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PERSONALIZATION IN THE AUTOMOTIVE AND BUILDING SECTOR – RESEARCH PROGRAM OF THE HIGH-PERFORMANCE CENTER »MASS PERSONALIZATION« IN STUTTGART

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Abstract: *In October 2017, the High-Performance Center »Mass Personalization« was launched in Stuttgart, a research initiative of the local Fraunhofer Institutes and the University of Stuttgart. The pilot phase of 2.5 years focusses on the major requirements of enabling technologies for successfully transferring Mass Personalization into the health, automotive and building sector. The research program is divided into 3 sector-related pilot projects with focus on an early involvement of the related industries to ensure that the developed methods and processes meet the requirements for industry application. This paper presents the pilot project 2, which is related to the automotive and building sector.*

Key Words: ***Mass Personalization, building industry, automotive industry, consumer products, personalized living spaces, enabler development***

1. INTRODUCTION

Individualization is a megatrend [1]. There is no doubt that the demand of personalized products and services will significantly increase in the future. New products that are tailored to the needs of changing users as well as to the versatile and situation-dependent user requirements will lead to new business models and markets. For this transformation, a close communication with the end user is necessary, which also offers high potential for a new dimension of sustainable customer relations.

The central research topic of the Stuttgart High-Performance Center Mass Personalization (German: Leistungszentrum Mass Personalization) is the development of products that meet detailed individual user requirements and covers a wide range of solutions, from enabling technologies for »lot size 1« scale production at the cost of mass production to the development of transformer products that continuously adapt to user requirements throughout their life cycle. The research initiative, supported by the state of Baden-Württemberg and launched in October 2017, involves a close co-operation of the four local Fraunhofer Institutes and currently eight institutes from the University of Stuttgart.

Main goal of the pilot phase of 2.5 years is the identification of the main requirements and the development of technologies that enable Mass Personalization in industry. These core technologies are referred to as enablers and are developed to address central cross-industry problems in the field of Mass Personalization. Therefore, early involvement of partners from various industries constitutes a key factor for the success of the Mass Personalization initiative.

Within the pilot phase of the initiative, the research is structured into 3 pilot projects covering the health, automotive and building sectors.

The research of pilot project 2 “Personalized Living Spaces” is focused on the development of enablers for Mass Personalization in the automotive and building sector.

2. PILOT PROJECT 2 »PROCESS CHAINS FOR PERSONALIZED LIVING SPACES«

2.1. General idea and framework of the pilot project

The goal of the pilot projects is to develop a generic methodological framework as well as the enablers for the integrated process chains that are required to create the products that allow the personalization of living spaces. These process chains cover all steps from the user involvement in the entire product engineering and production process to product-accompanying services and user interaction during product use.

Within pilot project 2, four different process chains are investigated that are to create essential products for living space personalization. Modular buildings set the scene for the first living space: people’s home. The automobile transformer not only connects people to other living space but also forms another living space by itself. Next to the general functionality of living spaces, consumer products and service models play a central role in living space personalization and require uninterrupted user experience between the different spaces.

Next to covering essential product types, these process chains were selected, as they clearly differ from each other regarding the degree and type of individualization, product development, planning and design processes as well as their utilization and life cycles. At the same time these process chains are facing similar challenges in terms of personalization and thus serve well for the development of cross-industry enabling technologies. The underlying cross-industry challenges can be summarized by the following questions:

- What do users need (e.g. specification and requirements)?
- What is the appropriate solution and how can it be implemented under the premise of Mass Personalization (e.g. integrated product development and manufacture)?
- How can be ensured that users find the appropriate solutions and that they use these solutions to meet their detailed individual requirements (e.g. seamless services and business models, integration of further products to enhance the personalization of living spaces)?

The goal of the pilot project is to develop a central basis of enablers that can be easily transferred or adapted to the specific frame conditions of the investigated process chains. Therefore, the general approach of the pilot project (see figure 1) follows a matrix structure. The vertical layers describe the specific research activities in the investigated process chains, whereas the horizontal layers represent the enabler development approach.

