Product Grammar
Cost Benefit Ratios for Product Customization

Thesis proposal for the degree of Doctor of Philosophy in Media Arts and Sciences at the Massachusetts Institute of Technology

Ryan Chin
Smart Cities group, MIT Media Lab
rchin@media.mit.edu

Abstract

The customization of products – the ability to produce many variations of a design – often has many benefits such as better performance in functionality, packaging, and aesthetics. However, the level of customization will always have associated costs. Typically, the higher the level of customization a product exhibits, the higher the costs. The costs can be quantified in terms of financial and time costs, whereas the benefits can be quantified in terms of overall product performance (appearance, functionality, reliability, etc.). Thus, the overall effectiveness of any customization strategy can be expressed as a ratio of the total costs vs. total benefits, otherwise known as the cost/benefit ratio (CBR). This thesis seeks to develop the optimal customization strategy by utilizing CBR methodologies for the GreenWheel, a customizable electric-assist bicycle, developed by the Smart Cities group at the MIT Media Lab.

This thesis will examine two major case studies to test and verify the CBR methodology. The initial case study will be the custom men's dress shirt industry which provides a wealth of data for quantifying costs (manufacturing and distribution) and benefits (fit, function, and look) of both custom and standard men's shirts. The level of customization of products like custom men's dress shirts can be defined by writing a product grammar. The number of product versions in the language specified by the grammar provides the range of customization possibilities. By altering the rules of the grammar we can change the level of customization. The problem of customizing the product will then be to find the level of customization that optimizes the CBR, subject to constraints that may apply. This thesis will then test the CBR methodology by conducting a series of user tests of electric-bike riders as the second major case study. Users will be able to configure a GreenWheel based on their performance needs and budget. A range of customized GreenWheels will then be built and matched with potential users from distinct user segments from the survey. Users will then test their custom GreenWheel and a set of analyses will be conducted on the effectiveness of each customized solution. The goal of this thesis is to develop effective customization strategies for custom products based on CBRs.

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Ryan Chin
Smart Cities group, MIT Media Lab
rchin@media.mit.edu

Thesis Advisor
William J. Mitchell
Professor of Architecture and Media Arts and Sciences
Massachusetts Institute of Technology

Thesis Reader
Kent Larson
Principal Research Scientist
Massachusetts Institute of Technology

Thesis Reader
Frank T. Piller
Professor of Management
RWTH Aachen University

Problem Statement

The customization of products – the ability to produce many variations of a design – often has many benefits such as better performance in fit, taste, and function. However, the level of customization will always have associated costs. Typically, the higher the level of customization a product possesses, the higher the costs. For example, a custom tailored suit will fit impeccably, matches your aesthetic tastes, and perhaps makes a positive impression at your job interview. However, the costs associated will be the high price and time spent at the tailor. A standard suit will be lower in cost, will be available in only a few colors, may not fit properly (and may require alterations). Costs can be quantified in terms of financial and time costs, whereas the benefits can be quantified in terms of overall product performance (aesthetics, functionality, reliability, etc.). Thus, the overall effectiveness of any customization strategy can be expressed as the cost/benefit ratio (CBR). This thesis seeks to develop the optimal customization strategy using the CBR methodology for the GreenWheel, a customizable electric-assist bicycle, developed by the Smart Cities group at the MIT Media Lab.[1]

The level of customization in any product can vary greatly and can be defined by writing a product grammar. The number of product versions in the language specified by the grammar provides the range of customization possibilities. By altering the rules of the grammar we can change the level of customization. The costs, benefits, and CBRs will also vary with the level of customization, thus there will be an optimal level of customization. The problem of customized product design is to find the level of customization that optimizes the CBR, subject to any constraints that may apply. Computing this ratio will require a thorough examination of both costs and benefits and how to quantify them.

The cost of customization will generally include:

1. Added set-up costs in creating a modular product architecture and its respective modules to enable customization.

2. Increased complexity in managing a higher number of components and subassemblies.

3. Added complexity and time costs due to increased product variety.

4. Performance penalties due to modular design (as opposed to an integrated standard design).

The benefits of customization will generally include:

1. More exact match of performance requirements of the end-user.

2. Elimination of overall waste due to over-design (under-design in some cases).

3. Ability to reach micro or niche market segments and expand existing markets.

4. Increased sales price over generic and standard products due to Hedonic value.

Developing a theoretical framework to solve this problem will dramatically increase the benefits of customization, extend customization to a wider audience, and identify key areas in the product lifecycle that can reduce waste in the manufacture and delivery of customized products.

