

Deliverable D5.8

*PDTI Manual*

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**Glossary of Terms**

**ECHORD++**: European Coordination Hub for Open Robotics Development Plus Plus (E++ for short)

# Introduction

The EU is currently moving heavily in the direction of “mission-driven innovation for social change”, as exemplified for instance by the Mazzucato report (1). In her report, Professor Marianna Mazzucato outlines major findings from the missions of the past to tackle the challenges of the future: “A key lesson is that missions must be bold, activating innovation across sectors, across actors and across disciplines. They must also enable bottom-up solutions and experimentation. “

PCP (Pre-Commercial Procurement) is an instrument used within Europe for “directed” innovation and social change. The EC considers PCP as an instrument not from the side of tech push, but really from a societal pull side. Frequently, such missions-based challenges are tied to the Sustainable Development Goals or their sub-aspects (2).

The European Commission sets a strong focus on Pre-Commercial Procurement (PCP) in Horizon 2020 because it intends to compete on equal terms with other countries (e.g. United States of America and China).

Public end-user Driven Technological Innovation (PDTI) within E++ is also clearly motivated by the fact that the modern society is faced with challenges in many respects: transport systems, climate change, energy supply, security, healthcare, etc. IN contrast to PCP, though, PDTI allocates a grant to beneficiaries following PF7 funding rules.

Pre-Commercial Procurement (PCP) emphasizes the tender aspect within the collaboration with the publich sector, considering public aurhorities as important lead buyers / first customers of technological solutions. The focus of PDTI, though, is on how to activtely integrate public end users in research and development of technology to master the societal challenges and to push innovation. Even though the actors involved in the process are the same, the focus is different: While PCP focuses on the tender, PDTI focuses on research and technology development, but based on public challenges with a very strong engagement of public stakeholders in the technology development process and the RTD teams involved in this development. The tool actively used to foster the involvement of public stakehoders in the technology development of PDTI is coaching. This approach is clearly in line with the mission of ECHORD++ to bring robotics technology from the lab space to the production facilities and end users.

To contribute to the creation of an open innovation environment for robotics technology for the public sector, matching the mission of the “Coordination Hub of Open Robotics Development!, ECHORD++ has implemented the PDTI instrument which addresses two public challenges during the runtime of the project: one in healthcare, the other one in urban robotics. These two application areas were selected because of their tremendous growth potential in robotics:

The process implemented shows parallels with the methodology in the SILVER project (3), the first PCP project in robotics funded by the European Commiision, but with deviations that had a significant impact on the entire process: The SILVER project searched for new technologies to assist elderly people in their everyday lives. The common denominator of the public stakeholders in SILVER was that a) the use of new robotics based technologies must allow the elderly to continue independent living at home even if they have physical or cognitive disabilities (a very broad scope) and b) the robotics solution had to offer a 10% cost reduction over the state of the art before SILVER. In ECHORD++, though, competing RTD development teams were asked to develop robotics solutions to meet precisely described challenges provided by public stakeholders.

The development was heavily hardware-based with specific implications on the development process (for instance intensive early-stage testing in a natural environment). While the choice of a specific technology is open in PCP, PDTI requesred a challenge to be met by robotics technology. Particularly in PDTI healthcare, this put an additional burden on the process: The RTD solutions which were not only required to meet the challenge properly but also restrictred the possible solutions by narrowing down the technical choices. This might be the proper way to promote the use of robotics technology, but it also raises the question how make sure that the challenge allows for the implementation of a specific technology.

One of the direct challenges to the E++ project is to ensure collaboration between developers and challenge providers, but at the same time to ensure a clear and identifiable level of separation of roles between the provider of the challenges and the developers. To ensure this, but also to add a broader level of expertise in different areas (technology development, robotics, market intelligence, technology transfer, user-perspective particularly in the healthcare area etc.), ECHORD++ had an independent panel of EU Commission registered experts in the areas of Healthcare and Urban Robotics involved in the milstone on-site reviews, but also at stages of the process where trends had to be set or in phases where specific expertise was requested (for instance market intelligence in the last phase of the technology development when the technology came closer to the earmark of commercialization).

This manual will share with the readers the processes implemented, the modes of collaboaraton between the different stakeholders which were implemented (and where adjustments to the original plan had to be made), process shifts (and their motivations) as well as the experience ECHORD++ made during the implementation of PDTI. As PDTI Urban Robotics and PDTI heatlchare have implemented different approaches on innovation (urban robotics working with a waterfall approach on project management, while healthcare had to shift to an agile approach mainly due to unforeseen events at a very early stage of the process), the manual also allows to comare different project management systems and their impact on the robotics technology development for and with a very active engagement of public challenge providers.

Apart from the independent experts, PDTI was able to rely on the input of another group of independent peers: The ECHORD++ Advisory Board, which – with high-level experts from Taiwan, South Corea and Japan on board – provided a direct brain intake from non-European countries heavily experienced in developing robotics technology for the public sector.

# Open Innovation with public stakeholders, what matters and how PDTI met these requirements

Two PDTIs have been developed under the E++ project: one in Healthcare and one in Urban scenarios. This article focuses on the PDTI procedure and the use case developed in urban scenario to contribute and join efforts to improve current public services or create new ones through robotic technology. The PDTI is included in the Innovative Public Procurement Instruments.

The Europe 2020 strategy includes innovative public procurement as one of the key market- based policy instruments for smart, sustainable and inclusive growth. Public Procurement has an immense potential to fully exploit research and technology for innovation while also delivering more cost effective and better quality of public services. In some cases, the technologies needed to make these breakthroughs exist or are close to the market (PPI); in other situations, investment in R& D is needed to assure the progress of technological solutions that meet the defined societal needs. In this last case, the instrument used by public entities is the Pre-Commercial Public Procurement (PCP) [1]. During the last years very few PCP have been initiated in Europe and in some cases the calls have been declared void.

