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Consumer Intervention Mapping—A Tool for Designing Future Product Strategies within Circular Product Service Systems

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Abstract: Re-distributed manufacturing presents a number of opportunities and challenges for New Product Development in a future Circular Economy. It has been argued that small-scale, flexible and localised production systems will reduce resource consumption, lower transport emissions and extend product lifetimes. At the same time smart products within the Internet of Things will gather and report data on user behaviour and product status. Many sustainable design tools have previously been developed but few are able to imagine and develop visions of how future sustainable product service systems might be manifested. This paper introduces the concept of Consumer Intervention Mapping as a tool for creating future product strategies. The tool visualises the points within a product's lifecycle where stakeholders are able to intervene in the product's expected journey. This perspective enables the rapid construction of scenarios that explore and describe future circular product service systems. Validation of the tool in three workshops is described and the outcomes are presented. Consumer Intervention Mapping is successful in creating scenarios that describe existing product service systems and new product concepts adapted to a Circular Economy paradigm. Further work is required to refine the tool's performance in more focused and reflective design exercises.

Keywords: circular design; circular economy; product lifecycle; intervention mapping; scenario matrix; sustainable futures

1. Introduction

Circular Design is an approach to the conception and creation of products and services that emphasises looking beyond single product lifecycles for single users, to designing products as entities within systems that enable multiple users and usages [1]. It can be situated in a tradition of design first expressed by Papanek in Design for the Real World [2], which urged designers to take responsibility for the external consequences of their work on users, society and the environment, rather than see themselves only as service providers to industry. Moreno et al. [3] describe an evolution, from Papanek, of environmental philosophies applied to design, beginning with 'Green Design', through 'Eco Design', 'Sustainable Design' and 'Design for Sustainability'. All have emerged in response to design's traditional role in a linear "take-make-dispose" model of resource use, maturing from a desire to develop 'less bad products', through to considerations of Product Service Systems (PSS), Design for Social Innovation and Transition Design [4]. Most recently, Circular Design has been used as an umbrella term to describe these approaches when used, either alone or in combination, in the context of a Circular Economy (CE) [5].

The CE is one "that is restorative or regenerative by intention and design" ([6] p. 7). It replaces the concept of the end-of-life of a product with one that emphasizes reuse, repair, remanufacturing or recycling "through the superior design of materials, products, systems and business models" ([6] p. 7). Examples of the application of this strategy include the European Commission action plan on the CE, intended to stimulate Europe's transition to a CE, which seeks to encourage reuse, repair and energy efficiency in products, and incentivises manufacturers to consider their reparability, upgradability, durability and recyclability [7]. In implementing such a plan, design research and practice are considered integral to the necessity of considering the needs of all stakeholders, enabling businesses to reconsider traditional assumptions about value creation [8].

A number of models have been created that recommend strategies for implementing circular design. The Great Recovery [9] proposes four approaches: design for longevity; design for service; design for reuse in manufacture; and design for material recovery. Similarly Bocken et al. [10] identify five circular design strategies aimed at slowing (designing long-life products; design for product-life extension) and closing (design for a technological cycle; design for a biological cycle; design for dis- and reassembly) resource loops. Hollander et al. [5] define circular product design as encompassing "design for product integrity (aimed at preventing and reversing obsolescence at a product and component level) and design for recycling (aimed at preventing obsolescence at a material level)". However, while these acknowledge both new manufacturing technologies and new relationships between users, manufacturers and brands, they offer little insight as to how "smarter technology, faster technology, more connected technology" ([9] p. 38) might influence the types of products that will be designed and used in a future CE, or indeed, how user interactions might change in more connected systems of products and services.

This paper describes research conducted as part of the 'Business as Unusual' project within the EPSRC-ESRC-funded Network in Consumer Goods, Big Data and Re-distributed Manufacturing (RECODE). It introduces the concept of Consumer Intervention Mapping (CIM), to visualise the opportunities for the consumer to intervene in, and modify, the intended or expected product lifecycle. The paper first describes the development of a generalised, spatial representation of the product lifecycle, drawing on theory and practice from the field of Customer Relationship Management (CRM). It details the conduct of a systematic literature review, enabling the map to be populated with people-product interactions across the entire lifecycle of a product from front end New Product Development (NPD) through to its repair and afterlife. This then formed the basis of a tool that was evaluated during the course of three workshops in the context of two research questions:

1. Is the tool useful in enabling the development of scenarios exploring how the promotion of resource efficient product lifecycles can be incorporated within future, more localised and responsive structures of manufacturing and product adaptation?
2. Do the PSS scenarios that are generated depict non-conventional strategies or business models?

The paper discusses the success of the tool against these two questions, and finally considers some of the issues arising from the scenarios developed in the workshops.

2. Background Research

The Engineering and Physical Sciences Research Council (EPSRC) defines Re-distributed manufacturing (RdM) as "technology, systems and strategies that change the economics and organisation of manufacturing, particularly with regard to location and scale" [11]. The term refers to the potential of new technologies and manufacturing processes, combined with flexible and small-scale manufacturing systems, to drive disruption in the currently established norms of mass production systems. Within a CE, RdM presents a number of opportunities and challenges for NPD in the product, process and practices [12] of environmentally-focused manufacturing. Digital fabrication technologies such as additive manufacturing (AM), more commonly referred to as "3D Printing", can enable reductions in resource consumption by the consolidation of parts and materials ([13] p. 101); lower transport emissions by the localisation of factories [14]; reduce material and part waste by 'make-on-demand' production models [15]; extend product lifetimes by the creation of bespoke or personalised products that more closely meet an individual user's needs [16]; and extend product lifetimes through repairs enabled by keeping 'digital stock' catalogues of replacement parts [17]. At the same time, concerns have been expressed regarding the reusability of personalised products [18]; quality control across multiple, distributed factories (and the potential for increased failure rates) [19]; and energy requirements in the production and post-processing of individual parts [20]. However, while much work is ongoing to both understand the sustainability implications of RdM and to optimize digital manufacturing processes to limit their environmental impact, little work has been done to conceptualise future scenarios of RdM, particularly in relation to stakeholders who (in a mass manufacturing paradigm), have little input but are nonetheless affected by the externalities of NPD. As a result, visions that do exist tend to focus primarily on the front-end, manufacturing (and remanufacturing) phase of future product lifecycles, giving little attention to the role of users in the use, reuse and eventual disposal of products.

Rossi et al. [21] identify seven categories of tools for ecodesign: Life Cycle Analysis (LCA), Simplified LCA, CAD Integrated tool, Diagram tools, Check List & Guidelines, Design for X Approach, and Methods. Despite significant academic focus on their development, such tools "are not internalised by industry ... because they diverge from industry needs, are overly complex, or too specific, or indeed companies require bespoke approaches" [22]. Furthermore, when reviewing the types of tools that have been developed, it is noticeable that almost all concentrate exclusively on the needs and processes of stakeholders internal to the company or manufacturer. Having acknowledged the difficulty in interpreting customer perception, for example, the recommended strategy is only to "involve departments that have contact with customers" [21], rather than involve customers themselves.

Notable exceptions to the tendency of sustainable design tools to be inward-facing and concerned with incremental, quantitative improvement are the Value Mapping tool for sustainable business modelling [23] and the Front End Eco-Innovation (FEEI) approach described by Tyl et al. [24]. In the first of these, a Design Thinking approach is applied with the aim of incorporating a human-centred philosophy into the process of sustainable business model innovation. This method "provides companies with different stakeholder perspectives and a *network-centric rather than firm-centric perspective on value* [authors' emphasis]" [23]. In so doing, the tool is able to help with issues such as the detection and resolution of conflicts between stakeholders; understanding of the current value proposition; and the elimination of negative and development of positive outcomes for stakeholders. These outcomes clearly go some way in addressing the shortcomings identified in the review by Rossi et al. [21]. Yet the value of the tool lies in its contribution to "the design of pragmatically improved business models and better integration of sustainability into the value propositions of businesses" [23]. It is unable, in its current implementation, to suggest visionary scenarios that enable organisations to understand the value proposition of products over multiple lifetimes and multiple uses.