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[1] The GreenWheel is an electric-assist bicycle invented by Professor William J. Mitchell and Michael Chia-Liang Lin (Phd Candidate, MIT Media Lab).

Research Questions

The core research question is to find appropriate level of customization of a product to achieve the most benefit given a set of constraints such as cost, time, and performance. Determining the best CBR will provide the ideal level of customization of the product. In order to compute the CBR, we must quantify costs and benefits. Below are a series of more specific questions that will help to quantify the major components of the CBR:

Costs:

1. Set-up costs for mass customization – Determine the investment costs to set up a new product line based on the principles of a modular product architecture. This can include an analysis of the costs to convert a product line that previously was configured with standard mass production techniques. These costs should also include investments in product configurators, web interface, and a sophisticated back-end computation capability to manage the system.

2. Management of increased complexity in production and distribution – Mass customization architectures will require many more modular components and subassemblies than traditional mass production. Manufacturers will be required to manage a more expansive solution space, where there maybe more possible product variations than customers.[2] Manufacturers will need to develop a sophisticated strategy for manufacture, assembly, and distribution that minimizes waste in excess inventory. The introduction of smart supply chain management systems will increase up-front costs for manufacturers. More importantly, manufacturers will need to stabilize a reliable solution space that can closely match consumer demand.

3. Costs due to increased end-product variety – The shear number of product configurations can burden the end-user during the customization process. Often, users will be confronted with too many product choices and poor configuration tools that don't match consumer need. This can lead to more time spent in the retail environment site or even frustration by the users (more difficult to quantify). This phenomenon has been well studied in the field of consumer behavior and exemplified by Swartz's book, "The Paradox of Choice" and Iyengar and Lepper's study, "When Choice is Demotivating: Can One Desire Too Much of a Good Thing?"[3] [4] This previous research will lay the foundation for examining the true costs of increased variety.

4. Performance penalties due to modular design – The utilization of modular design will provide flexibility, yet in some instances will suffer from extra weight and size.[5] For example, high performance sports and race cars will often utilize integrated body panels that are optimized for weight and structural performance. These designs are engineered to be lightweight and perform under racing conditions (integrated furniture will also exhibit similar characteristics). These penalties will incur penalties in manufacture (more components), distribution (more weight), and use (overall performance). These penalties will need to be quantified into direct costs relative in comparison with integrated designs.

Benefits:

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[2] Holweg, M., Pil, F.K. (2004). The Second Century: Reconnecting Customer and Value Chain Through Build-To-Order; Moving Beyond Mass and Lean Production in the Auto Industry. Cambridge, Mass.:MIT Press.
[3] Schwartz, Barry (2004) The Paradox of Choice: Why More Is Less, Ecco.
[4] Iyengar, S.S., Lepper, M. (2000). "When Choice is Demotivating: Can One Desire Too Much of a Good Thing?," Journal of Personality and Social Psychology, 79, 6 (Dec.): 995-1006.
[5] Ulrich, K. (1995). "The Role of Product Architecture in the Manufacturing firm." Research Policy, Vol. 24, No. 3, pp.419–440.

1. Matching the performance requirements of the end-user – Performance can be quantified in terms of the following major categories 1) Fit, 2) Function, and 3) Taste.[6] Fit can be quantified by how well the product matches the packaging requirements of the end-user. For example, a custom suit will fit exactly to the measurements made by the tailor to the specific individual. Furniture should be able to fit into the space allotted for them. The ideal customized product fulfills all the functional requirements of the end-user, but not have more or less than specified. For example, when customizing a new desktop computer, users should configure the machine to their needs. If the machine is intended for CAD work, then it should have the appropriate OS, software, and RAM required for the task. Performance measures for taste vary greatly depending on the context. Finding the appropriate color when painting an interior or when putting together an outfit is extremely important. When purchasing a new car, one of the first questions for the sales staff is the available color palette. If the color is not available it may forestall a sale. Developing a spectrum of benefit ranging from the ideal fit, function, and taste, will be crucial in quantifying this component the CBR.

2. Elimination of waste – The optimal level of customization will reduce waste in material and energy costs because manufacturers will know the exact demand for particular components and how to best deliver the product. Often, ignored by cost-benefit analyses, the incorporation of environmental impacts in this study will be critical in determining the CBR. A closer examination of the product lifecycle of the men's dress shirt industry has revealed a number of key areas of improvement that custom dress shirts can provide.[7] They include environmental benefits due to reduced material usage, overall inventory, distribution, and post-retail experience. These benefits can be quantified in terms of total material use, energy-use, and time-costs. Cumulative time costs can be computed by adding the total time for manufacture, distribution, retailing, and returns (a major factor in waste in retail).