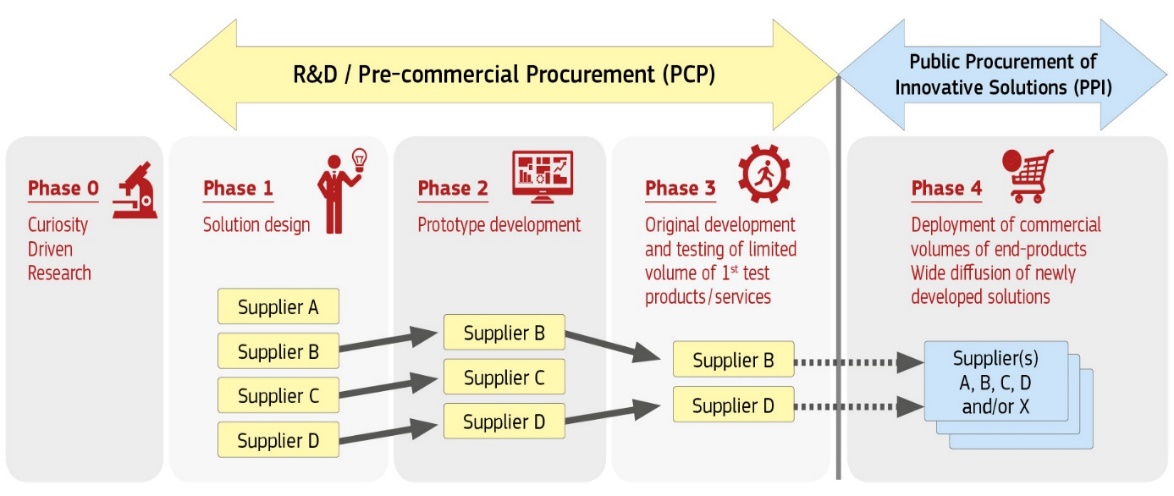


Figure 1 Innovation Procurement Instruments.

The PDTI uses cases developed under the E++ project offered us the opportunity to study and analyze the deficiencies that exist in the PCP process and propose improvements. Two main objectives lead the PDTI procedure: 1. To increase the number of urban robotic challenges proposed by Public Entities and 2. To boost new robotic products or services to the market. An intensive dialogue between all the stakeholders [5] involved and the coordination of their different roles has been essential for the PDTI success: the public entities as procurers; the technological consortiums as suppliers; the users and citizens as surveyors and an expert re-search team as coordinator of all the process.

Despite the perception of innovative procurement as something of a policy panacea and repeated efforts to put procurement budgets to work to drive innovation, efforts have been met with limited success. Numerous barriers exist from demand and supply side: there are market failures (information problems) and system failure (poor interaction); suppliers of potential new products and services often lack the knowledge on what customers might need in the future. User-producer interaction and communication do not help to produce synergies and link innovative companies, particularly start-ups, with the public procurers who very often lack expertise in the technological areas suitable to meet their requirements and consider innovative procurement (i.e. procurement of research & innovation instead of off-the-shelf products) as a strong barrier to successful producement. The reluctance of the public sector to fully adopt the notion of innovative procurement can also be attributed to its inherent “waste of resoucres”: Innovative procurement is based on technology development in a competitive approach with milestones which result in the reduction of competing teams. For the procurer this means per se to invest resources and energy into development teams which will not succeed in providing a solution to meet public requirements.

Due to the highly international composition of ECHORD++’s Advisory Board and the lab tours performed during its predecessor project – ECHORD -, the E++ core consortium could directly benefit from the experiences the AB members have gathered in their collaboration with the public sector. Particularly South Korea, but also Taiwan, have a strong track-record in developing robotics technology for the public sector. The products developed include but are not limited to service robotics.

The document Quantifying public procurement of R&D of ICT solutions in Europe (Digital Agenda for Europe. SMART 2011/0036. European Union, 2014) highlights the definciencies of the innovative public procurement initiatives developed by the 29 European Countries. Only one European country – Spain – was more successful in implementing the innovative public procurement strategy in 2014: This development was activtely stimulated by dedicated actions:

* the agreement of the Council of Ministers from 2/7/2010, where the State’s Innovation Strategy was adopted;
* the Science, Technology and Innovation Act (Law 14/2011, June 1st) explicitly mentioning innovative public procurement,
* while an agreement of the Council of Ministers from 8/7/2011 sets out the procedure for the implementation of innovative public procurement in all ministerial departments and public bodies.

13 innovative public procurement contracts were awarded in Spain between October 2012 and April 2013, with a combined total value of about EUR 18 million. The high level of engagement of Spanish public authorities with innovative procurement is also reflected in ECHORD++ where the challenge in PDTI urban robotics as well as the challenge in PDTI healthcare were submitted by public authorities located in Spain.

Urban Competiveness and Public Procurements for Innovation, an article published in XXX, reports on a case study of six Nordic-Baltic Sea cities having contracted six specific Innovative Public procurement developments between 1998 and 2007. The authors identify the social needs of citizens as the main driver of procurement of innovation. Due to the Nordic-Baltic Sea cities, the number of contracts is limited because public procurement of innovation is not very common at the urban level. Up to now, innovative procurement has not become an inherent part of the cities’ innovation policy (technology pull) and mostly the cities tend to implement supply-side policy measures (technology push).

Another reason for the limited success in implementing innovative procurement is that public procurers often lack a deep understanding of technology (particularly hardware-intensive technology like robotics, while innovative procurement is more popular with software solutions, for instance for public municipalities). The collaboration between developers and procurers therefore requires much more effort in the preliminary phases (see Phase 0 below) as well as precise, transparent and easy to understand specifications and descriptions of the features of the new technology. It is necessary to develop the initial phase, the phase 0, of the Pre-Commercial public procurement process, through intensive interactions revealing all facets of the requirements of both the public authorities and the users. It is this intensive action that allows to specify the expected impact of the new technology for the public sector and creates a mutual understanding of contraints and opportunities for both the RTD developing teams as well as the public procurer.

