



A User-Centred Approach to User Interface Languages and Icons: Co-evaluation and Co-creation of Accessible Digital Mobility Services

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Abstract. Challenging the acceptance of what have been defined as universal and standard pictograms, this paper promotes a conceptual approach to improve non-textual communication in digital mobility and delivery services, to ensure that different types of people may access content in an intuitive manner, overcoming language, cultural, physical and cognitive barriers. Starting from the user-centred methodological process applied in the development of the Universal Interface Language tool, one of the main outcomes of the INDIMO EU project (Inclusive Digital Mobility Solutions), this paper presents a methodological path that can provide UX/UI designers, developers and service providers with a practical guide to defining a proper set of accessible and inclusive icons as part of the user interface, be it digital or physical. In particular, this paper points out the need for bottom-up initiatives based on the co-design of physical and digital interfaces and their components to create symbols and icons with a higher degree of universality. To this end, user evaluations of mobility specific and general icons, and recommendations based on the empirical research in the INDIMO project, are presented. These address the design, selection and integration of visual icons in accessible user interfaces for digital applications.

1 Introduction

Visual icons are fundamental components of any digital application or service. They are supposed to transmit meanings in the fastest and most intuitive way. Whether we are aware of it or not, we daily interact with all kinds of icons—yet they are not accessible to all. Studies confirm that the comprehension of signs and symbols, be it in the real world or in the digital world, is not as obvious as it may seem (Bagagiolo et al. 2019).

The comprehension of icons and of the overall user interface (UI) are closely inter-related and they are both influenced by factors such as the context-of-use, socioeconomic and cultural background of users and their different levels of perception (i.e., the kind/s and degree/s of impairment). There are pictograms considered “universal”, either because their visual affordance is highly intuitive for most people globally, or because they are commonly accepted as global standards and used worldwide. Yet, high degrees of affordance (Norman 1999) and acceptance are not, by themselves, sufficient

to declare them universal. In this paper, the universality of the most common visual icons used by digital applications offering mobility and goods delivery services is challenged, applying a user-centred approach to their analysis and evaluation.

The purpose of this paper is to promote a conceptual approach to improve the efficiency of non-textual communication in digital mobility and delivery services (DMS and DDS, respectively) to ensure that different types of people may access content in an intuitive manner, overcoming language, cultural, physical and cognitive barriers. Starting from the methodological process applied in the development of the Universal Interface Language tool (UIL), one of the main outcomes of the INDIMO EU project (Inclusive Digital Mobility Solutions), the paper also aims at developing, refining and fostering a methodological path that can provide UX/UI designers, developers and service providers with a practical and comprehensive guide to planning, building and performing quick and intuitive exercises with users.

2 The Challenge of Using Icons, Pictograms and Signs in a Complex Society: The Universality Issue

The advantages of choosing pictograms and symbols over text to overcome the barriers of individual languages and literacy have been recognized from the beginning of the 20th century, with the *International System of Typographic Picture Education* (Isotype) method designed by Neurath. By the late 1960s, the concept of a standardised design system was considered necessary when communicating in large organisations or international events involving multilingual users (Rosa 2009). In 1972, Aichler (1996) designed a system of visual symbols “of universal intelligibility” for the Munich Olympic Games to help visitors with regard to information and communications. In 1974, the United States Department of Transportation commissioned the American Institute of Graphic Arts (AIGA) to create one of the most coherent and functional pictographic systems, in order to help large crowds easily find their way through public spaces, transport hubs and events. In the 1980s, the first international standard *ISO 7001:1980 Public information symbols*, which specified graphical symbols for the purposes of public information, was published. Even though the need for standardised and universal set of pictograms and symbols to use in international facilities or in any context involving multicultural audiences is recognized, pictograms are interpreted differently depending on culture, age, social identities and literacy levels. People’s capability to read and decode graphical forms always needs to be addressed with care, since interpretation systems change across countries and cultural groups. The graphic designer Rosa pointed out how “[...] *images are always ambiguous. Like other written languages, pictograms require learning, a conscious methodology and pedagogic support*” (Rosa 2009, p. 32).

A well-known study explored the comprehension of standard healthcare symbols by a sample of participants from different cultures, age groups and literacy levels (Hashim et al. 2014). The main results highlighted that: i) symbols referring to abstract concepts are the most misinterpreted; ii) interpretation rates vary across cultural backgrounds and increase with higher education and younger age; iii) pictograms with human figures and a synthetic description of actions are better understood than abstract concepts.

As argued by the Nielsen Norman Group, the universality of icons can also be questioned by considering the variability of their functionalities across digital interfaces. Most icons, in fact, “*continue to be ambiguous to users due to their association with different meanings across various interfaces*”¹.

In this regard, detailed information about the design of signs and symbols is included in the ISO 7010: 2019 (ISO 2019) safety colours and safety signs and in the ISO/IEC 11581 (ISO/IEC 2000), which provides a framework for the development and design of icons and their application on screens capable of displaying graphics as well as text.