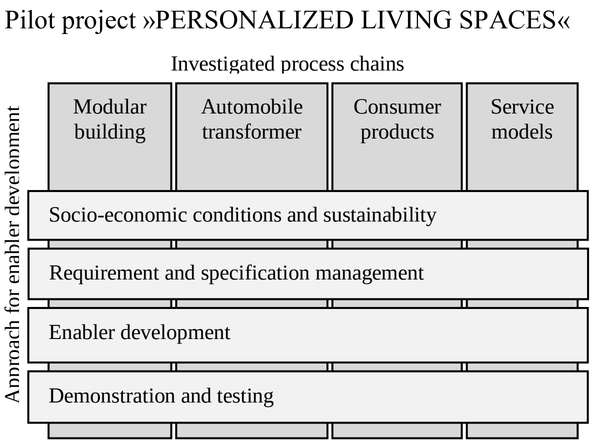

Fig. 1. *General approach of the pilot project*

2.2. Approach for enabler development

In order to create enablers that solve common cross-industry problems in the field of Mass Personalization, the enabler development approach involves stakeholders from all investigated process chains. Therefore, the approach is designed as horizontal layers across all investigated process chains (see figure 1).

All development activities of the enabler development approach are structured into four sections, are interconnected to each other, and follow an iterative work flow. Within the first two sections, the main requirements and specifications for the enabler development are identified.

The section of the analysis of the **socio-economic conditions and sustainability** is accompanying research that identifies general requirements from a higher societal perspective. The main aim is to identify and analyze potential benefits and risks of Mass Personalization from a broader perspective. It describes the required boundary conditions for a successful application of personalization, from different viewing angles, such as regulatory aspects for personalized mass products, sustainability [2] (e.g. environmental performance, resource efficiency, social acceptance) and concepts to manage the security of personal data and to ensure the users data sovereignty.

The section of **requirements and specification management** deals with the identification of the specific requirements for enabler development in the investigated process chains. For this purpose, user needs are described in user stories and requirements for the enabler development are derived. Furthermore, use cases are drafted that set one or more enablers into application to solve a certain problem of mass personalization.

The results of the first two sections provide the basis for the **enabler development.**

The enabler development follows the idea of creating a central basis of generic enablers that offer a broader application in different process chains by dealing with similar challenges (see figure 2). Hence, the enablers provide generic methods and tools for integrated process chains from the user involvement throughout the whole product engineering process.

For the pilot phase, the main developments of enablers are related to the following groups:

- user integration, development of user models, acquisition of user needs, analysis of utilization trends, tools for decision support
- methods, tools and databases for product design and product development
- methods and tools for the integration of hybrid production (conventional and additive manufacturing); optimized process strategies
- methods and tools for service engineering

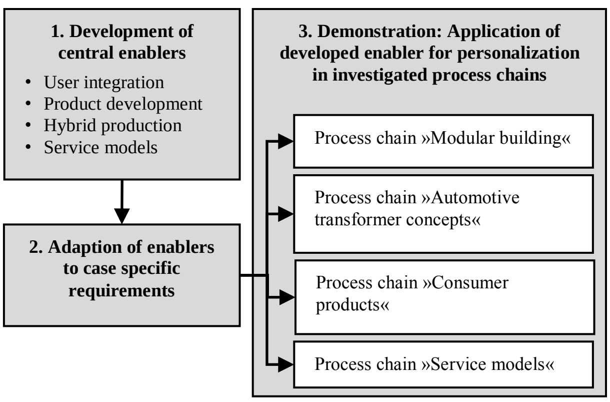

Fig. 2 Adaption and testing of central enablers within in the process chain specific demonstrators

To jointly use the enablers of the different groups to solve the problems related to a particular process chain, an enabler application framework is developed (called »Stuttgart Model«).

Within the **demonstration and testing**, the central functionalities of the developed enablers as well as their process chain-specific application according to the »Stuttgart Model« are tested. The test environment is provided by the use cases which are developed together with the stakeholders of the investigated process chains. Moreover, the demonstrators are used to communicate the base principles and functionalities of the developed enablers to related stakeholders, potential users and further interest groups. By experiencing the potentials of the enablers the exchange of ideas is fostered and will provide important information for further improvements regarding the fulfillment of their individual requirements.

