Deliverable 4.1

Recommendations for future Research Priorities, Business Opportunities and Innovation Strategies

<table>
<thead>
<tr>
<th>DISSEMINATION LEVEL</th>
<th>PU</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Public</td>
<td>Confidential, only for members of the consortium (including the Commission Services)</td>
</tr>
</tbody>
</table>
The Road2CPS project is co-funded by the European Community's Horizon 2020 Programme under grant agreement n° 644164.

The author is solely responsible for its content, it does not represent the opinion of the European Community and the Community is not responsible for any use that might be made of data appearing therein.

---

1 R=Report, DEC= Websites, patents filling, etc., O=Other
2 PU=Public, CO=Confidential, only for members of the consortium (including the Commission Services)
# Change Control

## Document History

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Change History</th>
<th>Author(s)</th>
<th>Organization(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>06/2016</td>
<td>Table of contents and structure of the document</td>
<td>Nuria de Lama</td>
<td>Atos</td>
</tr>
<tr>
<td>0.02</td>
<td>10/2016</td>
<td>Structure of document adapted to comments from Mallorca workshop</td>
<td>Nuria de Lama</td>
<td>Atos</td>
</tr>
<tr>
<td>0.03</td>
<td>11/2016</td>
<td>Innovation Strategies integrated in first version</td>
<td>Nuria de Lama</td>
<td>Atos</td>
</tr>
<tr>
<td>1.0</td>
<td>09/01/2017</td>
<td>Integration of section of Recommendations for future Research Priorities</td>
<td>Murray Sinclair</td>
<td>Loughborough University, integrator of contents of ALL partners</td>
</tr>
<tr>
<td>1.01</td>
<td>19/01/2017</td>
<td>Updated version of Recommendations for future Research Priorities</td>
<td>Murray Sinclair</td>
<td>Loughborough University</td>
</tr>
<tr>
<td>1.02</td>
<td>31/01/2017</td>
<td>Updated version of Recommendations for Innovation</td>
<td>Nuria de Lama</td>
<td>Atos</td>
</tr>
<tr>
<td>1.03</td>
<td>01/03/2017</td>
<td>Section on Business Opportunities and Business models integrated</td>
<td>Nuria de Lama</td>
<td>Atos</td>
</tr>
<tr>
<td>1.8</td>
<td>06/03/2017</td>
<td>Revised version</td>
<td>Nuria de Lama</td>
<td>Atos</td>
</tr>
<tr>
<td>1.9</td>
<td>08/03/2017</td>
<td>Formatting and wording changes; Table of figures corrected and table of acronyms completed</td>
<td>Nuria de Lama, adapting comments from partners, especially Loughborough University</td>
<td>Atos, Loughborough University</td>
</tr>
<tr>
<td>2.0</td>
<td>08/03/2017</td>
<td>Finalisation</td>
<td>Meike Reimann</td>
<td>SEZ</td>
</tr>
</tbody>
</table>
Consortium Information

<table>
<thead>
<tr>
<th>Name (and contact data)</th>
<th>Institution (incl. address)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. Reimann</td>
<td>Steinbeis-Europa-Zentrum Erbprinzenstrasse 4-12, Karlsruhe, DE</td>
</tr>
<tr>
<td><a href="mailto:reimann@steinbeis-europa.de">reimann@steinbeis-europa.de</a></td>
<td></td>
</tr>
<tr>
<td>M.J.D. Henshaw</td>
<td>Loughborough University Ashby Road, Loughborough, UK</td>
</tr>
<tr>
<td><a href="mailto:M.J.d.Henshaw@lboro.ac.uk">M.J.d.Henshaw@lboro.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>J. Fitzgerald</td>
<td>University of Newcastle King’s Road, Newcastle upon Tyne, UK</td>
</tr>
<tr>
<td><a href="mailto:john.fitzgerald@ncl.ac.uk">john.fitzgerald@ncl.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>David Servat</td>
<td>Commissariat à l’énergie atomique et aux énergies alternatives Paris 15, 75015, FR</td>
</tr>
<tr>
<td><a href="mailto:David.SERVAT@cea.fr">David.SERVAT@cea.fr</a></td>
<td></td>
</tr>
<tr>
<td>U. Rauschecker</td>
<td>Fraunhofer IPA 70569 Stuttgart, DE</td>
</tr>
<tr>
<td><a href="mailto:Ursula.rauschecker@ipa.fraunhofer.de">Ursula.rauschecker@ipa.fraunhofer.de</a></td>
<td></td>
</tr>
<tr>
<td>D. Ordonez</td>
<td>Anysolution SL 07010 Palma de Mallorca, ES</td>
</tr>
<tr>
<td><a href="mailto:dom@anysolution.eu">dom@anysolution.eu</a></td>
<td></td>
</tr>
<tr>
<td>N. de Lama</td>
<td>Atos España SA Madrid 28037, ES</td>
</tr>
<tr>
<td><a href="mailto:nuria.delama@atos.net">nuria.delama@atos.net</a></td>
<td></td>
</tr>
</tbody>
</table>

Authors

The table shows main authors, even though contents are based on contributions by all partners and this document builds upon previous deliverables submitted by Road2CPS, thus, including contributions from all partners.