However, the fast pace of technological innovation does not allow standards and regulations to adapt in timely fashion, and this is even truer if we look at the speed of new applications released on digital stores. The Universal Interface Language tool which we are presenting in this paper tries to bridge this gap by integrating the existing official guidance and standards with recommendations from the INDIMO research, which are useful to define a personalised step-by-step user-centred process for the inclusive design of icons and related application interfaces. As suggested by Alan Cooper, “*Obey standards unless there is a truly superior alternative*” (Cooper et al. 2014, p. 319). We argue that when it comes to visual icons, it’s more likely that there is a superior alternative than that the existing standard is indeed 100% appropriate.

In many cases, users do not recognize the existing universal standard symbols as the most appropriate ones to describe a specific action, condition or need. These symbols simply do not resonate with their everyday lives and environment. The “Accessible Icon Project”² offers telling examples. The project started in 2010 as a “design activism” project aimed to make cities more inclusive by altering existing signs concerning the internationally adopted wheelchair-access symbol³. The project’s founders considered this standard icon unable to represent the human body moving through space, “*like the rest of the standard isotype icons you see in the public space*” (Hendren 2016) and thus, unable to show the agency of persons with disabilities. The project team started an icon redesign process from the bottom up, directly addressing users’ need to clarify a misleading representation of people with disabilities. In creating a new formal icon to replace the old one, they hired a graphic designer to bring the new icon in line with professional standards. Today, the icon is global and used in hundreds of cities and towns, at private and public organisations, and by governments and individual citizens.

This success story makes it possible to challenge the acceptance of what have been defined as universal and standard pictograms and points to the need for more bottom-up initiatives based on the co-design of physical and digital interfaces and their components (e.g., icons). Starting from users’ needs and their everyday lives, such an approach could create symbols and icons with a higher degree of universality.

So, in conclusion, what about the “conscious methodology” previously mentioned by the designer Rosa? What does it consist of? In this paper, we argue that a conscious methodology needs to be based on user involvement when defining the most accessible and inclusive set of icons to include in a service digital interface.

¹ <https://www.nngroup.com/articles/icon-usability/>.

² <https://accessibleicon.org/#read>.

³ It refers to the International Symbol of Access designed in the 1960s by Susanne Koefoed.

3 The INDIMO Project and the Universal Interface Language Tool

The Universal Interface Language (Huetting et al. 2021) is one of the main outcomes of the INDIMO project. The EU-funded Horizon 2020 project aims to extend the benefits of new digital on-demand transport or logistic services to include user groups that currently face barriers and are partly or totally excluded from using such services due to a little-inclusive design approach. Overall, the proposed project methodology consists of a user-centred approach based on the co-design of different tools with a Co-Creation Community that integrates user representatives, policy makers, academia, industry, and local Communities of Practices (CoPs) established in the project's five pilot sites (i.e., Italy, Flanders/ Belgium, Galilee, Spain, Germany).

The UIL tool has been developed throughout the three years of the project, during which the methodological steps detailed in the next paragraph (see Sect. 4), have been identified.

The UIL tool offers user-centric recommendations for the development of visual icons as part of the user interface design, be it digital or physical. It derives from the need to answer the following key questions:

- Are people aware of the emerging role of visual icons in digital mobility applications?
- How can visual icons help all people navigate smoothly within the contents and features of digital mobility applications?
- Are the meanings of visual icons clear enough to all users?

The guidelines especially address UX/UI designers, developers, and service operators. Their main purpose is to improve non-textual communication in digital applications to ensure that different types of people may access content in an intuitive manner, overcoming language, cultural, physical and cognitive barriers. The final outcome is composed of: user-centred exercises and survey templates, an icons catalogue, an icon analysis template and an extensive set of recommendations. The icons catalogue includes the involved users' evaluation of the recurring icons used in digital mobility and delivery applications. These evaluations have been collected through easy-to-deliver exercises performed in each project pilot. The systematic qualitative collection of users' evaluations of icon comprehensibility considered their perception in relation to the interface of the applications under analysis. The recommendations derived from this address the design, selection and integration of visual icons in accessible user interfaces for digital applications and organisational measures to engage users in a continuous improvement process. They also concern the lessons learnt about the user recruitment and user testing in a co-creation and co-evaluation approach, and more general tips for inclusive design.

