EXPLORATORY RESEARCH ABOUT THE CUSTOMIZATION OR PERSONALIZATION OF ASSISTIVE PRODUCTS FOR WALKING

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Abstract

This paper presents an exploratory study performed in the context of the assistive products for walking. The aim was to verify the applicability of design strategies to increase the users' perceived value via the offer of controlled levels customization. For that, lean principle of standardization and the taxonomy of customization levels from the mass customization approaches guided this study. These concepts focused the research into design patterns identification, allowing the use of combinatorial modularization. The efforts consisted in a technologic research made in Abledata and Assisdata AT databases, which resulted in a selection of 200 walking aids and accessories. After, their features were analyzed, with special attention to the products architecture. The investigation concluded that assistive products for walking are able to incorporate high levels of product customization. This may be implemented by the design of a flexible modular product body configurable in different ways. Thus, the product differentiation between canes, crutches and walking frames, for example, will be done by an adaptable body and the respective accessories to complete the product structure.

Keywords: Lean design, Mass Customization, Walking aids, Modularization, Personalization

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

Product Development (PD) is the organizational activity charged of the definition of the product features, impacting consumers' satisfaction, production performance, suppliers operations etc. Thus, PD is often under pressure to ensure the success of a business. In the development of Assistive Technology (AT) products for disabled people the challengers in terms of customer's satisfaction and economic viability are even greater. In fact, AT users are very sensible to the trade-offs between personalized products, to respond specifics needs, or standardized product, which have a lower price.

Despite of the benefits delivered by AT use, studies reveal issues with its abandonment. It may emerge from personal factors, such as the acceptance of disability or changes in user's needs. Further, AT devices rejection is also linked with the PD decision, like product's features (durability, aesthetics etc.) and performance (comfort, usability etc.). It implies in improvement opportunities in the methods used on AT design (Phillips & Zhao 1993; Riemer-Reiss & Wacker 2000; Scherer et al. 2005).

Accordingly, this paper presents partial results of a research in progress which aims to propose a methodology for concept development of AT for personal mobility. This proposition aims improve customers' perceived value through affordable product variety (customization or personalization) to fit specific user's needs. Thus, the article presents the outcomes of an exploratory research of walking aids devices where were analysed the approach used on the AT design and the products' architectures.

The section 2 covers AT concept, classification and approaches of design. The section 3 presents the research method. The section 4 details the theoretical basis of the research. The section 5 presents research results. Finally, the section 6 gives the conclusions and identifies future research directions.

2 ASSISTIVE TECHNOLOGY: DEFINITION, CLASSIFICATION AND DESIGN

The definition of AT adopted in this study came from the norm ISO 9999, which details what is AT, how it is designed, made and delivered, and the benefit it provides. Thus, AT is defined as any "device or software, especially produced or generally available, used by or for persons with disability for participation; to protect, support, train, measure or substitute for body functions or structures and activities; or to prevent impairments, activity limitations or participation restrictions" (ISO 2011).

The norm ISO 9999 brings a wide terminology of AT, offering several categories of similar AT classified according to the delivered functions. For example, it details AT for housekeeping, communication, personal mobility etc. The norm is linked with the International Classification of Functioning, Disability and Health (ICF) from World Health Organization, which may be useful in characterization of users' needs in a design process (Bougie & Heerkens 2009; WHO 2001; ISO 2011).

There are two categories of approaches used in AT projects (Table 1). In the former the designers try to universalise the product including the widest spectrum of users. This approach is based on standardization and economies of scale. However, in the rehabilitation perspective, the products are specialized for each need and manufactured in small batches. Because of this, some AT unaffordable without the help of governments or charitable bodies (Couvreur & Goossens 2011; Plos 2011).