Tyl et al. [24] list a number of FEEI tools that integrate a stakeholder approach. However, few of these tools take an explicitly user-centred approach, instead regarding the final customer as one among many stakeholders within the value chain. In addition, by modelling the customer as having input to product development only through a company's marketing department, these tools overlook the capability of RdM technologies to facilitate consumer involvement in product development and manufacture [25]. Users who fall outside the value chain of the business, such as those who purchase a product second-hand or repair through a third party, are similarly ignored. Thus to date, a design tool that is user-centred, that accounts for all stakeholders throughout a product's lifecycle, and that considers future sustainable manufacturing scenarios, has not been developed. The value of such a tool would lie both in its ability to visualise the complexities of a PSS within a CE, but also in its visionary nature—as a tool for designers to co-create, with stakeholders, visions of how future sustainable PSS might be manifested.

3. Materials and Methods

3.1. Justification of the Use of User Experience Research Methods

The development of the CIM tool builds on both Geissdoerfer et al.'s [23] value mapping tool and Tyl et al.'s [24] aspirational vision for FEEI in which design is understood as "something that is not just related to the product itself, but relates to the whole product life, its systems, stakeholders and the activities and effects that emerge from this". Underlying its construction is the concept of the PSS, in which tangible goods and associated services are integrated such that "value creation is less about sales and ownership of individual products and more of a focus on the ongoing delivery of the service-value embedded in that product" [26]. Increasingly, product designers will be less involved in the design of stand-alone devices; instead the products they design will be part of PSS's enabled by sensors, GPS, RFID and the sharing of data in cloud computing networks. To the users of such devices the boundary between the product and its value-enhancing service is at the least blurred, and often indistinguishable—what the user encounters is not a product and a service, but an 'experience' [27]. The integration of microprocessors into products in order to make them 'smart' presents both opportunities and challenges to designers within a CE. On the one hand, models of Sustainable PSS that "replace product ownership with renting and leasing" or "dematerialise or servitize material goods" [28] often rely on sensing data to report usage patterns, record user behaviour and pre-empt product failure [29]. However, by "failing to incorporate effective means for repair, upgrade and recycling, the lifecycles of most electronic products are designed to be brief. They are further curtailed by routine changes to functionality, aesthetics and software, resulting in older devices becoming quickly outmoded by newer designs" [30]. This becomes even more urgent as the sophistication of products increases, in tandem with strategies such as Digital Rights Management (DRM) to police the use of PSS's. Previously consumer law has allowed for modification, third-party spares and servicing, resale, etc.,—often considered to be constituent elements of a CE. Yet increasingly service updates (often automatically installing) are able to bypass the law and alter the functionality, even break, a user's device (see for example the iOS 11.3 update, which disables an iPhone's touchscreen if it has been repaired by a third party not authorised by Apple [31]). Negotiating the interwoven relationships between stakeholders across a product's lifecycle within a PSS therefore demands that a user experience (UX) approach is taken.

Consumer Touchpoint diagrams [32] are commonly employed within CRM and are used for mapping the relationship between a brand and its customers [33]. Touchpoints are instances such as a TV advert, a point-of-purchase-display or an online support service, where the customer experiences the brand. However, CRM typically concentrates only on experiences that occur within the value chain and which a brand is able to influence. Consumer interventions such as post-purchase modification, repair and re-sale have therefore received little attention.

Within UX [34] design, Customer Journey Mapping (CJM) [35] is a method of documenting the way in which a customer experiences a PSS. CJM utilises consumer touchpoints in order to understand how a user perceives, and interacts with, a PSS over a relevant timescale or throughout a relevant process. CJM has been used to depict experiences as diverse as a single visit to Starbucks [36], selecting health insurance [37], and the use of library services by university students [38]. However, in order to control the chaotic data resulting from every customer experiencing their journey in their own, unique way, brands commonly develop personas to represent typical customers [32]. This can have the effect of focusing attention on core or existing customers, while overlooking stakeholders who are engaging with a PSS in new or unexpected ways. In addition, CRM literature has not previously considered CJM within NPD, in instances where RdM allows consumers to engage with the design and production of products and services, rather than just their consumption.

3.2. Construction of the Spatial Field of the Consumer Intervention Map

In order to determine both the scope and detail of information required to construct the CIM, an initial Literature Review was conducted to understand the relevant phases of a customer journey within a CE paradigm. In common with existing CJM models, the CIM models the customer journey space at increasing levels of detail. At the widest level only three phases were identified [39]: Purchase, Pre-Purchase and Post-Purchase (Figure 1). At the intermediary level, the CIM draws on a number of sources [33,40,41] to model six phases encompassing the NPD process through to Usage (Figure 2). Finally, at the narrowest level of detail, 18 discrete phases were identified from the literature [25,39,40,42] (Figure 3). In addition, the CIM places concentric rings to indicate the degree to which an organisation (i.e., a brand or manufacturer) is able to control consumer interventions, with decreasing ability moving away from the centre of the map (Figure 4). This is not a level of detail that commonly appears in CJM analyses of PSS's, because of the lack of focus on touchpoints outside of the value chain. However, for a tool that aims to account for all stakeholder interventions, including those that occur without authorisation, this information is important for portraying how a particular product lifecycle moves in and out of an organisation's control.

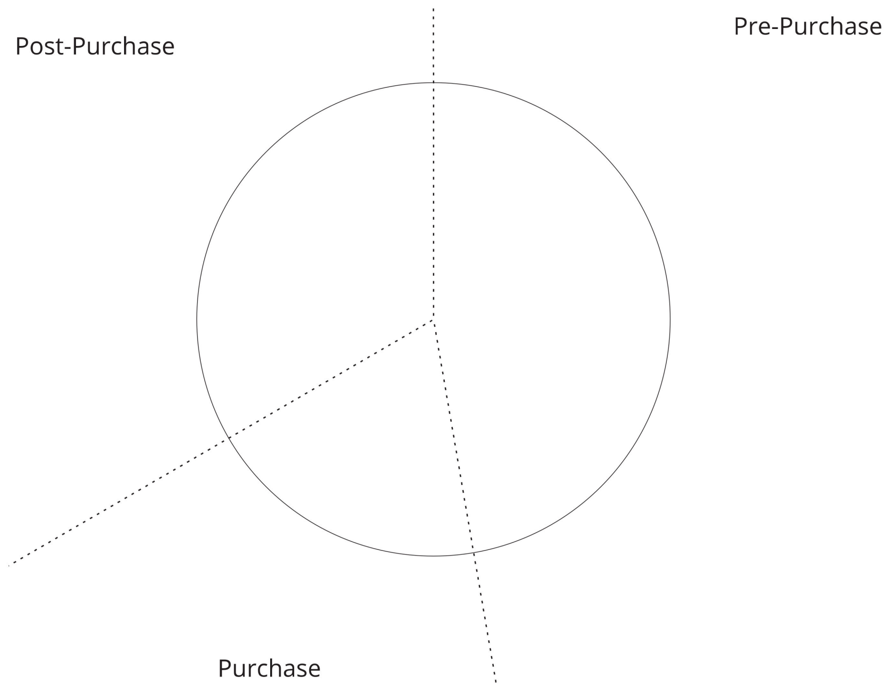

Figure 1. Spatial field of the Consumer Intervention Map at the widest level of detail.