4 Developing the “Universal Interface Language” Tool: The Methodological Approach

In the UIL, a methodological path was set up to evaluate the accessibility and inclusiveness of icons in relation to service and application interfaces. It consisted of three main steps, as follows:

1. A preliminary review of 62 digital mobility and delivery service applications (DMS/DDS) from over twenty different countries, in order to explore interface accessibility and the inclusivity of icons. In addition, another twenty applications commonly used in Europe offering both transit and food delivery services were explored. From this review, a catalogue of 27 recurring icons—both general and mobility-related ones—were identified;
2. The selection of icons collected in the previous phase was compared with those used in the pilot site applications. A UIL exercise was built to involve users in the evaluation of icons. Five similar interactive UIL exercises were performed, one for each pilot's community of practice;
3. The distribution of the online UIL survey to all stakeholders, followers and Co-Creation Community members. It aimed at bringing together the evaluations of visual icons, as collected through the previous two steps.

4.1 Preliminary Review

In the first step, a preliminary set of icons to be further evaluated in steps 2 and 3 was identified. The desk research reviewed 62 digital mobility and delivery service applications from over twenty different countries across the globe. The analysis included three main groups of applications: global routing and vehicle/ride sharing applications; digital delivery applications (including smart boxes); and local public transport (or other transport) service applications. The third group was further divided into regions, given that transport habits and regulations in different countries may vary, possibly leading to different interface designs for such applications. The testing personnel included software engineers usually working with the MBE–Budapest Association of People with Physical Disabilities, which is part of the INDIMO consortium.

The analysis mapped the existence and degree of inclusive interfaces and service solutions (e.g., public transport routes making provisions for wheelchair users), accessibility settings (personalisation accommodating specific needs), notifications (personalised info about real-time accessibility issues), voice-based options (search, route planning, navigation), also tracking personalisation options for vulnerable to exclusion groups. The analysis included the study of screenshots of the applications interfaces where both general icons and specific mobility icons were clearly identifiable. In addition, 20 applications⁴ commonly used in Europe offering both transit and food delivery services were explored, along with a few applications dedicated to people with visual impairments. Based on this quite extensive list of digital applications, a catalogue of 27 recurring icons was built up (see Sect. 7.2). These were evaluated through the UIL exercises and the UIL survey, as explained in the next sections.

⁴ The 20 common applications explored are: (DTS) blablacar, Cabify, Citymapper, Flixbus, FreeNow, Lyft, Moovit, Omio, Safr, Transit, Uber, and Waze; (DDS) Deliveroo, JustEat, Glovo, and UberEats; the apps for the visually impaired are BeMyEyes, Emit, Kimap, and Wheelmate.

5 The UIL Exercise in the INDIMO Pilot Sites: A Co-evaluation Experience

The selection of icons collected in the first step was compared with those used in the pilot sites' digital services. The pilot services consist of: a digital locker to enable e-commerce in rural areas (Emilia Romagna - Italy); inclusive traffic lights (Antwerp/Flanders); informal ride-sharing in multicultural towns (Galilee); cycle logistics platform for food delivery (Madrid - Spain); on-demand ride-sharing integrated into multimodal route planning (Berlin-Germany).

Thereafter, five similar interactive UIL exercises were built and performed starting from existing Human Factors design and UX testing examples (Bagagiolo et al. 2019) (ETSI 2002–2008), and questionnaires (Blees and Mak 2012) (Zender and Cassedy 2014). The UIL exercises took place in the pilots' communities of practice between March and April 2021. A total of 46 participants attended, including: users and non-users, civil society organisations representing groups vulnerable to exclusion, operators, policymakers, researchers, and other relevant stakeholders. Six recurring icons were tested in the pilot applications, and the participants of local communities of practice cooperated in evaluating the icons' use within the application interfaces during 1-h online sessions. An interactive Miro dashboard supported the activities being performed; in two cases, to accommodate specific users' needs, one-to-one sessions were organized to mitigate the “technological barrier” of the online board.


The participants in the pilots were asked to share their experience and comment about: i) the meaning of the icons; ii) potential matching with other icons that could be used to convey the same meaning; iii) elements that were unclear or produced confusion in the visual outlook; iv) elements that could be added for clarification or sharper communication; v) other elements that should be kept in consideration when designing graphic interfaces.

To ensure the highest degree of inclusivity during the meetings—which were held online, due to the pandemic situation—the interactive exercises were led by a guiding moderator who presented the slides on screen and facilitated an open discussion verbally.


The exercise consisted in two parts: one introducing the theme of the ambiguity of icons and the other exploring their use in the digital context of the application itself.

The first part consisted of the “icons pitch”. All the participants were shown a first set of icons that are typically part of the graphic language of most mobile apps and a second set of matching icons with similar meanings. Figure 1 shows a screenshot of the icons pitch. It includes the general icons to be tested, and the main points discussed (e.g., pictograms' meanings according to the participants' experience, matching with other icons with the same functionality, conflicting meanings, etc.).


1) Icons pitch



10 MINUTES – Please name and describe the meaning of each presented pictogram in your words. According to your experience, what does this icon mean or what action does it trigger in a digital application?



10 MINUTES – Your meanings have been added to the most used ones. Are there other pictograms you've seen that are used to issue the same message?



