation across industry sectors, the products were selected randomly from each industrial group that is defined within the "Global Industry Classification Standard" by "S&P Dow Jones Indices and MCI". Also, each grade of S-C was considered for the selection within each group. The data was organised on a table where the rows are the grade of S-C and the columns are each industrial group. The table and its simplification (Figure 2) demonstrate that the continuum considers any possible level of S-C of the randomly selected products, identifying that some group of industries consider more grades of S-C than others. Despite the lack of any individual industry group being identified as considering all the grades of the continuum, collectively all industries considers them. The analysis determines that a product could be correlated with different levels of S-C depending on the developing factors' effects. For example, a car seat can be classified as "product configuration" (commercial car) or "personalisation" (formula 1 race car). The continuum identifies that some industries offer more levels of S-C for a particular product than others.

5.2 Interpretation of product customisation within the market

The distribution of products against the continuum highlights that the industry mainly satisfies customers' needs with a "standardised selection" (Figure 2). The market tends to satisfy group needs rather than a particular customer need, reflecting that most products analysed are "off the shelf". Also, the preferred option to offer customisation is component customisation. Figure 2 shows that each industry group can offer a different number of levels of S-C, probably owing to the industry group limitations. Industries based on products with high complexity and number of components leads to higher possibilities of variations and levels of S-C.

S-C level	Industry group																								
	Energy	Materials	Capital Goods	Commercial & Professional Services	Transportation	Automobiles & Components	Consumer Durables & Apparel	Consumer Services	Media	Retailing	Food & Staples Retailing	Food, Beverage & Tobacco	Household & Personal Products	Health Care Equipment & Services	Pharmaceuticals, Biotechnology & Life Sciences	Banks	Diversified Financials	Insurance	Real Estate	Software & Services	Technology Hardware & Equipment	Semiconductors & Semiconductor Equipment	Telecommunication Services	Utilities	Number of products
Standardisation	v	v				v						v				v					v		v		7
Standardised Selection	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v				v	v	v	v	v	21
Adaptation	v		v			v	v		v		v	v	v		v						v				10
Product configuration	v		v		v	v	v	v	v	v						v				v	v				11
Modification customisation	v		v			v	v	v												v					6
Configurable customisation	v	v	v			v	v	v						v						v	v				9
Aesthetic customisation		v		v		v	v			v						v									6
Order customisation		v	v				v	v		v		v			v										7
Component customisation	v	v	v	v		v	v	v	v	v				v						v	v				12
Architecture customisation	v	v	v			v	v	v												v					7
Customisation	v	v	v				v																		3
Personalisation						v								v	v										3
Evolving customisation															v					v					2
Number of S-C level	8	8	9	3	2	10	10	7	4	5	2	4	2	4	5	4	0	0	0	7	6	1	2	1	

Figure 2: Distribution of market's products on S-C model.

6 CONCLUSION

A continuum has been developed that determines product levels of S-C and the characteristics that define the levels. The continuum defines thirteen different levels of S-C, starting by "standardisation" or absence of customisation, and ending on "evolution customisation" or absence of standardisation that satisfies a particular customer needs through time. Each level is defined by characteristics related to product development, customer interaction with the manufacturer and legal and safety reliability. The boundaries between two levels result from the differing characteristics. Additionally, the continuum organises the levels depending on the product's customisation depth (aesthetic, component, structure, etc.). The analysis proved the continuum capability for determining the level of S-C for a randomly selected sample of products. Furthermore, no industry develops a product for each level of customisation but collectively all industries support all levels of the continuum. The number of possible levels of S-C depends on the product's complexity and the number of components. In conclusion, the continuum clarifies the concept of customisation, provides a scale for determining the product's S-C and is a useful tool to analyse the situation of either market or industry against S-C.

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