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European regulatory framework for person carrier robots

E. Fosch Villaronga [a,*], A. Roig [b]

[a] University of Twente, Enschede, The Netherlands
[b] IDT Institute of Law and Technology, Universitat Autònoma de Barcelona, Spain

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A B S T R A C T

The aim of this paper is to establish the grounds for a future regulatory framework for Person Carrier Robots, which includes legal and ethical aspects. Current industrial standards focus on physical human–robot interaction, i.e. on the prevention of harm. Current robot technology nonetheless challenges other aspects in the legal domain. The main issues comprise privacy, data protection, liability, autonomy, dignity, and ethics. The paper first discusses the need to take into account other interdisciplinary aspects of robot technology to offer complete legal coverage to citizens. As the European Union starts using impact assessment methodology for completing new technologies regulations, a new methodology based on it to approach the insertion of personal care robots will be discussed. Then, after framing the discussion with a use case, analysis of the involved legal challenges will be conducted. Some concrete scenarios will contribute to easing the explanatory analysis.

1. Introduction

The exponential growth of robot technology in non-industrial settings challenges not only current safety standards but also user's rights. Until now, industrial robot regulations have guaranteed human safety by fencing off robots from humans. Service robots, however, imply a close human–robot interaction (HRI), non-expert usage, and work in non-structured environments. The International Standard Organization (ISO) has released the industrial standard ISO 13482:2014 "Robots and Robotics Devices – Safety Requirements for Personal Care Robots" to precisely cover this shift from industrial to service robotics and ensure human safety in this specific domain. Nonetheless, standard compliance does not give answers to a person that feels hopeless because his/her person carrier is in protective stop mode due to a system failure and has left him/her in the middle of nowhere; or when a person is afraid of using an exoskeleton because its gait pattern is slightly different from that of the user. Although standards ensure safety, safety is only one of the principles the Law protects. If the legislature confined legal compliance to compliance with industrial standards, not only would other principles protected by the Law be disregarded, but it would convey the impression that the Law is being privatised. The regulation of new technologies, therefore, has to find a balance between the four constraints that, by default, regulate a thing: technical norms, the Law, the market and social norms (Guidelines on Regulating Robots, 2014; Lessig, 2006).

As Nelson explains (Nelson, 2015), standards help provide risk management assistance limiting liability and helping producers to meet market demands. They are considered soft Law (Shelton, 2003). Soft legislation provides good alternatives for dealing with many international issues that are new, specific

* *Corresponding author.* Department of Governance and Technology for Sustainability (CSTM), Faculty of Behavioural, Management and Social Sciences, University of Twente, Building Ravelijn, P.O. Box 217, 7500 AE Enschede, The Netherlands.
E-mail address: e.foschvillaronga@utwente.nl (E. Fosch Villaronga).
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and complex, especially when States cannot foresee the consequences of a legal document. Standards are flexible, and seen as a tool of compromise, and sometimes the basis of legal corpuses such as the Machinery Directive 2006/42/EC or the Medical Device Directive 93/42/EEC (BSI, 2014; GROWTH; Krut and Gleckman, 2013).

In an ideal world, robots are clear of impacts and therefore threats can be responded to in terms of prevention and opportunities in the form of facilitation. In practice, nonetheless, certainty about impacts of robots are often less clear, especially when they are inserted with the aim of caring about someone else. Therefore, regulators will have to address uncertain risks, ambiguity of impacts and ignorance about the effects of impacts. At the same time, moreover, standards are non-binding and are voluntarily adopted. They represent the capitalisation of Law (because they cost money) and they are self-interpretations of industry reality. These characteristics lead to questioning the legitimisation of standards. On the contrary, legislation (or "hard law") stands for legally binding obligations. They are precise or can be specified through regulations. Contrary to soft-law, hard law enhances the capacity for enforcement (i.e. allowing allegations and defences to be tested under accepted standards and procedures when a violation is found). Hard-law constrains self-serving auto-interpretation; it fixes consequences for violations (and also provides "proportional countermeasures" where other remedies are unavailable); it implies a specific form of discourse (that disqualifies arguments based solely on interests and preferences); and it entails higher reputational costs (that reflect "distaste for breaking the law") (Abbott and Snidal, 2000).

Novel service robot standards focus on physical human–robot interaction (HRI) hazards by stipulating safety requirements on several design factors such as robot shape, robot motion, energy supply and storage or incorrect autonomous decisions. Current robot technology capabilities nonetheless go beyond mere physical HRI. In fact, the robot can put at risk other spheres of the users' rights without causing them actual physical harm. In Kuner et al.'s words: "an interference with data protection rights does not depend on whether there has been any harm or inconvenience to an individual" (Kuner et al., 2015): for instance, when the robot collects users' behavioural data to create profiles and use it for other purposes; or if it prevents the user from committing suicide because the system recognises safety over free will. Autonomy and shared-autonomy also challenge the current system of allocation of responsibility after harm occurrence.

Questions concerning the impact of robot technology on the legal/ethical layer, such as with regard to respect for private life, data protection, autonomy, or dignity, are not part of current standards while they are at the core of any legal system (and are considered fundamental rights in the European Union). Fortunately, both the engineering and the legal community have tried to include some of these principles into their field of research. From the engineering perspective, in April 2016 the standard BS 8611 "Robots and robotic devices – Guide to the ethical design and application of robots and robotic systems" was published. From the legal side, there is the strong belief that, at the same time that safety standards are being developed, supra-/national and state laws are needed to provide citizens with full legal coverage. In 2014, the European project RoboLaw addressed the impact of self-driving cars, computer integrated surgical systems, robotic prostheses and care robots. In "mapping robolaw" they identified five legal themes on robotics regulation: 1) health, safety, consumer and environmental regulation; 2) liability; 3) intellectual property rights; 4) privacy and data protection; and 5) capacity to perform legal transactions. The final resolution of the European Parliament (2015/2103 (INL) Civil Law Rules on Robotics) introduced some general and ethical principles concerning the development of robotics and artificial intelligence for civil use (European Parliament, Committee on Legal Affairs, 2017). The European Commission has not yet responded to it, but it describes quite precisely the suggested content of such a future rule. It is worth noting that the principles are similar to the robolaw project: liability, safety, privacy, integrity, dignity, autonomy, data ownership, ethics and justice. We will implement them in detail afterwards. Certainly, robots are many and not all challenge these identified themes nor in the same degree (see *infra*).

This article aims at taking one-step forward in the regulation of robotics by:

1) Addressing the legal dimension of a concrete type of robot – person carriers; and
2) Incorporating into the legal discussion the grounded knowledge provided by the HRI community.

The main idea is to gain concrete understanding without losing legal respect; working towards meaningful frameworks that can be a) applied by roboticists (because nowadays legal rules are seen as a burden and not practical) and b) give full coverage to the protection of the user; be freely available (avoiding the business model behind standards) and enhance *bindingness* and the capacity of enforcement.

The article is divided in different sections. After the introduction, section 2 establishes the methodology that will be followed thorough the article: context (section 3), robot type (section 4) and risk analysis (section 5). Conclusions will be provided at the end together with a draft set of guidelines. In principle this piece of work is intended for person carrier robots and Europe, although it could be adapted and extended to other types of robots and other frames having a partially different cultural context (although a case-by-case approach is preferred similar to what the Consumer Product Safety Commission in the United States propose in regard to Regulatory Robots (United States Consumer Product Safety Commission)).

2. Methodology

With the aim to adjust to current times, and at the risk of the Law becoming a list of virtual general policies not suitable for regulation (Roig-Batalla, 2016) (and the end of the Law as Hildebrandt argues (Hildebrandt, 2015)) the Law has had to adapt the way in which it approaches new phenomena. Moving away from the top-down approach and recognising the need for grounded knowledge, the European Union has opted to incorporate the Impact Assessment methodology within its legislative framework. Within the European Commission's Smart

Regulation Strategy, impact assessments (IAs) are considered to be "transparently assessing legislative and non-legislative policy options by comparing both potential benefits and costs in economic, social and environmental terms [. . .] performed for all proposals with significant direct impacts [. . .] been issued for analyzing impacts on fundamental rights [. . .]" (COM, 2012).

In other words, IAs are processes that point out the impacts of new projects, technologies, services or programs and, in consultation with the main stakeholders, they take remedial and corrective actions to eschew or mitigate any risks (Wright and Wadhwa, 2012). The application of the risk methodology in Law promotes communication between the involved stakeholders and takes into account other aspects normally left aside in safety regulations: economic, social, ethical, psychological or financial aspects. In short: interdisciplinary regulations for interdisciplinary problems. Furthermore, this risk-based approach goes beyond a simple harm-based-approach that focuses only on damage but includes every potential as well as actual adverse effect. This methodology has been widely used in different specific sectors: Privacy (PIA), Surveillance (SIA) or Environment (EIA). In fact, the recently approved General Data Protection Regulation (GDPR) incorporates in Art. 33 the general obligation for the data controllers to "carry out an assessment of the impact of the envisaged processing operations on the protection of personal data" (Council of the European Union, 2015).