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>N.de Lama</td>
<td>Atos España SA Madrid 28037, ES</td>
<td><a href="mailto:nuria.delama@atos.net">nuria.delama@atos.net</a></td>
</tr>
<tr>
<td>M.A. Sinclair</td>
<td>Loughborough University Ashby Road, Loughborough, UK</td>
<td><a href="mailto:m.a.sinclair@lboro.ac.uk">m.a.sinclair@lboro.ac.uk</a></td>
</tr>
</tbody>
</table>
# Table of Contents

Acronyms ............................................................................................................................ 8
Executive Summary ............................................................................................................... 10
1 Introduction ..................................................................................................................... 11
1.1 About this document ................................................................................................. 11
1.2 Intended Audience ................................................................................................. 11
1.3 Keyword list ............................................................................................................. 11
2 Recommendations for future Research Priorities ..................................................... 12
2.1 Introduction to this section ..................................................................................... 12
2.2 Examples of filtered nodes ..................................................................................... 14
2.3 Societal acceptance ................................................................................................. 15
2.4 CPS fall-back plans ................................................................................................. 16
2.5 Health monitoring of CPS ...................................................................................... 17
2.6 CPS authority and responsibility ........................................................................... 18
2.7 Platforms for domain-specific CPS: ....................................................................... 20
2.8 Recommendations for future research into the technologies of CPS................... 21
2.8.1 Recommendations for the European Commission ............................................. 21
2.8.2 Recommendations for platforms, architectures, interoperability and standards 25
2.8.3 Recommendations for modelling and simulation ............................................. 25
2.8.4 Recommendations for safety, security and privacy protection ..................... 26
2.8.5 Recommendations for Big Data ........................................................................ 26
2.8.6 Recommendations for Autonomy ..................................................................... 27
2.8.7 Recommendations for HMI .............................................................................. 28
2.8.8 Conclusions ....................................................................................................... 28
3 Recommendations for Innovation Strategies ............................................................. 30
3.1 Innovation in the EU: where are we? ..................................................................... 31
3.2 The Geographical aspect: coordination at European, national and regional levels 33
3.2.1 Recommendations ......................................................................................... 37
3.3 The challenge of Skills ......................................................................................... 37
3.3.1 Recommendations ......................................................................................... 37
3.4 Innovation Governance and Policy challenges ..................................................... 40
3.4.1 Recommendations ......................................................................................... 40
3.5 Research & Innovation Programmes ...................................................................... 45
4 Business Opportunities ............................................................................................... 49
4.1 Disruptions leading to market opportunities ......................................................... 49
4.2 Emerging business models................................................................. 52
4.2.1 Trends in Organizational, Production and Business models.......................... 54
5 Conclusions.......................................................................................... 57
References .............................................................................................. 59
List of figures

Figure 1 A Gephi® plot for all the Gaps, projects and links. The colour-coding represents an interoperability scale, derived from (NCOIC 2011); the levels are given in the legend ................................................. 13
Figure 2 Example of feedback loops ................................................................................................................................. 14
Figure 3 Filtered version of Figure 1 with Gap 4 as the focus of this plot, and showing its local interconnected neighbours ................................................................................................................................. 15
Figure 4 Filtered version of Figure 1 with Gap 10 as the focus of this plot, and showing its local interconnected neighbours ................................................................................................................................. 16
Figure 5 Filtered version of Figure 1 with Gap 27 as the focus of this plot, and showing its local interconnected neighbours ................................................................................................................................. 17
Figure 6 Filtered version of Figure 1 with Gap 27 as the focus of this plot, and showing its local interconnected neighbours ................................................................................................................................. 18
Figure 7 Filtered version of Figure 1 with Gap 57 as the focus of this plot, and showing its local interconnected neighbours ................................................................................................................................. 20
Figure 8 EU MS Innovation performance (source: European Innovation Scoreboard 2016) .................. 31
Figure 9 Diversity of efforts across Europe (source: European Commission, DG Connect) .................. 33
Figure 10 Planned ICT investments under ESIF in the areas of Smart Grids and Smart Cities (source: ICT Monitoring Tool of the Smart Specialisation Platform S3) .......................................................... 35
Figure 11 2020 Baseline Scenario for the indicator Data Market Value (source: European Data Market Monitoring Tool) ................................................................................................................................. 36
Figure 12 Results of the survey on skills and mobility performed by COBCOE Evolving Europe Report .................................................................................................................................. 38
Figure 13 Estimated numbers of supply and demand of data scientists (Data market Monitoring Tool, IDC 2015) ........................................................................................................................................... 39
Figure 14 Number of E-learning firms in EU, by country (source: Cedefop; IER estimates from StockMOD, 2012) ........................................................................................................................................... 40
Figure 15 Pro-Innovation Regulation in the EU (source: ITIF – Information Technology & Innovation Foundation) ........................................................................................................................................... 41
Figure 16 Demand-side Innovation Policy (source: Business Innovation Observatory) .................. 48
Figure 17 Left: Disruption of body monitoring (source: Business Innovation Observatory); right: Global mobile health industry market size projection from 2012 to 2020 (in EUR billions); source: Statista ............................................................................................................................................... 49
Figure 18 Left: Disruption of human-robot collaboration (source: Business Innovation Observatory); Right: e-vigilante is a surveillance robot for monitoring warehouses and other industrial sites (source: http://www.eos-innovation.eu/Produit/EVigilanteFr.sls) ............................................................................................................................................... 50
Figure 19 Disruption of autonomous cars: opportunities & challenges (source: Business Innovation Observatory) ............................................................................................................................................... 51
Figure 20 Economy of data: multi-sided platforms (source: Atos) ............................................................................................................................................... 53