Routed in the product innovation life cycle, and based on Pre-Commercial Procurements, the PDTI proposes a process that comprises two main phases (Figure 2):

+ Activities for understanding public demand

+ Activities for research and technological development of pre-commercial products

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **PRODUCT INNOVATION LIFE CYCLE** | | | | | |
|  | **PCP**  **PHASE 0** |  | **PCP**  **PHASE I-II-III** |  | **PPI**  **PHASE IV** |
| **ACTIVITIES FOR PUBLIC**  **DEMAND KNOWLEDGE** | |  | **ACTIVITIES FOR RESEARCH AND TECHNICAL DEVELOPMENT OF PRE-COMMERCIAL PRODUCTS** |  | **PUBLIC PROCUREMENT FOR COMMERCIAL ROLL-OUT** |
| **PDTI** | | | |  |  |

Figure 2 Relation between PCP and PDTI processes

The "Activities for understanding public demand" increase and structure the tasks developed in the phase 0 of a common PCP; the "Activities for research and technical development of pre-commercial products", match and improve the phases I, II and III of the PCP, ending in a pre-commercial product. Looking to bring future needs and future supply together at an early stage, the first part of the PDTI process, the Activities for understanding public demand, develops four qualitative phases inspired by the Delphi methodology (2-3): Brainstorming, Narrowing Down, Ranking and Challenge Description.

Coordinated rounds between the stakeholders involved is essential for the success of these activities in order to bring and explore innovative challenges. This group of activities ends in a Call for Proposals /Tenders, initiating the Activities for research and technical development of pre-commercial products structured in three phases: Solution Design, Prototype Development and Small Scale Test Series (Figure 3). A continuous and expert monitoring during these technological phases makes possible to offer pre-commercial products close to the market at the end.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PDTI** | | | | | | | | | | | | | | |
| **ACTIVITIES FOR PUBLIC DEMAND KNOWLEDGE** | | | | | | |  | **CALL FOR RTD PROPOSALS** |  | ACTIVITIES FOR RESEARCH AND TECHNICAL DEVELOPMENT OF PRE-COMMERCIAL PRODUCTS | | | | |
| **BRAINSTORMING** |  | **NARROWING DOWN** |  | **RANKING** |  | **CHALLENGE DESCRIPTION** |  |  | **SOLUTION DESIGN** |  | **PROTOTYPING** |  | **SMALL TEST SERIES** |

Figure 3 PDTI process and activities

Phase I of the PDTI Challenge is focused on the solution and system design. Three consortia per application scenario / challenge were selected to develop a system desing (Phase I), over a duration of 6 months (comparable to a proof of concept). Even though Phase II focuses on developing a reliable prototype for the solution, the consortia were supposed to show a working prototype already at the end of Phase I. Two consortia per scenario were invited – after an on-site review - to compete the development of prototypes and feasibility studies in Phase II. In the final phase III, the same consortia (if successful in Phase II) performed a small-scale test series to improve their prototypes and to prepare them for commercialization. Target TRLs (term used as in H2020) can be assigned to each phase of PDTI: Phase I is associated with TRL level 4, where technological components are built together in order to test if they would work together. This phase also includes design and technology implementation through laboratory testing (Horizon2020, 2014). Phase II is based on TRL level 6, where the technology has to be tested in a relevant environment. Here, the process demonstration should be carried in a real-life scenario. The final Phase is then associated with TRL level 7 where the prototype of the system has to be demonstrated in an operational environment. The aim here is to minimize the manufacturing risks. If all the tests run well, this phase could go up to level 8 of the TRL where the system has to be complete, which can represent the end of the actual system development.

# The Public end-user Driven Technological Innovation phases & process

## First Step of the PDTI Process: Challenge description and search for public bodies

Working independently from each other, both Urban Robotics and Healthcare came up with a very similar process consisting of the four phases: Brainstorming (to get a first idea of potential challenges of the public bodies in the two application areas), Narrowing down (reducing the pool of collected challenges to the strongest), from the pool identifying the challenge to be addressed by different robotics solutions (i.e. Selection of the challenge). The public body who presented the selected challenge joined he ECHORD++ consortium and the Grant Agreement.

The Urban Robotics approach was strongly designed along the principles of the Delphi method, while the PDTI Activity on Healthcare was focused on a broader design method[[1]](#footnote-1). The different approaches were mainly due to the different starting points: While Healthcare could rely on an existing network of healthcare stakeholders in various areas (and thus expect a higher response rate to email inquiries), Urban Robotics started from scratch and the target groups were less experienced in turning their needs into specifications for technology development. Thus, healthcare could collect input via mailings, while the approach in Urban Robotics heavily relied on personal interaction (workshops and interviews). During the subsequent phases, it became clear that the approach used for Urban Robotics is more beneficial because it is more thorough in the analysis and generates a generally better understanding of the user needs and the role of a robotics platform in the application. Thus, we describe this process in more detail below.

This part of the PDTI process, Activities for Understanding Public Demand, is a qualitative procedure inspired by Delphi methodology and allows a group of stakeholders to systematically approach a particular task or problem [4]. In our case, the objective is the reliable and creative exploration of social needs related to public services that could be solved through robotic technology. The stake- holders and their roles are: the public entities as procurers; the technological consortia as suppliers; the end users as surveyors and finally an expert team as coordinator. The coordinator will give the technological support to the public sector for developing and implementing the innovation-oriented procurement [5]. The role of the coordinator is needed to drive and lead the complete process based on innovation. At the same time the knowledge of what the new technology can offer to solve social needs is introduced into the public entities, departments and managers. Due to the complexity of this process, it is valuable that the coordinator has a team of people coming mainly from technological areas but also from other areas such as economics, psychology or political science fields [6]. The participation of users and citizens will take place all along the development of the PDTI to survey the process and participate in it, through several activities.