According to Cavoukian: "like other operational risks, those related to the protection of personal information benefit from the scrutiny of a formal risk management discipline" affirming that "Personal Information is an asset, the value of which is protected and enhanced by a suite of security practices and business processes" (Information and Privacy Commissioner, 2010). Likewise, inserting a robot in the society poses multifaceted risks that could be mitigated by several actors such as the legislator (through binding regulations), creator of the robot (by complying with standards), and the facility where this is going to be inserted, etc. Conducting a "Care Robot Impact Assessment" (CRIA) could help identify all these risks.

Specific-sector impact assessments differ in their scope, not in their structure (see Fig. 1). PIA for instance deals with the privacy impacts that a given technology will pose to the subjects (ISO 27005:2011; SGTF, 2014). According to the CNIL, "in the area of privacy, the only risks to consider are those that processing of personal data poses to privacy" (CNIL, 2012). SIA is on its side and is a wider instrument principally concerned with other impacts – not only privacy but also economic, financial or psychological impact; and focuses on groups and not individuals as PIA does (Wright and Raab, 2012).

In this regard, CRIA deals with all the impacts of any nature that a given care robot can pose to the users (Fosch-Villaronga, 2015). As Calo announced, "robotics combines [. . .] the promiscuity of information with the capacity to do physical harm" (Calo, 2015), but they can also be involved in psychological risk scenarios if "mental communication" (Fosch-Villaronga et al., 2016) is the only channel of communication, e.g. depression due to a decrease in human to human interaction, overreliance on the robot, frustration when robot does not understand human commands or increasing feelings of presence (FoP) (Blanke et al., 2014). Moreover, robots will be involved in privacy, autonomy and dignity risks.

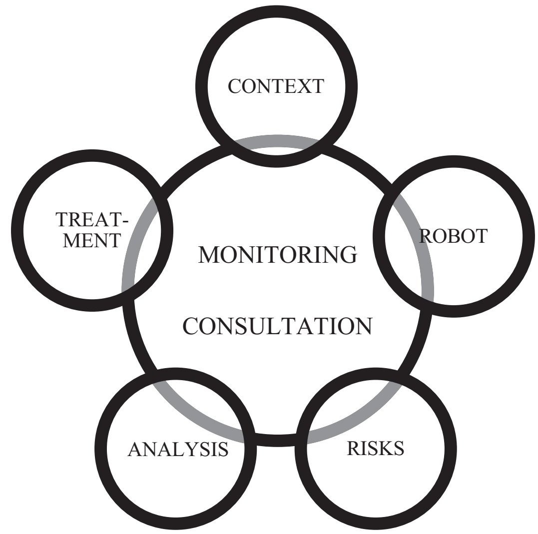


Fig. 1 – CRIA model: care robot risk management process (Fosch-Villaronga, 2015).

According to the Article 29 Working Party's opinion (A29WP) the: "risk-based approach goes beyond a narrow harm-based-approach that concentrates only on damage and should take into consideration every potential as well as actual adverse effect, assessed on a very wide scale ranging from an impact on the person concerned" but also remembers that "risk-based impact assessments are complements but do not substitute the general legal compliance" (14/EN WP 218, 2014). Likewise, the CRIA tries to address all the adverse effects of care robots to prevent any disproportionate impact on the subject, guaranteeing full compliance.

This article will focus concretely on Person Carrier Robots (PCaR) (see *infra*), a sub-type of Personal Care Robots (PCR). Special focus will be given to "wheeled passenger carriers". Possible existing functionalities of PCaR have been taken into account to cover the risk scenarios in the legal domain. PCaR risks are multidimensional and intertwined: they involve the user, the environment and the device itself. As we will see, these robotic devices can generate physical forces provoking fatal outcomes, which are not always in line with the user's intention. This can have consequences, not only at the engineering level (how can the mechanical design be changed to mitigate a certain risk?), but also from a legal perspective (who is responsible for a caused damage?). For the purpose of this article, section 5 will analyse the risks combining the identification, the analysis, and the treatment.

3. Context of use

A framework for the evaluation of the impact of personal robots demands special consideration in respect of the context of use: a hospital, a private dwelling or a public space. The type of user that will benefit from a personal robot is also relevant from a legal perspective – especially if elderly-infirm people or children use this technology (Van Wynsberghe, 2013). For this reason, it is essential to take into consideration both the internal and the external contexts, which can affect the personal care robot. Regarding the internal context, the institution needs to consider its own structure, the main objectives, roles, decision-making processes, division of responsibilities, and right timing for conducting the assessment. In the external context, the expectations of external stakeholders (patients, third parties, and companies), legal issues, and contracts with other undertakings should be considered.

For this study-case, the context will be a public nursing home for elderly people:

Nursing home Queen Charlotte has just incorporated 50 person carriers. These person carriers will improve current residents' mobility around the different pavilions the nursing home has. The person carriers will convey persons within fixed intended destinations, e.g. from the bedroom to the dining room or to the activity room. Residents are also free to use them for personal purposes such as going outdoors with them.

The World Health Organization (WHO) identifies 16 groups of stakeholders in a nursing environment (Health Service Planning and Policy-Making). Nursing homes are structured environments, with rules and timetables for meals, bathing, etc. In addition, although their correct functioning relies on several aspects (e.g. size, staffing hours, ownership, resident characteristics, etc.) (Harrington et al., 2000), they are more organised than personal homes. This affects the characteristics of the robot that will have to adapt to specific pre-established rules.

4. Type of robot

Although all service robots are in non-industrial environments and require close human–robot interaction (HRI), they largely differ between them depending on their attributes, capabilities, HRI or the contexts within which they are inserted.

In this regard, the characteristics of the robot should be identified: for example the hardware, software, network of transmission, etc. The level of human–robot interaction should be defined – patients, other people, children, pregnant women, etc. Then there is the level of autonomy this robot will have – who is in charge of it – the hospital, or the patient who purchased it and is using it in the same facilities, or has extended the use of the robot – if later on the robot is used in the dwelling of the patient but it still, for instance, communicates with the hospital.

Personal Care Robots (PCR) are defined as "service robots that perform actions contributing directly towards improvement in the quality of life of humans, excluding medical applications". Person Carrier Robots (PCaR) are a sub-type of PCR. ISO 13482:2014 defines PCaR as "personal care robot[s] with the purpose of transporting humans to an intended destination" (ISO 13482:2014). In addition to humans, the standard previews transporting also pets and property.

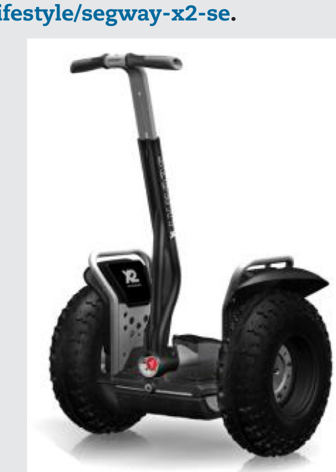
In theory, PCaR should not be confused with driverless cars as robots travelling faster than 20 km/h are expressly out of ISO's scope. Neither should they be confused with medical devices as these are also expressly excluded from the standard. The state-of-the-art, however, will reveal that rigidity in the application of these criteria will lead us to under-regulated scenarios: there are PCaR that can go faster than 20 km/h (SEGWAY); robotic wheelchairs that differ from manual/motorised wheelchairs (which are recognised medical devices) could not be considered medical devices but personal care robots (as Dinwiddie explains in Dinwiddie, 2015); or there are mixing categories, e.g. person carriers that transform into mobile servant robots [http://www.segwayrobotics.com]; robot toys used as person carriers, that at the same time are used in rehabilitation (but not considered wheelchair because there are no wheelchairs for 0- to 3-year-old children) (Fosch-Villaronga, 2016; Galloway et al., 2008). In any case, the standard categorisation should not prevent users from enjoying full legal coverage.

According to ISO, person carriers can be (Figs. 2–5):

Carriers with passenger standing on the foothold. This is segway®[s] case: conveyors intended to travel on smooth surfaces using wheeled mobile platforms where the travel direction is controlled by shifting the passenger's weight on the base foothold.

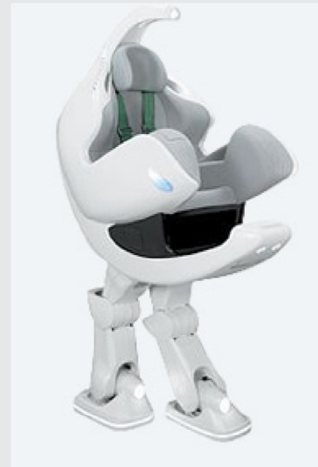
Although Toth explains that these robots transport people throughout domestic properties at a slow speed appropriate to moving about the house (Toth); it seems nevertheless that they were meant to be outsiders as people use it for going to work, do sightseeing tours or outdoor activities.

Fig. 2 – Segway ×2 SE. Source: www.segway.com/products/consumer-lifestyle/segway-x2-se.



Legged passenger carriers. Robotic bearers conceived to circumnavigate on 3D surfaces using legged instead of wheeled mobile platforms. These could be used in non-urban locations at the speed of a walker. Toyota released i-Foot in 2004 but never entered the market (TOYOTA).

Fig. 3 – i-Foot Toyota Model. Source: www.toyota-global.com/innovation/partner_robot/aichi_expo_2005/index03.html.