List of tables

Table 1 Listing of the 72 projects scanned in the Road2CPS project. Entries in italics are from the ARTEMIS and ECSEL JUs; the rest are from FP7 and H2020 programmes. Only project deliverables were scanned ................................................................. 12
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIOTI</td>
<td>Alliance for the Innovation on the Internet of Things</td>
</tr>
<tr>
<td>BDVA</td>
<td>Big Data Value Association</td>
</tr>
<tr>
<td>BDVe</td>
<td>Big Data Value ecosystem</td>
</tr>
<tr>
<td>BIO</td>
<td>Business Innovation Observatory</td>
</tr>
<tr>
<td>CIP</td>
<td>Competitiveness and Innovation Program</td>
</tr>
<tr>
<td>CKAN</td>
<td>Comprehensive Knowledge Archive Network</td>
</tr>
<tr>
<td>CPS</td>
<td>Cyber-Physical Systems</td>
</tr>
<tr>
<td>CPSoS</td>
<td>Cyber-Physical Systems of Systems</td>
</tr>
<tr>
<td>CSA</td>
<td>Coordination and Supporting Action</td>
</tr>
<tr>
<td>DG</td>
<td>Direction General</td>
</tr>
<tr>
<td>DEI</td>
<td>Digitizing European Industry</td>
</tr>
<tr>
<td>DIH</td>
<td>Digital Innovation Hub</td>
</tr>
<tr>
<td>DSM</td>
<td>Digital Single Market</td>
</tr>
<tr>
<td>E2E</td>
<td>End-to-end</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EDSA</td>
<td>European Data Science Academy</td>
</tr>
<tr>
<td>EIF</td>
<td>European Investment Fund</td>
</tr>
<tr>
<td>EIP</td>
<td>European Innovation Partnership</td>
</tr>
<tr>
<td>EIPE</td>
<td>European ICT Poles of Excellence</td>
</tr>
<tr>
<td>EIT</td>
<td>European Institute of Technology</td>
</tr>
<tr>
<td>EP</td>
<td>European Parliament</td>
</tr>
<tr>
<td>ESIF</td>
<td>European Structural and Investment Funds</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>ISG CIM</td>
<td>Industry Specification Group on Cross-sector Context Information Management</td>
</tr>
<tr>
<td>NGSI</td>
<td>Next Generation Sensors Initiative</td>
</tr>
<tr>
<td>FP7</td>
<td>Framework Programme 7</td>
</tr>
<tr>
<td>GSMA</td>
<td>GSM Association</td>
</tr>
<tr>
<td>H2020</td>
<td>Horizon 2020</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interaction</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technologies</td>
</tr>
<tr>
<td>IDC</td>
<td>International Data Corporation</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
</tr>
<tr>
<td>IPTS</td>
<td>Institute for Prospective Technological Studies</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technologies</td>
</tr>
<tr>
<td>JPF</td>
<td>Joint Programming Framework</td>
</tr>
<tr>
<td>JU</td>
<td>Joint Undertaking</td>
</tr>
<tr>
<td>KIC</td>
<td>Knowledge and Innovation Community</td>
</tr>
<tr>
<td>MOOC</td>
<td>Massive Open Online Course</td>
</tr>
<tr>
<td>MS</td>
<td>Member State</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>NME</td>
<td>New Manufacturing Engineering</td>
</tr>
<tr>
<td>OASC</td>
<td>Open and Agile Smart Cities</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
</tr>
<tr>
<td>PPP</td>
<td>Public Private Partnership</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>R&amp;I</td>
<td>Research and Innovation</td>
</tr>
<tr>
<td>RIS3</td>
<td>Research and Innovation Strategies in Smart Specialization</td>
</tr>
<tr>
<td>SCC</td>
<td>Smart Cities and Communities</td>
</tr>
<tr>
<td>SDIL</td>
<td>Smart Data Innovation Lab</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium Enterprise</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>US</td>
<td>United States (of America)</td>
</tr>
<tr>
<td>WP</td>
<td>Work Programme</td>
</tr>
</tbody>
</table>
Executive Summary

This document integrates the findings of the Road2CPS consortium along these two years of work and adds new angles related to innovation environments. It builds upon previous deliverables by summarizing major recommendations in terms of technological priorities as well as business opportunities. Since the project started and thanks to the numerous consultations carried out by the project, including workshops with different stakeholders, we have confirmed that adoption of CPS will only happen if some conditions are fulfilled, and in many cases they are not of technical nature. As important as technology development is the set-up of suitable innovation environments. But this entails challenges in terms of business models, skills development, legal and regulation frameworks.

As a result, and in order to provide a more comprehensive view of what needs to be done from different viewpoints we have included a specific chapter that brings together the Road2CPS recommendations for future research priorities (here, even though a lot of recommendations relate to technical areas of CPS there is already a good reasoning of other aspects that need to be tackled by future projects). Then, the document adds two additional chapters that focus on Innovation strategies and Business Opportunities (including emerging business models enabled by new technologies) respectively.