3. Ability to meet micro or niche markets – The deterioration of mass markets into niche markets has been enabled by the adoption of mass customization product strategies. B. Joe Pine's "Markets of One" provides the logic behind the shift to smaller market segments and eventually to the market of the individual customer or micro market.[8] This ability allows manufacturers to not only produce a one-of-a-kind design (which has intrinsic value in itself), but to also to gain unique knowledge of each customer's unique needs and thus improve future product offerings and stabilize existing solution sets. Quantifying this key benefit will be critical to the CBR.

4. Increased sales price due to Hedonic value – Studies have shown that the process of customization has value beyond the end-product (i.e., the customized product itself). For example, the act of designing a unique and personalized product with an online configurator is a form of value creation over and above the utilitarian value of the product. A study of custom watches by Franke and Piller has shown an additional premium (measured by willingness-to-pay) of twice the standard product for self designs.[9]

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[6] Frank T. Piller (2005). "Mass Customization: Reflections on the State of the Concept." The International Journal of Flexible Manufacturing Systems, 16, pp. 313-334.

[7] Chin, R., Smithwick, D. (2009). "Environmental Impacts of Utilizing Mass Customization: Energy and Material Use of Mass Customization vs. Mass Production", Mass Customization and Personalization Conference (MCPC) Paper, Helsinki, Finland.

[8] Gilmore, J.H., Pine, II, J.B. (Eds.) (2000). Markets of One: Creating Customer-Unique Value through Mass Customization. Boston, MA: Harvard Business School Press.

[9] Franke, N., Piller, F., (2004). "Value Creation by Toolkits for User Innovation and Design: The Case of the Watch Market." Journal of Product Innovation Management, 21, 401-415.

Background: Mass Customization

The consumer electronics industry has been the earliest adopters of the principles of mass customization. Consumers can customize a laptop online that approaches their computational needs and aesthetic tastes. After receiving the final product users can further personalize and adopt their laptop by utilizing software provided by other manufacturers. Electronic manufacturers can easily adjust their product offerings by utilizing modular product architectures that enable them to quickly integrate technological innovations and upgrades into the new offerings. Manufacturers can also intelligently tie their product configuration to fluctuations in the supply chain of new product modules. Widely known for advocating mass customization strategies, B. Joe Pine II describes, "The best method for achieving mass customization - minimizing costs while maximizing individualized customization - is by creating modular components that can be configured into a wide variety of end products and services. Economies of scale are gained through components rather than the products; economies of scope are gained by using modular components over and over in different products; and customization is gained by the myriad of products that can be configured."[10]

Mass Customization and its principles of highly individualized end-products has the advantages of better 1) fit, 2) function, and 3) taste, while maintaining economic competitiveness to mass production methods of manufacture.[11] Historically, traditional means of production have only been to accomplish in part, but not all of these key performance criteria without sacrificing economy of means. The earliest form of production, hand-craft, accomplished high levels of fit, function, and taste customization at the sacrifice of time and cost. Craft production does not fully utilize modularity or standardization, key tenets of both mass production and mass customization.

Background: Product Grammars

A product grammar is a set of logic and structural rules that govern the composition of the systems, subsystems, and components of any product. Product grammars are particularly useful in designing custom products because they allow many product variants established by a set of rules that ensure a functional, safe, and manufacturable product.

A foundation to product grammar is the well-established theory of formal grammars. They have a long history in linguistics and computer science, and generate strings of sentences and one-dimensional designs, but can be generalized to two-dimensional and three-dimensional objects.

A formal grammar consists of (1) a set of terminal vocabulary elements, (2) a set of marker vocabulary elements, (3) a starting element, and (4) a set of rewriting rules. Objects in the language specified by the grammar are generated by recursively applying the rewriting rules to the starting element.

In the context of custom product design, production, and supply chain management, grammars can rigorously specify ranges of possible variants of a product. Terminal vocabulary elements are manufactured parts. Rules can be written to assure that all variants have desired properties. The parsing (syntax tree) of a product instance shows the product's sub-assemblies at the various levels of integration, and forms the basis for supply chain management.

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[10] Ibid.

[11] Piller (2005).

Configurators derive objects in the language. Within a configurator, the syntax tree provides the basis for specifying which decisions can be made by the end user – alternatively (more usefully), you can say that some rewriting rules can be applied by the manufacturer, and some by the end user.