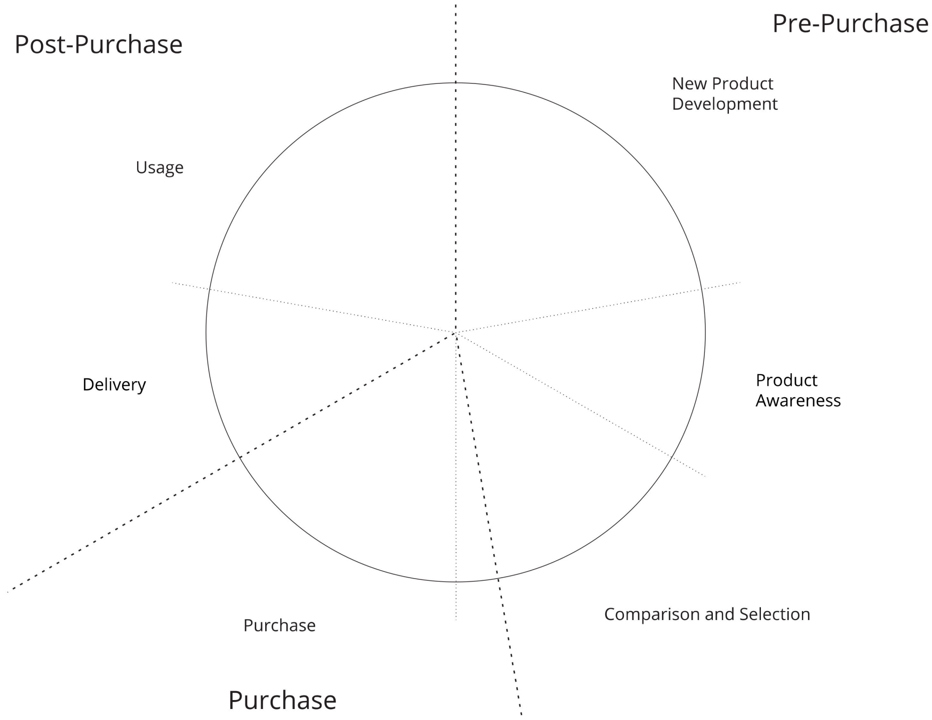

Figure 2. Spatial field of the Consumer Intervention Map at the intermediate level of detail.

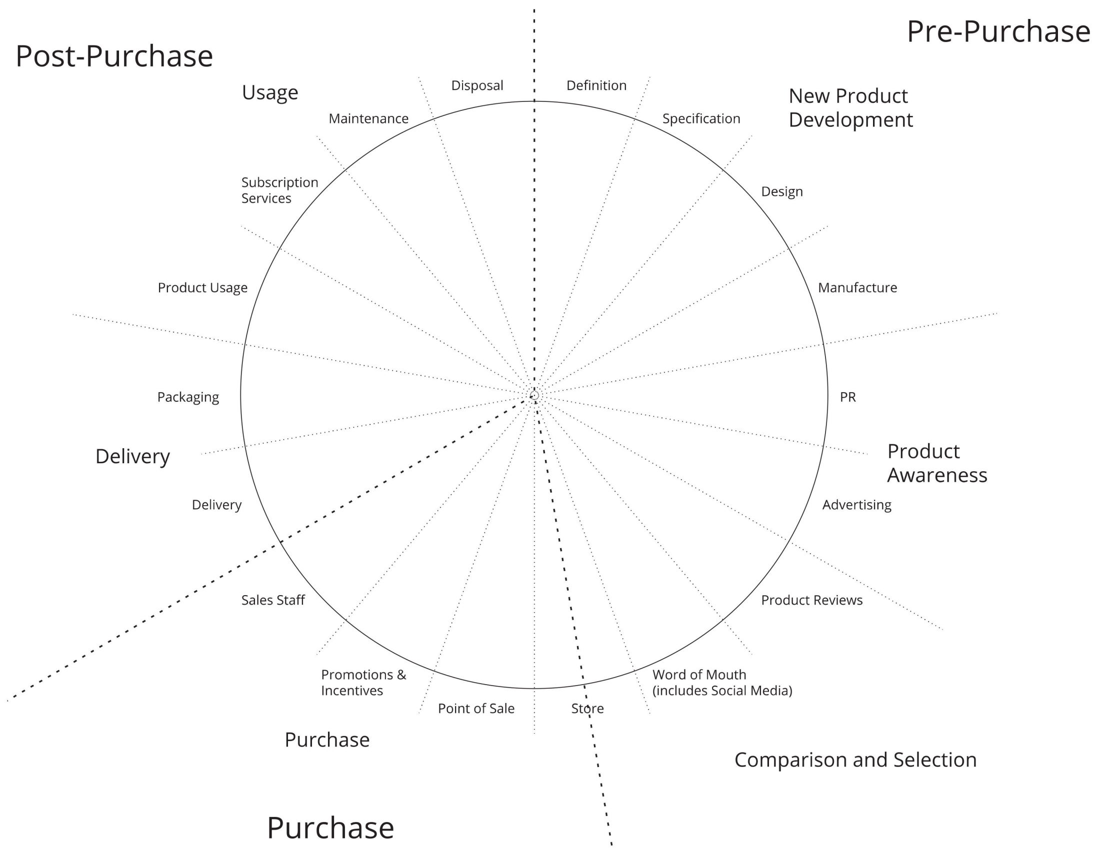

Figure 3. Spatial field of the Consumer Intervention Map at the narrowest level of detail.