In order to avoid a too long document we have focused on integrating and synthetizing views provided by experts (from inside and outside Road2CPS, including existing literature), but in all cases readers will see concrete recommendations, with a special view on future steps to be taken by the European Commission. The list is neither exhaustive nor complete, but this is about priorities and we think the areas highlighted by this document reflect very well the views of Road2CPS on where focus should be.
1 Introduction

This deliverable closes the cycle of work carried out by the Road2CPS project by providing a wide picture of recommendations that could greatly improve the adoption of Cyber Physical Systems (CPS) in the market. In order to do so we have had a look at three major aspects: (1) technologies in the CPS area (or related to it) that are promising or have been identified as potential solutions to well-known problems; (2) business opportunities derived from specific requirements and challenges associated to application domains/vertical markets, and (3) non-technical elements that fall under categories such as policy, regulation, business models or skills. The three of them are required in order to define a compelling strategy that allows Europe to stay at the forefront of CPS.

1.1 About this document

This report tries to offer an overall view of the areas where attention should be paid. In some cases we do so by identifying general topics that should be addressed; in some other cases we formulate concrete recommendations on very specific topics that are critical to the future of CPS. As it was previously stated, technology is not a value in itself when it comes to increasing business competitiveness. It is a major asset indeed, but some other elements need to come together to increase the probably of success in the market. That is why we have tried to bring complementary perspectives to this deliverable. On the one hand, we capitalize the work developed by Road2CPS on the analysis of different sectors (including energy, manufacturing, smart cities, or health, among others) to link technologies and real challenges/needs (all this has been further elaborated in the associated roadmaps and case studies); on the other hand, we bring a new perspective on elements that are essential in an innovation ecosystem (this includes many non-technical aspects that are of utmost importance for technologies to be adopted). For this part we have carried out additional work to the technology or domain-oriented tasks that guided previous documents.

Therefore, this document builds on top of previous work carried out by the Road2CPS team in both technologies and sectorial domains, but adds a third angle of innovation-related challenges that do not fall necessarily under technical themes, but have been constantly pointed out by experts in almost, if not all, workshops attended or organized by Road2CPS.

In this case we do not intend to carry out a deep research on innovation policies or regulatory environments. We rather try to synthetize the myriad of sources of information and initiatives that have been pushed forward by different EU stakeholders, including the EC, in an attempt to address the struggling situation of the EU with respect to Innovation.

1.2 Intended Audience

This is a guide that should facilitate the definition of innovation strategies by different stakeholders (industry, academia, public institutions). It looks carefully at actions that should be considered by public-funding bodies and specifically, by the European Commission. Nevertheless, as said, it is not exclusively targeted at this single institution. The document is wide in scope on purpose and does not intend to be a complete and exhaustive guide to all the topics that are mentioned; on the contrary, its main purpose is to provide a comprehensive list of recommendations to enhance Innovation ecosystems in the EU in general, and in the context of CPS in particular.

1.3 Keyword list

CPS, Innovation, business models, policies, regulation, skills, coordination, platforms, Digital Innovation Hubs, industrial challenges, open innovation.
2 Recommendations for future Research Priorities

2.1 Introduction to this section

This section presents a technological perspective for the EU, extending to about 2050. Necessarily, it is based on current facts and trends, since future facts are not available, and therefore it should be accepted that these prognostications should be treated as indicators. Furthermore, the text below is based on work carried out in four roadmapping projects, all funded by the H2020 programme and all oriented towards technological aspects of Cyber-Physical Systems (CPS) and Systems of Systems (CPSoS): Road2SoS, T-AREA-SoS; TAMS4CPS and Road2CPS.

The latter project, Road2CPS, was specifically focussed on the findings of CPS projects funded under the FP7 and H2020 R&D programmes, 54 in number, and a further 18 CPS innovation and implementation projects in the ARTEMIS and ECSEL Joint Undertakings. These 72 projects, listed below, provide most of the evidence base for the comments that follow in this report.

<table>
<thead>
<tr>
<th>72 EU projects providing the data set for Road2CPS project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3CCar</strong></td>
</tr>
<tr>
<td><strong>ACCUS</strong></td>
</tr>
<tr>
<td><strong>ADVANCE</strong></td>
</tr>
<tr>
<td><strong>AGILE</strong></td>
</tr>
<tr>
<td><strong>ALMARVI</strong></td>
</tr>
<tr>
<td><strong>AMADEOS</strong></td>
</tr>
<tr>
<td><strong>Arrowhead</strong></td>
</tr>
<tr>
<td><strong>Autoprofit</strong></td>
</tr>
<tr>
<td><strong>AXIOM</strong></td>
</tr>
<tr>
<td><strong>BALCON</strong></td>
</tr>
<tr>
<td><strong>BEMO-COFRA</strong></td>
</tr>
<tr>
<td><strong>CLAM</strong></td>
</tr>
<tr>
<td><strong>COMPASS</strong></td>
</tr>
<tr>
<td><strong>CONCERTO</strong></td>
</tr>
<tr>
<td><strong>CONSERN</strong></td>
</tr>
<tr>
<td><strong>COPCAMS</strong></td>
</tr>
<tr>
<td><strong>COSSIM</strong></td>
</tr>
<tr>
<td><strong>CP-SETIS</strong></td>
</tr>
<tr>
<td><strong>CPS-SUMMIT</strong></td>
</tr>
<tr>
<td><strong>CPSELABS</strong></td>
</tr>
<tr>
<td><strong>CPSoS</strong></td>
</tr>
<tr>
<td><strong>CRYSTAL</strong></td>
</tr>
<tr>
<td><strong>CyPhERS</strong></td>
</tr>
<tr>
<td><strong>DANSE</strong></td>
</tr>
</tbody>
</table>

Table 1 Listing of the 72 projects scanned in the Road2CPS project. Entries in italics are from the ARTEMIS and ECSEL JUs; the rest are from FP7 and H2020 programmes. Only project deliverables were scanned.