These are the major product categories (1) amorphous (i.e., mixed drinks), (2) one-dimensional (i.e., English Sentences), (3) two-dimensional (i.e., architectural plans), (4) two-and-a-half dimensional (i.e., candle sticks), (5) three-dimensional (i.e., cars, scooters), and (6) four-dimensional products (i.e., foldable structures).

Grammars can work with rigid objects or parametric objects. In the case of parametric objects, distances and angles are defined by variables and expressions instead of by constants. The syntax tree for an object provides a framework for managing the parameterization and propagating changes.

Formal grammars provide the foundation for a rigorous, general theory of customization, with many practical applications.

Strategies for Cost-Effective Customization

A wide range of cost-effective strategies have been utilized by custom manufacturers with varying success. Pizza Pies provide a simple example, as they can be customized by substituting different modules (toppings), a pizza maker can easily customize a pie by building on top of a standardized base (dough and tomato sauce). If the restaurant utilizes just a dozen toppings, then thousands of types of pizzas can be created. By judiciously utilizing varying levels of standardized and customized components, the pizza maker can reduce cost by being selective on the component that is most commonly used. Overall, this strategy would yield a much better CBR, than customizing all components including the pizza dough (i.e., costs will go up giving the complexity of having different types of dough for every pizza).

The use of a modular product architecture (like that of pizza pies) is well-studied strategy and made into common practice by B. Joe Pine II's foundational book "Mass Customization: The New Frontier in Business Competition." Today, many manufacturers of computers, automobiles, and cell phones have essentially embraced this strategy. This thesis will examine some non-obvious, but clever strategies that will yield beneficial CBRs. For example, iPhones achieve a very high level of customization by standardizing all of the hardware (which have very high set-up costs), and making it easy for third-party manufacturers to integrate software (apps), hardware (accessories), and skins (cosmetic customization). They achieve this by not only standardizing the operating system, but also the interfaces (power and data transfer connections). Below are some additional cost-effective customization strategies that this thesis will explore and build upon:

1. Carefully thought-through modularization of elements and subsystems and establishment of standard interfaces between elements and subsystems. This facilitates substitution of elements and subsystems.

2. Use of parametric models and CAD/CAM fabrication. This facilitates variation of elements and subsystems without high additional costs.

3. Standardizing those parts of a product where setup costs are high and benefits from customization low, while allowing variation where the costs of this are low and the benefits high.

4. Keeping as much as hardware standard (since hardware customization tends to be expensive) as possible while allowing lots of customization through software (since software-based customization tends to be cheaper).

5. Invest heavily in quality of design of those few components that are standardized.

Research Plan

A series of case studies examining in detail the CBR of existing customizable products will provide a baseline understanding of the key quantifiable parameters required for this research. The research will require the acquisition of key data from custom manufacturers and will follow closely to traditional product lifecycle analysis methods.

The first case study will examine the custom men's dress shirt industry and will closely examine the tradeoffs between costs and benefits at every key stage of the product lifecycle. The stages include:

1. Manufacturing – Analysis of set up costs for mass custom shirt making, material usage, energy usage, processing time, inventory, and labor costs.
2. Distribution – Comparison of energy use, CO_2 emissions, and total time in the distribution of the product (from factory to home).
3. Retail Experience – Examine total time and energy used in shopping online or in a "Bricks and mortar" establishment.
4. Post Retail – Examine product use after purchase including use patterns, returns for modifications, redistribution, restocking, and resale.

The goal of this case study is to establish the key metrics for quantifying cost and benefit, thus providing linkages to establishing a set of rules for a product grammar which define the level of customization for the product in question.

The primary case study for the thesis will be the GreenWheel electric bicycle developed by the Smart Cities group. The GreenWheel is a customizable product that integrates electric motors and batteries into the hub of a bicycle tire. The GreenWheel provides electric assist to the user and its modular design enables easy retrofitting into any standard bicycle. The GreenWheel can be customized both physically and electronically to meet varying needs of different users. For example, the modular design allows for different configurations of electric motors, battery capacity, and control electronics. The GreenWheel can also be cosmetically customized with different material finishes, coatings, and transparency. The ideal GreenWheel for any one user should be the optimal combination of hardware components enabled by programmable software given user constraints.

The CBR of the GreenWheel case study will be divided into costs and benefits. The costs include (1) Set up costs – including design, engineering development, manufacture, and distribution of the GreenWheel, (2) Management of complexity – examine the management of the components (motors, batteries, motor controllers, casings, wiring, etc.), (3) Increased variety – examine costs (financial and time) for increased variety for the consumer experience, (4) Performance penalties for modular design – examine performance penalties for an integrated battery (normally attached to frame of bike) in terms of weight, installation, and riding experience.