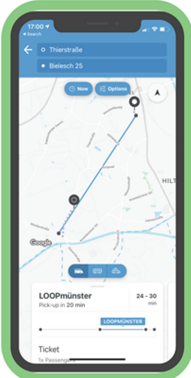
5 MINUTES – Here some examples, who would like to comment? Do you think they are equivalent?

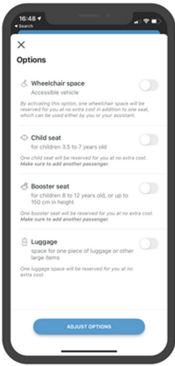
Fig. 1. An example of UIL exercise – icons pitch

In the second part, participants were invited to observe the same icons as they appeared in the different pilots' application screens and to comment on them. Figure 2 shows the use of the pinpoint icon in the Berlin pilot application.

The exercises provided a clear understanding of the common interpretations that people give to visual icons, the variety of meanings attached to them, the interaction between their intrinsic characteristics and the relationship with the other components of the user interface.

5) Options





INDIMO WP2 - UIL exercise for P5 | Berlin

This is the related screen

5 MINUTES: What other information would you like to be included here?

Fig. 2. An example of the UIL exercise - Berlin app screens

6 The Online Survey Involving Stakeholders and the Co-creation Community

The third and final step was that of collecting more quantitative data about visual icons through an online survey. This aimed at exploring end users' comprehension of the visual icons most used in digital mobility and delivery services. The UIL survey complemented the icon-evaluation results collected through the review of DMS and DDS applications, and the UIL exercises performed in the local CoPs. The survey was distributed online to all project partners and stakeholders, social media followers, and to the members of the INDIMO Co-Creation Community. Different sections were included to investigate: i) the perceived comprehensibility and ambiguity of recurrent pictograms in digital mobility and goods delivery services (see Fig. 3 and 4), ii) the overall perception of such services' accessibility, and iii) respondents' socio-economic background (e.g., age, gender, education, employment status, caregiving activities, income). The collection of responses lasted for three weeks in May 2021. In total, 89 responses were gathered. A frequency analysis was performed. The full set of results is included in the INDIMO project deliverable "Universal Interface Language – Version 1" (Huetting et al. 2021).

Sample questions related to the first section of the survey are reported in Fig. 3 and 4.

Please evaluate how clearly the pictogram represents the function "PLAN TRIP".

* 13. Please evaluate how clearly the pictograms represent the function "PLAN TRIP".





	Extremely clearly	Clearly	Somewhat clearly	Not at all clearly
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 3. Example question concerning the perceived level of ambiguity of recurrent icons in DMS and DDS

Based on your experience, shortly describe the meaning of each pictogram:

* 2. Based on your experience, shortly describe the meaning of each pictogram

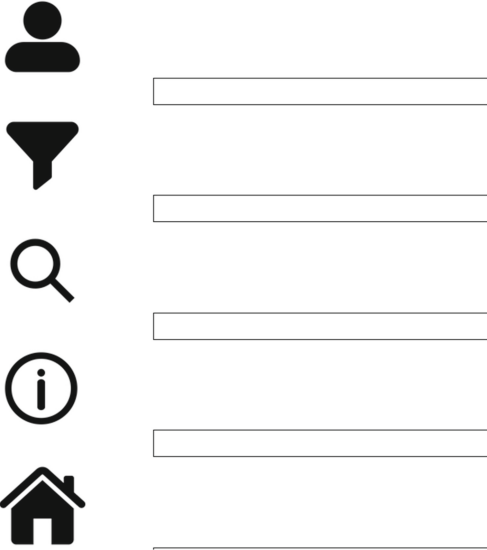


Fig. 4. Example question concerning the perceived comprehensibility of recurrent icons in DMS and DDS

7 Main Results

The main results collected during the research for the Universal Interface Language tool development have to do with honing a methodological approach to evaluate the accessibility of icons and inclusiveness in relation to services and application interfaces, the design of an icons catalogue, and the identification of a set of recommendations for a more user-centred design and use of icons in digital and physical user interfaces.

7.1 A Methodological Path to Identifying a Proper Set of Accessible and Inclusive Icons: Suggestions and Lessons Learnt

The methodology for building the UIL as described in the previous sections, can also be seen as one of the main results of our research.

To identify a proper set of accessible and inclusive icons, we suggest following four main steps.

Step 1 - Carry out a preliminary review of similar services to explore icon use and the accessibility of UI. The review aims at identifying an initial set of icons to be evaluated and discussed with users in the next steps. The analysis of other applications and services will highlight potential icons' ambiguity issues and/or best practices to consider when designing your application/service.

Although the review does require considerable time and effort, this first step is crucial for identifying an initial set of icons to work with, and becoming aware of icons' ambiguity across different digital interfaces. Furthermore, no existing reviews or literature are available in this regard, except for some icon usability studies^{5,6} published online by the UX designer community.