Supplementing this evidence base were the results of the earlier three road-mapping projects, plus a literature scan of many other documents summarising the state of the CPS scene. Examples of the latter sources include Industrie 4.0 documents (Kagermann, Wahlster et al. 2013, Geisberger and Broy 2015), HiPEAC (Duranton, Bosschere et al. 2015), robotics (SPARC 2015, STOA’16 2016), ultra-

From this evidence base a total of 76 ‘Gaps’ in the knowledge requirements for the design, instantiation and operation of CPS systems were identified. As the analysis proceeded and knowledge links between the Gaps were developed, these 76 Gaps were reduced to 75, as overlaps were discovered. Figure 1 below illustrates the Gaps, the links between them, and the projects that gave rise to the Gaps. This figure is one of the results of a Gephi™ network analysis; several other graphical plots using this tool will be found in this section of the Deliverable. A full report on the method of generating the Gaps and the first analysis of them can be found in Deliverable 1.2 Gap Analysis of a dataset obtained from 54 FP7/ H2020 Cyber-Physical Systems projects.

![Gephi plot for all the Gaps, projects and links. The colour-coding represents an interoperability scale, derived from (NCOIC 2011); the levels are given in the legend](image)

Self-evidently, this figure is hard to interpret, though there is structure within it. Filtered versions of this figure targeted at each of the Gaps in turn were developed, enabling the recommendations below to be generated, and a limited selection of these are included for illustration purposes.

Nevertheless, it is possible visually to develop some inferences from Figure 1 above:

1. The dense network of links between the Gaps, allied with the intermingling of Gaps from different levels of interoperability implies that future H2020 Calls should not focus on
individual Gaps. Instead, a more general set of objectives for each individual Call is likely to achieve better outcomes for the EU.

2. Secondly, perhaps less obviously, this dense network has many feedback loops within it. Figure 2 below is an example of this. Since research and innovation starts with known current facts but with little knowledge of future facts, these feedback loops imply surprises, sometimes nasty, and often more awkward the later that the surprises are discovered and project resources have been depleted. This in turn implies that future individual Calls should encompass obvious feedback loops linking sets of gaps. This observation supports the argument above.

3. Even when looking at the Gaps at lower levels of interoperability, where one might expect the Gaps to be purely technical with little attention required to societal issues, there are often links to higher-level, more strategic Gaps, implying that most individual Calls should be multi-disciplinary.

Figure 2 Example of feedback loops

In this case, between networking Gaps (red nodes plus pink node all reciprocally interconnected). There are many of these loops scattered through the full network; reciprocals, triangles and more complex loops. They imply that H2020 Calls should embrace these loops, rather than focus on individual Gaps.

A warning is necessary at this point; the Gaps in this figure have been given short names, in place of much longer definitions to be found in Deliverable 1.2. Misinterpretations of the gaps are possible. Furthermore, most of the Gaps are individually complex, encompassing a wide range of different disciplines within the boundary of the Gap, and frequently falling into the class of ‘Wicked Problems’ (Rittel and Webber 1973, Daw 2007, Siemieniuch and Sinclair 2014) when seeking the knowledge to close the Gaps.

2.2 Examples of filtered nodes

Five examples of filtering figure 1 are included below. Each one covers an aspect of importance for the EU in the future. Collectively, these five examples provide much of the basis for the recommendations given in section 3 below:

- **Gap 4 Societal acceptance**: Need for concerted, integrated, co-ordinated efforts by governments and other agencies to bring about cultural, social & educational change to encourage wide adoption of CPS.

- **Gap 10 Fall-back plans**: assurance & adequacy of fall-back plans for major CPS failures (e.g. energy, other essential infrastructure networks)
- **Gap 27  Health monitoring of CPS:** theories, tools, architectures and devices for continuous ‘health monitoring’ of the fitness of operational CPS
- **Gap 31  CPS authority & responsibility:** theory and tools to explore architectures for the allocation of human authority and responsibility for CPS operations and behaviours, including legal and liability aspects, resilience and agility, etc.
- **Gap 57  Platforms for domain-specific CPS:** development of platforms and demonstrators for all domains (manufacturing, health care, etc) to provide infrastructure and tools to enable swift construction and operation of CPS, and to show benefits and approaches of CPS

### 2.3 Societal acceptance

Figure 3 below shows the Gaps closely-connected to Gap 4: Social acceptance of CPS. It also shows those projects (grey nodes) clearly identified as direct contributors to closing the Gap.

**Comments on Figure 3:**

- Social acceptance of CPS is an important goal for the EU, its member states and for the communities and individuals who will find CPS technology essential to everyday life and to the accomplishment of goals. In the same way that people do not expect to have daily battles with their washing machines, or automobiles, they will expect CPS to work, and to have minimum fuss in achieving their individual goals. As with automobiles, CPS will be used for a multitude of purposes, some unexpected by their implementers, but all expected to be accomplished with little effort. There will be expectations of transparency, ethical behaviour (safety, privacy, etc.) in delivering the purpose(s), and failure-free performance. Furthermore, different communities of the EU will have different cultural norms; recognition of these is important for acceptance.
• It is for these reasons above that Figure 3 is complex. There is a wide range of complementary strategic Gaps (green nodes) that should be addressed to bring about acceptance by the public, each of which will have its own network of neighbouring technology Gaps. Combined, these strategic Gaps indicate the scope of effort required for good acceptance of CPS.