Table 1. Design Approaches for Assistive Technology

Approaches	Universalist	Specialized
Bases	Mass Production; Economies of Scale	Small Batches; Tailored Products
Results	Inexpensive and poorly adapted products	Expensive well-fitted products

The specialized branch contains practices like adaptable design, rehabilitation design and design for disability. In the first, adaptations in standard products are made, allowing its use by disabled people. In the second, the solutions are unique and adapted to a person or a small group. The last one consists in develop technical aids for everyday life and buildings adaptations. In turn, the universalist branch minimize the need for product adaptations via inclusive or barriers-free design. Moreover, some design principles are proposed, such as equitability and flexibility in use, perceptible information, tolerance for error, low physical effort etc. (Plos 2011; Mcguire et al. 2006; Wobbrock et al. 2011).

Thus, it is important to develop a convergence between these extremes in order to exploit both approaches' advantages. That means an balance between the complete standardization and the increasing demand of higher levels of product personalization or customization (Silveira et al. 2001).

3 RESEARCH METHODOLOGY

This paper brings the results of an exploratory study about walking aids for personal mobility, such as canes, crutches and rollators. A broad spectrum of products available in the market was analysed in order to verify design patterns in order to increase products' variety to fit the user's needs. Furthermore, the design approach used on products' design was examined in order to indicate if a product is universal or specialized to disabled people, or if it was originally design for disability or adapted later. To achieve those aims, the research followed the phases presented in the Figure 1.

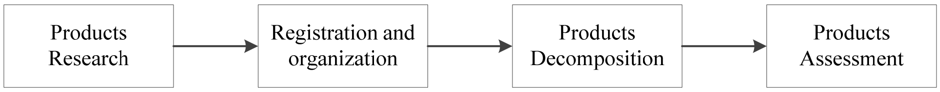

Figure 1. Phases of exploratory study of walking aids for personal mobility

The products were searched via some AT databases like Abledata and Assistdata, which allowed the selection of 200 products to compose a landscape of walking aids the offered. Then, the products were registered and organized according to the ISO 9999 structure. Important data were collected, like product features, images, technical diagrams, instruction manuals, product's variants etc.

Thereafter, the data was analysed via product decomposition into elements, which provides insights into the structure of the problem and the choice of architecture (Pimmler & Eppinger 1994). Thus, the products assessment was done the guide presented in the Table 3, which divides the phase in design approach and product architecture dimensions. Each phase was performed in the MS Excel due to its flexibility to alterations, which was important when some topics or insights emerged in the research.

Table 3. Products Assessment Guide

Dimension	Variables	Investigated Concepts	Method of analysis
Design Approach	Specialized	Adaptable design, design for disability and rehabilitation design	Check-list to assessment of product features
	Universalist	Universal Design	
Product Architecture	Product variants	Levels of Customization or Personalization of Products	Identification of core product and product variants
	Architecture types	Modular or Integral	Integration analysis of product decompositions
	Modularity criteria	Product complexity, final product configuration, stability of the function and nature of interfaces	

4 LEAN PRODUCT DEVELOPMENT AND MASS CUSTOMIZATION

A bibliographic research preceded the exploratory study, providing the theoretical basis to the walking aids assessment. Lean product development (LPD) and mass customization (MC) were considered the approaches that bring more contribution for the research, taking into account the aim of improve customers' perceived value through affordable product variety. Moreover, both approaches use the products platforms strategy for allowing products variety (León & Farris 2011; Silveira et al. 2001).

The LPD is defined as an approach that gathers cross-functional design practices (techniques and tools) governed by the lean principles of value, value stream, flow, pull, and perfection. LPD concentrates the efforts of development in the maximization of customers' value and the elimination of waste, such as engineering mistakes or inefficiency (León & Farris 2011; Morgan & Liker 2006).

There are some LDP frameworks in the literature, and one of the most complete categorizes the LPD principles in three subsystems: process, people, and tools and technology (Morgan & Liker 2006). In this work, the analyses were centred in the process subsystem, even if the others are also important. Yet, it is difficult to analyse people, and tools and technology regarding only the final result of PD.