3. STATE OF DEVELOPMENT

In the following the state of the developments of the running pilot project »Personalized Living Spaces« is described. The results comprise the major requirements of the investigated process chains as well as the related enabler development topics. Moreover, the »Stuttgart Model« is introduced, outlining how the various enablers under development can be jointly applied in solving process chain-specific problems.

Starting point for the requirements specification and the development of user stories are the results of the previous study on the main challenges for Mass Personalization and Business-to-User (B2U) [3].

3.1 State of Use Case development in investigated process chains

3.1.1 .Modular building

Challenges and requirements

The building sector, especially building under construction, is already characterized by a high degree of individualization and unique solutions. However, this is mainly an option for the high price segment, as this requires the early and continuous involvement of the end users in the planning processes. With today's solutions this is time-consuming and complex.

Moreover, for existing buildings, there are only minor possibilities for individualization in terms of configuration or re-configuration of living spaces. Possible adjustments and modifications are generally associated with building measures and respectively high costs.

Modular building is already a standard for many office buildings and a promising trend for customizing houses in lower price segments, and hence, increasing the degree of individualization and reconfiguration during the utilization.

Furthermore, buildings are characterized by comparatively long life cycles from 30-50 years and more. During these long periods, also user demands on buildings change over time, e.g. situational needs over life periods.

Thus, changing user needs and potential utilization trends have to be considered in the early planning phases and communicated to the users, as the personalization of living spaces can only be achieved when the buildings and indoor environments are compliant with the user needs (e.g. comfort). Furthermore, a major requirement for mass personalization is to reduce the decision complexity for planners and users.

Therefore, requirements for enabler developed have been identified in the following fields:

- Reduce decision complexity for users: Enhance the user experience throughout the planning phases using virtualization and simulation.
- Establish a working information and communication flow between users, planners and product designers.
- Interconnection of interdisciplinary decision tools (configurators, planning, design, simulation, processing tools).
- Enabling intelligent configuration of living spaces.
- Enhanced design for adaptivity of living spaces to match changing requirements during the utilization.
- Development of system components that offer personalization using industrial building system solutions.

Enablers currently under development

Current enablers under development comply with the requirements for user involvement, decision support, planning tools and communication flows which will be presented using the example of the hybrid mock-up and a digital configurator for personalized building solutions.

The hybrid mock-up

This enabler focuses on the development of solutions for virtual experience of building physical impact mechanisms in living spaces using digital twins. Therefore, the development goal of this enabler is to transfer planning and design data into a virtual environment and to link them with impact models and sensors / actuators of a hybrid mock-up.

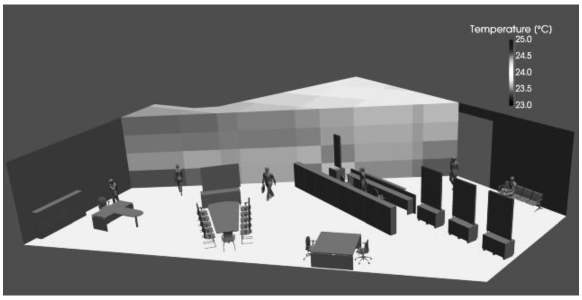

Fig 3. *Illustration example of the hybrid mock-up for mixed reality solution for user specific configuration of living spaces © Fraunhofer IBP*

The implementation of the hybrid mock-up can be understood as a mixed reality demonstrator. It allows experiencing virtual and real interfered impact mechanisms via advanced interconnection of simulation and building systems such as lighting, acoustics, heat and air quality. The hybrid mock-up will allow users to better understand and communicate their comfort needs to planners as well as reflecting consequences of their decision making.

Digital configurator for personalized building system solutions

Development goal of this enabler is to create a digital building and product configurator for modular building systems that will provide the decision-relevant information from the early planning phase throughout the whole planning process. Furthermore, the configurator can be used to analyze configurations according to future utilization trends and varying user needs. To do this, the configurator interlinks the planning information with interdisciplinary impact models and evaluation methods. This allows comprehensive assessments of user specific configurations from the perspective of building physics but also other aspects, like sustainability (e.g. environmental, economical). For realizing such a configurator, the interconnection of building information models (BIM) with web-based configurators and product catalogues (data sheets) and the software tools of Fraunhofer IBP related to building physical assessment are planned.