• There is a set of more directly-contributing Gaps (blue, pink nodes) for social acceptance, together with some CPS projects (grey nodes) that have generated (or are generating) appropriate technology to help close the Gaps.

• As a specific point, Gap 10, ‘Fall-back plans’ appears as a contributor to social acceptance. The implication of this is that in the event of a failure, the smooth adoption of a fall-back plan does derogate from the public’s level of trust.

2.4 CPS fall-back plans

Figure 4 Filtered version of Figure 1 with Gap 10 as the focus of this plot, and showing its local interconnected neighbours

Comments on Figure 4:

• Illustrating the point above, Gap 10, a single node in Figure 3, has its own network of neighbouring Gaps that contribute to it.

• There is also a considerable overlap of nodes in this network with the nodes in network in Figure 3; however, there are differences in the links between them. This indicates transfers
of different kinds of knowledge in different directions between the same Gaps, and that some of this knowledge may have accrued from other Gaps.

- It is instructive that a majority of the links involving Gap 10 are inwards, and that many of them originate from other strategic Gaps. The implication is that fall-back plans are not just exercises in technological resilience and recovery for CPS; they will need to take account of other societal and community-level issues as well.
- A wide range of technological gaps are directly linked to this Gap; this is not surprising, but it is useful to have some labels for the Gaps within the range.
- It is noted that only one project contributes directly to closing this Gap. One might expect that most of the ARTEMIS and ECSEL projects would have an interest in this Gap, but it may be that Deliverables that discuss this have not yet become available from the projects. It is acknowledged, however, that for critical infrastructures and industries there are significant efforts already being made elsewhere to address this Gap, so the apparent lack of attention may well be apparent and not real.

2.5 Health monitoring of CPS

Figure 5 Filtered version of Figure 1 with Gap 27 as the focus of this plot, and showing its local interconnected neighbours
Comments on Figure 5:

- The role of this Gap is to fulfill the feedback role implied by the third question of the Management Triad: ‘Are we doing the right things?’, ‘Are we doing those things right?’, and ‘How do we know this?’. This function, the ability to assess the performance and integrity of a CPS, is of great importance in successfully closing the seven strategic gaps shown and there is an outward link to each one of these in the figure.

- Links to this Gap from the non-strategic nodes (blue and pink) indicate a strong reliance on models and real-time evaluation. Unfortunately, as many other road-mapping projects (e.g. CyPHERs, CPSoS, SCorPius, TAMS4CPS, …) have also indicated, there are sparse contributions of knowledge to these two topics. Both of these are difficult research areas, requiring injections of resources to close the Gaps, and it would be of some benefit to the EU to address these more forcefully.

- It is noticeable that the projects with a direct connection to this network of Gaps are all from the ARTEMIS and ECSEL JUs, with no detected direct contribution from H2020. While this is understandable, it indicates a need for some basic research in what is a difficult area.

2.6 CPS authority and responsibility

Figure 6 Filtered version of Figure 1 with Gap 27 as the focus of this plot, and showing its local interconnected neighbours
**Comments on Figure 6:**

- Control of CPS is of fundamental importance both for industries and for the communities and individuals who interact with these systems. It is therefore a little surprising that there appears to be only one project, HoLiDes, in the ARTEMIS JU that is exploring this Gap, particularly when one considers that (a) the physical configuration of the CPS may be determined only at run-time\(^3\) and may change at any point thereafter; (b) autonomous decision-making components may be included in the CPS, and (c) the nature of interaction between the CPS and its components with human co-workers will undergo significant changes\(^4\). It becomes more problematic when autonomous components have the ability to learn and change their behaviour\(^5\).

- Under current legal convention throughout the EU (the *aquis*), it is humans who will have authority over, and be held responsible for, the operations and behaviours of CPS. For humans to be able to exercise this authority and responsibility, and to accept liability if necessary, they must be educated, trained, and be able to work on interfaces that provide suitable sensing facilities to gain situation awareness and have access to decision support tools including modelling and simulation tools, communication facilities and command and control capabilities in order that they may exercise Informed Command and Informed Consent. Because of the changes to tasks and jobs that the CPS environment and its technologies will entrain, current interfaces are likely to be insufficient. This represents a critical gap in CPS technology.

- Furthermore, when members of the general public interact with a CPS, they are given delegated control to do so, through a dedicated interface. The more capable the CPS, and the more complicated the purpose of the customer, the more flexible the interface must be. This, too, represents a gap, particularly when it is understood that most lay customers are not interested in how the CPS works; the customer just wants the CPS to deliver its results with minimum fuss and time demands and with neither complications nor errors. The realisation of such interfaces is currently under-developed, particularly when one considers the disadvantaged, the disabled, the vulnerable and the less technologically aware.

