FreeWheel project: developing a solution for inclusive mobility for and with wheelchair users

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Abstract

The EU Horizon2020 project FreeWheel aims to develop an inclusive mobility solution for people with lower limbs motion impairment. The solution will be delivered as a service and it consists of two main components:

- *a smart active unit for the motorisation and autonomous driving of manual wheelchairs, which is attached to the chair through customised connectors made in Additive Manufacturing (AM);*
- *an app, introducing the users to the service and accompanying them in its utilisation.*

This paper describes both the solution as it is developing and the process followed by the consortium for devising an innovative service that is designed for and with the users adopting a truly co-creation based, pragmatic approach. The involvement of end users (sponsors) is an important feature of this project. And it is considered the key factor to ensure the delivery to market of a product-service with good chances of wide adoption.

Proyecto FreeWheel (EU Horizon2020) tiene como objetivo desarrollar una solución de movilidad inclusiva para personas con discapacidades de movimiento de miembros inferiores. La solución se entregará como un servicio y consta de dos componentes principales:

- *una unidad activa inteligente para la motorización y la conducción autónoma de sillas de ruedas manuales, que se adjunta a la silla a través de conectores personalizados hechos en Fabricación Aditiva (AM);*
- *una aplicación, que introduce a los usuarios al servicio y los acompaña en su utilización.*

Este documento describe la solución a medida que se está desarrollando y el proceso seguido por el consorcio para diseñar un servicio innovador que esté diseñado para y con los usuarios que adopten un enfoque pragmático verdaderamente basado en la creación conjunta. La participación de los usuarios finales (patrocinadores) es una característica importante de este proyecto. Y se considera el factor clave para garantizar la entrega al mercado de un producto-servicio con buenas posibilidades de amplia adopción.

1. Introduction

The EU Horizon2020 project FreeWheel - Lifecycle-reconfigurable Smart Mobility Platform to enable autonomous and cost-effective personalised solutions for social inclusion of disabled and elderly while leveraging Additive Manufacturing technologies (Grant Agreement No 768908) aims to develop an inclusive mobility solution for people with lower limbs motion impairment. This mobility solution will be offered as a service and it will be demonstrated within this project in specific locations, namely an indoor retail parks and an outdoor cultural heritage location.

The project consortium includes engineering companies and Universities, end users and hosting facilities representatives and service designers. The consortium presents a strong synergy between the business/technological profiles and the human and social oriented in order to comprehensively capture all the desires from the target groups considered while nourishing a scenario where innovation supports and empowers social wellbeing.

This paper describes both the solution as it is developing and the process followed by the consortium for devising an innovative service that is designed for and with the users adopting a truly co-creation, pragmatic approach that will ensure the delivery to market of a product-service with good chances of wide adoption.

2. The FreeWheel project mobility solution

The FreeWheel project mobility solution consists in two main components:

- a smart active unit for the motorisation and autonomous driving of manual wheelchairs, which is attached to the chair through customised connectors made in Additive Manufacturing (AM);
- an app, introducing the user to the service and accompanying him or her in its utilisation.

The solution is to be delivered mainly as a service to people with physical motion limitations, mainly wheelchairs users with lower limbs motion impairment (paraplegia).

Flexible consumption-based models are not new. Long employed by utilities (bus, metro, taxi, airplanes, trains) and telecom companies (pay-as-you-go plans and subscriptions), flexible consumption is now expanding to businesses in other industries, creating value for both customers and the companies that adopt them. Whichever the business models supporting the FreeWheel service, they are all being developed to maximise the benefits to the FreeWheel solution users, i.e.: flexibility, convenience and affordability.

The service relies upon a fleet of smart active units - grouped into a rack - located in important points of interests. Customers can book the unit or access them "on the fly". The rack is both the holding system and the smart unit's battery charger. The renting system manages the unit on the racks so that the smart units with the higher level of charge are ready to be released first.

Once assigned for the rent by the renting system, the smart unit can be unplugged from the rack and connected with the wheelchair using the custom AM-designed connectors, previously installed on customer's wheelchair as part of the service experience.

3. Designing the overall mobility solution

The project started with the definition of the requirements for the whole integrated system design, with the main objective of identifying the functional requirements for FreeWheel integrated solution. The work focused on collecting and analysing data about social behaviours, customers' needs, contexts and constraints, to then translate them into desired service solutions and specific product design requirements. FreeWheel project therefore follows the main steps of a human-centered design (HCD) methodology, made iterative in shaping the service features to better define experience according to the technology development and the feedbacks from the sponsors.