Step 2 - Build a user-centred exercise to involve users in the co-evaluation of icons related to UI. Perform a quick and simple exercise with users to assess the comprehensibility of icons in relation to the application interface. The exercise focuses on collecting feedback about the user experience, from the viewpoint of vulnerable users. The main objectives are the following:

- Raising participants' awareness (of both users and developers) concerning the ambiguity of icons;
- Identifying the most common issues in the usability of icons;
- Identifying how the application interface and internal structure influences the comprehension of icons;
- Finding potential solutions or mitigations to accessibility barriers in digital applications.

Participants will provide you with feedback about:

- The meaning of the icons;
- The potential matching with other icons that could be used to convey the same meaning;
- Elements that are unclear or create confusion in the application interface;
- Elements that could be added for clarification or more accurate communication;
- Other elements that should be kept in consideration when designing a user interface.

Step 3 – Consolidate the results of the preliminary review and exercises with a UIL survey. A survey can be a useful tool to complement the icon-evaluation results collected in the exercise. Such a survey explores the use of pictograms in digital mobility and goods delivery services mainly by using four-step Likert scales, thereby identifying which icon best represents the given function with the least ambiguity (see Fig. 3 as example). The survey should be answered by all users, especially involving those categories who experience some kind of barrier in using such an application/service (people with different kinds and degrees of impairments).

Step 4 - Organise the results into an icon catalogue to aid the improvement of the chosen set of icons. The final outcome of this suggested methodology should be an in-depth evaluation of the identified icons. This can be organised into an icon catalogue integrating the main results collected throughout the different steps. The catalogue can

⁵ <https://www.usertesting.com/blog/user-friendly-ui-icons> - last access on 29th June 2021.

⁶ <http://babich.biz/icons-as-part-of-an-awesome-user-experience/> - last access on 29th June 2021.

be further improved and updated with time, and used as internal reference for all further services which the designers or developers team want to analyse or enhance. The next section will describe how the icon catalogue was built up in the INDIMO research.

Especially in steps 3 and 4, the involvement of users and other significant stakeholders is crucial for successfully achieving the aim to co-create and identify the most appropriate set of icons for a service or application. From the INDIMO experience, we learnt some key lessons in this regard.

First of all, involving vulnerable-to-exclusion users requires a fair amount of time and sincere commitment since it is not easy to identify and convince them or their representatives to participate.

Recruitment and relationship building could focus more on creating an open and direct relationship with the people involved, both end users and their representatives, to ensure continuity and trust building.

Due to the COVID-19 pandemic, it has been a challenge to engage people with the characteristics that we wanted to address in online meetings and activities. Many people declared connection fatigue. A small positive remark is that, for some people, it was easier participating directly from their homes instead of being required to come to a meeting in person.

Finally, tools for online events are not yet accessible enough and there are few and poorly designed alternatives overcoming such barriers (live captions, interactive boards, WebEx meeting platforms). In many cases, WhatsApp and Zoom turned out to be the most feasible options, since they were already used on a daily basis by most users.

Despite the above considerations, the project consortium members, the authors of this chapter and all involved participants were surprised by the richness of insights gained from the discussion about the applications' usability and the icons used during the UIL exercise sessions. An open and non-judgmental setting was an important feature, together with the preliminary knowledge participants had about the applications. These allowed more problems and consequent ideas for improvement to emerge.

7.2 The INDIMO Icon Catalogue

As a result of the extensive desk research across the digital mobility and goods delivery applications, the exercises performed in the pilots' communities of practices, and the online survey distributed among the INDIMO consortium and the Co-Creation Community, a total of twenty-seven common icons were identified. Figure 5 shows the 27 identified icons. It includes the pictograms and their related functionalities (e.g., timetable). The catalogue includes both mobility specific icons and general icons. For each icon, the catalogue reports: a) examples and participants' evaluations of the icons used in the pilot applications and collected during the UIL exercises; b) a summary of the results from the UIL survey concerning the icons' comprehensibility.

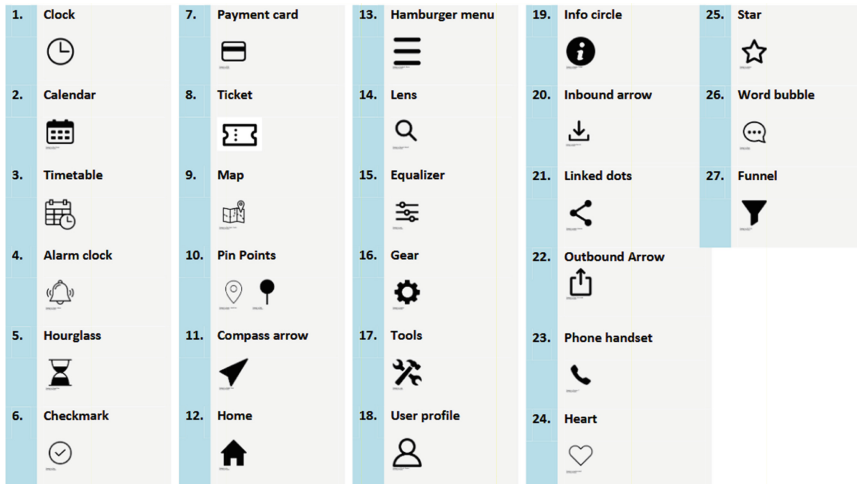


Fig. 5. The INDIMO icon catalogue

The following table reports two examples from the INDIMO icon catalogue. The first concerns the “clock” as a specific mobility icon, the second the “tools” as a general icon⁷.