Use Cases and Demonstrators under development

Use Case: Virtual sampling and inspection of living spaces

This use case aims to support users in the individual configuration of interior equipment of their living space, such as furniture, materials and color composition.

Fig 4. *Illustration example of virtual sampling and inspections using immersive visualization (© Bauunion 1905)*

To achieve this, user model based suggestions are presented in a virtual environment of the user's specific building blueprint.

In an immersive system, like a VR-Head-Mounted, 3D-TV or VR-Projection system, the building blueprint is interconnected to the user profiles and product models of furniture and further interior equipment. Based on this information, a set of individual suggestion are calculated and visually arranged for the user. Suggestions can be modified an (re)configured over the utilization period of the building.

The immersive visualization system (figure 4) offers the user to benefit from experiencing his individual planning of the building true to scale, accurate in look-and-feel. Based on the individual user profile, a selection of potential interior equipment variants are generated and visualized in the virtual model. After choosing a suitable variant, the users can further adapt configurations in more detail.

In addition, users can extend their benefits of the virtual sampling inspection by connecting results with the simulation tools of the hybrid-mock up and the digital configurator to further evaluate and optimize their interior configuration in terms of building physics, and hence maximize the comfort conditions of their living spaces.

Use Case: Optimized utilization processes in living spaces

This use case is targeted to allow a better evaluation of the usability of living spaces according to the individual user requirements and utilization behavior, e.g. for user decision processes in the configuration of new living spaces or show suitability of existing spaces matched against single users or group profiles.

The idea to solve this problem is to implement individual user processes by using digital user models and digital planning tools along with immersive visualization systems in order to allow for the visualization and testing of alternative solutions according to feasibility and user requirements. Examples are geometrical or time-related collisions. As a result, key parameters can be determined for fulfilling current and future user requirements.

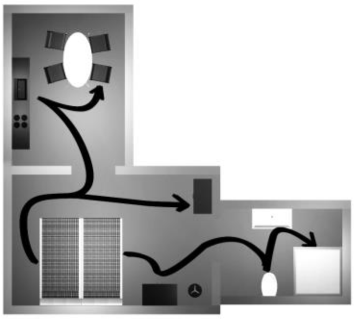

Fig 5. *Illustration example of utilization processes in a digital building model*

The demonstrator of this use case is planned as a software tool for the visualization of the use processes in the specific building environments. For personalization, the tool will be fed with the user profiles, predefined modules of use processes in living spaces as well as modules of building variants. Based on the user profile and utilization scenarios, the users are able to choose planning variants of living spaces or choose an existing space which will fit best to their current and simulated future individual needs.

Integrated demonstration platform for building

The integrated demonstration platform represents the idea of a core interface for data management and data exchange between developed enablers, such as software tools, data models etc.. The aim of the demonstration platform is to enable a comprehensive interdisciplinary assessment of use cases with reasonable work and time effort.

For interoperability purposes, the demonstration platform will follow an open data structure which allows converting and completing data by at the same time maintaining consistency.

For this purpose, the demonstration platform has to process data from enablers related to

- user profiles
- calculation, balancing and simulation tools (e.g. from building physics, life cycle assessment, process planning)
- VR environments
- algorithm databases, product and data models

During the pilot phase, developed use cases are adapted and used for evaluating and proving the applicability of the integrated demonstration platform.

3.1.2. Automobile transformer concept

Challenges and requirements

The entire field of mobility and particularly the automotive sector is amidst a dramatic transition process driven by several factors. Technologically, these are the increasing importance of electric drivetrains, and, more importantly, the rapid progress in autonomous vehicles. Especially the latter leads to a new role of the product "car" from the consumer's point of view: from a means of transport towards a third living space. This will have a significant impact on the current value chains of the automotive sector. Manufacturers and fleet operators have to handle the personalization of vehicles and services not only on production, but also during the utilization - the automobile turns into a "transformer".

One approach to fit the missing links into the personalized value chains is to design vehicles as a cyber-physical system, which offers the application of new business models by using the vehicle as a service platform. Personalization could be realized by cloud-based systems and app-based services.