Carriers whose passenger sits on a monocycle. These are similar to segways (HONDA). Their particularity is that the person is sitting down. Shifting the passenger's weight controls the travelling direction. In the Domeo Project, Toth argues that these carriers are for large indoor public spaces such as airport terminals, large exhibition centres or shopping malls

Fig. 4 – U3-X Honda. Source: world.honda.com/U3-X/.

Wheeled passenger carriers. ISO 13482:2014 defines their functional tasks to be performed as follows "physically transporting a person from one destination to another on smooth surfaces, either autonomous mode or manual mode using a wheeled mobile platform". The PCR standard wanted to avoid the use of the "wheelchair" term even if this type of robot look like wheelchairs, their functionalities are very similar, and elderly and disabled people can use them. Other wheeled passenger carriers might include Cybercars (CyberCars) that can actually convey more than one person at the same time.

Fig. 5 – Toyota i-Real. Source: en.wikipedia.org/wiki/Toyota_i-REAL.

Due to its novelty, not only specific regulations dealing with person carrier robots are missing, but literature referring to "wheeled passenger carriers" is also practically non-existent. In addition, this "lack of legal clarity leaves device makers, doctors, patients and insurers in the dark" (The Economist, 2012). The purpose of this article is to help to devise what principles are involved in this precise technology beyond safety and beyond current categorisation. The majority of the relevant scientific publications in the major bibliographical engines refer to robotic wheelchairs – which currently are not all considered to be medical devices (only the stair-climbing function). Robotic wheelchairs and person carriers, with navigation capabilities and that use obstacle avoidance or environment sensing, are described in relevant literature.

The case scenario is as follows:

Queen Charlotte's person carriers are programmed to pick patients up at 7 am, 12 pm and 6 pm in their bedrooms for breakfast, lunch and dinnertime. Depending on each patient, they are also programmed to convey them back for a siesta or for activities. Doctor and hairdresser's appointments are included automatically in the robots' schedules. Patient's free time is from 9 am to 11:30 am and from 2 pm to 5:30 pm.

Current wheeled passenger carriers have other capabilities worth analysing that go beyond the sensors and their capacity to transport a person from one location to another. They can be transformed into beds (Panasonic) or become powered walking aids (Lee and Jung, 2010); they can offer personalised services applying machine-learning techniques (The MIT Intelligent Wheelchair Project); they can incorporate cameras and communication capabilities or they can be connected to an internet-of-things platform, as already mentioned. They can also offer the possibility to be tracked and monitored or even to be requested from a smartphone or tablet. In order to include different possible scenarios, the concrete robot of our scenario is a modified version of the Toyota i-Real project (Fig. 5), which includes the above-mentioned characteristics.

Concerning autonomy, in this particular scenario, the carriers will in some cases be fully autonomous – when going to meals or going to activities of the nursing home; and in other cases its autonomy will be shared between the user and the robot, if the user wants to go for a walk. To perform the function of conveying from one place to another, the carrier will have to intertwine the user, the robot and the environment.

Regarding the user, his/her volitional control is always paramount. Motion intention can be determined through different sensor modalities although manual inputs in this kind of robot are the most frequent. Voice commands are also used, especially with the increasing use of systems like SIRI.

A wheeled passenger carrier needs to be capable of recognising the environment in order fully to convey users. To accomplish other functions, the carrier can also include communication devices, voice recognition and also tablets and smartphones. Each of these devices proportionally increases the complexity of the regulatory framework behind them: the more sensors and the more capabilities the carrier will have, the more legal principles will be involved.

In the following sections we will identify the legal and ethical principles that have been appointed in the latest European documents for the robotic regulation. Moreover, we will enrich them with the ongoing discussion taking place within the Human Robot Interaction (HRI) community. That will help develop a clearer definition of the principles for a future regulatory framework.

5. Risk analysis

5.1. *Introduction*

"The mutual shaping of law, technology, and society implies that we cannot take the existing fundamental-right framework for granted, but must always also consider to what extent socio-technical changes should lead to a re-interpretation or re-evaluation of legal norms, including fundamental rights". The same researchers involved in the European Robolaw Project wrote an article in 2013 concerning how robotics challenges the Constitutional European Framework (Koops et al., 2013). They speculated whether, in the end, we should extend legal protection to robots (addressed before by Coeckelbergh 2010 and Darling 2012); however, how would the 'right to be forgotten' be applied if hybrid-bionic applications are recognised to have expanding brain function. They argued that new emerging robotic technologies could put at risk the various foundations of any legal order: dignity; human integrity; equality; freedom of thought; good administration; privacy; cultural/religious/linguistic diversity; data protection; access to healthcare; and non-discrimination or fair working conditions.

A year later, the Guidelines on Regulating Robotics were published. As already stated, this was the result of a 27-month European funded project called "Regulating Emerging Robotic Technologies in Europe: Robotics Facing Law and Ethics" (also called "RoboLaw"). They dedicated one chapter to the regulation of Care Robots, including an ethical and legal analysis. According to the authors and from the legal perspective, care robotics regulation should respect fundamental rights, independence and autonomy in the light of independent living and participation in community life, equality and access, liability and insurance, privacy, as well as the legal capacity and legal acts performed by robots. Safety, responsibility, autonomy, independence, enablement, privacy and justice were included in the ethical analysis.

Based on the above-mentioned principles developed in the most known and recognised European initiative on the regulation of robotic technology, here below are the principles that will be taken into consideration for the analysis that follows (Table 1):

In May 2016, the European Parliament released a draft report, with several recommendations to the European Commission on Civil Law Rules on Robotics that has been approved in February 2017 (European Parliament, Committee on Legal Affairs, 2017). While the Parliament expects the Commission to draft a Directive in 10–15 years' time, it already suggests some valuable information worth taking into account. This complies with the principles suggested by the Robolaw project.

As already mentioned, robots differ largely as to their attributes, capabilities, and HRI, and that is precisely why not

Table 1 – Principles involved in the regulation of robotics.

Principle	Explanation
Safety	For users and third parties
Consumer robotics	Health, consumer protection, environmental regulation
Liability	General and prospective liability
User's rights	Privacy, data protection and intellectual property rights
Autonomy	Independence, final say, acceptance
Dignity	Non-replacement of human touch or emotions, non-replacement of human caregivers, isolation
Ethics	Robot decision-making process in open scenarios
Justice	Access to technology

all care robots will be involved in the above scenarios. Indeed, current wheeled passenger carriers do not perform similar legal transactions to those that mobile servants could undertake when they purchase goods on the Internet for the user. Our hypothesis, therefore, is that PCaR are mainly involved in safety, liability and consumer robotics scenarios.

In order to confirm or reject the hypothesis, further subsections below will describe the principles and firm them up, including the vision that the HRI community has provided so far. One should notice that, although some of these principles could be considered for future regulation of robotics (as the RoboLaw project sustains), fixing the position on a case-by-case study is always needed, i.e., safety may include cognitive aspects – that is, if the only way to communicate with the robot is at the cognitive level; otherwise acceptance will include social awareness, apart from proxemics in social robotics. At the beginning of each principle, we will include a short use case to explain the concrete scenario. This will help to enrich our interdisciplinary regulatory framework introduced here in the following section.

5.2. *Analysis of the principles*

5.2.1. *Safety*

Anna is new to the nursing home. On the very first week, she takes the person carrier to go outside the nursing home. She presses some buttons and the carrier transforms into a bed. After she fixes it, she goes into a pedestrian zone. The carrier stops every now and then to avoid collision with objects and pedestrians. Some pedestrians complain about the person carrier on the sidewalk. The system detects a failure and stops in front of a garage. Anna cannot move it and has no phone to call the residence. A car wants to go out from the garage. There are some roadworks on the street and there are some sewers without cover. Unfortunately, she goes in one and falls down.

5.2.2. *General*

The safety scenario is probably the most common scenario in robotics in general, although the forthcoming indications are focused on Person Carrier Robots. Robotic safety is usually focused on the precautionary principle, and more specifically on collision avoidance, and human contact safety. Therefore, safety requires both high-precision sensory information and fast reaction times. This is highly important as the physical integrity of the person must be protected in the legal order.

5.2.3. *HRI discussion*

Hazards analysis is often limited to the mission tasks of the robot and risks associated with human users. For instance, children's persistent obstruction of social robot activity is a risk scenario that has been modelled and successfully lowered (Kato et al., 2015).

Mission tasks need to be properly elicited and secured, but the main concern ought to be directed to non-mission tasks. One general rule for enhancing safety and comfort is to implement what has been called user “legibility”: humans should easily understand and foresee robots' intentions in order to anticipate what is going to happen and thus avoid as many potential risks as possible (Kirsch et al., 2010; Lichtenthäler, 2011).

However, the identification of mission task risks and users' empowerment with legibility are not enough, because the number of non-mission interactions is growing quickly. It will soon be impossible to program a robot with a complete set of specified safety functions for foreseeable non-mission interactions. Thus, a person carrier robot will need to maintain safety when facing unforeseen non-mission interactions. How can a robot successfully achieve this? Some robots have now enhanced capabilities embedded for this purpose. For instance, they will learn from past situations, according to user behavioural analysis (Dillmann et al., 2000). Others will benefit from semantic network platform support (Kamei et al., 2012). Thus internal machine learning and external semantic networks support will combine to provide safer person carrier robots.