Benefits will include (1) Matching performance requirements – based on the rider's performance preferences for power assist, range, torque, programmability, (2) Waste reduction – Examine reduction of energy and material use in the design, manufacture, distribution and use of the product, (3) Micro markets

– Examine the ability to customize a GreenWheel solution to a specific customer, (4) Increased sales price due to Hedonic value.

Obtaining the CBR from this analysis will then determine the correct level of customization, which can then be in formatted into the set of write rules for the GreenWheel product grammar. The rules of the grammar will dictate how all the parts (components) fit together in subassemblies and into the final product. A well written grammar will yield products that can be assembled, are functional, and are safe. The next phase of the research will then be to create a product configurator capable of instantiating all the possible solutions by the product grammar.

The final phase of the research is to evaluate a set of GreenWheels configured with varying levels of customization with real users. The users will then be tested and the results evaluated to validate assumptions, product grammar rules, and product use. The user test will provide the opportunity to tune the model by adjusting the product rules to better match CBRs.

Customization Strategies for the GreenWheel

Ideally, the best customization strategies should allow the most variation of the properties of the element or component that you would like to customize. In the case of the GreenWheel, users may want to vary the amount of power output from the electric motor in order to accelerate faster or have enough boost to overcome a steep incline, thus having the ability to customize different sizes of motors will be key to the design package. Another likely area of customization is the battery of the GreenWheel because of the importance of driving range in electric vehicles. The relationships between battery pack size and range are well understood. A vehicle with a larger battery pack will travel further, however, it will cost more and the vehicle will be heavier. The extreme ends of this customization spectrum will not be useful for most users. For example, a GreenWheel with a very large battery pack will be prohibitively expensive, bulky, and significantly the overall packaging. A GreenWheel with a very small battery pack will need constant recharging and will have very little power to overcome hills. Examining these conditions will provide upper and lower limits for battery pack size giving us a range to examine.

It will also be critical to layout a product architecture that allows a wide range of variation of customizable features. For example, the GreenWheel combines battery and electric motors to produce a modular unit that is easy to retrofit. The 3D geometric relationship between the battery pack and electric motor can be configured either by (1) configuring the battery pack surround the electric motor in a concentric circular fashion or (2) place batteries inside the electric motor if the motor is large enough. We can rule out some obvious configurations since they are inherently contradictory to the GreenWheel concept such as battery and motor in a side-by-side configuration (enough width within the bike frame) or battery separate from the motor (traditional e-bikes already do this). The battery pack inside the motor will be difficult to expand because it will require a change in the electric motor design. This design is also problematic when reducing the size of the battery pack as the void space will be empty (this is less of a problem than the expansion case as the space could be used for other modules). The battery pack surrounding the motor provides more freedom to expand and contract the battery pack because it does not affect the sizing of the motor. As the battery pack grows only the outer packaging will change which will have less of a penalty than the electric motor.[12] Examining the exact trade-offs between cost and benefit of battery size, range, and weight will be one of key areas of study in the GreenWheel case.

[12] The utilization of CAD/CAM technologies as described in "Strategies for Cost-Effective Customization" section will enable flexibility and low-cost customizability in the manufacturing process if employed in a smart and modular fashion.

Detailed Timeline

Formal Grammars (1 month) – Develop an array of formal grammars for each major product grammar category. This will establish the theoretical base for developing a product grammar for GreenWheel case study.

1. One-dimensional grammars (English sentences, stings of beads and trains)
2. Two-dimensional grammars (hexagons, architectural plans, printable circuit boards)
3. Two-and-a-half dimensional grammars (sushi, hockey pucks, candle stick)
4. Three-dimensional grammars (Froebel and Lego blocks, Palladian villas)
5. Four-dimensional grammars (folding structures)
6. Parametric grammars (shoes, clothing, shirts)

Case Study 1: Men's Custom Dress Shirts (1 month)

1. Examine Costs (energy and material use, CO_2 emissions)
2. Examine Benefits (fit, function, taste)
3. Compute Cost/Benefit Ratios for each parameter
4. Conduct Cost/Benefit analysis

Case Study 2: GreenWheel (7 months total)