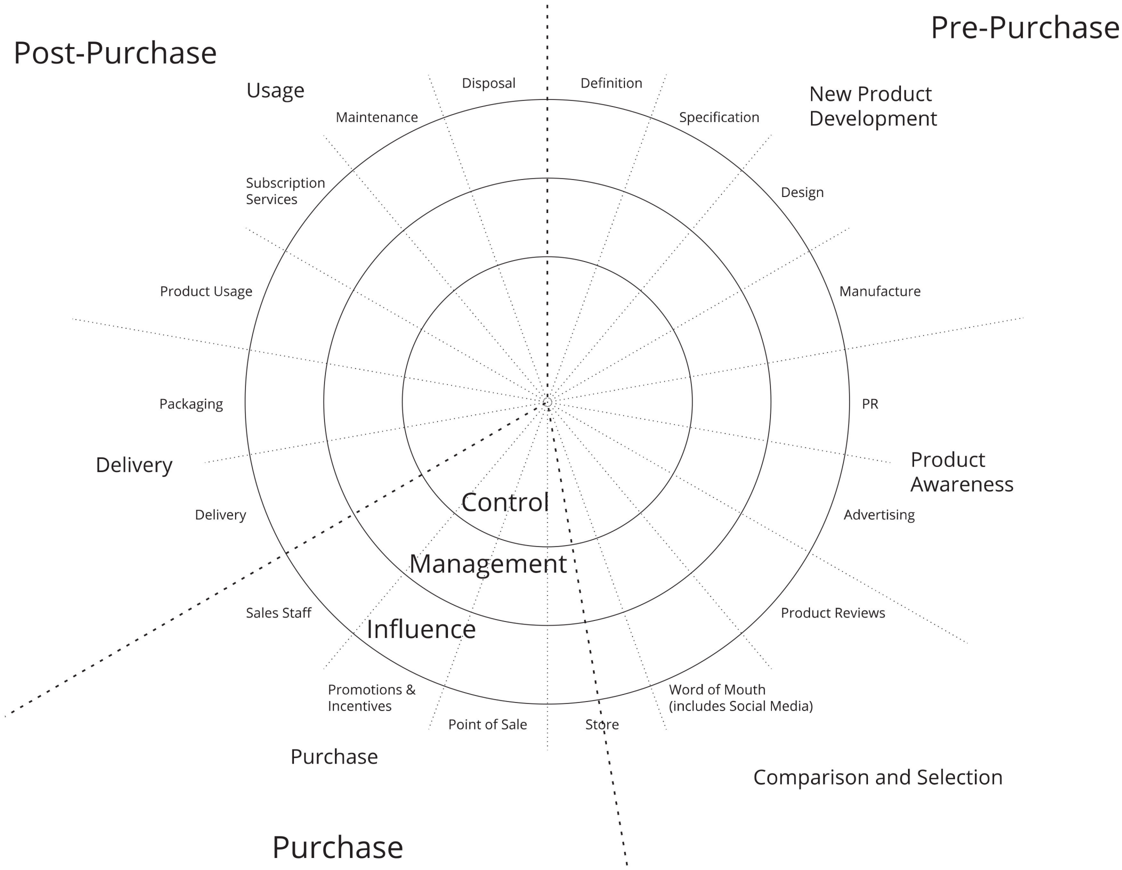

Figure 4. Spatial field of the Consumer Intervention Map showing levels of organisational control.

3.3. Population of the Consumer Intervention Map with Intervention Touchpoints

Populating the CIM involved identifying which touchpoints were relevant to the map, and then placing them in the appropriate position. Due to the wide-ranging nature of the subject material, a systematic review [43] of the literature was conducted. Following the method guidelines proposed by Hidalgo-Landa et al. [44], the review was organised in four stages:

Stage 1: Define and Refine Search Terms. Based on prior understanding of the research areas, an initial list of 54 potential search terms were identified. Using these to conduct queries (stage 2), the terms were either selected, eliminated (if an alternative term yielded more relevant results), or combined within a boolean search term. a final list of search terms used is as follows (Supplementary Materials). Scopus search string queries are available at 10.17028/rd.lboro.4772275:

- (Bespoke);
- (Consumer OR User OR End-user) AND (Product Customi*ation OR Personali*ation);
- (Prosum* AND Grass Roots Innovation) AND NOT (Software OR Video OR Media);
- (Digital Fabrication OR 3D Print* OR Additive Manufactur*) AND (Makerspace OR Maker Movement OR Fab OR Fabbing OR Personal Fabricat* OR Personal Manufactur* OR Personal Produc*);
- (Digital Fabrication OR 3D Printing OR Additive Manufacturing) AND (Co-Production OR Social production OR social manufacturing);
- (Open Design);
- (Crowdsourc* OR Crowd Sourc*);
- (Participatory Design OR User Participation) OR (Cooperative Design) OR (Co Design OR Codesign OR Co-design) OR (Collaborative Design OR Co-creation)

- (DIY OR Do-It-Yourself)
- (Upcycl* OR Domestic Recycl* OR Household Recycl*) AND (Consumer Goods OR Consumer Products OR Domestic Products);
- (Repair) AND (Maintenance OR Servic*) AND (Consumer OR Customer OR User)

Stage 2: Identify Databases and Search Engines and Query Using Terms Identified in Stage 1. The search engine used was (Elsevier) Scopus, searching within the Physical Sciences and Social Sciences and Humanities databases. This provided coverage of approximately 12,500 academic titles. Using the initial search terms above, a total of approximately 48,000 articles were found.

Stage 3: Create and Apply Filter Criteria. The search terms derived in Stage 1 were subjected to a number of global filters (specifically the search was limited to the abstract, title and keywords of English language articles) and semantic filters (to exclude returns from subject areas not relevant to the review) within the Scopus search engine, resulting in 1992 potential sources. The title and keywords of documents in this list were then manually reviewed to apply evidence-grade filters to the title and keywords, resulting in the identification of 176 sources.

Stage 4: Verify the Sub-selection is Representative. Hidalgo-Landa et al. [44] require that where a randomised subset of papers is manually reviewed in Stage 3 (when semantic filtering has not sufficiently reduced the list of papers), a second randomised subset is created to verify the first is representative. Stage 4 was therefore redundant, as all papers were manually reviewed in Stage 3.

Following the systematic review, the intervention touchpoints to appear on the CIM were extracted from the identified sources. For inclusion on the map, it was required that a touchpoint referred to an event in which a stakeholder actively and intentionally intervenes in a product's intended, or expected, customer journey model; passive touchpoints that do not involve consumer intervention were excluded. For example, an event in which a consumer observes a billboard advertising poster (a common touchpoint in conventional CJM outputs) does not appear in the CIM. However, an event in which a stakeholder defaces a billboard advertising poster to subvert its intended message does appear (under the intervention point 'Brandalism'). Observing the defaced poster would not, alone, be considered an intervention (since there is no intentionality), but photographing the poster and sharing the image on Twitter would appear on the map (under the intervention point 'Social Media Commentary). In total, 66 intervention touchpoints were identified and mapped to their appropriate phases in the product lifecycle (Figure 5). a system of colour coding was introduced to identify touchpoints as occurring at different stages in the product lifecycle—manufacturing (orange), communication (pink), supply (blue) and usage (green); these were coloured darker or lighter according to the degree of intentionality a brand or manufacturer has in allowing consumers to intervene at this touchpoint. Figure 6 shows an example product lifecycle for an imaginary, mass customised product.

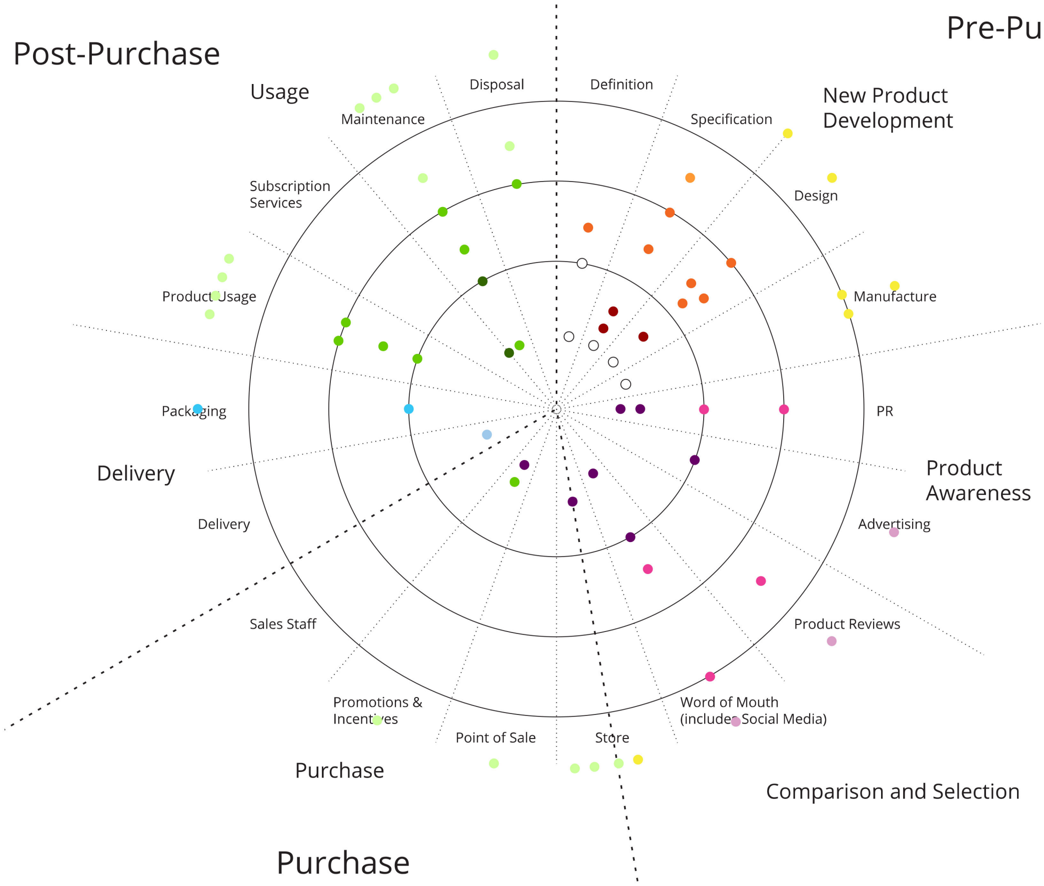

Figure 5. Consumer Intervention Map fully populated with intervention touchpoints (for full size version with captions please download from: 10.17028/rd.lboro.4743577).