The methodology employs iterations of questionnaires and feedback through series of rounds to develop a consensus of opinion from the participants. There is not a limit of time, but it is necessary to consider a minimum and a maximum number of rounds. After each step, specific documentation will be generated as the conclusion of the developed activities as well as the starting point of the next phase.

**Brainstorming:** The process starts with an identification of the real needs as perceived by the users and budget holders. A draft Questionnaire of Public Needs and its associated Innovative Technology will be prepared based on an improvement of existing public services. The success arises through interactions between the stakeholders in several rounds. The information elaborated in each round will be collected, edited and returned by the coordinator to prepare the next round. Finally, an agreed upon PDTI Questionnaire is elaborated.

**Narrowing down:** This phase has the objective of focusing the needs proposed in the PDTI Questionnaire using specific criteria. A group of impact indicators already used by the public entities or created during the process will be used in the evaluation and selection of the PDTI Challenge List. Users, Industry and Academia Consortiums are invited to participate in order to gain their opinion through workshops and Open consultations.

**Ranking:** The third phase is undertaken by an expert panel composed by designated people from the Public Entity and the Expert Team that will evaluate and select a number of Innovative Challenges to be developed under an Innovative Public Procurement. The number of innovative challenges will depend on the budget of the Public Entity and of the potential market offered by the procurer weighted according to the size relative to the costs involved in the development of the Innovation.

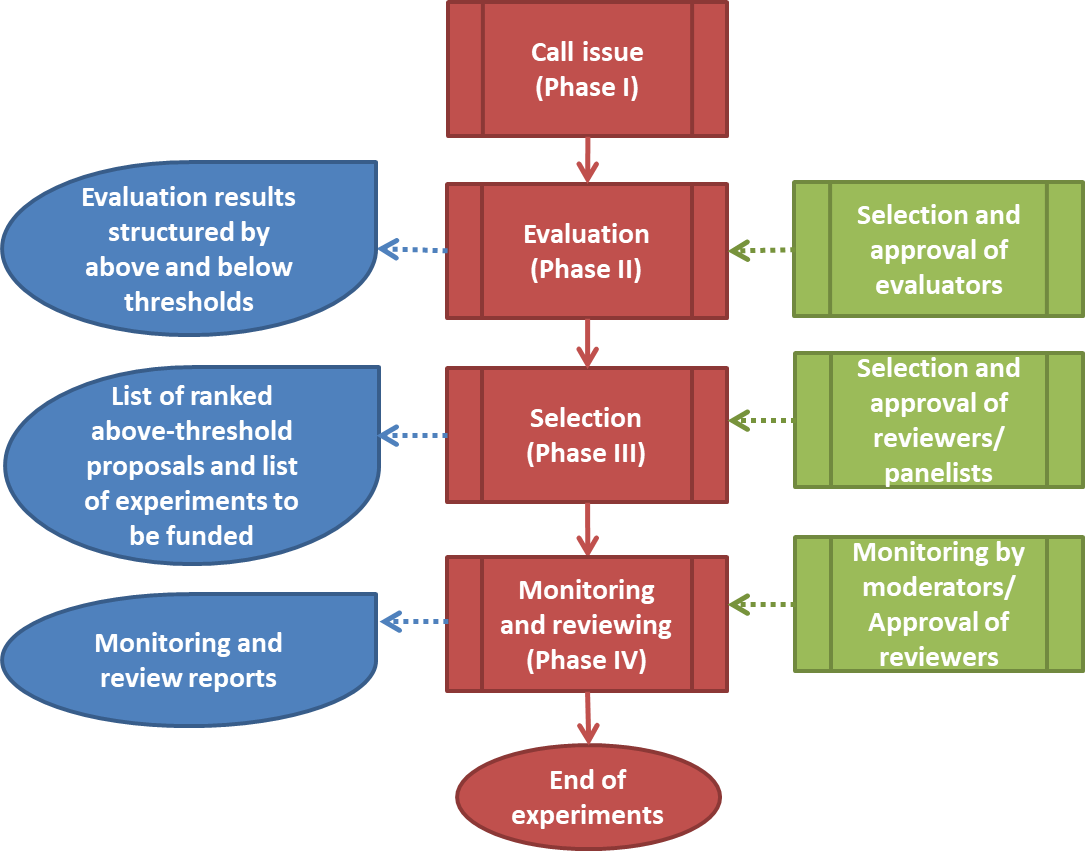
**Challenge Brief**: Finally, a document with a clear explanation of the public product or service should be described with enough information about the functions to be developed by the new technology. It is important to ensure that this Challenge Brief is not a common procurement document, but an innovative one, and has to be written taking into account the required innovative functionalities benefitting the public service instead of the standard requirements that could narrow the innovation field [4]. The translation of needs/problems/challenges into functionalities requires highly developed competences, or at least understanding, at the technological level on the part of the procuring organization [6] and the role of the expert coordinators is essential. The Challenge Brief will be the main document for the Call for Proposals/Tenders and the starting point of the second part of the PDTI process, the "Activities for research and technical development of pre-commercial products".

Lessons learned during this Phase 0 Of PDTI are:

* Deeper development of Phase 0 is required, especially close collaboration of public bodies and technical partners
* Public entities can use innovative public procurement instruments as PDTI to be more competitive
* Tailor-made solutions for both scenarios: swift and effective process adaptation to address specific requirements of the different public bodies is needed
* Close collaboration with public entities will increase innovative technological challenges (PDTI has received more than 20 innovative technological proposals from public entities)
* The importance of this interaction is lessons learned from E++ based on a comparison between the approaches between urban and healthcare.

## Second Step of the PDTI process: Open call and search for RTD consortia

In principle, the management of the Open Calls to attract RTD consortia for PDTI follow the same formula as the Open Calls in the ECHORD++ experiments. The following illustration provides an executive view of this process.