During the pilot phase our research will focus on enablers related to the following topics:

- User model based configuration of vehicles and mobility services
- User involvement by virtual experience
- Automobile transformer concepts

Enabler under development

Current development activities target a generalized platform that delivers a convincing and consistent virtual experience of the future vehicle in all its degrees of freedom. This will reach out far beyond the established car configurators towards a digital twin of the real car that can be experienced as a vehicle as well as a living space in many environments and under different usage scenarios. Besides being a prototype of future Business-to-User client solutions, the virtual car experience platform is also intended as a testbed for the development of novel vehicle-related service businesses.

Use Case: Personal Mobile Living Space – the (partially) autonomous vehicle as individual living space

This use case addresses the question on suitable vehicle concepts for autonomous vehicles that transform the automobile into a third living space. Such a living space offers the driver a significant amount of time during travel that is no longer dedicated to the act of driving. This additional degree of freedom has to be reflected by the vehicle that now has to fulfill diverse and situation-related user needs. These affect the travel itself, e.g. short or long travel, number of passengers, luggage space, but also intended activities or occupations during travel. The vehicle interior should be capable of seamlessly changing to different living spaces e.g. for work, relaxing, or communication.

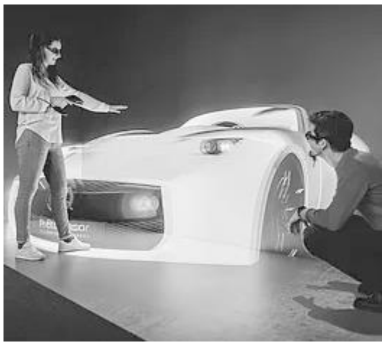

Fig 6. *Illustration example of the virtual car concept © Fraunhofer IAO*

Also for this use case, the user experience delivered by a virtual or mixed reality environment such as the Virtual Car Experience platform offers a high potential to help developing vehicle concepts by strongly supporting the interaction between end users and designers.

Therefore, the goal of this use case is to create a re-configurable virtual vehicle that enables experiencing user stories and allows visualizing acquired user requirements as well as the degrees of freedom of configurability. This will require incorporating user specific data, such as physical dimensions, but also individual preferences (comfort in indoor environments) into the vehicle model.

3.1.3. Consumer products

Challenges and requirements

While the topic of the process chains described above is the design and development of personalized living spaces, this process chain investigates how consumer products can be applied to increase the grade of personalization in living spaces.

For building and living, there is a wide range of consumer products that show a high potential for further personalization such as technical building equipment, furniture, consumer electronics, and flexible, adjustable vehicle equipment in case of the automobile.

In comparison to the process chains of the building and automotive sector, consumer products are characterized by significantly shorter life cycles. Thus, consumer products can be exchanged several times during the utilization phase of the living spaces and hence, play a decisive role for the adaptivity of these living spaces.

Regarding consumer products, the enablers of the following topics are investigated:

- optimizing the selection and configuration of consumer products in living spaces
- design for personalization

- integrated manufacturing strategies for personalized consumer products
- production planning and process limits of hybrid production systems

In the pilot phase, the development of enablers and use cases for consumer products is focused on the personalization of lighting systems. Today's lighting systems already have high potential for customization (e.g. [4,5]) and can further benefit from new manufacturing technologies, such as additive manufacturing (e.g. 3D-printing [6,7]).

Furthermore, a main requirement for a beneficial personalization of lighting systems is that these are configured and adjusted according to the intended living space (e.g. building, automotive) and utilization profiles. Hence, solutions for personalized lighting can only be achieved when interactions between the specific living spaces are accounted for. At the same time, the applications of a personalized lighting will noticeably improve the quality of working or living spaces.

Enablers under development

For meeting this challenge, required enablers are investigated throughout the whole process chain of lighting systems, which are summarized as follows.

Personalization of light quality

The lighting has to be adapted according to the personal preferences of user by also addressing subliminal needs for the use in living and working spaces. This requires the implementation and interaction of user profiles into intelligent lighting technologies using measurement techniques and feedback systems to apply for situational user demands.