5.2.4. *PCaR risk scenario and recommendations*

Since these robots are meant to transport users from A to B, person carrier safety safeguards are based on collision avoidance, tipping over prevention and safe manoeuvring (see following sections). Their sources of danger are:

- extrinsic to the device: unstructured environments (either outdoor or indoor contexts), weather conditions, internet of things environment;
- inherent to the device: non-mission tasks, mode transitions, sensors that detect the intention of movement, internal parts of the robot (charging battery, energy storage), external parts (robot shape and motion), etc.;
- concerning the user: user's perception and lack of experience, feeling of pain or discomfort;
- concerning its transformations: if the carrier transforms into a bed, or if it transforms into a mobile servant robot;
- in general all the risks identified by ISO 13482:2014.

ISO 13482:2014 establishes a detailed hazard breakdown either for 1) the internal parts of the robot: charging battery, energy storage and supply, robot start-up electrostatic potential, electromagnetic interference; 2) its external parts: robot shape, robot motion; 3) but also includes human-related hazards such as stress, posture and usage, contact with moving components, lack of awareness of robots by humans, etc. The standard adds hazardous environmental conditions and hazards due to localisation and navigation errors. These are generally attributed to all personal care robots, even though some specificity is given for person carriers. Within this section, we will identify these hazards for person carrier robots, with a particular focus on wheeled passenger carriers.

Common risks for robotic wheelchairs in the safety scenario were identified in the EPIOC project (Evans et al., 2007). These include tipping over; collision with people, furniture, and even cars; and difficulties in manoeuvring in certain environments. Wheeled passenger carriers have similar risks. Collision avoidance systems are at the core of any carrier (wheelchair, driverless cars, person carriers, etc.). Unstructured environments are still a problem (Talebifard et al., 2014) even though some efforts have been made to solve it, including real-time navigation systems, similar to the systems other technologies employ, e.g. unmanned aerial vehicles or missiles (Wang et al., 2013).

In respect of obstacle avoidance, collision avoidance systems are at the core of any carrier (wheelchair, driverless cars) especially in unstructured environments like the street. Person carriers also incorporate collision avoidance systems. Some efforts have been made to solve collisions including real-time navigation systems, similar to the systems other technologies employ, e.g. unmanned aerial vehicles or missiles. Yet, this is not an extended case for person carriers. In fact, there is much diversity on the used systems, as there are no set guidelines. ISO 13482:2014 recommends the robot to perform an adjustment to the type of path, or to stop the robot motion and provide a warning (singularity protection explained in the section 6.8 of the standard).

To avoid collision with people, some of the participants in the EPIOC project suggested adding a horn or a sounding device to make people aware of their presence, similar to bikes or other means of transportation. In fact, "silent operations can increase the probability of collision with persons", and that is why ISO13482:2014 suggests the inclusion of a sounding device. At the same time, the standard reminds the reader that alternative indications should be required for people with sensory impairment. Concerning other lacks of awareness, e.g. the lack of awareness of the collection of personal data from the user, nothing is said in the standard, although the violation of personal data rights can lead to unfortunate scenarios not directly related to physical harm (see section user's rights safeguards).

Beyond the fact that from the policy perspective a robot should incorporate the best avoidance collision system, as a general recommendation a person carrier conceived for structured environments should not be used in outdoor contexts without adaptation. The manual of use could warn of this. The standard states that localisation errors can lead the robot to enter forbidden places or to lose mechanical stability in a hazardous manner (e.g. falling downstairs) and this should be prevented. If the person falls down a manhole in the street because the system was not geared to detect such a sporadic hole in the outdoor context, the roboticist might not be held liable if he had already set down the rules for indoor contexts. On the contrary, if the wheelchair can go outside the premises of the institution and it is not capable of detecting such a hole, then the collision avoidance system should be revised (as it is important both to avoid collision as well as any architectonic barriers there might be in the path of the robot).

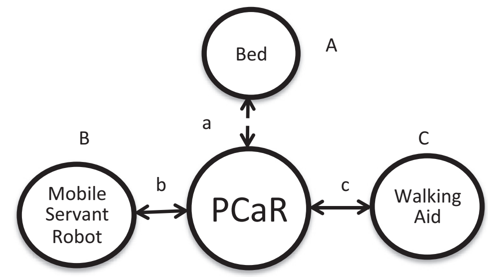


Fig. 6 – States and transitions in person carrier.

Control strategy plays a major role in coping with the abovementioned risks, especially shared and autonomous control. The project of researchers Wang and Gao aim at creating autonomous person carriers, although shared control is found to be preferable (Faria et al., 2014). It is true that an autonomously controlled carrier could perfect the shared control deficiencies; but at the same time, autonomy in non-mission tasks is still without fault: complete sensor coverage to detect nearby objects remains a challenge due to financial, computational, aesthetic, user identity and sensor reliability reasons (Shiomi et al., 2015). Sensors also have their scarcities and are sometimes a source of risk. This has a direct impact on liability and insurance that is still unsolved.

Environmental sensing could help reduce the volume of sensors incorporated into the device. In any case, sensors should be used for the purposes they were created for: if cameras are added to detect obstacles, they should be used for that purpose and not to identify users or third parties. In this regard, some blur the mechanisms for avoiding third party facial recognition which could be included. A massive collection of data for other purposes, competing with personal identifiable information, should be limited. It could aim, for example, to balance the amount of data needed to perform the task with the principles of data minimisation and data minimum storage (although it might not be feasible sometimes).

Person carriers can be transformed in several other devices such as a bed, a walking aid, or even a mobile servant robot. Resyone was the first robotic device to obtain ISO 13482:2014 certification. This is a robotic bed that transforms into a wheelchair. Although "wheelchair" refers to the medical device category, and although "wheeled passenger carrier" is a subtype of the person carrier robot category, Resyone was assessed within the mobile servant category. Similar to Resyone, if the person carrier can be transformed into different robots, a risk assessment concerning both the states and the transitions will have to be conducted. Here, states are identified in uppercase (A, B, C, and zero state would be the person carrier, here as PCaR) and transitions in lowercase (a, b, c, and then transitions back to the same position) (Fig. 6).

With regard to the protection of the user within the modes and the transitions between modes in multi-functional person carriers, heuristic rule-based classifiers could be a simple but effective method to apply. These rules could prevent the device from inappropriately switching back and forth between modes if the user does not allow it. For instance, if the carrier had a stair-climbing function, it could be pre-established that this function will not be operative once State A (bed) is on. State A could also be prevented if the carrier is outside the nursing home premises (to avoid what happened to Anna in the case scenario). In any case, mode transitions should be carried out smoothly and in a way that ensures that protection of the user is granted in both the state and the transition between states.

Safety also depends on how the user controls the person carrier when it is in shared control. In fact, the disability of the user may blur some boundaries, well defined by non-mentally impaired users. That is why ISO 13482:2014 directs manufacturers to pay attention to the design of the user-interface. This can strengthen the reliability of the user to the device and therefore a reduction in the fear of using it.

The standard also addresses the concept of "protective stop". System failure leads the device into a protective stop mode. Although the stop is "protective", some scenarios can imply the feel of hopelessness for the user, because the user cannot then reach their destination and cannot move the device. Creators of PCaR should consider this in order to prevent the user from having this problem, especially if this can imply third parties (the user from the garage that wants to leave out the car). Incorporating communication capabilities could be an adequate solution.

Intangible and intrinsic factors to the user, such as the user's safety perception, or the user control, can also constrain carrier performance in shared autonomous mode. Current ISO 13482:2014 does not contemplate different categories of people, regardless of the fact that elderly, handicapped or children can use them. In fact, the disability of the user may blur some boundaries, well defined by non-mentally impaired users, and this is something producers should take into account independently of the availability of standards in this regard. This is particularly so in cases where ISO recognises that several target groups should receive different specifications. Paying attention to the design of the user-interface, as ISO 13482:2014 suggests, could strengthen the reliability of the user to the device and reduce the fear of using it (safeguards for different types of users should be *mise-en-place*). Shared control percentages could also be reviewed in the case of vulnerable parts of society, e.g. leaving less room for human decision when the elderly drive them (see autonomy section). Lack of user experience can significantly affect self-confidence and thus the correct performance of the device. Indeed, the user of the carrier needs to feel secure during all stages of use.

If users are afraid of the device, their control over it may not be adequate. There should be mechanisms to compensate this state of mind, such as safety-related speed control if the device acknowledges strange directions (ISARC2006). Some researchers at Dalhousie University in Canada have speculated whether to institute a driving test without which PCaR (in that case wheelchairs) could not be operated (Dalhousie University). This driving test could be preceded by a period of training, where all the safety measures and all the issues could be explained, not only to the user but also to the relatives. This is similar to what the Unmanned Vehicle University has established: a drone pilot training certificate (Unmanned Vehicle University). Another source of risk is the feeling of pain and discomfort. In the early stages of a project, this sometimes cannot be detected, but addressing physical risks is of vital importance. As ISO points out, ergonomics and stress are both hazards.