The process subsystem englobes the PD tasks and theirs flow. The main principle is the establishment of customer's value. After, the second principle highlights the importance of front-loading the PD in order to explore concurrent alternatives in a broad design space. Then, the emphasis moves toward the creation of levelled PDP flow (third principle), which is allowed by initiatives like standardization (fourth principle) to reduce variation, create flexibility and predictability (Morgan & Liker 2006).

The MC is a production strategy focused on the broad provision of personalized products, mostly through modularized product design, flexible processes, and integration with supply chain members. Design postponement is an element that enables MC initiatives, which is the stage where customers may influence the design and the manufacture (Fogliatto et al. 2012). The Table 2 presents different levels of customization or personalization, or the points of postponement offered (Silveira et al. 2001).

Table 2. Levels of Customization or Personalization of Products (Silveira et al. 2001)

Customization Level	Definition
Usage	Products that can be adapted to different functions or situations
Package and distribution	Packaging similar products in different ways for each market segment
Additional Services	Adding custom work or services to standard products, often at the point of delivery
Additional Custom Work	
Assembly	Arranging of modular components into different configurations
Fabrication	Manufacturing tailored products following basic, pre-defined designs
Design Collaborative	Collaborative project according to individual customer requirements

From these concepts, the research emphasizes converged to the principle of standardization, focusing in design patterns identification. This allows the development of product platforms with modular architecture, which aims to respond to a heterogeneous customer demand through a controlled product variety. Therefore, the next subsection is centred in the aspects of product architecture modularization.

4.1 Design standardization: controlling customization through modularity

Product architecture is the scheme by which the function is allocated to physical components of a product (Ulrich 1995). In turn, modularization is a strategy of product architecture that enhances the development of family of products and the offer of customization or personalization. There are some dimensions of modularity: the stability of the function allocated to components, how the final product configuration is built and the nature of interfaces (Salvador et al. 2002).

In relation to the function stability, the modules can be basic and auxiliary, that implement common functions in a product family; special, that implements functions present in some variants; and adaptive, that implements functions to marginal conditions. The final configuration is built via component swapping; fabricate-to-fit, changing a continuous component; matching any component in a bus component; and mixing arbitrarily components set. In terms of interfaces, they can be different among components (slot); identical to every components (sectional); and identical with a central (bus) component (Salvador et al. 2002; Pahl & Beitz 1984; Ulrich & Tung 1991; Ulrich 1995).

From those variables derives the concept of combinatorial modularity, which is a generalization of component swapping via slot interfaces. In fact, the component swapping and combinatorial modularity are two extremes of a spectrum of situations with a gradually increasing incidence of component families to common components. In the combinatorial level, the whole product's structure is variable (Figure 2) and the product family earns the components family layer (Salvador et al. 2002).

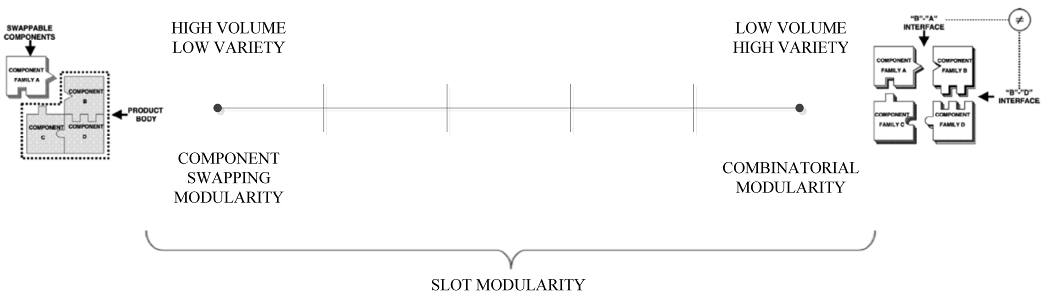

Figure 2. Component swapping - combinatorial modularity spectrum (Salvador et al. 2002).