More detailed descriptions of the management of Open Calls in ECHORD++ can be found in the respective deliverables. Even though PDTI relies on the best practices of Open Call Management implemented in the “experiments”, there are fundamental differences which have an impact on the process and the open call documents needed:

1. At the beginning of PDTI, public stakeholders were unexposed to robotics, the development of robotics technology and the collaboration with robotics research. Therefore, the precise description of the challenge needed for the “Challenge Brief” (a call document which is unique for PCP and PDTI) was very time-consuming and highly interactive. Pulbic stakeholders in healthcare were more familiar with robotics technology and more used to defining development requirements than those in urban robotics.
2. The competitive approach in the technology development directly impacts the “scope” of the call. On the one hand, this scope needs to be broad enough to motivate a sufficient number of RTD consortia to submit proposals. One the other hand it needs to be precise enough to provide a solution for the public stakeholder(s). The pre-definition of the “technology” (in case of PDTI robotics) increases the complexity of the task to define the scope of the call (but it also makes it easier to check the state of the art and the patent search).
3. In order to achieve a good result, it is vital to have all the stakeholders and their interests on the screen. In PDTI healthcare the user perspective was not adequately reflected in the open call at the beginning. Having missed this important stakeholder group, the open call in PDTI healthcare had to be repeated in order to attract enough strong proposals.
4. It the technology to address a specific challenge is pre-defined (as in PDTO calling for robotics solutions) it is important to make sure that the challenge actually allows for such a restriction. Again, the situation was clear in urban robotics (sewer inspection requires robotics), but it was less clear in healthcare (where one of the solutions at the end was not purely robotics, lacking the aspect of autonomy).

Lessons learned during the preparation of the Open Call to attract the RTD consortia who develop in a competitive approach the technology to address the challenge of the public body acquired in Phase 0 of the PDTI process:

* Challenge Brief should have detailed description, if possible, including exact knowledge about environment that robotic solution will be
* PDTI process gives the link between public entities, industry, researchers and endusers and PCP should incorporate this lesson into the process, especially in Phase 0 because to include the direct opinion and ethical considerations of end-users
* Lightweight and effective mode to track the progress of the experiments is essential
* Be careful in defining the expected impact beforehand (KPI documents). When doing so, the roles and decision-taking power of the different stakeholders – public end-user and procurement agency – need to be clear. It is also important that the KPIs are aligned with the criteria that trigger procurement-decisions of public bodies. Some insititutions have very clear processes with clear criteria in place and will not adjust their entire process for one development project.
* Time investment during negotiations make experiment monitoring during runtime efficient and easy
* Specifications must be crystal-clear to all partners from the start
* Kick-off meeting with partners essential to create transparency from the beginning

## Third Step fo the PDTI process: Robotics technology development by competing teams

## Phase I: Solution Design

Phase I of the PDTI Challenge is focused on the solution and system design. Three consortia per application scenario were chosen to compete in Phase I, which lasted 6 months. Even though Phase II focuses on developing a reliable prototype for the solution, the consortia already had to show a working prototype at the end of Phase I. Based on an on-site review by independent experts, the number of competing consortia for Phase II was reduced from three to two per challenge. Two consortia are the minimum because the public body should not be bound to just one solution per challenge at the end (which would contradigt tender regulations in the public sector).

For the entire PDTI progress in technological maturity is measured based on the Technology Readiness Levels (TRL) used by Horizon 2020. Therefore, Phase I is associated with TRL level 4 (Horizon2020, 2014).

During the first phase, the monitoring teams had continuous contacts with the consortia, answering technical questions. Several visits to the public body have been organized by the consortia in order to test the prototypes. The public entity managed all these visits.

The assessment by the independent experts on-site at the end of phase I has been based on three basic criteria: Scientific and/or technological excel- lence, Quality and efficiency of the implementation and the management of the project and potential Impact through the development, dissemination and use of the project. Also, the involvement of the stakeholders, including the end-users was evaluated as important. Moreover, the items based on the challenge brief used for the evaluation were:

+  Positive evaluation of the tasks and documentation required during the period (Deliverables, milestones and dissemination milestones)

+  Solution design and the logistics required and operational issues by using the solution

+  Test Series based on the viability of the robotic solution

+  Economic Viability of the proposal

During Phase I, the learned lessons can be summarized as followed:

* Qualified, possibly interdisciplinary, team is necessary to converse public body’s needs and requirements into technological functions
* Phase I should require the development of a first prototype instead of only a solution design
* Phase I should also include design requirements to make sure end-users are considered from day 1
* Evaluation criteria should be clearly stated and distributed at the beginning of each phase
* Involved personnel e.g. reviewers should be clearly communicated and confirmed
* Transparency in documentation and organization to avoid possible redresses and delays in process
  + 1. Phase II: Prototyping

Phase II of the PDTI Challenge is focused on the feasibility study. Two consortia are chosen to compete in this phase. Phase II targets on TRL level 6, where the technology has to be tested in a relevant environment. This is a very ambitious target as the development teams are requested to advance two TRL lelves within 12 months. Here, the process demonstration should be carried in a real-life scenario.

Differences between the two PDTI challenges in terms of timeline and stakeholder groups involved in the design of the product (in case of healthcare two end-users – the hospital and the patients – call for patient-centred care) triggered differences in the approach of the two challenges. Even though this imposed a huge organizational change on the management team of E++, it also provided the opportunity to implement two different technology development philosophies: sequential development via agile approach in loops.

Sequential development models have an emphasis on planning, in which development is seen as flowing steadily downwards through several pre-planned phases. This model relies on intensive periods such as drafting requirements for a product before design and development activities take place. It has also an emphasis on time schedules, target dates and documentation. Products developed using this model are intended to be complete according to set-out requirements when released to customers.

In contrast to this, the agile approach prioritizes the iterative way of working, encouraging regular feedback from stakeholders, where requirements and solutions evolve via collaboration between self-organizing cross-functional teams. This model has an emphasis on testing stakeholder’s responses throughout the process and adjusting to that feedback; refining ideas and development activities with the intention of delivering products which better reflect what the stakeholders need.