6. Liability and "consumer robotics"

6.1. Consumer robotics

Another day Anna gets the PCaR and it breaks. Anna is afraid of using it again because she feels she might have an accident in the end if the carrier does not work properly.

Consumer robotics refers to the correct robot categories, what to do to insert the robot into the market (certifications, conformité européenne), health, consumer protection, and environmental regulation. It could be said that these do not deal with robot scenarios and, to the best of our knowledge, are not directly mentioned by HRI community either. ISO 13482:2014 is thus the only available regulation. This is not strictly mentioned by the European Parliament but, according to the Robolaw project, it is the first aspect to take into account in a future regulation of robotics.

6.1.1. *HRI discussion*

Consumer robotics, however, can certainly benefit from existing consumer protection decisions and for leading institutions, like the Federal Trade Commission in the USA, to tackle some problems such as unfair and deceptive robots (Hartzog, 2015).

With regard to the manufacturer of PCR, as Salem et al. state, we need to differentiate between the "certified safety" and its "perceived safety" (Salem et al., 2015). Certified safety relates to the obtaining of standards and certifications ensuring its compliance (although sometimes the certification is obtained without testing the quality of the product itself (Le Monde, 2012)). In addition, perceived safety is the perception that consumers have of the product. For example, as already mentioned, the lack of user experience can affect self-confidence and thus the performance of the PCaR.

6.1.2. *PCaR risk scenario and recommendations*

Correct attribution of robot categories (not only for PCaR but also for PCR in general) is a fundamental issue in the user protection scenario. As described in (Richards and Smart, 2013), correct categorisation of robots is indispensable for an appropriate risk assessment, posterior legal compliance and user protection. As stated before, as their website indicates, the robot Resyone is a robotic bed that transforms into a wheelchair. It was awarded ISO 13482:2014 under the parameter of "mobile servant robots" (MSR), not person carriers. The standard, however, describes MSR as personal care robots meant to travel to perform serving tasks by way of interaction with humans, such as handling objects or exchanging information. When Resyone's state is that of a wheelchair, this robotic device should be assessed according to the PCaR criteria. At most, if we consider that Resyone "assist(s) elderly/tired people to and from a chair, bed, etc." Resyone could be considered as a restraint-free assistant robot. In any case, "wheelchairs" per se are medical devices, unless one argues that robotic wheelchairs have no recognised category yet and that they could also fit into the category of "personal care robot with the purpose of transporting humans to an intended destination" (as we argued).

A person carrier that is capable of monitoring the user's vital signs, such as measuring blood pressure or heart rate, either directly or indirectly (through wearable devices worn by the patient), would have to be assessed according to the medical device legislation, although there is no answer yet from the major institutions, i.e. FDA or EU Commission. Due to the rapid development of robotic technology and the mixing of categories that we have seen, this is still a fundamentally unsolved problem. A clear definition of the context and the robot type could help determine the correct categorisation of the legal framework to be applied. Although the medical device regulation has a long tradition of "intended use", what makes more sense is to make a robot compliant with the legal system through a combination of variables: by its own capabilities, the context wherein it is inserted and its HRI. In order to avoid under-/over-regulated scenarios, some sort of personalised dynamic legislation would be needed.

6.2. Liability

Going to the garden with the person carrier, Anna accidentally runs over a child that was visiting her grandma. The mother of the child sues her for damages. Pepa claims that responsibility lies with the nursing home, but it is subsequently argued in court that it was the person carrier's fault because it worked autonomously. The manufacturer says that once the warranty expires, they are not responsible for the person carrier.

6.2.1. General

The autonomy in the decision-making process of robot technology challenges the legal domain in two correlated aspects: the allocation of responsibility and, because of this, the grant or not of agency status to the robot. Indeed, some person carriers have already caused some trouble as found in Vienna (Roider et al., 2016). The RoboLaw project realised that damage to third parties, which is not attributable to producers, manufacturers, designers or users, will require additional robotic tort litigation clauses and perhaps compulsory third-party insurance.

Some time ago, part of the legal community concluded that: "any self-aware robot that speaks English and is able to recognise moral alternatives, and thus make moral choices, should be considered a worthy 'robot person' in our society" (Freitas, 1985). The need for autonomy, in the decision-making process, could produce a rethink of old legal concepts such as "thing" or "agent" (Richards and Smart, 2013). Just as other institutions in our legal system, such as the nasciturus (that to be born), conceptus (the non-conceived), animals or corporations have a recognised legal status (i.e. are subjects of Law), so does part of the legal community believe that robots should be granted a form of agenthood (Laukyte, 2014).

This goes in line with the so-called "responsibility gap". The responsibility gap theory suggests that, if robots learn as they operate, and the robots themselves can, during the course of operation, change the rules by which they act, then robots and not humans should be held responsible for their autonomous decisions (Hellström, 2013). Although this theory might be controversial, because it exempts human responsibility solely based on the nature of technology (Johnson, 2015), the European Parliament has expressed recently its worries in this regard and has suggested to the European Commission that it establish the "responsibility of the teacher". However, the responsibility gap might not be bridged if the teacher is the robot itself.

The European Parliament also suggests applying strict liability rules for roboticists, which means that it will only be necessary to prove a causal link between the harmful behaviour of the robot and the damage suffered by the injured party. Finally yet importantly, a European Parliament Motion for a Resolution also suggests that the Commission should consider making roboticists accountable for any social and environmental impact their creations might cause to "present and future generations". Likewise corporate social responsibility.

6.2.2. HRI discussion

Some of the HRI community are worried about liability for damages caused by artificial intelligence (Čerka et al., 2015), either through robotics or software agents (Asaro, 2016). From the HRI side, the new standard BS 8611 "Robots and robotic devices – Guide to the ethical design and application of robots and robotic systems" will generate a rethink among robot creators as to what extent they should be held responsible for their creations: if it is going to involve either safety or ethical considerations. Although it seems a strictly legal problem, the quasi-legal nature of standards may inspire future regulations that increase the legal responsibilities of robot creators.

6.2.3. PCaR risk scenario and recommendations

From the legal point of view, the occurrence of harm is the basis of "liability". The right to the integrity of the person, the right to an effective treatment and the rights of the elderly and of people with disabilities are considered to be Fundamental Rights by the European Charter of Fundamental Rights (see articles 3, 25, 26, and 47).

Internal control failures of the system, as well as external factors (weather conditions, a hole in the street, etc.), can cause direct harm to users, for instance, causing them to tip over. This is very important because tipping over is one of the first sources of risk for the person in wheeled passenger carriers. Between 1973 and 1987, of all reported wheelchair related deaths in the United States, 77.4% of wheelchair users died because they had fallen from their chair (Calder, 1990). In the above-mentioned case scenario, this could happen because travel instability or incorrect use of the chair had not been taken into consideration.

ISO and IEC certifications compliance may allow robot manufacturers exemption from product liability in ordinary cases. The development risk defence must be considered (Article 7 (e) of the European directive 85/374/CE), according to which: "The producer shall not be liable as a result of this Directive if he proves (. . .) that the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered". The fast development of robot technology, mixing categories, as well as the use of machine learning techniques, will challenge this clause: how could the robot creator anticipate the scenarios if the robot learns as it operates?

Liability can be addressed before (as a prevention) and after any occurrence of harm (as legal protection after the fact). In line with the Japan's Robot Strategy, some living labs have been created to test robot technology, e.g. the Fukushima Hama-Dori Robot Testing Zone No. 1, or others in Fukuoka (Ministry of Economy, Trade and Industry, 2015; Weng et al., 2015). "Tokku" for Robotics Testing (RT special zone in English) would be the best legal approach with respect to what could be done for protection prior to the occurrence of harm. Since 2003, the RT special zone has provided valuable information for robotics' regulation. The adopted statutes have included road traffic law, radio law, privacy protection, tax regulation and safety governance. These living labs should specialise as each robot differs largely from the next.

European Parliament Recommendations for future regulation of robotics retains the need for traceability. According to this recommendation, black boxes, already used in several robotic devices, are a measure that could help tackle liability issues *a posteriori*. It would then be easier to decide who is responsible for an accident that may involve several parties. Restricted access to those black boxes or use of encryption, should avoid privacy infringements. From the legal perspective, it should then be important to recognise that data from these black boxes could be admissible in evidence at trial.

7. Privacy, integrity and data ownership

Queen Charlotte has currently 134 residents. Although the carriers need to be shared, they are personalised: when Anna takes it, the carrier knows that at 4 pm her daughter comes to the nursing home; at 5 pm she has the hairdresser and at 5:30 pm she needs to head for the dining room. The system collects information about their outdoor rides and other carriers, so converging behaviours can be inferred.

7.1. General

Intellectual property rights are not an issue for the HRI community. Thus, legal principles will fully apply here. Privacy and data protection together are one of the most relevant legal aspects of current technology regulatory frameworks. The HRI community does not give these principles the prominent role that the Law does. Roboticists need to be aware, nevertheless, of the newly approved GDPR. Binding from May 2018, this *corpus iuris* will bring about direct consequences for any roboticist working on robotics that processes personal data, either from or outside in Europe.