Tools for simulation and automatized planning of light systems

In this context, a main requirement is to enhance the quality within the planning process. Currently, a major part in the planning of lighting equipment is not done according to the state of the art. The introduction of an automated planning system for selection and positioning of adequate luminaires (e.g. office lighting solution luminaires), optimized mounting of sensors and electronic controls (luminous flux) can help solving this issue. These measurements could lead to a significant increase of lighting quality (e.g. [8], fig. 7) and at the same time shows a high potential for cost reduction.

Intelligent configurators and software mock-up for planning systems and brokerage of personalized lighting systems

Intelligent configurators and software mock-ups support users and planners with the required information of direct effect and mechanisms of the configuration and positioning of lighting systems in intended living spaces. By creating an interface between digital models of living spaces, light simulation effect mechanisms are made visible. Furthermore, the interconnection to electronic catalogues of luminaires and lighting equipment will provide suitable solutions and product suggestions based on existing, customizable products.

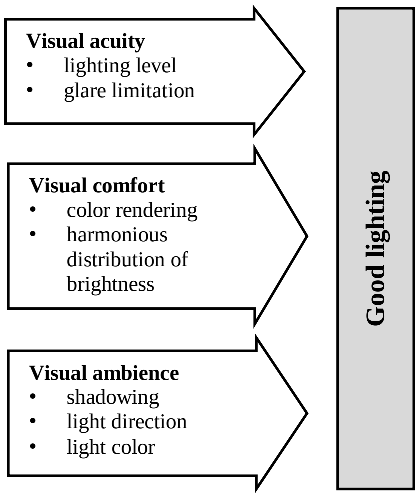

Fig 7. *Dimensions of good lighting according to [9]*

Multi-axis Additive Manufacturing

The fast and cost-effective production of complex workpiece geometries plays a key role in the context of mass personalized products. Here, Additive Manufacturing technologies are significant enablers for producing required geometries in small batch sizes economically, in contrast to conventional manufacturing processes [10].

However, Additive Manufacturing technologies still have certain process constraints, which must be overcome by technical developments and exactly defined for production modeling. Thus, the development and design process of personalized products are simplified and the future user gets support at an early stage of planning. Regarding the technology-related process constraints must be pointed out that free-form extrusion processes (e.g. FDM) have higher build rates and greater freedom in the choice of building direction compared to powder-bed or liquid-based processes, which usually offer higher accuracies.

Fig. 8. *Multi-axis FDM-printed consumer product at the example of a personalized handle of a walking frame*

Systematic investigations of conventional FDM have shown that this layer-based three-axis process has disadvantages concerning the stair-case effect, the necessity of support structures by printing overhangs (extra effort) and trajectory-dependent, anisotropic, conditionally optimizable strength properties.

The precise use of additional kinematic rotational axes in this process overcomes these limitations (described in [11]). Efficient path planning strategies enable the production of individual, type-specific components, such as anthropomorphic handles, which can be produced specifically for a patient (fig. 8). A discussion of further activities can be found in [12].

Use Cases and Demonstrators under development

Personalized lighting for working places and television

Optimum lighting conditions play a significant role for the productivity at working places but also to make comfortable conditions in free time activities such as watching TV. Thus, this use case targets to develop solutions for using sensor concepts for optimized lighting control in interaction with screens, smart home systems, lighting and sun shading systems. Potential solutions are tested in virtual environments but also under realistic conditions within a living lab at Fraunhofer IBP [13] [14].

Fig 9. *Sensor-based light control for personalized lighting conditions © Fraunhofer IBP*

Personalized luminaires and lighting systems

This use case combines the enablers described above to offer users personal lighting. Besides the user-specific lighting in functionality and design, this use case aims to provide configurable and additive product architectures for manufacturers. Intelligent and simple configurator concepts are developed to empower end users, but also product designers or light planners to create individual, but cost-neutral solutions.

3.1.4. Service models

In this process chain we investigate how the identified needs and developed solutions can be merged to create new user-integrated services and business models. The basic idea is that a seamless combination of the process chains offers a high potential to increase the overall user benefit in the daily live.

In terms of creating advanced personalized services, there is a high potential for living spaces with high user fluctuations and a broad spectrum of user needs, such as in the mobility services or hotel business.

Currently these services are based on the provision of a range of rooms or vehicles, from which the users are able to choose the most appropriate for their intention. Online services or apps are available to support the users' decisions. The personalization of services is limited to additional booking options. Exceeding services that include the personalization of the room configurations and personalized indoor environments are limited.