The next sessions presents the results of an investigation on design patterns of walking aids devices. To achieve this, the products were decomposed in systems and subsystems, and their architecture was analysed taking into account the dimensions of modularity. Furthermore, the implementation of combinatorial modularity was studied in order to increase of product variety available.

5 WALKING AIDS DEVICES STUDY

This section presents the results of the analyses realised on assistive products for walking manipulated by one and both arms, and their accessories. Such investigations had a twofold perspective: the design approach (session 5.1) used in the products design and the product architecture (session 5.2). The former aspect permitted to identify how the assistive products are originated and the impact of design approach in terms of personalisation and customization. After that, the investigation was conducted towards the product architecture assessment in a perspective of compatibility between combinatorial modularity concept and the architecture of selected products.
There is an enormous quantity of assistive products for walking available in the databases. Thus, the definition of some criteria of selection was required. The product was selected whereas (1) it is classified as a walking aid and whereas (2) it brings at least one different solution when compared to the others devices already registered. This difference could a way to deliver a function, the presence of additional attributes, innovations in terms of shapes or other breakthroughs. The Table 4 presents a balance sheet of selected products in the 3 subclasses enrolled in the research.

Table 4. Researched Products

Subclasses of Researched Products	Number
Assistive products for walking, manipulated by one arm	48
Assistive products for walking, manipulated by both arms	25
Accessories for assistive products for walking	127
Total	200

5.1 Design Approach

The first analysis was made in terms of main design approach identified in the products' conception. Walking Aids for Personal Mobility are rather specialized (95% of selected products) then universalist products (5% of selected products). According to the Figure 3, this characteristic is also verified in the detailed categories, even if the AT for walking manipulated by both arms (walk frames, e.g.) are rather designed for disabled people then those manipulated by one arm (canes and crutches, e.g.) and their accessories. The larger presence of adapted or universal products was identified among the accessories responsible for specific purposes, such as properly grip or to improve the safety of a walking aid.
An analysis of Figure 3 suggests that such products might be well adjusted to the users' needs, because there is a large concentration in specialized devices. For the same reasons, there is a high expectation in terms of customization or personalisation. However, the selected walking aids demonstrated to be rather standardized (38.5% of selected products) or with low degree of customizability (Table 5).

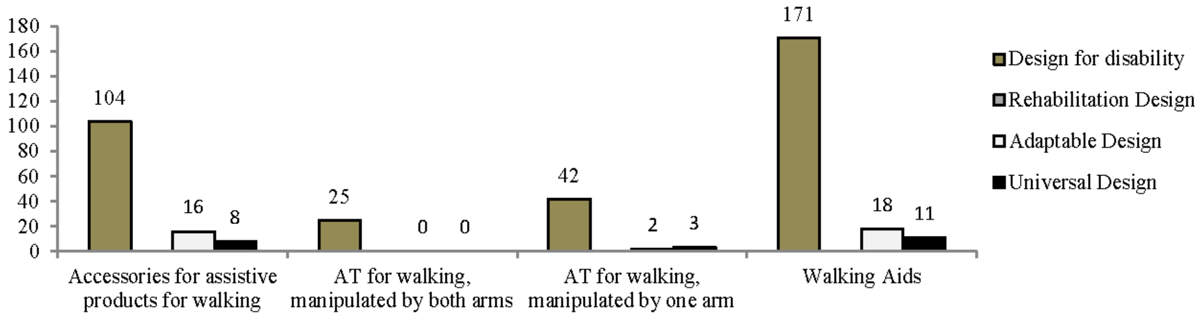

Figure 3. Design Approach used in the Walking Aids

In terms of customization, adaptations in the Usage phase, such as embedded size adjustments, were identified (50.5% of products). Besides, Additional Custom Work like size and aesthetic options (29.0%), and little amount of customization during the product Assembly (3.0%) are available. In the latter, the possibilities are centred in assembling additional modules in a way to convert the product category (from cane to crutch, e.g.); or changing the product size. Technical changes modifying the product performance are also available, like product's tips permutation to respond to different needs.