7.2. HRI discussion

In the HRI community, the invasion of human space in shared environments is very important, especially for acceptance purposes. As people have a stronger reaction when robots invade their personal space than compared with humans (Joosse et al., 2013), proxemics studies the appropriate negotiation of personal and shared space (Koay et al., 2014; Rios-Martinez et al., 2015). We could expect humans to hold other people more strongly to social and legal norms, and to be less tolerant of the socially non-normative behaviour of a person compared to a robot. This is crucial for robot acceptance, as well as to address cultural differences (Joosse et al., 2014).

It cannot be taken for granted that the IT systems, incorporated to the device, are secure just because they are being released into the market. Similar to what we said about certified safety, in a newspaper article, Valasek and Miller admitted that they hacked a Jeep "altering its code to remotely control its air conditioning, radio, windshield wipers, transmission, braking and steering" (Mail Online, 2016; Protect Driverless Cars). Furthermore, even if the user is aware of the collection of data and has given the consent, it will still be hard to ensure that the user's consent was informed.

7.3. PCaR risk scenario and recommendations

Depending on the technology applied to the person carrier, the users' privacy could be undermined. For instance, obstacle recognition through cameras can pose privacy risks if cameras record other things than the obstacles to avoid, especially if the user's private information or the data of third parties is recorded. A more crucial aspect, however, will be what cooperative driving will bring about: data gathering, lack of user awareness (track of each ride, position where it is, time spent on it, schedules, etc.) and robotic decision-making processes (even of ethical/moral dilemmas) among others. As Calo argues, robots are capable of recording every item of data about the user and the environment, which could be of extraordinary use in both loss prevention and marketing research (Calo, 2012).

This is extremely important, because the legal domain in data protection matters is worried about the awareness of the collected data, informed consent, legitimate purpose and all the new rights coming with the GDPR implementation: data portability, right to be forgotten or privacy-by-design. Indeed, users are not aware of what data is collected from them (The Economist, 2014). One of the big concerns in data protection is the loss of control over data, especially in sensor or data fusion and its secondary uses. On the one hand, it is true that the N = All analysis aims at finding hidden connections that could possibly be useful for future developments or better HRI (Mayer-Schönberger and Cukier, 2013); but, on the other hand, "finding the correlation does not retrospectively justify obtaining the data in the first place" (Information Commissioner's Office UK, 2014), especially if there has been no consent for that.

As far as module profile is concerned, the carrier would first need to be protected against acts of vandalism and include a password or some bionic identification system to avoid a possible misuse, although this does not come without fault (BBC, 2015). The device should allow for data-portability because if it breaks down, or if the producer stops producing it (as happened with the iBot project), the user should must have the possibility to transmit setting information and their preferences to a new carrier. This is going to be fundamental for elderly or disabled users, because it may be that when that happens, the user's impairment has worsened and they cannot re-train the carrier as previously done with the prior wheelchair. Third, the information collected should be used only for the proper functioning of the device, e.g. increasing the knowledge of the person carrier provider to ameliorate difficulties, or other business-related issues such as: selling new components to compensate some failures or selling some new gadgets to be incorporated to the carrier like a robotic arm, etc.

8. Autonomy

Thanks to the PCaR, Anna feels young again because she can go outside with it. She feels constrained by the timetable and sometimes is obliged to go to dinner because the PCaR does not stop beeping until she takes it back to the nursing home.

8.1. General

As we have seen, autonomy can be understood, both from the robot perspective (the behaviour of the robot) and from the user's perspective. If we retain the definition given by the RoboLaw project, i.e. independence as the ability to manage ADL and satisfy personal needs by oneself, it is clear that the Person Carrier Robots of the Queen Charlotte nursing home allow users to be more independent. In fact, other person carriers for general use might also contribute to the independence of their user, as these devices are not programmed to provide any personal care on behalf of the user The European Parliament's Recommendations for future regulation of robotics outlines the reversibility of the robot's decision and the opt-out capacities (kill switches).

8.2. HRI discussion

From the robot's perspective, and relating to the control strategy built in the robot, special attention should be given to shared and autonomous modes. ISO 13482:2014 underlines the need for robot stopping in case of doubt. Autonomous robot behaviour could lead to an uncertain scenario where it becomes very difficult to allocate responsibility. A three-level control strategy, similar to what is suggested in Tuker et al., could be of help in the legal layer, although the chain of responsibility gets more complex as the autonomous behaviour of the robot increases: a clearly defined hierarchical controller that could include 1) an execution layer for error calculation and loop control; 2) a translation layer that could map the intentions and convert them into states; and 3) a perception layer that could identify the human volitional control. This could, simultaneously, be connected to the environment, the user and the device and could help identify where the error was in case of failure.

Although no report stating a dependence on this type of technology has been found, the autonomy and independence of the user needs to be balanced with the dependency the user might have on the device. Declining mobility and worsening memory should not justify per se user decision-making substitution when the robot is in shared control mode and used in outdoor contexts, unless it is stated that the person is cognitively impaired. A supervised autonomy has been considered in order to provide a safety margin when the system is uncertain as to how to proceed before a non-mission task. This system, called "automated transport and retrieval system (ATRS)" works for mobile robotics in outdoor contexts that operate in the vicinity of the premises of the robot – the nursing home in this case (Sorell and Draper, 2014).

8.3. PCaR risk scenario and recommendations

Person Carrier Robots allow people to be more independent. As a rule, this is a clear improvement. However, there is a risk of users' lack of control in some cases. Appropriate training should be implemented before people can use these devices, especially if they are used in outdoor contexts.

The autonomy and independence of users could cause a dependency on the devices, be detrimental and affect the rights of third parties. The study in Japan conducted by Shiomi et al. demonstrated that caregivers were worried about the activity decrease that person carriers would bring about, although they were referring to wheelchairs. They argued that "moving support to an autonomous wheelchair robot might decrease opportunities for rehabilitation". They also added: "if seniors become dependent on such a robot and stop moving by themselves, their own physical activity will decrease". The implementation of the use of robots, nevertheless, seems inevitable in some countries (Japan's Robot Strategy, 2015).

One way of respecting the user's independence is to apply machine-learning capabilities to the robot: the robot could learn from the patient's daily routine and take it as a frame of reference for future scenarios. This could entail a lightening in the decision-making computing weight, but of course it could imply much more behavioural data analysis. The technical determinism that leads current robotics, i.e. that society responds more to technology than technology responds to society, implies social concerns and different acceptance rates among society (Frennert and Östlund, 2014). Next editions of ISO 13482:2014 will take into account special parts of the population, such as children or the elderly. This is important in order to fulfil user's expectations if the robot is to be personalised.

9. Dignity

The inclusion of the PCaR increases the efficiency of the nursing home, and workers can take care of other more important things. Anna starts feeling down because she realises that the time spent with caregivers is less and less.

9.1. General

Dignity includes aspects such as the fear of the replacement of humans through robot technologies, the replacement of human emotions as well as exclusion contexts. Concerning the latter, some researchers believe that the sophisticated presence of robots (mainly mobile servant robots because they can talk back to the person for instance), could lead to some isolation scenarios. Person carriers, however, do not offer any special/sophisticated presence. This does not mean that the isolation scenarios cannot come along, as it seems that bulkiness of the carrier and weather conditions can pose some isolation problems in this context. Person carriers that can be used restrictively in several contexts such as holidays, in other friends' houses, in other buildings or in snowy terrains, and can pose a major barrier to the user.

9.2. HRI discussion

Current PCaR are not supposed to provide a presence, but in the near future this might be the case. Non-assistive robots can only add a simple presence, such as being co-located with another person. This might be enough if the user only needs a presence to avoid isolation.

Person carrier robots are not so far suitable for therapy or company. This is limited to socially assistive robots that can play different roles: helpers, enablers, co-learners and companions. A list of social robots and their functionalities is available in the work of Robinson et al. (2014)). We envision the next generation of person carrier robots will also include some assistive robots' capabilities. Current Person Carrier Robots are not expected to be of this kind, but this might change if they include assistive capabilities or a 'beep' to remember to go to dinner (as in the use case). In any event, caregivers from disability organisations do not envision social assistive robots will be suitable for social interaction such as giving a gentle touch of a hand, the warmth of a hug or the understanding of a conflict (Wolbring and Yumakulov, 2014).

9.3. PCaR risk scenario and recommendations

Person carriers, in any case, do not contribute per se to the feeling of loneliness. If, in the future, this robotic technology includes more social characteristics (incorporating communication capabilities for instance), they could lead to more isolation scenarios.

Some pseudo-roboticists have tried to solve these isolation issues in a down-to-earth manner: Soden, a veteran with no engineering background, has created the Tankchair, a person carrier that can be used in all terrains: snow, grassed fields, etc. (Steinert, 2014; TANKCHAIR; The Huffington Post, 2014). This could promote sociability regardless of the weather condition. The shape of it can become a problem for ease of use on holiday for example or to carry to a friends' house (it is actually very big). A practical solution could be to work on its shape and weight and make it transportable. Another option would be to connect the carrier to the internet and to change its own parameters according the weather forecast (using any weather platform) downloaded. This way the carrier could autonomously decide not to go out that day because of the weather conditions or could calculate a different route, based on this condition. An appropriate balance should be established to let the user know the intention of the carrier and to align it with the intentions of the user.

10. Ethics and justice

One day, tired of living, Anna decides to fall down the stairs with the carrier. The person carrier prevents her from doing so and reports to the nursing home this strange behaviour.