The continuous dialogue with the engineers responsible for designing the product, mainly the smart motorising unit and the app, ensured that feedback on the feasibility of the specific requirements contributed to achieve a definite set of service and technical objectives. A further analysis on future scenarios of implementation allowed for the definition of social impacts objectives and indicators which fed back into the definition of the service. This section explains in detail the pragmatic and very effective approach for the design of the solution, which started with the definition of the users' archetypes.

3.1. Definition of users' archetypes

Behavioural archetypes are structured models of people responses to a specific stimulus. As the name suggests, they tap into the behavioural level of cognitive processing. In a nutshell, the focus is on who does what, how they do it, and why.

The behavioural archetypes represent typical motivations, goals and general attitudes of the target users of the FreeWheel mobility solution and also how these can change based on the quality of their experience with the service over time. Archetypes most directly help determining the approach and functionality of a user experience, as well as contributing to determining, validating, and prioritising products features. Additionally, behavioural archetypes are scenario-based, hence, pragmatically, the analysis made also reference to the specific scenarios of the demonstrations: a shopping mall and a cultural heritage location.

The definition of the archetypes started with a reflection on the categories of disability that can be serviced and those that cannot, then went through identification of the generic clusters of people that led to the identification of a panel of interviewees, whose responses formed the basis for the formulation of definitions sought.

The disability categories were reviewed and defined internally to establish which ones should be taken into consideration for the service and those to be excluded because of objective barriers to the use of the FreeWheel mobility solution. They are presented in Table 1 and Table 2 respectively, where the main category of injury or illness and specific applicable cases are identified. Temporary disability (e.g. because of lower limbs injury) is not identified in the table but is also an eligible motion impairment.

Table 1. Disability categories to be taken into account for the FreeWheel mobility solution

Injury or illness	Subcategory
Lower limbs medullary lesions (paraplegia)	All kinds
Lower and upper limbs	Incomplete

medullary lesions (tetraplegia)	(NB: the compatibility characteristics with the module need to be identified)
Neurodegenerative diseases	All kinds (at the initial stage)
Lower limbs amputations	All kinds
Poliomyelitis	Yes
Neurological disorders affecting movements	All kinds (to be defined)

Table 2. Disability categories not applicable for the FreeWheel mobility solution

Injury or illness	**Subcategory**
Neurological disorders affecting cognition	All kinds
Lower and upper limbs medullary lesions (tetraplegia)	Complete
Neurodegenerative diseases	At the advanced/final stage
Upper limbs amputations	All kinds

A panel of people of various ages, family and work status, with different kind (and experience) of eligible disabilities was set up and their experience related to shopping and cultural activities were collected using qualitative research techniques (structured and unstructured interviews, performed remotely or in person).

Four main behavioural archetypes were identified:

- The soloist is the archetype of complete acceptance and independence. Within this behaviour, people develop specific routines for reaching the higher level of autonomy in almost all the activities.
- The energy saver archetype is connected with a recent disability status everything seems tiresome and the person tries to save energy with all the means possible.
- The would-be archetype resents of the challenge of dealing with - at the same time - the desire of moving independently and the loss of strength, with the fatigue of manoeuvring the wheelchair for a long time.
- The denier is the archetype of denial of disability and not acceptance. Even with small mobility impairments, the person in this status refuses of appearing, acting and even thinking as a “disabled”.

Many insights were gained by this study:

- Using a wheelchair requires physical effort, however the attitude towards being helped can vary from full acceptance of being pushed, which might however mean loss of privacy, to complete refusal and therefore reduction of time spent visiting or shopping, to the extreme cases of not leaving the house altogether.
- Using a manual (but often also a motorised) wheelchair means it is impossible to go fully “hands free”, which limits other activities (carrying bags, using the mobile phone, etc) but also emotional.
- Wheelchair users have to focus their attention to the path they are taking: the environment wheelchair users move in is full of obstacles,

from small gaps, holes or steps on the pavement where wheels might get stuck to moving obstacles including e.g. people changing suddenly direction or distracted. There is little time to enjoy the scenery.

3.2 The users' experience map

The human-centred approach was used also to identify specific needs and pain points linked to the use of the service. To objectivise them, the journey of a user of the service in both demosite locations was run through with different user representatives and depicted in two maps. The maps allowed, in a preliminary phase, to highlight the facilities, tools, technologies etc the wheelchair users would like to be able to access to ease their journey through the location and/or to make their experience more enjoyable up to level of an abled-person. As such, the exercise allowed to collect and organise the main issues experienced by the users in the specific locations and their desires. At this point the knowledge collected include the thoughts and emotions of the users to deliver a story.

From a pragmatic point of view, the visualisation of the journey and the mapping of the pain points and desires enabled the team also to start identifying the components of the service (use phase of the whole service) that satisfy them. This required further crystallisation for the preparation of the service blueprint recently finalised [1] but was extremely useful to gain further and more detailed insight of the user's requirements.