Table 5. Researched products

Customization Type	Walking aids (1 arm)	Walking aids (2 arms)	Accessories	Total
Standardization	2	0	75	77
Usage	43	25	33	101
Additional custom work	19	18	21	58
Assembly	6	0	0	6

The Table 5 shows a different scenario in terms of customization levels in the bottom level (categories) compared with of walking aids as a whole. Those manipulated by one arm can be standardized (4.3%), adjustable in the use (91.5%), in the assembly (12.8%) or with additional custom work (40.4%). On its turn, all devices manipulated by both arms are adaptable in the use and 72% of them are customizable with additional work. Finally, the majority of its accessories are standardized (58.6%), and the remaining are customizable while using (25.8%) and by additional work (16.4%).

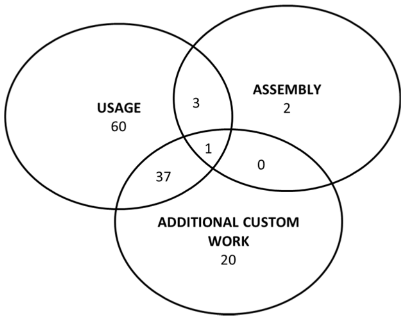

Figure 4. Intersection among Customization Levels available in the selected Walking Aids

The degree of embedded customization in walking aids manipulated by both arms was high. Thus, all products include size regulations and some permit aesthetics choices and embedding accessories. The same aspects were found in the walking aids manipulated by one arm. Even whereas the product emerges from an Adaptable Design, such as hiking sticks converted in canes, the adaptation is embedded in the product (size regulations). On the other hand, although the accessories are rather standardized, they allow the customization in terms of functions aggregation to a walking aid.

It was also interesting to verify whereas a product had more than one type of customization. The result of this assessment (Figure 4) indicates a large co-existence of adaptation in the Usage and Additional Custom Work, which might indicates a high degree of customizability. Yet, in these types of customization the products' features are defined taking into account population anthropometric averages. It has negative impacts in the product customization or personalization.

Furthermore, others types of customization such as Package and Distribution, Additional Services, Fabrication or by Collaborative Design were not verified in the selected products. It suggests the existence of improvement opportunities in terms of fitting the customer's needs, which may be responded in the product design process, with consequences in the product architecture.

5.2 Product Architecture

The investigation about the product architecture was initially performed with regard in the assistive products for manipulated by one arm and those manipulated by both arms. The accessories were analysed in a second moment, and this was made in function of conclusions from the former analyse.

The first issues investigated in the selected products were the type of architecture presented (modular or integral) and their complexity, concerning the number of elements and the technology embedded.

The analysis exposed that almost all products are modular. The only product with integral architecture is a one-piece cane. With respect to the complexity, it was verified that 70% products are composed in less than 10 pieces and the rest to do not reach to 100 pieces. In sequence, a products technology exam revealed that those products are mainly mechanical products without sophisticated components.

After, the analyses focused the modularity criteria, in particular the how final product configuration is built, the nature of interfaces between components and stability of the function allocated to the component. The first two aspects were analysed for the product as a whole. However, with respect to

the function stability, a decomposition of products in systems and subsystems was required. From this, the function performer by each item was classified as basic or auxiliary, special and adaptive.
The final configuration of modular product products presented in the selected products showed that those products use almost exclusively component swapping modularity. Just one product is designed with other configuration, which is fabricated-to-fit modularization. Concerning to the nature of interfaces, the result in terms of concentration in one type of morphology was similar. In almost products the modules were connected by slot modularity. These results in these variables showed that the walking aids architecture allows its evolution toward the combinatorial modularization utilization.
However, the characteristics found in those variables are necessary but insufficient to ensure the combinatorial modularization bases. For that, the product's architecture was investigated through hierarchical in subdivisions in order to demonstrate the stability of functions allocated. In this sense, it was essential to define a core product as a reference to classify basic, special and adaptive functions.
For instance, the ISO 9999 norm lists assistive products for walking manipulated by one arm as walking sticks and canes, elbow crutches, forearm support crutches, auxiliary crutches, walking sticks and canes with three or more legs, walking sticks and canes with seat and lateral support frames. If this detailing level was used, the core product for walking sticks and canes and walking sticks or canes with seats would not be composed with the same functions set. The same would happen with the different crutches types and so on. Therefore, a family layer was created to identify products which could be classified as a core product loaded with basic and auxiliary functions (Table 6).