Table 1. Examples fom INDIMO Icon catalogue with pilot applications

Icons' group, name and function	1. Clock
UIL Exercises results: Galilee, Madrid, Berlin pilots	<p>In transport apps, this icon may represent schedules or calendars, and maybe also the availability of service/opening hours, and the expected time of arrival of the ride-sharing vehicle. In delivery apps, it could represent the waiting time before preparation, the time of delivery or the opening hours of the restaurant/food provider</p> <p>It is not clear if the clock is associated with the departure or arrival time. The fact that it is used in multiple ways creates confusion. Unfortunately, there is no text label in most screens where it is used. It would be clearer with numbered hours</p> <p>UIL survey results – Q14 - Please match the pictogram with the function it best represents, based on your personal experience</p> <ul style="list-style-type: none"> - 56% (of responses) - “Set alarms”; - 20% - “View current timing” of something/ someone arriving or of an item that has to be delivered; - 10% - “View expected date /time of arrival/ delivery”

(continued)

⁷ The full content of the catalogue is included in the “Universal Interface Language – Version 1” (Huetting et al. 2021).

Table 1. (continued)

Icons' group, name and function	1. Clock
Example of use (Madrid pilot):	"La Pajara" food delivery app order screen using the clock icon to notify time of delivery (see Fig. 6)
Pros:	The contrast and position of the icon is appropriate
Cons:	The size is too small for users with low vision; there is no textual explanation and the same icon is used with multiple meanings in the same app, affecting consistency
Icons' group, name and function:	17. Tools
UIL Exercises results: Emilia-Romagna pilot	This icon is clear, but it is not clear who is going to fix the problem with those tools. To low-digital-skilled users it is ambiguous since it does not tell them if it is there to offer external assistance or if she/ he (the user) should operate with (digital) tools and try to solve problems (see Fig. 7) UIL survey results Q4 - Please evaluate how clearly the pictograms represent the function "GO TO SETTINGS" The tools icon is considered the second choice for access to settings functions (68% of positive preferences), after the gear icon Example of use (Emilia-Romagna pilot): "Punto Poste da Te" (digital locker service) app error screen using the tools icon to notify the user that the process has been interrupted
Pros:	The design of the tools is clear; contrast and size are appropriate and the textual description supports comprehension. The spacing across elements is appropriate for all users, including those with digitisation issues. The icon associated with the cross in a red circle helps the user understand that something is wrong
Cons:	The icon meaning cannot be read by text-to-speech systems. Since this function is related to parcel delivery in mailboxes, users with low digital skills or non-native speakers may think that someone will physically provide help to adjust/recover the service

7.3 Recommendations for the Design of Accessible and Inclusive Interfaces

Recommendations based on the empirical research in the INDIMO project address the design, selection and integration of pictographic icons in accessible user interfaces for mobile applications. They also include those derived from the literature, standards, desk research and tips for user-testing and recruitment.

Since the main reference for web-developers and designers in terms of web accessibility are the WCAG guidelines, we chose to use the same categorisation to offer UIL readers a sample of recommendations aligned with its structure: perceivable, adaptable, robust, operable and understandable interfaces (W3.org 2018).

From the INDIMO user research the following accessibility topics emerged as the most problematic, and they have been grouped as follows:

Perceivable Interfaces

- *Pay attention when designing welcome screens:* Welcome screens are often overlooked, despite being the first hook for catching users' attention. The service provided should be quickly recognised, clearly stated and the navigation facilitated by labels and tips. Especially in the first screens, it is important to avoid information overload.