1. GreenWheel Product Grammar (0.5 months)
    a) Establish GreenWheel grammar based on formal grammar exercise (define parameters for elements, set of rewrite rules).
2. Compute Cost/Benefit Ratios (1 month)
    a)Examine Costs (motors, batteries, motor controllers, etc.).
    b) Examine benefits (range, aesthetics, and torque).
    c) Establish a range of custom GreenWheels with different CBRs.
3. Design of Experiment (1 month)
    a) Create survey of potential testers to establish a range of users that represent different market segments such as urban commuters, bike messengers, bike share users, leisure, senior riders, etc.
    b) Develop a configurator (paper or online) for users to design their own GreenWheel.
    c) Conduct user survey by utilizing social networking sites like Facebook, biking clubs, and local bike shops, etc. to solicit testers.
    d) Select ideal range testers from survey.
4. Build/Fabricate GreenWheels (2 months)
    a) 5-10 different custom GreenWheels (number determined by total budget).
5. User Testing (1.5 months)
    a) Match GreenWheels with ideal testers (determined by survey results).
    b) Conduct user-test that includes daily use analysis (2-4 weeks).
6. Analysis of cost/benefits and use patterns (1 Month).

Conclusion (Writing Period) (3 months)

Summary of Timeline

Task	Duration (months)
Formal Grammars (1, 2, 2.5, 3, 4-dimensional, parametric)	1
Case Study 1: Men's Custom Dress Shirts	
Cost/Benefit Analysis	1

Case Study 2: GreenWheel	
GreenWheel Product Grammar	0.5
GreenWheel Cost/Benefit Ratio/Analysis	1
Design Experiment	1
Fabricate GreenWheel Designs	2
GreenWheel User Testing Period	1.5
Evaluation and Analysis of test	1
Conclusion (writing period)	3
Total	12

Expected Results

The PhD's original contribution will be to quantify the value and effectiveness of customization in the design of products. This research will establish a theoretical and formal framework for making strategic design decisions in the development of customizable products by critically thinking what constitutes a *meaningful* level of customization. Quantifying the exact benefits of customization will enable the breakdown of the core features of the product in order to discover which elements should exhibit a high level of customization and which elements are better to be standardized. Quantifying the costs of customization will bring insights on what the true costs are from the perspective of the user, manufacturer, and the environment. Quantifying the benefits will help determine the true value of performance and its affect on product use. The ratio between costs and benefits will then provide a guideline on how best to customize a product. In some cases, little or no customization will be necessary, in other cases, a complete custom solution will be appropriate.

This thesis will also map out the theoretical linkages between level of customization, formal product grammars, and real world testing of the product. Often, the effectiveness of any customization strategy is never tested after the product leaves the manufacturers, this thesis will begin to build a model that can be tested, improved, and retested in order to gain a full understanding of how these systems work.

In the course of executing the research, the thesis will create following:

1. <u>Custom Product Storyboards</u> – An illustrative narrative of the product design, customization, manufacture, distribution, and use of the product. Successive story boards will then distill the key costs and benefits as inputs in the narrative.

2. <u>Demos</u> – GreenWheel Product Grammar (3D models, Product Trees, Customized GreenWheels)

3. <u>User Survey and Beta Test</u> – The design of an experiment that can be tested with a set of customized GreenWheels given to beta testers.

4. <u>Video Documentation</u> – recordings of the product survey and configuration along with footage of user testing.

Required Resources
Case Study 1: Men's custom dress shirts (Travel for data gathering).
Custom GreenWheels for Beta test (Approximately 5-10 GreenWheels).
Smart Phones for capturing data from users (Approximately 5-10).

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Short Bio

Ryan Chin is PhD student at the MIT Media laboratory in the Smart Cities research group. His research focuses on the development of personal urban mobility systems that tackle the problems of energy efficiency, congestion, and pollution in today's crowded cities. He has led and managed the design development of lightweight electric vehicles (LEVs) including the CityCar, RoboScooter, and GreenWheel electric bicycle. He has also led in the development of "Mobility-on-Demand" Systems – a network of one-way shared-use LEVs enabled by electric charging infrastructure and smart fleet management systems. In 2007 Chin co-founded the MIT Smart Customization group with Professors William J. Mitchell, Marvin Minsky, and Frank T. Piller with the task of improving the ability of companies to efficiently customize products and services across a diverse set of industries and customer groups. Chin at MIT earned a Master of Science in Media Arts and Sciences (2004) and a Master of Architecture (2000); and Bachelor's degrees in Civil Engineering and Architecture from the Catholic University of America (1997).