The below table compares the work on the challenges in terms of timeline, definition of KPIs, involvement of stakeholders during the monitoring, the major challenges and the expected technology readiness at the end of Phase III.

Table 1 Comparison Healthcare and Urban Challenge at the end of Phase II

|  |  |  |
| --- | --- | --- |
|  | **Healthcare** | **Urban** |
| Monitoring | Combination of remote monitoring based on KPIs and on-site review at the end of Phase II; in-between physical testing in hospitals to involve end-users.  The monitoring was based on KPIs discussed between the E++ core consortium and both RTD teams between June 2017 and September 2017. The active monitoring implemented since early September with monthly calls. | 4 monitoring periods with documentation and tests required from both consortia to describe and illustrate the progress (for further description of the phases see section 3).  Evaluation criteria for Phase II discussed between public body and E++ core; presented to the two RTD teams in a kick-off meeting and summarized in a dedicated document; recommendation after Phase I: improve the prototype and the technological solutions. |
| Benefits of the respective approach on monitoring | Allowed for an open dialogue with all stakeholders (RTD teams, public body, E++ core consortium, and the independent experts) to assess the performance in the on-site review after Phase II.  Democratic approach on negotiating KPIs with all stakeholders (based on a suggestion by TUM / BOR) led to identification of “bottlenecks” which otherwise might have caused problems later on (i.e. voice recognition).  Stakeholder engagement led to inclusion of test and metrics which facilitated a shift from qualitative towards quantitative (more objective) KPIs for performance assessment and comparability between the teams. | The more top-down approach on the definition of the evaluation criteria allows for a swift process as fewer interactions and verification loops are necessary. Sewer started with full-fledged set of evaluation criteria from the beginning. Thus, the targets were very transparent for both teams from the very beginning of Phase II.  Physical demonstrations are essential to assess performance if the refinement of prototypes is key.  The constant access to the physical testing environment strengthened the links between the end-user and the RTD teams. The end-user – unexposed to robotics at the beginning, now clearly sees the benefits. |
| Budget | Equally divided between Phase II and Phase III (230.000 €) | 2/3 for Phase II and 1/3 for Phase III |
| Number of prototypes expected: | After Phase II: One per team After Phase III: 3 per team | After Phase II: One improved prototype for each team  After Phase III: Two prototypes per team |

During Phase II, the learned lessons can be summarized as followed:

* In order to develop technology which meets the expectations of the public sector, the end-users have to be tightly integrated into the development process and need to put quite a lot of effort into the collaboration to trigger an effective (an enjoyable) co-creation process
* PDTI requires the precise definition and tight collaboration between all the stakeholders relevant to the final product; adjusting communication to the reception abilities of the different target groups is key to achieve understanding
* The access to test environments has proven a crucial success factor
* The “quality” of the public stakeholders (also in terms of their willingness to purchase and actively contribute to the technology development) needs to be assessed prior to the collaboration or accepting a challenge.
* Procurement agency and end-user can be separated institutions with very different assessment criteria to motivate innovative procurement.

## Phase III: Small Test Series

Phase III of the PDTI Challenge is focused on small scale test studies. This final Phase is associated with TRL level 7 where the prototype of the system has to be demonstrated in an operational environment. The goal for this reporting period of Public end-user Driven Technological Innovation (PDTI) was to develop the prototypes from Phase II further to achieve a TRL of 7-8 (Urban Robotics) and 6-7 (Healthcare Robotics), to improve the characteristics of the prototypes evaluated in Phase I and II, and to incorporate the technological improvements into the prototype that are needed to perform the challenges set out in the Challenge Brief. At the same time this last phase of PDTI also aimed at increasing the marketability of the developed robotic solutions. The main objectives of Phase III were:

* Improvement of the prototypes developed in Phase II
* Periodical tests and final test
* Market research to identify scalability and transferability of the solution
* Commercialization preparation

Lessons learned from Phase III:

# Outcome and final results

By involving all relevant stakeholder groups – the public bodies (challenge providers) with their corresponding testing environments, academia and industry (as RTD consortia) combined with additional external expertise (depending on the challenge), as well as members of the E++ core consortium (as coordinators and facilitators of the process), PDTI can be taken as a prototypical example of user-centred design and technology development.

All four development teams have developed business plans. ASSESSTRONIC needs to further finetune the costs in their plan. Three out of the four teams – ASSESSTRONIC, SIAR and ARSI – would need about two additional years to fully commercialize their solutions (the gap and the route to market being different for all three of them). CLARC has generated new third-party funded projects to further develop the technology and to exploit their scientific findings in education and research. In both applications – „Comprehesive Geriatric Assessment“ and „Sewer Inspection“ – the experiments would meet a high market potential. With Sewer Inspection – motivated and driven by the E++ core partner UPC – ECHORD++ has even identified a concrete new application area for robotics with a very high market potential.

## Urban Robotics

The **ARSI** team has developed a solution with a high commercialization potential. The drone stil has some challenges regarding the control system, the engines, and the physical dynamics. The current platform works well in the lab, but has stability issues when tested in the sewer. In order to prepare commercialization, the consortium is encouraged to look for an off-the-shelf drone supplier who could provide a better design solution for the platform and to set up a realist mock-up of the sewer environment within the lab where the platform is tested, which should be used to test different solutions from multiple suppliers in order to select the one that works better in that environment**. ARSI**’s software should be taken as a stand-alone solution and commercialized at short notice to generate funds to invest in the full-fledged solution. The availability on the market of **ARSI**’s software solution would enable service providers to shift most of their resources to inspection tasks for the early detection of problematic areas allowing intervention before actual damage happens, thus spending less funds on major repairs. FCC – the service provider who is part of **ARSI**’s consortium - employs 200 operators in Barcelona’s sewer network daily, with 20 of them working on inspection tasks. The **ARSI** system would allow FCC to reduce this effort to 10 staff members, who wouldn’t need to enter the sewer. However, at the current stage they cannot support the further development of the system with their own funds. To maximize the commercialization potential of **ARSI**’s solution, the consortium is recommended to build a business case that goes beyond selling a “small” number of drones to one service provider only. Bringing **ARSI** to the market would entail investments to increase their manpower. Because of regulation within their organization, Eurecat cannot commercialize the product directly but they are exploring different solutions, from licensing to selling the solution to a company. Their preferred option would be licensing to FCC, who could then sell an additional service to their customers. They have also received many contact requests from potential competitors, thus confirming the market potential for this technology. An aerial solution is very suited for the sewer environment, despite the challenges imposed by the hardware, for it can adapt to different sewer architectures (diameters, shapes etc.). Moreover, in order to operate, a drone would not require the sewer to be cleaned in order to adequately perform, but there is no one drone size to fit every sewer. Thus **ARSI**’s portfolio would need to include different drones,