Table 6. Family layer between subclass and category of walking aids

ISO 9999 - Subclass	Family Layer	ISO 9999 - Category
Assistive products for walking, manipulated by one arm	Cane	Walking sticks and canes
		Walking sticks and canes with seat
		Walking sticks and canes with three or more legs
	Crutches	Auxiliary crutches
		Elbow crutches
		Forearm support crutches
	Walking frames (wheeled or not)	Lateral support frames
Assistive products for walking, manipulated by both arms		Walking frames
		Walking chairs
		Walking tables
		Rollators

After the introduction of a family layer, the products decomposition in systems and subsystems became more clear. It had consequences in the development of a framework permitting a certain level of abstraction concerning to the core product (basic and auxiliary functions) and the product variants carried out from the addition of elements (special and adaptive functions). In a particular example, the decomposition of canes in subsystems evidenced that those products could be conveniently divided in 4 systems (Figure 5) englobing their respective subsystems (Table 7).

Figure 5. Structure of Canes

After this previous structuration, each item was associated with the functions performed in the products. The cane as a whole was associated to the global function of increasing user's balance. After, the (1) stem performs the arm's extension toward the ground, being composed by its (1.1) structure performing the extension itself and a (1.2) size adjustment system, which adapts the product for different user's heights. After, the (2) handle performs the product interface, the (2.1) manipulation element as the interface itself, (2.2) additional holder as a provider of supplementary body support and the (2.3) Appendices are responsible for marginal support functions. In sequence, the (3) tips allow the contact with the crosswalk in a certain level of grip through its (3.1) element of contact, which can be completed by (3.2) additional elements like ice-pics and articulation. Finally, the (4) supplementary elements are used for specific transversal purposes not associated to any subsystem.

Table 7. Structures of canes in subsystems

Subsystems	Subsystem Composition	Types of Composition Found
1. Stem	1.1 Structure	"I" Stem (fixe, foldable and convertible)
	1.2 Size adjustment	Screws, pins, blockers (mountain bike, turn-to-lock)
2. Handle	2.1 Manipulation Element	Anatomical, derby, offset, round, straight, "T", york
	2.2 Additional Holder	Strap
	2.3 Appendix Element	Seat
3. Tips	3.1 Element of contact	Quad-pod, tip and tripod
	3.2 Additional Element	Articulation, pic
4. Supplementary elements	4.1 Signalling	Module Laser
	4.2 Lighting	Light

After the subdivision for all selected products and the association of parts with their respective functions, the stability of functions in the modules was analysed. In the canes example (Table 8) the components within the Stem (structure and size adjustment), the manipulation element of handle and element of contact (tips) are responsible by the functions present transversally in the canes. Some composition elements are responsible for special functions, not present in all the product variants, like appendix or additional element. On the other hand, some elements allow changes in product categories when they are present: for example a seat which reclassifies a "walking stick" into "walking stick with seat" or a tripod tip characterizing a "walking stick" into "walking stick with 3 or more legs". In fact, this subdivision permitted the comprehension of canes composition, the associated functions, and also permitted to classify the canes with seats and those with 3 or more legs as special cases of canes.