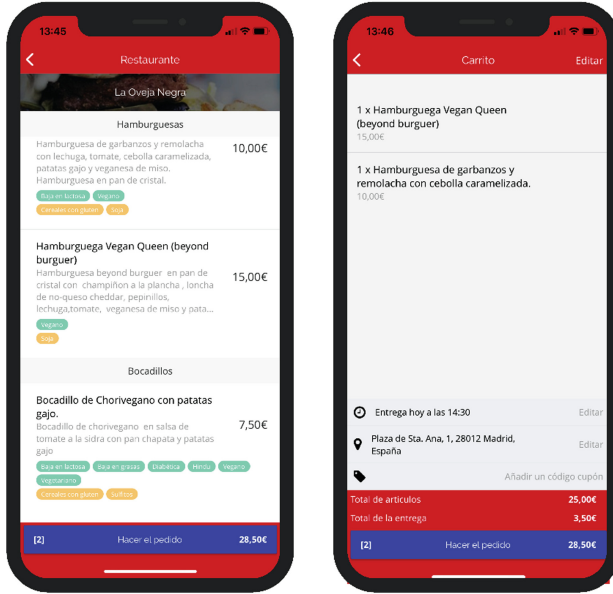


Fig. 6. Example of use for the tool “clock” in Madrid pilot

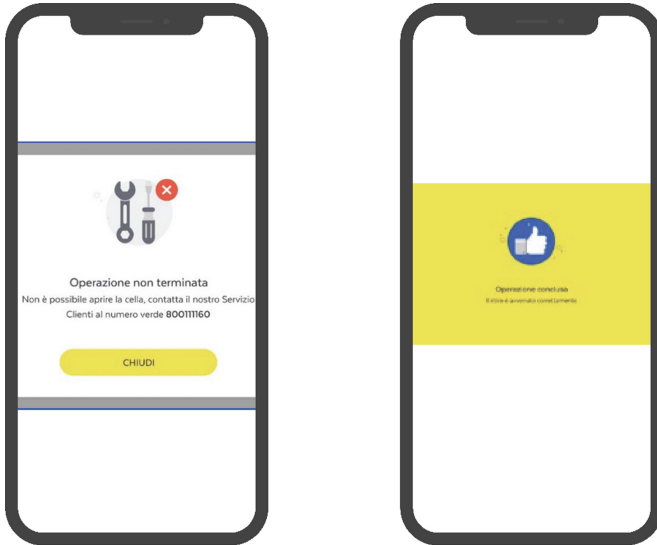


Fig. 7. Example of use for the tool “tools” in Emilia-Romagna pilot

Thus, it is important to provide direct access to the few features needed to easily access the service.

- *Colour coding*: Colour coding brings a lot of information to users, though this is very much related to culture. Global standards and guidelines fail in providing information on this concern. The use, misuse and non-use of colour can be misleading in different ways, depending on the context of use and socio-cultural environment. Test colour palettes of buttons and icons with diverse people with different socio-cultural backgrounds.
- *Themes and backgrounds*: Situational impairments or changing conditions should be considered when choosing colour themes and backgrounds of user interfaces. Solutions could be identified for other contextual conditions affecting perception, for all kinds of users and on different sensory channels (e.g., road navigation maps offering light-sensitive backgrounds, which change dynamically when sensors detect low-light conditions such as tunnels).
- *Contrast*: contrast is very important to colour-blind people: to avoid losing the information conveyed by colours, and misunderstandings, developers should design mock-ups in grayscale and choose colour palettes and opacity options based on the preliminary results of online contrast accessibility checking tools.

Adaptable Interfaces

- *Sorting*: pay attention to lists/elements sorting: they have to make sense depending on use frequency and process priority, not alphabetical order; whenever possible, offer the option to choose sorting order and filter options.
- *Accessibility settings*: offer the possibility of partly customise the theme (colour, contrast, fonts and content behaviour), provided that at least one of them is fully-accessible.
- *Inclusive fields/travel options*: when asking users to fill in information about themselves or about service requirements/ preferences, add inclusive fields where users can specify additional needs.

Robust Interfaces

- *Constraints*: add constraints to ensure that users are not required to insert identical data multiple times, offering options to verify, edit or specify changes before proceeding with transport or delivery service order confirmation.
- *Provide automated error detection function*: provide help buttons, show how the error detection works, explore advanced strategies for error-prevention, such as user input constraints (e.g., poka-yoke).
- *User rating and reviews*: offer users the possibility to rate and review your application in terms of accessibility, with a transparent and open app-rating area, and be sure to address/solve the issues that may emerge. Consider this an opportunity for further improvement.
- *Long-term user engagement strategies*: think in a long-term perspective and invest a proper amount of time, money and effort to testing ideas and prototypes, taking advantage of the experience and knowledge of the real experts—that is, those users experiencing accessibility barriers who can provide real feedback about services.

Operable Interfaces

- Increase broad operability: ensure that your service, both in its desktop and mobile versions, is operable and compatible with as many devices, operating systems and browsers as possible and that it is easily accessible also in different contexts of use. Develop a light version of the App which is operable with a variety of equipment, including older models of devices, and which does not require too much storage space or operating memory (RAM) nor overly affect battery consumption. A web-based alternative should be available.
- Transparency about accessibility limits: be honest about your limits and offer users explanations concerning the accessibility limits of your services, either through the frequently asked questions (FAQ) section or a dedicated area for open comments or specific complaint forms.