- Most CPS in their final operational configuration will be held together by a whole series of contracts between carriers, devices, processes, organisations and support services. These may be of very short to very long duration, ‘incomplete’\(^6\), and repetitive. Four key aspects of contracts are promise, performance, payment and trust. Clearly, in a CPS world, current approaches to contracts are infeasible, and this appears to be a lacuna within this Gap. It may be that block-chain technology\(^7\) offers a means to combine the four aspects above that is convenient for its non-centralised, trusted-ledger qualities. It was not evident in any of the snippets, etc. that this aspect is being fully explored.

---


2.7 Platforms for domain-specific CPS:

Figure 7 Filtered version of Figure 1 with Gap 57 as the focus of this plot, and showing its local interconnected neighbours

Comments on Figure 7:

- This plot reflects the importance attached to platforms by the EC and by industry, as evidenced by the 12 H2020 projects and the 12 ARTEMIS/ECSEL projects involved in this topic. Given the importance of platforms across the strategic goals listed in Gaps 1 to 18, it is perhaps unfortunate that none of the 24 projects has focused efforts on addressing such strategic goals.
- The wide range of Gaps identified in this plot together with the high degree of linkage among the Gaps indicates the sophistication and complexity of this Gap. This nexus of Gaps indicates that large projects, of the scope of ARTEMIS or ECSEL projects, are necessary to deliver substantial progress. While there is scope for smaller projects with a focus on an identifiable generic issue, such projects should attend closely to the requirements that emerge from the larger projects in order that the contribution of the smaller projects is properly usable.
- It is laudable that the EC and industry jointly is prepared to invest so heavily in this domain to ensure future competitiveness; however, it does raise questions of overlap of focus and work, and whether there is enough co-operation and concertation among these 24 projects in the planning and utilisation of outputs, albeit respecting the importance and ownership of IPRs.
- The amplitude of links indicates a strong role for standards and semantics; this might be one of the important side-benefits of the work in generating platforms.
2.8 Recommendations for future research into the technologies of CPS

These recommendations regarding the technologies of CPS arise from the following sources:

- the 75 Gap analyses, including the examples in the section above
- the database of project snippets collected from the Deliverables that were available from the 72 projects listed in Table 1 that are available in the Vulture database
- other snippets collected from other widely-respected reports and publications within the field of CPS

Many of these recommendations appear in other deliverables from the Road2CPS project. They are integrated in this section, together with other recommendations that have surfaced after those deliverables were completed, and a synoptic perspective has become possible.

The recommendations below have been clustered under a number of convenient headings, for the benefit of the reader.

- Recommendations about CPS technologies directed towards the Commission.
- Recommendations for platforms, architectures, interoperability and standards
- Recommendations about modelling and simulation
- Recommendations on safety, security and privacy
- Recommendations on Big Data and analytics
- Recommendations on Autonomy
- Recommendations on the Human-Machine Interface

2.8.1 Recommendations for the European Commission

1. Combining all the sources above, it is evident that CPS networks have no geographic boundaries regarding security, privacy, liability, efficiency and effectiveness. There is a strong need for standards, codes of practice, and international agreements to deliver the implied benefits that should arise from closing these gaps, at the same time avoiding their negative possibilities. In particular, agreements on cyber-security, allowable classes of interoperability and on legal and liability issues should be priorities.

2. The technology-focussed Gap Analysis, examples of which are in Section 1, provides an insight into the scope of each targeted Gap that might not be immediately apparent. If the Gap that is targeted in the plot is to be properly closed, the implication is that each of the directly-related Gaps in the plot (and perhaps others not directly related to the target Gap) need to be closed as well, either partially or fully, for the targeted Gap’s benefits to be fully realised. In the real world of decision-making this may not be possible; however, it does indicate the need for careful thought about grouping related Gaps before formalising a research topic in a Call and committing resources to that research topic. A convenient mantra for future R&I plans is: ‘No Call stands alone’ (a clumsy version is: ‘All Calls must be vertical and horizontal).

3. It is noticeable that where a Gap involves political or societal aspects, there is a much greater inclusion of other top-level strategic Gaps than for Gaps that focus mainly on technology. This is not surprising, but the message of this is that the EC might be reducing the effectiveness of its disbursement of funds and resources if it does not take greater account of societal issues in its planning of Calls. Because of its intended pervasiveness, CPS technology cannot be separated from society if it is to work well and achieve acceptance.
4. Many of the plots have links between Gaps that are essentially technological and Gaps that are much more concerned with human involvement. The implied interfaces indicate that closing a technological gap should always include consideration of these interfaces and their socio-technical aspects; the pervasion of CPS technology into the everyday life of people is likely to require this; not just the co-workers within the CPS. It is already recognised that large-scale CPS and CPSoS will operate in fault mode for much of the time. Of course the converse is also true: projects dealing mainly with organisational, human and social issues cannot ignore the technological context within which these issues may sit.

5. For many of the Gaps, both the plot and the comments may seem well-known and obvious; nevertheless, these plots show a scope and a depth that may be of benefit to research planners and implementers in ensuring sufficient coverage of a Gap to deliver a good solution.

6. The full set of plots in the Gap analysis has shown that there are many overlaps among the plots, indicating the connected nature of research and innovation for CPS in achieving strategic goals. An implication of this is that there is a need for H2020 to adopt a ‘mega-project’ approach, characterised by an umbrella project that provides strategy and support to a number of smaller, focussed projects, with an emphasis on complementarity, interoperability and temporal co-ordination among the smaller projects to address the implied feed-back loops.