Table 8. Structures of canes and respective functions stability analyse

Subsystems	Subsystem Composition	Stability of functions
1. Stem	1.1 Structure	Basic and Auxiliary
	1.2 Size adjustment	Basic and Auxiliary
2. Handle	2.1 Manipulation Element	Basic and Auxiliary
	2.2 Additional Holder	Adaptive modules
	2.3 Appendix Element	Special modules
3. Tips	3.1 Element of contact	Basic and auxiliary, Special or Adaptive modules
	3.2 Additional Element	Special modules
4. Supplementary elements	4.1 Signalling	Special modules
	4.2 Lighting	Special modules

The same process was carried out with crutches and walking frames. It permitted to concentrate the research work in searching similar functions in products toward the recognition of a mainstreaming between different products. The final disposition resulted in a generic structure to understand and generalize the design of assistive products for walking in the divisions presented in the Table 9.

Table 9. Generalization of assistive products for walking structure

Canes	Crutches	Walking Frames	Generalization
Handle	Body Support	Handle	Supports
Stem	Stem and Handle	Chassis & holders	Product Body
Tips	Tips	Tips and wheels	Ground contact
Supplementary elements			Supplementary elements

After these analyses done in the assistive products for walking manipulated by one or both arms, the investigation was concentrating in the selected accessories for walking aids. In this phase, the family layer was also helpful, since it permitted the abstraction level required to propose a generalized structure for assistive products for walking presented in the Table 8. Thus, the accessories categories (ISO 9999) showed to be well-adjusted to each subsystem proposed in the structure (Table 10).

Table 10. Relation between assistive products for walking structure and theirs accessories

Family Layer	ISO 9999 - Category
Support	01 Accessories for walking aids to provide support for specific parts of body
	02 Pads, cushions and other items to prevent bruising or skin injury
	03 Products to properly grip walking aids
	04 Seats for walking aids
Product Body	05 Accessories to adjust height of rollators and walking frames
Ground contact	06 Accessories to help manoeuvre walking aids
	07 Tips for walking aids
	08 Tyres and wheels for walking aids
Supplementary elements	09 Accessories attached to walking aids to hold or carry objects
	10 Lights and safety signaling devices for walking aids
	11 Products to hold walking aids in place when not in use

The association between the categories of accessories and the subsystems defined as a generic structure of assistive products for walking (Table 10) was used as a guide to compose walking aids' architecture by a modular product body and for assistive products for walking. The product body, composed by structure and size adjustment subsystems would be composed by a tubular that allows the body adaptation in a twofold way.

Table 11. Architecture of Walking Aids: relation between structures and accessories

Subsystem	Subsystems Composition	Basic	Special	Adaptive
Body	Structure	-		
	Size Adjustment	05	05	
Support	Manipulation element	03	03, 04	03
	Additional Holder	01	01, 04	01, 04
	Appendices Elements		03	
Ground Contact	Element of contact	07, 08	07, 08	07, 08
	Additional Element	06	06, 07	
Supplementary elements	Transversal Functions		09, 10, 11	

The modules assemblage permitting the body modification within a family layer (canes, e.g.) or even among different layers, assembling different bodies with the same modules set. After, for each function required a choice would be made in accessories associated with that functionality. Through the Table 11 is possible to understand how it may works.

6 CONCLUSION

This article presented the results of an exploratory study performed about products for personal mobility, in particular assistive products for walking. The aim was to verify the applicability of design strategies that allows the offer of controlled levels of product customization or personalization, such as combinatorial modularization. The analyses results demonstrate that the architecture of these products allows the use of product platform strategies. On the other hand, even if products architecture are enough simple and easily decomposable in modules, the level of customization available is weak.