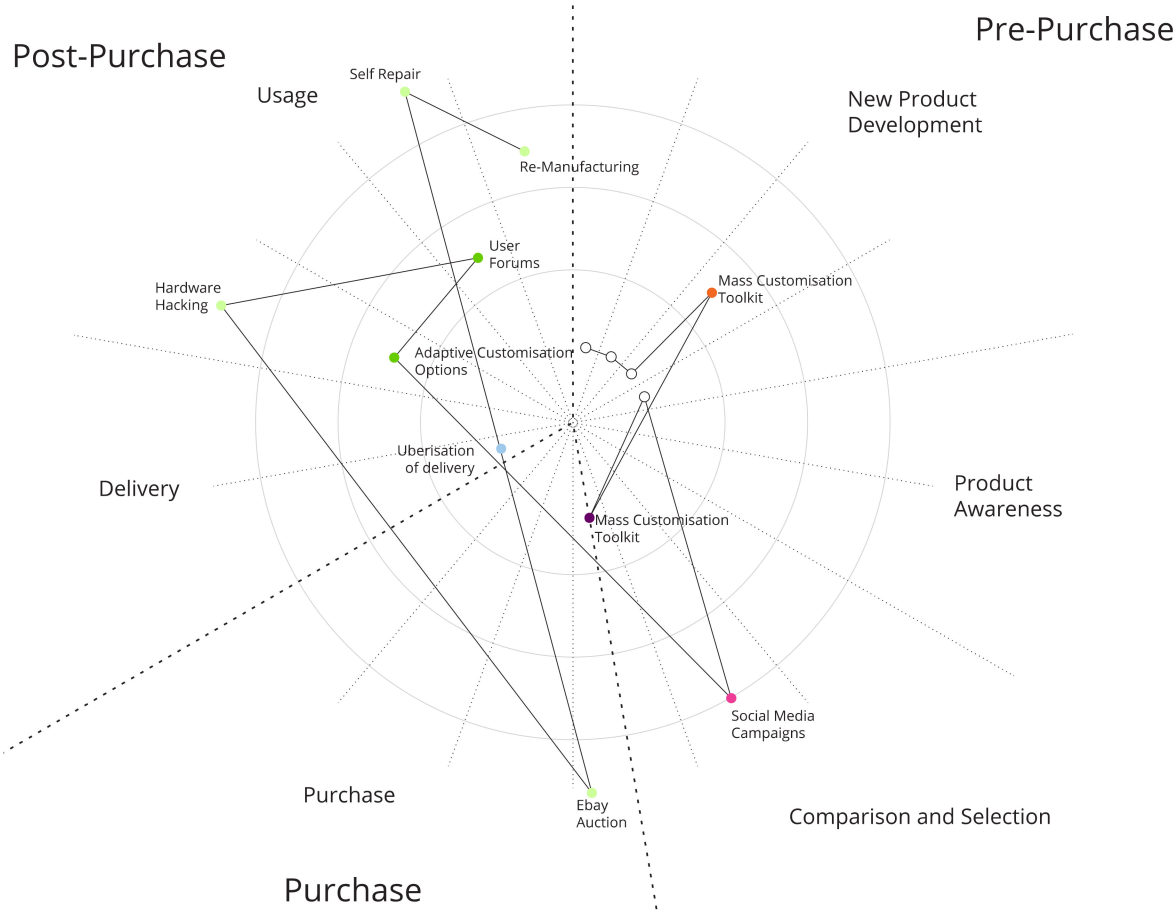

Figure 6. Consumer Intervention Map of an imaginary mass customised product.

3.4. Validation and Testing

Validation and testing of the CIM has occurred in three workshops (Table 1) involving industry professionals, academics and post-graduate students. The process has involved first developing a set of four contrasting scenarios concerned with RdM in a CE, which have formed the 'boundary conditions' within which the CIM could be tested. Workshop participants have then been assigned one of the scenarios and tasked with using the CIM to develop the 'story' of a future sustainable PSS for the year 2030, throughout its lifecycle. This story therefore becomes a 'scenario within a scenario'—one of many possible visions of how a PSS might be manifested within a CE.

In the field of strategic foresighting, a scenario is a vision or description of the future, which assumes certain key events to have happened between the current time and the time in which the scenario is set [45]. The purpose of a scenario is to illustrate future conditions, framed within a number of hypotheses about which events will occur and what outcomes will ensue. a fundamental tenet of Future Studies, however, is that the future is not fixed, rather "an image of the future is an expectation about the state of things to come at some future time. We may think most usefully of such expectations as a range of differentially probable possibilities rather than a single point on a continuum" ([46] p. 23). It therefore follows that scenarios do not attempt to predict the future, instead they enable those engaged in foresight and planning to clarify what actions are needed to move towards a desirable future.

Table 1. Details of validation workshops.

	Workshop 1 Imperial College, London Nov. 2016	**Workshop 2 IMechE, London June 2017**	**Workshop 3 PLATE Conference, TU Delft Nov. 2017**
Participants Total	17	15	21
Industry Professionals	3	6	0
Academics	4	4	9
Post-graduate Students	10	5	9
Unknown	0	0	3
Duration	4 h	2 h	90 min
Task Description	Within one of the four boundary condition scenarios (Circular Consumables, Democratic Desirables, Engaging Endurables or Tailored Temporaries): Develop a future PSS scenario and describe the product's lifecycle Develop a scenario-specific PSS lifecycle diagram Present to other participants	Within one of the four boundary condition scenarios (Circular Consumables, Democratic Desirables, Engaging Endurables or Tailored Temporaries): Develop a future PSS scenario and describe the product's lifecycle Develop a scenario-specific PSS lifecycle diagram Present to other participants	Within one of two boundary condition scenarios (Democratic Desirables or Engaging Endurables): Develop a scenario-specific PSS lifecycle diagram Present to other participants
Outputs	Worksheet 1: PSS scenario describing the product's design, purpose, use and disposal. Worksheet 2: Consumer Intervention Map visualising the product's lifecycle	Worksheet 1: PSS scenario describing the product's design, purpose, use and disposal. Consumer Intervention Map visualising the product's lifecycle	Worksheet 1: Consumer Intervention Map visualising the product's lifecycle

When developing scenarios, the "2 × 2 scenario matrix" is generally regarded as the standard tool ([47] p. 174). In this method, two contextual factors which are considered causally independent are aligned to two perpendicular axes [48], resulting in four contrasting sets of conditions that can be developed into detailed scenarios. The advantages of this method is that the resulting scenarios are clearly differentiated with little overlap, and the structured format allows them to be compared and communicated [48]. This makes it particularly effective in workshop situations, where the aim is often to generate and share scenarios amongst groups of participants.