FRANK THOMAS PILLER
CURRICULUM VITAE

Contact

RWTH Aachen, Technology & Innovation Management Group, RWTH School of Business,
Templergraben 64, 52056 Aachen, Germany | piller@tim.rwth-aachen.de

+49 241 809 3523 Office | +49 163 605 0276 Cell Europe | +1 617 326 3748 Cell USA | +49 241 809 3567 Fax
tim.rwth-aachen.de/piller | scg.mit.edu | mass-customization.blogs.com | open-innovation.com | twitter.com/masscustom

Academic Positions

Since March 2007	Full Professor of Management (tenured), Business School, RWTH Aachen University, Germany Chair, Technology and Innovation Management Group, RWTH Aachen University, Germany (tim.rwth-aachen.de)
Since 2007	Co-Director, MIT Smart Customization Group, MIT Design Lab, Massachusetts Institute of Technology (MIT), Cambridge, MA, USA (scg.mit.edu)
Oct 2004 - Jan. 2007	Research Fellow, Massachusetts Institute of Technology (MIT), MIT Sloan School of Management, BPS / Innovation & Entrepreneurship Group (Head: Eric von Hippel), Cambridge, MA, USA
2001-2007	Position comparable to an "Associate Professor" (Reader), Department of Information, Organization & Management (Head: Prof. R. Reichwald), TUM Business School, Technische Universität München (TUM), Munich, Germany *(on leave of absence 2004-2007)* Director: TUM Research Group Customer Driven Value Creation (formerly: TUM Research Group Mass Customization and Customer Interaction)
Spring 2004	Visiting Professor, Hong Kong University of Science and Technology (HKUST), Department of Industrial Engineering and Engineering Management
Summer 2001	Visiting Scholar, Hong Kong University of Science and Technology (HKUST) , Advanced Manufacturing Institute
1999-2000	Position comparable to an "Assistant Professor" (Lecturer), Department of General & Industrial Management (Head: Prof. R. Reichwald), TUM Business School, TUM, Munich, Germany
1995-1999	Lecturer and Research Assistant, Department of Production and Operations Management, Julius-Maximilians-Universität Würzburg, Germany

Academic Education

July-Aug 2009, Jan. 2010	HBS Global Colloquium on Participant Centered Learning. Intensive executive education program on better teaching with the case method. Harvard Business School, Boston.
2001-2004	Habilitation (research program leading to tenured professorship within the German, Swiss, and Austrian university systems), Habilitation thesis on "Innovation and Value Co-Creation: Evidence and Implications of Integrating Customers & Users in the Innovation Process", completed in Sept 2004; evaluation completed with highest distinction in April 2005.
1995-1999	Ph.D. studies (Dr. rer.pol.) in Business Administration (Production and Operations Management) at the Julius-Maximilians-Universität Würzburg, Germany, Ph.D. thesis on "Mass Customization", with highest distinction ('summa cum laude')
1989-1994	Bachelor and Master ("Diplomkaufmann") in Business Administration (majors: Production & Operations Mgmt, Marketing) at Julius-Maximilians-Universität Würzburg, Germany; GPA: 1.5 (on a scale from 1.0 'outstanding' to 5.0 'insufficient'), Top 1% of the graduating class

Business Work Experience

1999-2007	**ThinkConsult Unternehmensberatung** Piller, Rogoll, Schaller & Tasch Partnerschaft, Munich, Germany: Co-Founder and Managing Partner: Management Consultancy and Corporate Education
2001-2007	**Adidas AG**, Herzogenaurach, Germany, and Portland, USA: Process Consultant & Coach to the BU Director Mass Customization (Coaching and Consulting Assignment; Action Research Project)
1993	**Unilever B.V.**, Utrecht, The Netherlands: Consumer Marketing Iglo-Ola (Traineeship)
1992/93	**Holzbrinck AG**, Mainpresse Würzburg, Germany: Marketing Management (Project Studies)
1991	**Voest-Alpine Group**, Graz, Austria: Information management / PPC systems (Internship)

Board Positions & Technology Transfer (Spin-off companies)

Since 2000	**corpus.e AG**, Stuttgart (manufacturer of 3D scanning solutions and mass customization toolkits), member of the board of directors
Since 2009	**Dialego AG**, Aachen (provider of advanced market research techniques for the new product creation process, online panels), member of the board of directors
2006-2009	**My Virtual Model, Inc.**, Montreal (provider of online personalization and virtualization technologies), member of the board of directors
Since 2006	**Selve AG**, Munich (mass customization of footwear), member of the advisory board
Since 2008	**Hyve AG**, Munich (open innovation intermediary and technology provider), member of the scientific advisory committee (since 2007); member of the board of directors
Since 2000	**Think Consult**, Munich (management consultancy), co-founder and member of the management board

Affiliation with Scholarly Associations

American Academy of Marketing (AMA)

Academy of Management (AOM)

ACATECH – Akademie der Technikwissenschaften. Mitglied des Fachbeirats Produktentstehung

Erich-Gutenberg-Arbeitsgemeinschaft Köln e.V.