In order to be ready for commercialization, the system presented by **SIAR** needs additional testing to (i) improve the technical features of the platform (e.g. in terms of autonomous navigation), (ii) package the software modules and improve its usability, and finally (iii) obtain the CE mark. The platform is suitable also for the inspection of other environments, such as underground galleries, which most of the time require an easier setting than the sewer network. The target price of the platform is 50k Euro. The target unitary cost given by BCASA, the public body who provided the challenge on sewer inspection first place, was 0,50 Euro/m on inspection tasks. The **SIAR** system could reach 0,20 Euro/m. IDMind and the University of Seville have already signed an IP agreement to continue the development of the software. Different setups are currently discussed to guarantee the continuous update of the software and the transfer of the technology between the University of Seville and IDMind. IDMind is interested in commercializing the solution, but they need additional funding to support two additional small pilot projects, which can inform the next steps of the platform development and advance the commercialization of their solution. Their approach so far has been to avoid narrowing down the fields of application of the platform too much, even though they are aware that this has an impact on the effort they can devote to looking for financial support or potential end-users. Finding a professional investor seems to be quite difficult because of the high degree of specification of the solution. Furthermore, a critical mass of potential clients needs to be reached for investors to pay attention. There are, though, multiple valuable modules of the software developed by **SIAR** that could easily be integrated with other systems. IDMind is trying to commercialize the communication system developed and they are already receiving request for quotations. Most providers use 360-degree cameras that don’t have image processing. Hence, there will already be a market for the image processing software. This solution would also limit potential issues of acceptance, because it won’t have an impact on the current number of operators employed but it would pave the way for the introduction of incremental solutions. Additional support can come from small contracts (for Barcelona the limit is 15k Euro) for the supply of limited services that can leverage the interest of larger investors, also allowing IDMind to provide services to city councils without having to participate in tender processes. BCASA could further stimulate the dissemination among current providers of inspection services by including a series of trials for procurers to prepare upcoming tenders.

A lot of interesting technology has been developed and/or integrated in the **ARSI** and **SIAR** projects and that might have separate market potential, such as wireless communications, sensors, data handling and analysis, robotics. Some solutions, combined with the current systems used by service providers can already generate cash flow. Each separate value package can help the consortia to counterbalance the immaturity of the platforms and help them to arrive to the market sooner, in an easier and cheaper fashion, but more importantly help the market to understand the potential of the technology they are developing and be ready to accept an improved product.

* 1. Healthcare Robotics

**CLARC** has shown significant progress towards integrating user needs into their design process since an additional partner was added to the consortium. There was, for instance, careful attention to the interface between the older person and the system - recognising fears and uncertainties that may have militated against effective ‘engagement’ with the robot. The attention given to adjusting the design and appearance of the robot was therefore important. Also, the data representation and management was rated very positive by the medical experts. Another positive element in the CLARC project is the large number of patients with whom tests have been carried out (more than 400 patients so far), even though the sample as not fully representative. This has helped to better integrate the user perspective in the development.

Overall, though, the system displayed significant shortcomings. The system was frequently not able to understand the response of the person to the questions. For the Stand Up and Go Test, the machine was not able to recognize the person and thus to initiate the test. Due to important deficiencies in the technical implementation, the current offer is not ready for an exploitation path. This is mainly due to the robotic platform that fails to demonstrate the required level of reliability to be operational in an unstructured environment (as found in a hospital).

The presented business plan has been well developed and could be feasible if the technology worked. However, the business is based on assumptions that could not be demonstrated successfully. The business plan foresees the intake of venture capital. The preconditions to successfully pitch in front of venture capitalists, among others, are: 1) market and need; 2) solution and technology; 3) IP; and 4) Implementation. All 4 preconditions need to be more or less met. At the current stage 2), 3), and 4) are not sufficiently developed and/or they pose serious problems. As such, the product still requires a high amount of research, specifically when the envisioned autonomy of the robotic solution should be part of the offering.

A number of scientific results have been disseminated. This builds scientific impact. However, this does not necessarily represent innovation.

**ASSESSTRONIC** made significant progress. The system benefits a lot from its simplicity, scalability and thus does not impair a high risk of failure. The TRL level is rated at TRL 6. The system is on its way to a market-ready solution. From the user perspective, many good elements are demonstrated. This is the result of some previous technical recommendations of the reviewers having been taken into account carefully. business plan is solid with regards to market expectations, the market approach, and foreseen sales estimates.

The current business plan, however, neglects the fact that a CGA system is a medical product. Therefore, the costs for medical certification are underestimated. There is also a certain risk that the currently chosen alternative to the Kinect camera (no longer available) system still requires R&D - i.e. improvements in its stability to be able to reliably analyse gait patterns for patients. Currently also missing are results from a larger group trial that should be undertaken either sponsored by the commercialising company or through funding schemes, e.g. through innovation programmes like EIT-Health.