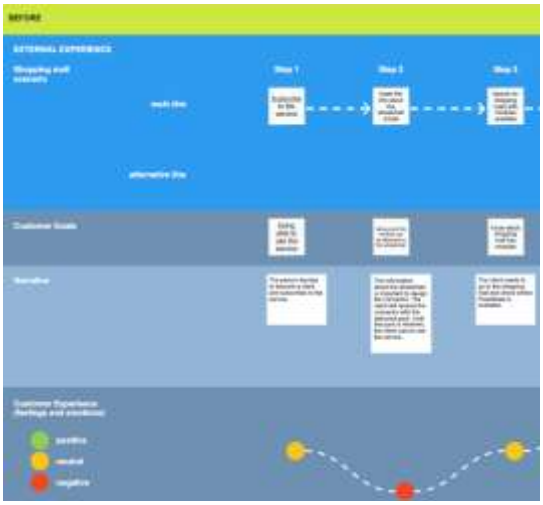

Figure 1: A snapshot of the users experience map

Figure 1 shows a snapshot of the external experience map: at the top are listed the steps of the process of booking and using the service, on the levels below are the objectives of the user and an explanation of its experience, matched by a colour coded visualisation of their emotional engagement, which depends from the archetypes perspective.

3.3 Technical and service objectives, including key results and key performance indicators

In parallel with the users' perspective, the project team also worked on their vision of the service through statement of intents (stories) describing the desired outcomes from the FreeWheel mobility solution from the point of view of those operating it or contributing to it. A stories repository containing about 130 stories was built up since day one of the project describing:

1. The perspective about FreeWheel from various stakeholders:
    a. The Client
    b. The Accompanying Person
    c. The Module Manufacturer
    d. The Service Provider
    e. The Third-party Service Provider
    f. The Add-on parts Manufacturer
    g. Anyone else interacting with FreeWheel
2. Different topics concerning the product and the service:
    a. Renting the module
    b. Connecting the module
    c. Buying the module or some related components
    d. The module in motion
    e. Customer feedback
    f. How to use the module
    g. Accompanying person role
    h. Manufacturing requirements
    i. Using the app
    j. Module and Service Maintenance
    k. Using the module

The stories are a way to describe the goals nor the process to achieve them, hence are a useful basis to describe targets. As the stories were told mainly from the perspective of the operators, they needed to be matched with the narrative gathered from the users. The cross check with the experience map refined even more the information acquired by contextualising it to the two demo-sites. The further step was to match this knowledge acquired with respect to the expectations with the project objectives to define a set of Technical and Service Objectives which together form the Design Objectives of the solution.

Both sets of objectives were built applying the MECE and the SMART frameworks, i.e.:

- MECE framework refers to "Mutually Exclusive and Collectively Exhaustive", meaning that there are no objectives with overlapping domains and that all the objectives together will draw an exhaustive set of indicators to drive the project on the right path.
- SMART framework allows the creation of crystal clear objectives that are Specific, Measurable, Agreed between all the partners, Realistic and Time-based.

3.4 How to estimate the social impact of the project

FreeWheel mobility solution has a clear potential for significative social impact, however the project developing the solution will end well before being able to measure and monitor such impact. However, there is a need to ensure the desired social impact are "designed in", which equates to a reframing of FreeWheel physical devices and digital interaction touchpoints as tools for reaching the social impact on final beneficiaries. This has been done adopting the Theory of Change (ToC) methodology, which is a conceptual roadmap to envision how the project is expected to achieve its intended impact. In long-term project aiming at bringing social changes, a ToC is a powerful alignment tool for all the project members. It is also the basis for choosing relevant social impact objectives and define indicators to measure them. It has the following advantages:

- It allows to clarify a common vision of success of the project and get a clearer shared picture of the social change to achieve after having clarified the end-user's needs;
- It recognises that the social impacts cannot be reached within the timeframe of the project, hence any Logic Model based social metric applied and measured would not actually describe the potential. Furthermore, it allows to include the complexity of an operational phase not covered by the project;
- It allows to include the additional actors who will be required to introduce the solution onto the market.
- It provides guidelines provides as to how to adapt the service to any new location by bringing some criteria to assess the context and understand the specificities of its ecosystem of stakeholders.

A Theory of Change is co-created with all actors in the project both as a way to increase the probability of success and ensure adaptability to the challenges the consortium may face during the initial phase of the project and after, once the test has been run and funding period is over.