Design patterns were identified through the insertion of a family layer in the ISO 9999 framework and the products decomposition in systems and subsystems. It made clear the potential connections among assistive products for walking and combinatorial modularization. In this sense, these products could be designed via the definition of a modular structure where accessories would be assembled to make products variants. The implementation of such suggestion would push engineering creativity toward customer-value improvement tasks, allow modules sharing, cost reductions and so on. In the context of walking aids, it would mean the concentration of design efforts in designing a modular structure that could be flexible in different levels of product differentiation (categories, family layer or higher). This research is inserted in a larger context of increasing the AT perceived value by the users. Thus new investigation phases are previewed. First of all, the proposition of design a flexible structure will aim an action research which can demonstrate its viability. Moreover, the results of this work will be studied toward the definition of product's value by the users. In particular the authors will study the potential links with the International Classification of Functioning, Disability and Health and PD activities of identification of clients' needs and definition of product's requirements. Finally, the method in the process of elaboration will be tested in other mobility devices listed in the ISO 9999, like motorized and no-motorized vehicles, vehicles adaptations and devices to transfer, turning and lifting and orientation. It will provide opportunities to improve the method and making it versatile to different product designs.

REFERENCES

Bougie, T. & Heerkens, Y., 2009. ISO 9999 with ICF – References, Available at: http://www.rivm.nl/who-fic/in/ISO9999withICFreferences.pdf.

Couvreur, L. De & Goossens, R., 2011. Design for (every) one : co-creation as a bridge between universal design and rehabilitation engineering. CoDesign, 7(2), pp.107–121.

Fogliatto, F.S., Da Silveira, G.J.C. & Borenstein, D., 2012. The mass customization decade: An updated review of the literature. International Journal of Production Economics, 138(1), pp.14–25. Available at: http://dx.doi.org/10.1016/j.ijpe.2012.03.002.

ISO, 2011. ISO 9999: Assistive products for persons with disability - Classification and terminology 5th ed. International Organization for Standardization, ed., Bruxelles: International Organization for Standardization.

León, H. & Farris, J., 2011. Lean Product Development Research: Current State and Future Directions. Engineering Management Journal, 23(1), pp.29–52.

Mcguire, J.M., Scott, S.S. & Shaw, S.F., 2006. Universal Design and Its Applications in Educational Environments. Remedial and Special Education, 27(3), pp.166–175.

Morgan, J.M. & Liker, J.K., 2006. The Toyota Product Development System: Integrating People, Process And Technology 1st ed., New York, New York, USA: Productivity Press.

Pahl, G. & Beitz, W., 1984. Developing size ranges and modular products. In K. Wallace, ed. Engineering Design. London: The Design Council, pp. 315–361.

Phillips, B. & Zhao, H., 1993. Predictors of assistive technology abandonment. Assistive Technology, 5, pp.36 – 45.

Pimmler, T.U. & Eppinger, S.D., 1994. Integration analysis of product decompositions. ASME Design Theory and Methodology Conference, (September), pp.1–10.

Plos, O., 2011. Méthodologie de conception de produits adaptée aux marchés de niche : application au marché du handicap moteur. Paris Institute of Technology.

Riemer-Reiss, M. & Wacker, R., 2000. Factors associated with assistive technology discontinuance among individuals with disabilities. Journal of Rehabilitation, 66(3), pp.44 – 50.

Salvador, F., Forza, C. & Rungtusanatham, M., 2002. Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. Journal of Operations Management, 20, pp.549–575.

Scherer, M.J. et al., 2005. Predictors of assistive technology use: the importance of personal and psychosocial factors. Disability and rehabilitation, 27(21), pp.1321–31.

Silveira, G. Da, Borenstein, D. & Fogliatto, F., 2001. Mass customization: Literature review and research directions. International Journal of Production Economics, 72(49), pp.1 – 13.

Ulrich, K., 1995. The role of product architecture in the manufacturing firm. Research Policy, 24(3), pp.419–440.

Ulrich, K. & Tung, K., 1991. Fundamentals of product modularity. In ASME Winter Annual Meeting Symposium on Design and Manufacturing Integration. Atlanta, pp. 73 – 79.

WHO, 2001. The International Classification of Functioning, Disability and Health: ICF W. H. O. 2001, ed., Geneva: World Health Organization.

Wobbrock, J., Kane, S. & Gajos, K., 2011. Ability-based design: Concept, principles and examples. ACM Transactions on on Accessible Computing, 1(212), pp.1–36.