In line with the aim of the RECODE Network and its understanding of the potential of RdM, the Business as Unusual project was based on three key assertions: that in a future CE resource loops will be slowed, production will be localised, and consumers will be engaged in the design and manufacture of their own products. Based on these three founding concepts, two contextual factors were identified:

- *Product Longevity.* Within a CE, the length of product lifecycles will continue to vary greatly. Food, personal care and fashion products will have shorter lifecycles than consumer electronics, furniture and automotive products.
- *Stakeholder Data.* The type of stakeholder engagement in the PSS will vary, depending on the types of user data and mechanisms of interaction available. Consumer-inspired design will occur when large amounts of anonymised trend and usage data are available to help direct design;

consumer-led design will occur when individual users are able to engage in the design and manufacture of their own, bespoke products.

These contextual factors then became the axes of the 2 × 2 matrix used in the validation and testing of the CIM, and were used to develop the boundary conditions scenarios, within which workshop participants would generate their own future product strategies (Figure 7). The details of each scenario, as communicated during workshops, were as follows:

1. **Circular Consumables** (Short Life Cycle + Consumer-Inspired Design). In this scenario, circular products with short life cycles are produced, consumed, and recycled in a localised system. They are designed by gathering crowd sourced data to understand the needs of many. Technology development is focussed on the realisation of flexible and comprehensive recycling processes, and online systems that enable the collection and interpretation of these consumer preferences. Large multinational corporations use these big-data feedback mechanisms to dictate the products to be manufactured in localised flexible production systems.
2. **Democratic Desirables** (Long Life Cycle + Consumer-Inspired Design). In this scenario, connected products with extended life cycles are produced, maintained and exchanged in a localised system. They are designed by monitoring life cycle data collected from embedded sensors. Technology development is focussed on realising flexible systems of supply and assembly, and in mechanisms that encourage simple maintenance and upgrade. Large companies gather big-data in real time to understand trends and behaviours and translate these into targeted offerings a localised branches and assembly centres.
3. **Tailored Temporaries** (Short Life Cycle + Consumer-Led Design). In this scenario, circular products with short life cycles are personalised, used, and recycled in a localised system. They are designed by individual consumers who tailor their products through dedicated online portals. Technology development is focussed in the realisation of flexible production, recovery and recycling processes that facilitate these new consumer-centric business models. Businesses of various scales work with end users in both online and physical portals to enable customisation and production of their products locally.
4. **Engaging Endurables** (Long Life Cycle + Consumer-Led Design). In this scenario, durable products with very long-life cycles are crafted and exchanged in localised systems. They are designed by individual customers who work with the makers to customise their purchases. Technology development is focussed in platforms to facilitate consumer engagement and co-design, and build local networks of makers, maintainers and exchangers. Local businesses work with end users through apps, service provision, and physical purchase and repair points.

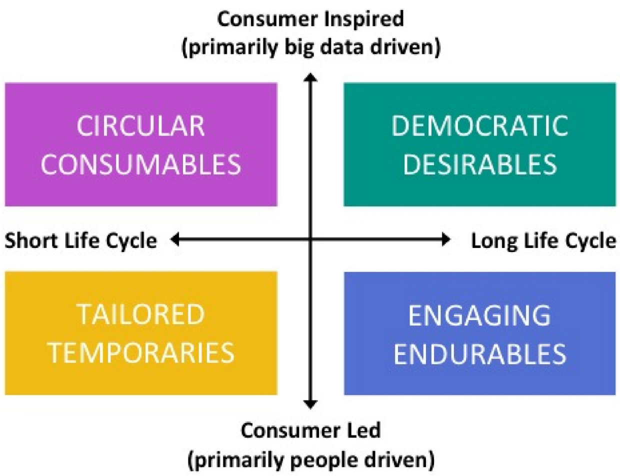

Figure 7. Contextual factors and the resultant boundary condition scenarios.

Working in groups, participants used pre-prepared worksheets to describe specific PSS scenarios within one of the boundary condition scenarios above (workshop materials and intervention cards are available at https://doi.org/10.6084/m9.figshare.4749727. They then used a second worksheet showing the spatial field of the CIM (previously shown in Figure 4) to visualise product lifecycles specific to their own PSS scenario (in workshops 2 and 3 these two worksheets were combined). To help participants generate visions of their product lifecycles, a set of Consumer Intervention cards were developed. Method cards such as these are used widely in design practice as a tool for enabling collaborative ideas exchange and allowing participants to visualise and converge on concepts together [49]. One card was made for each intervention touchpoint appearing on the CIM (Figure 8), and each group was given a full set of cards. In addition a number of blank cards were also created, to encourage participants to detail new interventions if they felt those provided were insufficient. Participants were asked to place cards on the spatial field worksheet and draw lines connecting the cards in order to describe journeys through their PSS scenarios.

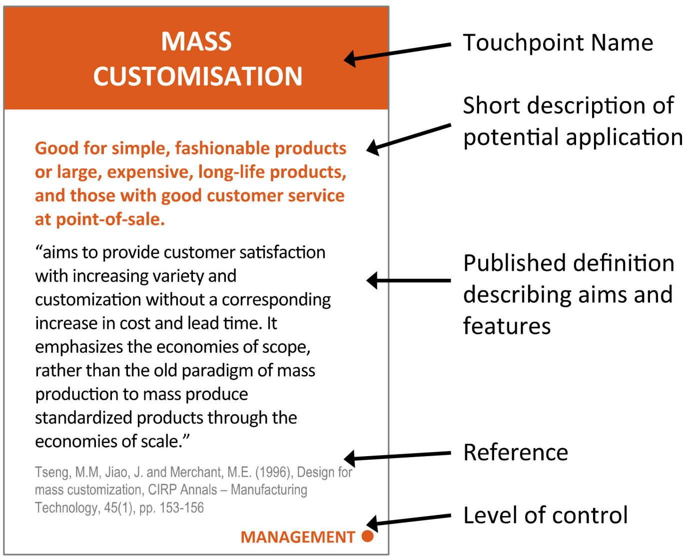

Figure 8. Example of intervention touchpoint card.

4. Findings

Validation and assessment of the CIM tool as a method for designing future product strategies was measured against two questions:

1. Was the tool useful in facilitating the task given to workshop participants?
2. Did the PSS scenarios that were generated depict non-conventional strategies or business models?

Workshops began with an introduction to the tool and the task to be carried out. Despite the time available for the introduction being significantly reduced in workshops 2 and 3, participant groups in all workshops were able to engage with the task and present their outputs within the given time. The underlying concept of 'consumer interventions' was readily understood, and groups were able to engage in the PSS mapping exercise, whether or not they were previously familiar with CJM as a method. The outputs of all three workshops show that the CIM tool enabled participants (who were, in most cases, unknown to each other), to rapidly create, discuss and refine future circular PSS strategies (Figure 9). Qualitative feedback indicates that the tool is successful at enabling workshop participants to engage in creative imagining of future scenarios, and that it was refreshing to be encouraged to think about 'possibilities' rather than constraints. Other comments have particularly mentioned the way that the tool encourages a focus on users and other non-traditional stakeholders.