10.1. General

Person Carrier Robots are far from being ethical agents. However, the more autonomous a robot is, such as multifunctional social assistive robots, the more it needs to be tuned in to values and norms (Kuestenmacher et al., 2014). The European Parliament's Recommendations for a future regulation on robotics identifies the principles of beneficence and non-maleficence. According to the former, the robot should search for the best interest of humans; the latter urges the robot to prioritise no harm to humans. A general clause of maximising the benefit and minimising harm should prevail. On the other hand, for the European Parliament, the justice principle means fair distribution of the benefits associated with robotics (European Parliament, Committee on Legal Affairs, 2017). Both ethics and justice are general principles and require expert explanation. Before testing robots on humans, a Research Ethics Committee should certify that all these recommendations are properly fulfilled, according to the Motion. Moreover, the European Parliament suggests the need for a European Agency for Robotics and A.I. to preserve rules and transparency.

10.2. HRI discussion

The robot, as a moral agent, needs to learn from experiences and adapt to unforeseen scenarios. To interact with a domestic environment, the robot needs to be autonomous. This does not only mean that it has to follow pre-existing rules; it has also to be able to face unexpected situations such as glass doors, unexpected moving objects or between Scylla and Charybdis risk scenarios like the trolley problem. Unforeseen new situations are called external faults. The robot needs to go beyond the internal troubleshooting methodologies to deal successfully with these scenarios (Mast et al., 2015). External errors may include inadequate description of planner operator, external disturbance, imprecision of perception devices and consequences of previous inaccuracies. Consequent fault handling techniques would involve qualitative reasoning, simulation-based methods, re-plan, asking humans, estimation-based methods, and belief-based management.

An easier alternative is semi-autonomy. If a robot has to face an unexpected scenario or fails during execution, a human operator may take control remotely, solve the problem, and hand back control to the robot (Wilson and Scheutz, 2015). The problem with this is that it relies on the type of "semi"-autonomy: teleoperation (a third person) or shared control (the person involved in the HRI). Any choice will have a direct impact on other aspects: allocation of responsibility or the assurance that the person is fully capable of making the appropriate decision. Other researchers have studied the possibility of configuring a computational model for moral judgments based on moral expectation and the principle of double effect (Malle et al., 2015). Other researchers, like Malle, argue that humans do not always expect robots to act according to the same moral norms applied to humans (Sharkey and Sharkey, 2010). Humans might expect robots to perform actions than to sacrifice one person for the good of many (a "utilitarian choice"). In addition, robots are often blamed for choosing this option rather than doing nothing. In that study, Humans expect robot action over in-

Table 2 –List of possible controls for person carrier robots. Recommendations to roboticists and lawmakers.

Task-oriented
User-oriented
Social interaction

Context

Risks	Recommendations
Place	Specific requirements for different types of public/private institutions
	Specific requirement for the type of architecture/environment: cloud, IoT
Users	Specific requirements: special attention to elderly, children and disabled people
Robot	CRIA development for each robot the institution has
	Different safeguards depending on the technology applied to it, the robot's capabilities and the HRI
	Clarity on the type of robot and the regulation that applies to it
	Mixing categories: addressing different robots
CRIA	Identify the internal/external stakeholders

Safety

Risks	Recommendations
Navigation	The robot should have a map of the institution for navigation purposes.
	It is important to identify tricky information, e.g. glass walls.
	Consider mapping and remapping indoor and outdoor environment from time to time so as to avoid any changes in the environment.
	Consider sensor coverage: internal/external to the robot.
	In lack of sensor information, electromagnetic tapes on corridors could be of great help for navigation purposes.
	In buildings of new construction, the infrastructure of the building should be truly adaptable to the size of the devices to be inserted: corridors, doors and elevators should not be a constraint.
	If possible, the inclusion of robot-exclusive corridors and elevators could help avoid third parties problems. If not, the sharing of space between robot users and non-robot users should be carefully taken into account.
	If the carrier is going to be used outdoors, a GPS system for outdoor contexts, including relevant information about the environment (e.g. localisation of trees, rubbish bins, traffic lights, etc.) could be of help. The use of an Automated Transport and Retrieval System could help too.
	The security of the carrier's navigation can be improved by intertwining inputs from the user, and the environment. Sensor coordination could lighten the weight of the carrier.
	Periter monitoring sensors could give a wider perspective to the robot.
	When including an obstacle collision warning sign, the different target users need to be taken into account. A vibration signal could help avoid further problems with other impairments as sound or visual signs may have (deaf/blind people).
	Navigation pattern systems could be included to improve safety. Although this might challenge data protection, on the contrary, certain users could benefit from this: the detection of an anomalous behaviour could lead to a protective stop.
	If not protective stop, a safety-related speed control if the device detects strange navigation patterns in the shared-mode could also be considered.
	Outdoor contexts should be avoided if the carrier is not prepared to do so.
	If used in outdoor contexts, compliance with traffic rules is mandatory.
	Consider the possibility of real-time navigation systems like the ones used for unmanned aerial vehicles.
	If the carrier depends on Wi-Fi connection or other connections, loss of connection leads to protective stop.
	Using deep map technologies could help improve navigation.
	Using pre-built smart maps could help in speeding the process of navigation planning and avoidance collision.
Collisions	High-precision sensory information is required.
	Fast reaction times for moving obstacle avoidance are crucial.
	It is important to increase user legibility so that third users can understand what the carrier is doing.
	Collision avoidance systems should be mandatory.
	A horn or a sounding device as well as some lights to warn third users could be of use to avoid collisions.
	After the device comes to a protective stop, or it collides with someone or something, the user should be capable of communicating with a person that could help him/her to go back to the institution, go to the hospital, etc.
	Impact absorbing surfaces and mechanics could be used to guarantee human physical safety.
	Any roboticist should be working towards perfecting the autonomous mode and establishing supportive systems for the shared autonomous mode. Providing guidelines to other roboticists should be mandatory.
Tipping over	Systems that provide smoothness of the action when the terrain is not smooth should be included, especially in outdoor contexts.
	Stability control should be implemented.
	Sensors to detect architectonic barriers such as holes, stairs, etc. should be a fundamental part of the carrier.
	If the carrier tips over, there should be an autonomous communication capability with Healthcare system/Ambulance independent of the user.
Manoeuvring	There should be an effort to reduce the bulkiness of the carrier.
	A 360 Degree rotation could improve manoeuvring.
Non-mission task	For the non-mission tasks, behavioural analysis could help in deciding what to do.
	Hierarchical Controller to could help in evaluating the decision.
	Real-time navigation system could help face this situation.
	Environmental sensing could be of help.
	External semantic support could be provided. If the support is given from humans, special safeguards should be provided (to avoid hazards concerning the time delay); and the same happens if robots are the ones to provide support.
HRI	For the physical HRI, there should be compliance with specific technical instruments such as ISO 13482:2014.
	The cognitive aspects need to be taken into account. For instance, addressing the feel of pain or discomfort of the user, or the feeling of hopelessness after a protective stop.
	Perceived safety is of major importance, so roboticists will have to make sure that the users feel safe when using their device.

(*continued on next page*)

Table 2 – *(continued)*

Risks	Recommendations
Safety	
Sensor invasiveness	As a general rule, used sensors need to maximise the richness of information while minimising the invasiveness of the required instrumentation. Electromyography is preferred in BCI. Environmental sensing could be preferred rather than invasive techniques.
Stair-climbing function	Smoothness of the action is mandatory. Horizontal position of the wheelchair is preferred.
Specific capabilities	If the wheelchair has any special feature, it will need to be addressed in order to see what safeguards and protective measures need to be applied.
Mode transition	Heuristic rule-based classifiers can provide safety in mode transitions. Certain functions in certain modes should be avoided, e.g. avoid climb function if mode bed is on. The roboticist should provide protection in both moments: during the state and during the transition between states.
Weather conditions	Incorporate all-terrain features, especially if the device is going to be outdoors.
Hacking attacks	Incorporate a protective stop after the system is hacked. Protect the user from any harm after the carrier is hacked. There should be an autonomous notification to the competent authority of the hacking; it could be Data Protection Authority or European Robot Agency if ever created. Secure wide area communication.
Others	Consider incorporating house indicators which are self-actuated when the device enters a turn. Consider coordination between devices when there are more devices than charging points. If the institution is big enough, ensure that there are available fully charged carriers for the night, and that the rest are charging in valley moments. Incorporate sensors and communication capabilities to the elevators if more than one floor. Incorporate smart power management for maximal energy efficiency. Incorporate seatbelt to offer a maximum level of protection.
User protection	
Risks	Recommendations
Robot categories confusion	The roboticists should place the appropriate definition of his/her device and its capabilities to avoid further confusion not only to users but also to authorities. The compliance needs to be done according to its capabilities, which may imply compliance with different regulations. Special attention to Medical Device Regulation for “wheeled passenger carrier”. Different standards will have to be applied for transforming/mixing categories, e.g. a carrier that transforms into a mobile servant. The authorities should be working on avoiding over-/under-regulated scenarios. A dynamic personalised regulatory model for each specific robot could be placed. The granted certification should go in line with the product, not with the intentions of the creators. The roboticist needs to be sure that the certification agency has conducted the appropriate checks because if someone will be responsible, it will be the creator, not the agency.
Consumer robotics	The categorisation of the robot should not lead to deception. Roboticists need to be conscious of the use of green technology: electric motors, acceptable audible warnings and green materials for the creation of the device (kenaf-fibre bioplastic in its softer panels and Acrylic resin panels to offer more strength). Exploration of new materials with different physical properties (mechanical, electrical, etc.) could be of help to go green. Protection of the Health of Users is of primordial importance. For hygienic reasons, devices need to be cleaned and disinfected, if necessary, by a specialised company. Both certified safety and perceived safety are important. The user interface should be user friendly, easy to use and user-centred. The interface should incorporate the vocabulary according to the context of use and also be impairment adaptable. The user needs to be correctly informed about the carrier capabilities. Driving Tests should be placed in case of need. Addressing Cosmesis is very important for the self-esteem of the users.
Contract law	In General Contract condition there should be avoidance of abusive clauses.
Liability	
Risks	Recommendations
Before harm occurs	There is the need to create a Living lab or an Empirical Testing Zone for regulatory purposes that can test person carriers and their transformations. It is crucial to embed by-Design Principles (using programming language incorporating privacy by design, for instance). There should be compliance with main safety certifications. Roboticists need to be sure that ethical design certifications apply or do not apply to their case, and follow them too. If the European Robot Agency is ever created, there should be the obligation to register the device with the specifications.
After harm occurs	The roboticist will need to argue that he/she did all the best to apply the available knowledge to the device (Development risk defence: Art. 7.e of Directive 85/374/EC). Black boxes could help identify the problem. If used, it will need to be clear who has access to them and also whether it is going to be valid in Court. Creation of European Robot Agency (accountability and enhancing liability) should be considered.
Autonomy	Solve division of responsibility on the autonomous behaviour of the robot. Insurance: determine whether the robot needs self-/mandatory insurance or just a complementary insurance.