Based on the new technical possibilities and the better understanding of the user requirements from the other process chains, enablers regarding the following topics are investigated:

- the development of user integrated services
- the development of concepts for the technical implementation of personalized services

3.2 »Stuttgart Model« – methodological framework for the application of central enablers

According to the current results of the requirement management first specifications for the implementation into the central enabler development can be drawn.

All investigated process chains show similar needs, which can be summarized in the following general requirements for personalized products.

Enable direct user involvement

Since mass personalization cannot be realized without consideration of the individual user needs, the creation and exchange of user profiles with data models is mandatory. Hence, individual user preferences and requirements have to be implemented into planning systems to allow personalized product suggestions instead of providing solutions based on standard users and generalized utilization profiles. To achieve this, tools and methods for efficient acquisition of context-specific user demands are required that can be fed into modular and expandable user models.

Furthermore, the complexity of user decisions needs to be significantly reduced. This requires that information for user decisions is provided in a comprehensible way that also enables users to reflect the consequences of their decisions. At the same time, the number of decisions has to be reduced to those relevant to the users. This requires providing potential users with suitable suggestions that fit to their needs, and that can be further specified.

Since the potential end users and providers of personalized products express their requirements in different languages, e.g. users describe their needs on a qualitative level whereas planners and designers need quantified technical parameters, a working communication flow has to be established throughout the whole process.

Establish interconnectivity of interdisciplinary tools in the product development process

Especially the development of personalized products requires an early and comprehensive evaluation of solutions from different perspectives such as technical, economic or environmental aspects, to allow an early feedback on personalization measures, like the verification of feasibility, cost structures, processing or manufacturing time.

Methods and tools for integrated process chains and user involvement

The development of personalized products as well as the personalization of products and services requires integrated process chains from the early user involvement until the manufacturing of the final product. Thus, a generic methodological application framework for central enablers has to be developed that guides manufacturers and providers of personalized products and services through the whole process and supports them with the necessary solutions.

For realizing the described requirements for mass personalizing, the following tools have been identified as important junctions in terms of merging user involvement, user experience with planning and product design:

- Use of intelligent configurators for user demand acquisition and adjustment of product models.
- Implementation and interconnection of digital models (calculation, balancing, simulation, analysis, and concept).
- Use of virtual reality and augmented reality solutions to make user experience possible. This can reduce the complexity of user decisions and at the same time reduce communication barriers between users, planners and providers of personalized product and services.

Thus, these requirements are the starting point for the development of the »Stuttgart Model« for providing a generic methodological framework for the integrated application of central enablers. To achieve this, the »Stuttgart Model« takes up these major enabler requirements and prescribes the necessary order of information flows and processes to enable an integrated processing that can be adapted to various process chains.

The current state of the development of the »Stuttgart Model« is illustrated in figure 10, which presents the core features and information flows and will be continuously extended over the duration of the pilot phase, e.g. by attaching additional enablers to the core features of the model for addressing further specific requirements of users and involved stakeholders.

In the following, the basic idea and main features of the »Stuttgart Model« are briefly described.

Basic idea and main features of the Stuttgart Model

A main criticism of mass personalization is the agony of choice for the customer, since nobody has an interest and the possibility to determine all objects and services of his life down to the smallest detail.

The Stuttgart Model of mass personalization therefore provides for a flexible integration of the customer or user in the product development process.

Because the customer does not necessarily prefer to make all decisions about his product himself, a competent consultant who knows the customer and makes suitable suggestions is the model for the industrial process of customer-centered product development.

The required knowledge about the customer in relation to the product is incorporated in a user model. The generic user model, the associated individual user data and the generic product model are used to create a personalized product model that meets the known needs of the customer as far as possible. The implementation of such processes is not trivial, partly due to the requirements of data protection.

The customer or user also has the opportunity to get involved in the process beyond the manufacturer's user model. This is typically achieved by configurators that use virtual and augmented reality technologies to simulate the product experience, thus supporting user decisions for personalization. The result of this personalization process is the final product model that goes into production.