The team adopted a 3 steps approach, adapted from a framework coming from Keystone Accountability® [2] that best suited the needs of the research project:

1. Envisioning the success
2. Mapping the pre-conditions of success
3. Identifying the key elements to measure the social impact of the project

The success of the solution is described by the vision aimed to be achieved by FreeWheel by 2022: "People with motion limitation (temporary or permanent) have a more autonomous and inclusive experience of mobility in their daily life".

Applying the vision to the different stakeholders, it was translated into key outcomes, for example: for FreeWheel users the vision translates into a lift of the accessibility constraints in daily life, hence easier access to job positions, ability to choose their holidays according to their preferences, enjoyment of visiting any location alone or with accompanying persons etc. For each outcome statement of the vision of success, a series of pre-conditions are determined for this change to happen. These conditions formed "the pathway to outcomes". For example, for having easier access to job positions, the workplace needs to become more accessible i.e.:

a) the workplace must be located within an area covered by the FreeWheel mobility solution and
b) the service needs to be interconnected to accessible public transport.

Conditions and preconditions of change could then be translated into indicators: for example, a) above translate into number of workplaces in the area covered by the service and b) number of FreeWheel racks within a certain radius of a public transport station or stop.

The example above clarifies why social impacts transcend the current development project, as actual wide spread of the solution is implied as well as the involvement of many actors (e.g. public transport). The exercise however is extremely important to drive the actions towards commercialisation of the solution (e.g. business planning, exploitation etc).

4. Challenges and Blueprint

The understanding of the user needs and the envisioning of change facilitated the alignment of the consortium and allowed to define a set of Design Challenges. These are again a way to define the aim of the project and work properly to address specific needs. The activity of identification and shaping, made more effective by the interaction with sponsors, gave a great contribution to the evolution of the technical and service features.

The synthesis of the research done is the Service Blueprint, a public deliverable that maps all the service aspects. This is a co-created document that addresses the Challenges while taking into consideration all the requirements. This document displays the whole service experience and highlight the interactions between all the actors coming from customer's side, frontend and backend operations and support processes enabling the features.

5. Conclusion and lessons learned

The co-creative approach taken by this project has the advantage of ensuring that the solution developed will have a good chance of buy-in from the potential end users, who in turns have had the opportunity to shape a service built as much as possible for their needs. On one hand the direct dialogue also highlighted potential barriers (regulatory and operational) and ways of overcoming them, on the other it paved the way to ensure that the solution will not be a "missed opportunity" for the end users. The co-creation approach required some effort and a degree of mediation between the two worlds – the engineers and the users, which started with some fundamental alignment over key concepts and the terminology thereof: for example, while the project definition addresses "disabled" (see the project title) people, working with the sponsors highlighted that the solution can only be suitable for a specific category of mobility impaired people. This is not seen as a limitation but, on the contrary, it adds value to the service as it ensures to target the right category of users avoiding disappointment of others and ensuring the safety of the users. Indeed, this lesson learned has become a feature of the service, which allows the potential users to self-check the suitability of the FreeWheel mobility solution for their disability BEFORE subscribing to the service.

Similarly, tools such as the Theory of change enabled the designers and engineers to firm up into quantitative objectives the social impact of the FreeWheel mobility solution. Instead of seeing such impacts as a consequence of the solution developed, they were actually translated into drivers for defining the commercialisation of service and the product: this is key for the successful implementation of a solution which addresses a very socially-charged issue such as improved mobility of people with motion impairment.

6. Next steps

The project has reached the mid term point and is now finalising, on one hand, the definition of the service and, on the other, the process and production aspects of the smart motorisation unit, focusing mainly on the connectors. Key part of the service is the customisation of the brackets that connect the smart motorising unit to the wheelchairs, and a short lead time between the subscription, and therefore ordering of the customised connectors, and their delivery to the user. Both customisation and quick manufacture can be obtained by leveraging digitalisation, e.g. for the exchange of technical details, and advanced production technologies such as Additive Manufacturing. The project team include experts in such advanced production processes and equipment who are now working in defining the best production strategies to maximise cost effectiveness and minimise environmental impact of the manufacture. In parallel, the digital touch points identified are being translated into features of the app accompanying the user of the service.

The project will culminate in a public demonstration of the solution in the Autumn of 2020. However, the solution developed has raised already some interest from funders and the consortium is hoping to deliver the solution to the market in three – four years time.

9. Acknowledgements

This paper describes work undertaken within project FreeWheel, which started in October 2017 and will last three years. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768908. The project is an Innovation Action and it was granted funding under the call FOF-10-2017 - New technologies and life cycle management for reconfigurable and reusable customised products. The project is managed by the EU Commission DG Research & Innovation and it is coordinated by IRIS srl. The work described has been led by Keen Bull and has involved all partners of the project. More information on the project, including the list of all partners and the public deliverables, is available at www.freewheelproject.eu.

10. References

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