European Academy of Management (EURAM), founding member

INFORMS (Institute for Operations Research and the Management Sciences)

Product Development Management Association (PDMA)

The International Institute of Mass Customization & Personalization (IIMCP), founding director

Strategic Management Society (SMS)

Research

Frank Piller has been building a worldwide reputation on research about strategies of customer-centric value creation like Mass Customization, Personalization, User Innovation, and Customer Co-Creation to manage heterogeneous customer demands more efficiently. Frequently quoted in media like The New York Times, The Economist, CNN, and Business Week, amongst others, Frank Piller is regarded as one of the leading experts in this field. His blog, mass-customization.blogs.com, is the premier source of information on mass customization and customer driven value creation.

In 1997, his article in the German edition of the Harvard Business Review and his first book on mass customization (1998) brought this topic on the management agenda in Europe. His recent analysis of "Threadless" (co-authored with Susumu Ogawa), an innovative crowdsourcing business model in the fashion industry, has been selected as one of the Top-20 articles in MIT Sloan Management Review. Numerous research contracts and consulting assignments have transferred his research results into real business impact for the management practice. He has been invited to provide more than 50 keynote and plenary presentations on conferences or business meetings and 25 research seminars for the faculty of leading business schools around the world. From a methodological standpoint, Frank Piller's research includes conceptual, qualitative theory-building and quantitative theory-testing publications.

During his tenure at RWTH Aachen, he has established one of Germany's top research groups in technology and innovation management (TIM), growing its employee base from four to more than 15 full-time research positions in 2009. The RWTH-TIM Group has gained thought leadership on strategies to include information from a firm's periphery in the innovation process (open innovation), managing contingencies at the front end of the innovation process, and creating a culture for innovation. Frank Piller's research is supported by grants from industry and the Deutsche Forschungsgemeinschaft (DFG), German Federal Ministry of Research (BMBF), the European Community, and other institutions.

Academic Honors and Research Awards

2009	Listed in the **Top-100 Research Performance Ranking** of German speaking professors of business administration (Handelsblatt/VHB ranking); research performance measured by publication impact 2004-2009; ranked in top 3 percentile out of more than 2100 professor in Germany, Switzerland and Austra across all disciplines of business administration.
2008	Named as **"The International Leading Expert"** in the field of customized products by EPSRC, the Engineering and Physical Sciences Research Council of the United Kingdom.
2008	Invited Member to an **Expert Panel on Innovation advising President Horst Köhler** (President of the Federal Republic of Germany)
2008	Appointed **RWTH Representative of the German Scholarship Foundation** (Studienstiftung des Dt.Volkes)
2006	Paper "Reducing the Risk of New Product Development" (MIT Sloan Management Review) elected into the **"Top 20 of Articles Chosen by Business School Faculty"** (with S. Ogawa)
2006	**Appointment offer of full chaired Professor of Management**, Technology & Innovation Management Group, RWTH Aachen University, Aachen, Germany *(accepted)*
2006	**Appointment offer of full Professor of Management**, Innovation Management Group, Zeppelin University, Friedrichshafen, Germany *(rejected)*
2005/06	**Research Fellowship of DFG / Deutsche Forschungsgemeinschaft** (German National Science Foundation)
2004	HICSS 2004 **Best Track Paper** "Customers as part of value webs" (with R. Reichwald)
2002	**Award for Scientific Achievements of the Unterfränkische Gedenkjahrstiftung** (Wissenschaftspreis 2002 der Unterfränkischen Gedenkjahrstiftung für Wissenschaft)
2002	**Nomination for the Heinz Maier Leibnitz-Preis 2003** by the President of the Technische Universität München (highest German award for young scholars)
2000	**Poco-Handels-Preis of the University Witten-Herdecke** for the book "Mass Customization"
2000	**First Price of the Foundation of the German Industry** (Stiftung Industrieforschung) for the book "Mass Customization"
1999	**Wolfgang-Ritter-Preis for Scientific Contributions in Management Research** for the Ph.D. thesis
1991	Fellow of the **German Scholarship Foundation** (Studienstiftung des deutschen Volkes)

***Invited keynotes and plenary addresses**: See list of publications*