»Stuttgart Model« for Mass Personalization

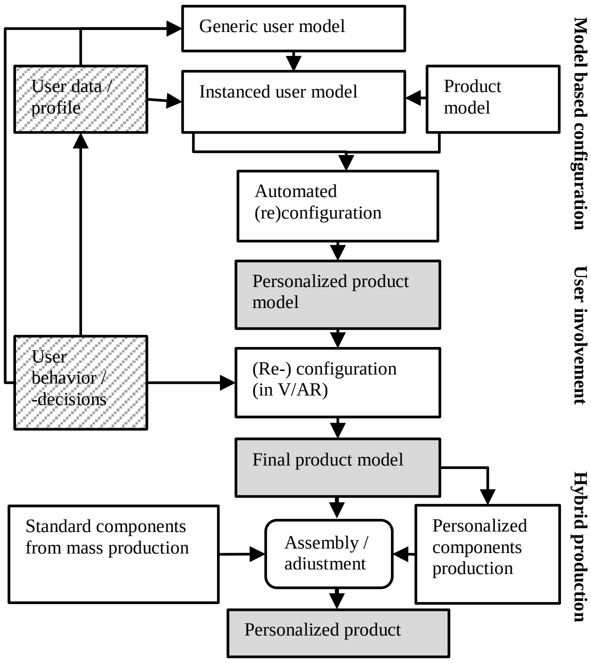

Fig 10. *Core structure and information flows of the »Stuttgart Model«*

Based on the data of this personalized final product model, the required personalized product components are manufactured. The possibilities of additive manufacturing play an increasing role here. However, personalized components might also originate from conventional manufacturing processes. In contrast to mass production, which limits the variety of variants, the processes also need to be applicable to “lot size 1” requirements, too. However, the aim is still to keep the number of personalized components as low as possible and therefore to use as many standard components as possible from mass production in order to exploit economies of scale and keep costs low.

The objective is thus a hybrid production that combines individualized components with standard components. At a time when personalization also stands for cyber-physical products and digital services in new business models, we have to see the assembly of the product in a broader sense to characterize the process of integrating hardware, software and services tailored to the user.

Mass Personalization according to the Stuttgart Model does not only stand for the initial product development, but also for the reconfiguration of products during their lifetime and their adaptation during use, in order to enable an adaptation to changing users and changing user needs during the course of the day or in different stages of life.

4. CONCLUSION

Mass Personalization is one solution to satisfy the increasing demand for individualization. Compared to mass customization, mass personalization requires a more detailed understanding of the users and their individual needs. Besides the aspects of ensuring the data security and the user's sovereignty of personal data, a major challenge is not to overstrain the users with selectable options, but to reduce the decision complexity to the relevant factors. The intelligent application of technologies with user involvement and user experience as well as the easy exchange of user preferences and requirements by means of user models indicates a high potential for meeting this challenge.

Furthermore, the development of personalized products and services requires an integrated process chain from user involvement, product configuration and product design up to the production and utilization of the final product.

In summary, meeting the requirements for using the benefits from Mass Personalization is a large-scale challenge requiring substantial efforts that can hardly be made by individual companies or research groups.

The High-Performance Center »Mass Personalization« addresses this challenge by a cross-industry-cross-science initiative. The initiative is built on anticipating that Mass Personalization in different industries and for different applications share similar requirements and structures.

During the first specifications of the process chains, main requirements from the perspective of users and providers of personalized products and services in the building and automotive industry were identified and addressed by the development of a central basis of solutions, specified as "enablers".

At the same time, an enabler application framework was developed (»Stuttgart Model«) and its general capability of guiding the joint use of different enablers for solving various problems related to a particular process chain was demonstrated.

The findings of pilot project 2 at the current state of developments support the conclusion that the cross-industry-cross-science approach of the High-Performance Center »Mass Personalization« as well as the approach for the development of central enablers and their joint use after the Stuttgart Model is likely to yield an important lever for realizing Mass Personalization. However, further enhancements of the developed enablers and the demonstration of their use for mass personalization are necessary and will be addressed in the upcoming phases of the pilot project. Moreover, further use cases for the application and further improvements of the developments are to be identified to potentially also address challenges in Mass Personalization beyond the scope of the pilot project, e.g. in further industries.

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