As ECHORD++ will not find further support for the two teams to continue their route to commercialization, the reviewers gave the following recommendations:

**ASSESSTRONIC** has presented a very interesting, scalable solution with an interesting cost-benefit ratio for the end users. The technology needs an additional two years’ funding to be mature enough to make it to the prioritization list of Acetiam, a large company groups standing behind ASSESSTRONIC. Going for the next EIT Health call with the hospital and Tecnalia (via Thierry Keller) is an option to generate funds for the further development of the system. The business plan needs more care in terms of certification costs and sales numbers. But the market potential is huge, and the solution finds the approval of the medical staff.

The merit of **CLARC** mainly lies with the scientific knowledge so far. But components of the solution are worth further developing – for instance in additional EU-funded projects which have already been acquainted. The shortcoming lies in the robustness of the platform which needs to be replaced. The data representation and management interface certainly is an asset the solution can build on. To this end, strategies for integration into IT-infrastructure should be further developed.

## Lessons learned/ conclusion

Having performed also Phase III of PDTI, the core consortium of ECHORD++ is now able to fully assess the achievements and commercial potential of the different solutions. ECHORD’s recommendations to the EC and the stakeholders involved in developing robotics technology for and with the public sector in the future can be summarized as follows:

* If the technology development in a PDTI-like activity is from the beginning restricted to a specific technology (in our case robotics) it is vital to make sure from the beginning that the challenge allows for such a restriction.
* When setting up the teams (both for the technology development as well as for the monitoring resp. coaching) it is important to make sure that all stakeholder groups are identified and actively involved in the process. The level of engagement of the different groups can vary in the different phases of the technology development process, but it is important to have all stakeholders with their interests on the screen.
* When collaborating with the public sector it is important to understand that user and purchaser of the technology are not necessarily the same entity and that the interests of these two can be very different from each other. So, it is necessary at the beginning to clarify the role and decision-taking power of each stakeholder. It is also vital to understand the criteria, which the procurer implements to motivate the purchase decision. This goes in line with the learnings from the RIFs: In projects like ECHORD++ the core consortium implements processes which need to be compatible with the purchase-triggering procedures which are already in place in the respective organizations.
* When dealing with hardware it is important for the development teams to have a proper mock-up in their labs.
* The coaching by the tandems business-technical from the core teams was tremendously important to achieve the results outlined in this deliverable. Coaching needs to include technical as well as business competence. At the end of ECHORD++, there are three prototypes, which will make their way to market within maximum two years if they are able to generate the funds and continue to get the support needed to make this happen. CLARC’s way to market is longer, but this team has generated very valuable scientific knowledge and has already managed to acquire additional funds to continue their development. CLARC is probably the team which shifted their mind-set most: They have adopted the agile project management approach, have learned how to integrate user perspective in their healthcare development and have forged a lot of new contacts (including hospitals with patients for testing) which will help them a lot to be successful in the future. Future applications need to be investigated and tested more – CLARC’s solution is very future oriented, ASSESSTRONIC’s solutions clearly solves today’s end-user needs
* Having an additional in-person review meeting between the development teams and the external experts was particularly helpful. Done is sewer inspection, this helped to identify opportunities in commercialization as well as in the collaboration between the two teams, which started as competing organizations, but now benefit a lot from collaborating with each other.
* The monitoring and coaching in PDTI healthcare and PDTI sewer have followed a different approach: While sewer worked with monitoring session alternating between on-site testing and a common set of deliverables, PDTI healthcare developed a common set of KPIs which were applied to teams with a completely different system (modular system instead of a mobile platform). What counts is that the intensive coaching takes place. Any effort spent is well-spent.
* PDTI in ECHORD++ has demonstrated that public bodies are highly interested in working in interdisciplinary teams to develop the technology they need. The intensive collaboration is extremely important to lower the entrance barrier for the public body. The collaboration is most beneficial if the end user benefitting most is directly involved in the project. In case of sewer inspection, it is the owner of the infrastructure rather than the service provider, in case of healthcare it is the medical doctors and not the procurement agency. PDTI has managed to develop two public bodies who will be ambassadors of the collaboration with roboticists and the implementation of robotics technology. So, innovative procurement in Europe can happen and be very beneficial if the right coaches are in place and are committed to spend the necessary effort. And PDTI requires a lot of effort. The market, though, is potentially very high then, as well.
* The active involvement of the public sector is key to the success of the technology development. Both, public procurers as well as end users contribute know-how and experiences which are unique. Often the procurement agency is organizationally separated from the end-user of the technology. This separation can be tricky if the weight of the end-user in the purchase decision is not entirely clear. It makes sense to put an emphasis on clarifying the roles prior before setting up joint projects. It also makes sense to implement a methodology on how to assess a public stakeholder in terms of purchase power, organizational structure, engagement, contribution to commercialization etc.
* The PDTI activities have demonstrated that inspiring the user-centred approach in development teams is a tremendous effort, particularly if the teams have not been exposed to such an approach before. The coordination during all the process by a multidisciplinary team, not only technological one (robotic in our case) is crucial to prevent the development of research-driven technology which fails to meet market needs.
* Before committing resources in a collaboration with public bodies which is very demanding and time-consuming, it is recommendable to assess the qualification of the public body (resources, track record in commercialization – particularly in EU-funded projects, network etc.). This can be extremely important for the DIH networks in robotics which have just started their activities. The situation has changed now in comparison to the early days of PDTI: Public bodies need less motivation as they start seeing the benefit. Therefore, the EC can be selective.
* Delays need to be avoided by all costs in any technology development project which is structured in phases. This holds true for PDTI-like activities, but also for huge Flagship projects like HBP. Reliability and a sound planning ground are key to success.

1. The Design of Business: Why Design Thinking is the Next Competitive Advantage, Roger L. Martin (2009); Design School Kolding, toolkit when implementing healthcare technologies (analysis and toolkit developed based on best case practices), Design Thinking, Harvard Business Review, Tim Brown (2008). [↑](#footnote-ref-1)