Understandable Interfaces

- *Easy-to-read privacy policies and terms of use*: full and easy access to your Privacy Policy, Terms of Use and Personal Data Treatment information should be provided to all users, mitigating readability issues through easy-to-read texts, visual explanations and simplified navigation across contents (text blocks, sections).
- *Quick and easy editing of personal data treatment settings*: personal data should always be available for users to edit, posing no time-limits and no risk of data loss during compilation. Also, a higher level of control and support should be available, for example by offering direct links to organisations that users can call anonymously to receive help (trusted referees).
- *Tips*: At key steps, ask the user for suggestions or complaints concerning the service; send e-mails to users to ask for their ratings and comments about service quality and satisfaction, allowing in-message reply; include the possibility of viewing other users' rating of the service; include a service agent and offer users the possibility to directly contribute to the FAQ area.
- *Tutorials*: realise first-use tutorials in different media formats, languages and easy-to-read textual contents, to ensure all users find the ones most appropriate to their needs (textual, audio, images, hard printed/printable copies), including the option to skip.

Concerning our focus on inclusive visual icons, recommendations include results derived from the Communities of Practice meetings in pilot sites and the UIL survey, i.e.:

- Choose icons describing actions rather than objects or symbols;
- Ensure the internal consistency of the icons;
- Label icons;
- Get familiar with naturalistic observation of users interacting with icons;
- Test iteratively for recognisability and memorability;
- Consider a flat and minimalistic design of icons;
- Keep in mind that ambiguity may increase over time or be misunderstood in diverse socio-cultural context;

- Use skeuomorphism only if it is essential;
- Limit the use of animated icons.

Last but not least, we shared our lessons learnt in terms of user recruitment and testing in the service prototyping or co-design phases. This sub-set of recommendations suggests that it is important to:

- *Build a network of people* who will participate in design iteration through co-creation workshops and interviews from the early phases. Such collaborative communities are intended to ensure cooperation across developers and design experts and all the potential customers left out by traditional user-testing, namely the people who experience barriers in using digital mobility applications. Due to these barriers, they are poorly reached by market-oriented campaigns, so a targeted strategy should be put in place.
- *Reach out to local advocacy groups* in advance, as they may help get in contact with users willing to share their experiences and as a result have their voices heard in the development process, in order to build inclusive-by-design services.
- *Organise both online and real-life meetings and workshops* to tackle potential barriers to inclusion; if you really want your participants to enjoy the activities you organise and provide honest feedback, you should share and verify workplans in advance and collect their suggestions prior to the meeting. Empathise with involved people's needs and you'll be rewarded by the experience.
- *Define a clear, simple and continuous inclusive design process*, using existing templates or building your custom set. Instruct team members to follow the same guidelines and track results in the most efficient and systematic way possible.

This initial set of recommendations grew considerably during the research. It has been collected as a browsable online catalogue that integrates all the recommendations derived from the INDIMO research⁸. The main ambition of the INDIMO set of recommendations is that of guiding UX/UI designers, service providers and developers in a truly inclusive approach to the design of digital mobility services.

8 Conclusions

When people or objects travel, they move across the four dimensions of space and time. How can icons representing objects or actions related with time and movement be designed in such a way that they are clear enough and unambiguous for all people over time and across countries? The fascinating history of signs and symbols is a never-ending one. The challenge remains open, and the main lesson is that no universal icon can be defined once and for all.

Nowadays, thanks to digital technologies, we are finally able to create dynamic contents and adapt all services and related applications to the changing needs of all kinds of people. When referring to needs, it is essential to include those expressed by the 15% of world population living with some kind of impairment. Undoubtedly, the usability of

⁸ To see the full set of the INDIMO recommendations, see the online catalogue at <https://spet.indimoproject.eu/recommendations/>.

every icon and user interface can be increased by applying user-centred design techniques and the Universal Interface Language approach proposed by the INDIMO project. But without the direct involvement of the targeted end users, they will have a limited reach, since without such a commitment to involving them, even good ideas will surely be poorly implemented. Thanks to co-creation, a direct exchange between end-users and service design teams was enabled, allowing the people involved to become familiar with each other and grow their awareness about their mutual needs and the complexity of the job at hand. This ultimately activated empathy, awareness and a commitment for change and adaptation. The main lesson learnt—as reported by the service operators, designers and developers involved as members of the INDIMO pilots’ communities of practice in the co-evaluation and co-design process—is that having the opportunity to learn directly from these usually neglected end users brings a win-win situation. For the end users gain more satisfaction from using digital applications, and service providers, developers and designers improve the quality of their service, thus reach better market positioning while also growing personally. The INDIMO Universal Interface Language tool’s main ambition is exactly that of providing practical tools to bridge the “communication” gap between accessibility needs and the diverse solutions in the digital world. The INDIMO results can represent the starting point for further research and developments, and help others unleash the huge potential of collaborative design-for-all.

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