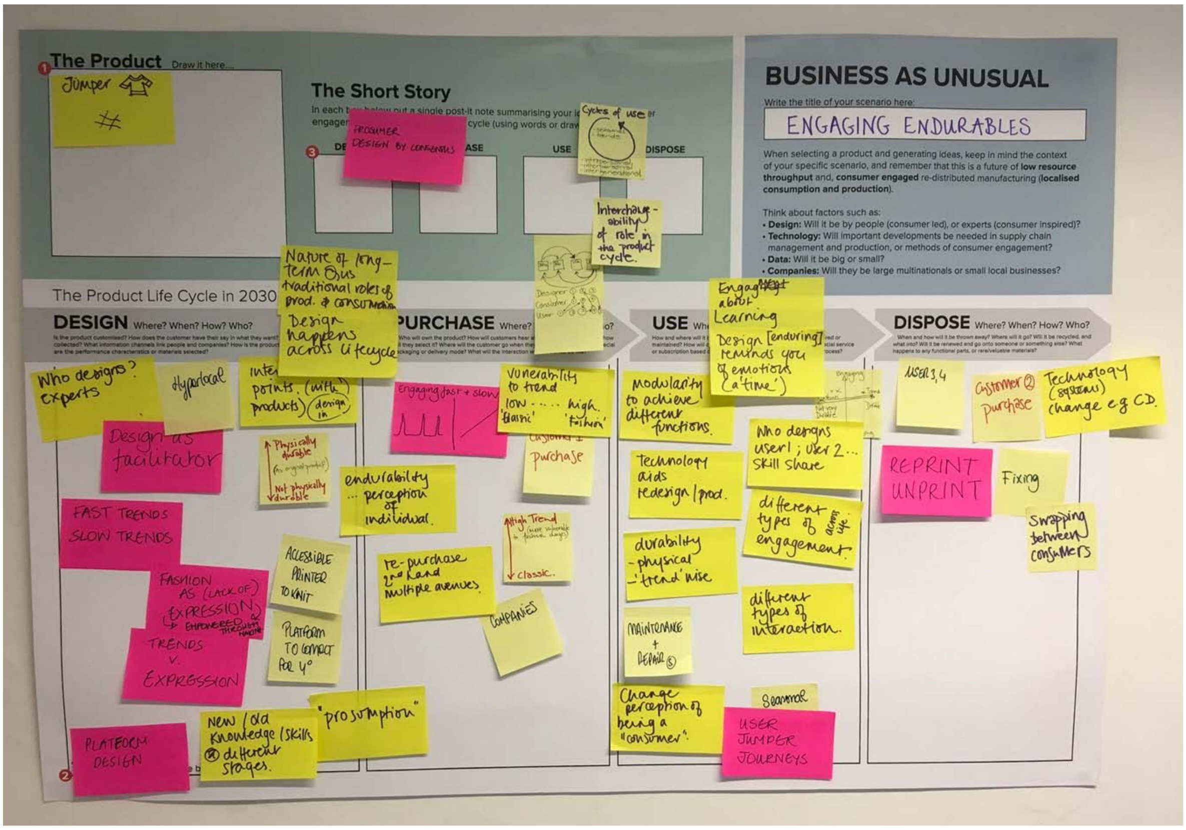

Figure 9. PSS scenario from workshop 1.

The use of boundary condition scenarios proved very effective in concentrating efforts on developing the PSS, rather than developing a 'bigger picture' perspective of the world in 2030. When observing group discussions during workshops, it was apparent the initial boundary condition scenarios provided an immediate, shared understanding which was accepted by participants and provided the foundation on which the PSS scenario was built. In the limited time available, the scenario boundaries provided helpful constraints, directing participants to think about the vision they were creating rather than discussing the premises underlying that vision.

In workshop 1, the number of intervention cards provided was problematic. In all four groups, a significant amount of time was spent reading each card and discussing or asking for clarification about the touchpoint definitions. To some extent this hindered the development of the scenario-specific PSS lifecycle, as participants were concerned whether they had chosen the correct card to describe the intervention. During this workshop, the facilitators encouraged groups to use the blank cards to describe an intervention if they were unsure which of the pre-populated cards to use. Subsequently, for workshops 2 and 3, it was decided to remove some of the cards that were unused in workshop 1, but to provide more blank cards for participants to describe their own interventions. The extent to which this may have restricted the scope of the scenarios created in the latter two workshops is unclear, however, particularly given the shorter timescales involved it was agreed this was the most pragmatic decision.

When looking at the blank intervention cards that have been completed in workshops, it is interesting to note that no entirely new intervention touchpoint has been revealed. Instead, the cards completed by participants have tended either to detail a specific instance of a more generalised intervention (e.g., 'predictive maintenance', in which sensing data informs the user when to service a product), or to combine two intervention points (for example 'mass customisation' via an 'on-demand manufacturing platform'). It therefore appears that the CIM tool is also validated in terms of the scope of touchpoints identified in the literature review.

In terms of the ability of the CIM tool to aid in the creation of visionary, non-conventional business models, the findings are more nuanced. Examples of scenarios created in workshops are provided in Table 2. Of the 14 scenarios that have been created to date, there are none that are entirely new to the authors. Rather, the scenarios have fallen into one of two categories:

1. an existing PSS that has been adapted to a CE paradigm.
2. an existing CE PSS that has been applied to a new product concept.

Table 2. Workshop PSS scenario concepts.

	Circular Consumables	**Democratic Desirables**	**Engaging Endurables**	**Tailored Temporaries**
Which Product?	Personalised Party Game Bundles Rental	Smart Kettle Service	Personalised Jumpers	Washing Liquid
Design phase description	Trend scanning for the company (with consumer as an observer)	Data collected locally from smart kettles is used by companies who share the insights	Prosumer designed across the lifecycle by consensus, with the designer as a facilitator	an online platform provides customisation choices of fragrance, formulation, format, etc.
Purchase phase description	Online marketplace for brokering and customising deal	Tier pricing is used as an incentive, based on the data shared with the companies	There is a perception of individuality at initial purchase, with multiple avenues for swapping and repurchasing second hand	User forum allows customers to review and rate creations, or to create a store to allow others to purchase their product
Use phase description	During the special event the product is used and retained	Data is gathered to allow local maintenance to be scheduled as needed, and trust is built. Findings shared with legislative bodies	Different cycles of use with consumers engaged in re-design of a second life where needed	Subscription service provides automatic renewal and delivery of concentrated liquid
Disposal phase description	Collected by company for re-use and recycling where applicable	Data from use phase enables prediction of best end of life management options	Swap, resell, or unprint/reprint to make something new	Packaging taken back for cleaning and reuse

However, within these categories, the scenario-specific PSS lifecycles provide a number of interesting observations that indicate the value of the tool and that suggest future research directions:

- *Life Cycle Stages:* Most PSS lifecycles have concentrated stakeholder intervention activity in the right-hand side of the spatial field (Pre-Purchase). This is the area conventionally occupied by an organisation's internal stakeholders, utilising data on users to provide what the business believes its customers want or need. Visions of circular PSS lifecycles that place consumer interventions in this space suggests that workshop participants believe RdM will challenge the traditional distinctions between manufacturer, designer and consumer. In contrast the bottom left hand quadrant of the spatial field (Purchase and Delivery) has remained relatively unpopulated in all PSS lifecycles. This implies that participants found it difficult to imagine the applicability of a CE approach to this area of the map and suggests there may be new business opportunities which remain relatively unexplored. Many of the new touchpoints created by the groups were in the Post-Purchase phase, suggesting participants had difficulty matching their visions of a future PSS with current understandings of stakeholder interventions during ownership. Again, this indicates the potential for new areas of business opportunity.