(continued on next page)

Table 2 – *(continued)*

User rights	
Data protection	The third users of the collected data should be prevented if there is no consent for that. Attention should be done to the general clauses for the consent to not be abusive. The lack of awareness of the collected data should be avoided. There should be placed transparency, especially with elderly and impaired people. If the robot is personalised, protection against vandalism acts should be offered. The inclusion of a password or bionic identification could help in this regard. It is fundamental to state the clear purpose of the data usage. Roboticists need to understand how informed consent works and collect it before using their device. There should be an effort to assure that the consent is actually informed. A dynamic consent schema could be considered to ensure consent over time. If there are profile modules, the right to portability needs to be guaranteed. A cloud platform could help manage all the information collected from the sensors. Data protection issues need to be addressed in this environment. Encrypting the tunnel between robot and cloud could protect data-in-motion and the use of a private cloud without neighbours could promote an added safeguard in this regard. The user should be the owner of the data and should be the one who can clearly and easily cancel the data. Assurance that this procedure is placed is a must. If the environment is Internet-of-Things, more precaution should be placed on the massive collection of data. Right to be forgotten should be a reality and should be placed by default.
Privacy	Proxemics should be studied in scenarios with third users.
Autonomy	
Risks	Recommendations
Robot's perspective	For the autonomous mode, a detailed Control Strategy should be implemented, the limits of the workspace should be defined, and a clear definition of the autonomous task should be defined. In autonomous mode, it is crucial to set which are the forbidden areas. In shared mode, a driving test could improve efficiency of the task and provide more safety. It is important to know when the device works on autonomous, in shared, or in other modes. Level of autonomy should be clearly defined. Shared control percentages could also be reviewed in the case of vulnerable members of the society, e.g. leaving less room for human decision when elderly drive the machine. Compensation rules should be modelled and personalised for the user. The use of machine learning techniques could help improve the efficiency of the task. Attention to the data protection is required. In case of doubt, the autonomous mode should mandatorily come to a protective stop. A human supervision should be preferred among automative decision-support systems, but future seems inevitably going to the autonomous version. This will have to be especially considered.
User's perspective	From the user's perspective, his autonomy should be promoted. The user should be involved in the decision-making process of the machine, even if it is in autonomous mode, e.g. asking permission to go to certain destinations. It will need to be decided in which cases the autonomy of the user prevails in front of the one from the carrier. There should be respect and validation of the user's decisions. There should be balance between user's safety and user's decision-making. Consider inclusion of Automated Transport and Retrieval System for supervised autonomy to provide safety margin when the system is uncertain on how to proceed before a non-mission task. The system should promote the user's independence without causing a dependence that is beyond what is considered normal for carriers.
Dignity	
Risks	Recommendations
Isolation	The bulkiness of the carrier cannot provoke an isolation scenario. The device should be made transportable and integrated.
Substitution of human workers	The technology should not be created to replace human workers, but to help them perform their tasks better. In the case technology substitute workers, a replacement plan for these workers should be drafted.
Decrease of human touch	It is crucial that robots promote Human–Human Interaction.
Ethics	
Risks	Recommendations
Autonomy	In case the carrier needs to stop, it will only do so if it is less dangerous than continuing to perform the task.
Free will	Elderly should make decisions about their welfare. The system will need to decide whether the free will of the user prevails (in case of a suicidal request) over his/her safety.
Impaired patients	Consider balance between interests.
Moral judgements	If there are any moral judgements, empathy should be modelled to help the device in decision making. Moral Expectation and principle of double effect should be taken into account. The respect for social norms is crucial.
User-centred	Include a user-centred design to cope with real needs of the users. Include reposition function. Design the Institution in a way that these devices can be accommodated with less impact on users and workers.
Justice	
Access	Consider low-cost technology to enhance equal access. Consider aids and grants for those in need.

action, and they blame robots less for acting than for failing to act.

10.3. PCaR risk scenario and recommendations

Current Person Carriers have not evolved as much as to consider them as ethical autonomous agents although they can be involved in certain dilemmas. Currently, new person carrier prototypes are being created in research labs and they are entering the market. The more capabilities these devices include, the more complex the legal framework that is needed. Indeed, if the person carrier includes some highly sophisticated HRI capability and it is connected to the environment, then more aspects will need to be analysed.

Similar to what Sharkey and Sharkey discussed in 2010 (Dang and Tapus, 2015), what could happen if a user asks the person carrier to go down the stairs and allow him/her to fall? Should the person carrier prioritise the safety of the user?

Although robots have had a positive effect on stress relief (Pistono, 2014), roboticists will still need to pay attention to all these other aspects of the technology, especially if the ethics by design principle is implemented. For instance, suicidal requests should be held back from robots at risk of misinterpreting such human requests. Aborting a requested activity if the robot detects the user has fallen or if their vital signs have suddenly and significantly changed (and of course informing a caregiver of this) could also be adopted. In addition, although robot technology should be created in a way designed to respect human dignity and human values, everything becomes more difficult when the decision-making process is translated from the user to the machine.

11. Resulting regulatory framework for person carrier robots

All the above-mentioned risks and solutions can be grouped and presented in a more practical chart. This chart can be useful to roboticists to understand long juridical discussions and jurists to understand and translate into technical terms some legal requirements (Table 2).

12. Conclusions

Our hypothesis is that current PCaR would not require a complex regulatory framework, like other more complex robots (e.g. social assistive robots), because their level of HRI is not as high as the latter. Their regulatory framework is envisioned to be mainly based on safety, user protection (health, consumer protection, environmental regulation, and prevention from patients harming themselves) and liability, as all robots should have if intended to have market value.

Nevertheless, after applying CRIA, we discovered that current person carriers can be involved in different scenarios that are worth taking into consideration. In order to provide a personalised service, person carriers process large quantities of personal data that are processed and stored in the cloud. This data is highly sensitive, because it can help in profiling and analysis of the patient's behaviour. An impact assessment that only concerns personal data of these systems will have to be conducted when the GDPR comes into force. Other rights that this piece of legislation must incorporate will also have to be estimated.

Person carriers must face increasing types of non-mission tasks, especially if used in outdoor contexts. A number of rules will have to be taken into account to deal with traffic or social norms. Ethical dilemmas will need to be definitely and urgently addressed. Some considerations concerning the "protective stop" will have to be considered by the creators of the technology, to avoid certain chaotic scenarios. Adding communication capabilities to the carrier could provide a good solution. Other alternatives such as preventing users from using the device in public spaces could also be considered, although then their independence might be indirectly undermined.

Some researchers worry about the impact of this technology in nursing homes. Others wonder what is going to be the global impact of computerisation upon society (Frey and Osborne, 2013; Nelson, 2015). The robotic revolution is unavoidable and, given its exponential growth, robots should be designed in a way that avoids replacing human touch or human feelings.

Binding legislation is needed that could give full legal coverage and could fix consequences for violations. Similar to laws concerning autonomous self-driving cars or drones, there is indeed a need for legislatures to start thinking about what form a regulatory framework for personal care robots would look like, given that this technology largely differs from other robotics. In fact, governments and NGOs, not only industry, should be deciding these matters. If society could work towards creating a bridge between these three stakeholders, it could actually produce a safer technology that promotes human–human interaction which, in the end, is what really matters to us all.

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