- *Organisational Control:* Few PSS lifecycle diagrams have placed intervention points close to the centre (and therefore under complete control of the company). During the mapping exercise, groups often initially placed many cards around the outside of the spatial field, indicating interventions over which the organisation had no control or influence. However, when creating the final version of the lifecycle (Figure 10), these outlying touchpoints were used less frequently. Most stakeholder intervention therefore takes place in the central ring, under the management of the organisation, but outside of its complete control. It should be noted however, that placement of intervention points is likely to have been influenced by those stakeholders represented in the workshop: by their roles within a company or organisation and their knowledge of current legislation. This is a limitation that should be addressed in future work to refine the tool.
- *Journey Start Points:* When reviewing all scenarios, it is noticeable that many lifecycles do not begin in the Pre-Purchase phase usually assumed within CRM. This was again an unexpected development, but on reflection corresponds very well with the logic of circular design. In a theoretically perfect CE, where no resources are lost from the system [5], any point in the lifecycle can be the first intervention point for a particular stakeholder.
- *Intervention Point Positioning:* When creating the PSS lifecycles, a number of groups moved the position of an intervention touchpoint to a different position on the spatial map, for example 'Self Assembly' moved from 'Packaging' to 'Store'. This was an unexpected outcome but indicates that participants did not feel the tool was over-constraining, and were prepared to question some of its assumptions. It also demonstrates the flexibility of the tool in terms of suggesting new instances of existing intervention touchpoints; for example, one scenario moved the 'Social Media Commentary' touchpoint to place it within 'Product Usage', to describe a product that tweeted about its status independently of its user.

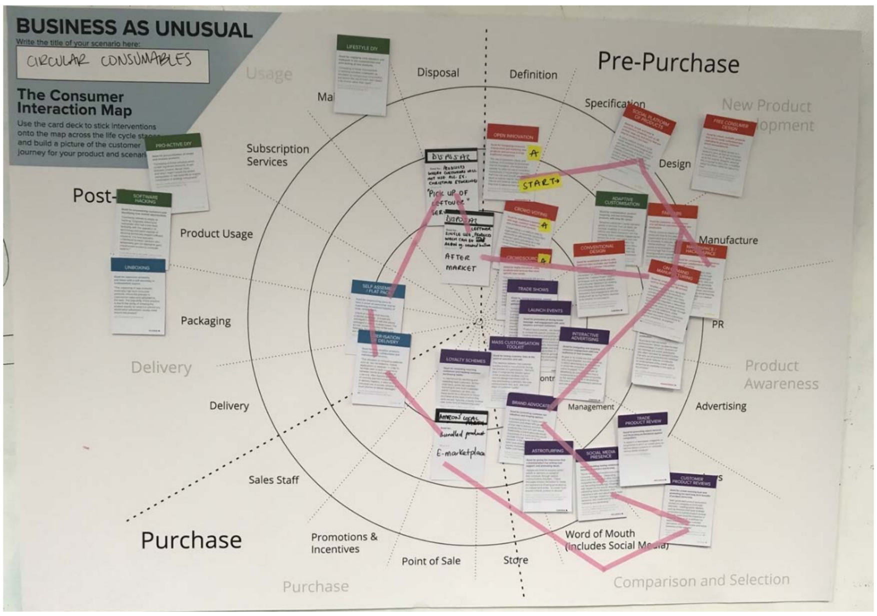

Figure 10. PSS lifecycle diagram from workshop 1.

5. Discussion and Conclusions

This paper describes the development of a tool intended to enable the design of future, circular product strategies. Fundamental to the use of the tool is an understanding of stakeholders as those who are willing and capable of intervening in the expected lifecycle of a product within a PSS, such that the product's journey takes it outside of the control of the manufacturer. This in turn has allowed the creation of future PSS scenarios. The outputs of workshops held to validate this approach have been visionary and speculative in nature. The findings from this research places the tool in contrast to most existing eco-design tools [21], and instead aligns it with the FEEI approach described by Tyl et al. [24]. Relatively few examples exist of the application of speculative design [50] to the imagining of sustainable futures [30,51,52], though in common with this previous work the nature of the PSS scenarios generated through the CIM tool means they do not provide definitive 'answers' to circular design problems; rather they illustrate possible futures that cause questioning of assumptions and act as the starting point for future investigations.

When validating the effectiveness of the tool, a 2 × 2 matrix was used to develop boundary condition scenarios, within which workshop participants could create visions of future circular PSS lifecycles. These scenarios were constructed from contextual factors of product longevity and stakeholder data, which were considered most relevant to the aims of the RECODE Network. Inevitably, and intentionally, the outcomes of the workshops have been influenced by these two contextual factors, and so further work should be conducted to determine the types of scenarios that might result if one or both factors were changed. The CIM tool has proven effective at generating visions of future PSS in three different workshops involving industry professionals, academics and post-graduate students. However longer, more reflective exercises involving more industrial stakeholders are required to give more depth to the scenarios and to encourage participants to develop concepts for new products inside new PSS. Additionally, future research should be undertaken inside an interested organisation, to explore the possibilities for innovation when the business constraints of the organisation are built into the boundary condition scenarios.

Reflecting on the outputs of the workshops, it has become apparent that one attribute of the CIM tool is its ability to help generate scenarios that call into question some common assumptions regarding the CE. First among these is the distinction between an organisation and the designers it employs, and the consumers of the products it manufactures. In considerations of the future of RdM, the concept of consumers as designers and manufacturers of their own products is not a new one [53], but the prevalent view within the CE literature has tended to be one where the user is the 'subject of' rather than 'participant in' NPD activities. Of particular note is Design for Sustainable Behaviour, a process that attempts to steer consumer behaviour in a more sustainable direction and away from environmentally damaging practices [4]. Hobson and Lynch [54] critique this approach as one in which the citizen is "inseparable from the consumer, whose role is to respond to correct labelling and price signals, produce less household waste, and participate in innovative forms of consumption such as the much-lauded sharing economy and forms of 'collaborative consumption'." What the CIM scenarios reveal is that a future CE will involve two types of relationship between PSS and stakeholders. In the first, unaware and disinterested consumers are observed and reported on by products enabled by sensors, internet connectivity and cloud databases, persuading consumers to engage in sustainable behaviour whether or not they are aware of the persuasion. In the second relationship, engaged and interested consumers specify, design, repair and re-sell products whose life-cycles do not match those of conventionally conceived products.

In order to account for both types of behaviour and working from the belief that future products will be owned and used by a number of consumers, rather than just one, a further assumption that is questioned by outputs from the workshop is that of a user-centred approach to design. In a CE, products will have lives that are ambivalent to traditional models of ownership and will have memories and 'smartness' that are independent of their current users. This provokes the suggestion that in future, designers will take a more product-centric approach to specifying, conceiving and designing products, even that, in some cases, the needs of the product will be seen as more important than the needs of the user.

If this appears a somewhat pessimistic vision, it is one that is nonetheless supported by expectations that future circular business models will embrace renting, leasing and the sevitization of material goods [28]. These models will inevitably rely on smart devices, connected via the Internet of Things to the organisation that has manufactured and deployed them, reporting on usage and product status without the user's informed consent. This mirrors the vision that technology-focused corporations promote as the future of consumption—one where books, DVD's, cars and even roof-mounted solar panels are no longer owned, and where opportunities to repair, modify or resell are restricted or prohibited. a future CE may not be well served by business models that encourage, even demand, that users replace devices for the newest model.

The value of the CIM tool and process is demonstrated in the discussions it raises. It is the authors' intention that further work will be conducted that expands on the points raised above, in particular regarding the role of consumer engagement and product literacy in strategies to create cultures of sufficiency. Case studies of existing Business as Unusual models will be undertaken, and these will inform a revised model of the CIM tool, that will allow the depiction in more detail of circular product journeys.

Supplementary Materials: The following are available online at the Institutional Repositories of the authors: Scopus search string queries for systematic literature review: 10.17028/rd.lboro.4772275; Consumer Intervention Map: 10.17028/rd.lboro.4743577; Workshop materials and Intervention cards: https://doi.org/10.6084/m9.figshare.4749727.

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