There is an associated requirement for co-ordination and orchestration in closing these various strategic gaps. Given the complexity of achieving this before eternity arrives, it is suggested that the EC (and H2020 in particular) should adopt an approach based on a ‘wicked problems’ perspective. For a discussion of wicked problems, see for example (Rittel and Webber 1973, deMeyer, Loch et al. 2002, Beck and Andres 2004, Williams 2005, Conklin 2006, Siemieniuch and Sinclair 2014). For convenience, a list of attributes of ‘wicked problems’ is included:

- There is no definitive formulation of a wicked problem
- Wicked problems have no stopping rule
- Solutions are not true or false, but rather better or worse
- There is no immediate nor ultimate test of a solution to a wicked problem
- Every solution to a wicked problem has a time horizon
- Each wicked problem is essentially unique, and can be considered to be a symptom of a larger wicked problem
- How a wicked problem is described determines the nature of its solution

For a project consortium, these characteristics again indicate a need for strong co-ordination among the partners, allied to frequent planning and re-planning. For the partners, it implies a need for flexibility and resilience in approach, allied to broad-based knowledge.

It may also suggest some additional criteria in the evaluation of proposals. It is also important to note that these co-ordination and cross-fertilisation activities should be directly funded in the same way that technological research is currently funded within projects to ensure that the importance of this activity is recognised. Inter-project agreements may also be necessary.

7. There are several groups of Gaps that recur in the plots and that are important in generating acceptance of the likely pervasive role of CPS in both individual and societal life. It is important
to ensure that these gaps are addressed soon, to prepare those people about to be impacted by CPS, rather than surprise them. As the CPSoS project has stated, we may expect that large-scale CPS will operate permanently in a fault state, implying that resilience, agility and adaptability in these networks will be of high importance throughout their lifecycles.

Examples of community-related groups are:

- Gaps 4 ‘Social acceptance of CPS’, 7 ‘Need for CPS trained people’ and 8 ‘CPS education & training’
- Gaps 13 ‘Regulations for CPS information privacy’, 14 ‘Regulations for sustainable CPS’ and 17 ‘Regulations for autonomy’

8. Combining many of the recommendations above, it seems that mega-projects would be best accomplished by being directed at communities, to ensure that the strategic aims of Responsible Research and Innovation⁹, interoperability, security, and benefits that CPSoS are intended to bring are continually at the forefront of mega-project planning and thinking because of the inclusion of a substantial set of end-users. That this is directed at specific communities (e.g. towns, specific innovation districts in cities such as Barcelona and Munich; Singapore might be another example), with results measurable at that level that are sufficiently evident for other EU communities to see, may provide a powerful spur to the adoption of CPS technology (politics and other economic considerations permitting).

It is suggested that a complementary, more convivial, bottom-up user-oriented approach should be adopted for these mega-projects, concentrating attention on user needs, (individual and community), both for lay people (including the disabled, the disadvantaged and the vulnerable) and for co-workers.

However, there are additional problems with community-oriented problems. Firstly, there are issues of acceptance and ownership by the affected community, indicating that resources will be required not just for the technology, but also for the community to provide and sustain the social infrastructure necessary to support the technology insertion. Secondly, when the project ceases, there are consequences for the social fabric of the community in either continuing with the technology without external support, or discontinuing it and filling the hole that is left.

9. All 72 projects accessed in Road2CPS employed or emphasised the importance of modelling and simulation for the design and operations of CPS. As an example, it has been said that for many CPS the physical configuration may not be determined until run-time¹⁰. Consequently, the necessary processes of verification and validation for safety, etc. must rely on modelling and simulation, plus established trust in the individual components of the CPS. However, taking into account the recommendations above and the need for societal acceptance, there is a clear requirement for modelling and simulation tools, methods and approaches to adopt a socio-technical perspective, to ensure that the needs, fears, and support that individuals (lay people, co-workers within CPS, etc.) and of communities are addressed. As we all move into an urban-focussed world where daily life is mediated and supported by CPS-based services, modelling and simulation approaches based solely on a technological perspective will be inadequate.

10. Compounding the verification and validation issues in the previous point is the contract environment that binds all the CPS components together into a coherent system, determines how it operates, and allocates rewards as appropriate. These contracts span the whole range of CPS interoperability, from interconnections to component interactions to business processes and to business alliances and forming a parallel network of permissions, constraints, relationships and responsibility allocations for the technological CPS network. The configuration of this network has to be fully-functional at the time that the physical configuration is ready to operate, and must be at least as efficient. It is not clear within the Road2CPS project that this network has been explored sufficiently in the 72 projects; it appears to be an area where the distributed secure ledger approach of Block-chain technology might be important in the rapid creation, certification and subsequent operation of CPS. It seems important for future Calls to explore the network of contracts in respect of CPS more completely because it will be a pervasive issue for all CPS implementations.

11. Gap 60, ‘Cross-domain knowledge’ can be found in many of the gap analyses, and is one of the ‘obvious’ Gaps mentioned earlier. However, this is seen a very significant Gap, needing a strong commitment of resources to it. The implication of this Gap is that knowledge conservation is required. This goes beyond theoretical, abstract knowledge, to include applied aspects as well (what in antiquity was termed ‘nous’). Conservation in this sense is a complex, never-ending operation; the cornucopia of publications in this area stands in testimony to this fact. As many organisations have discovered slowly, its architecture involves IT&C, organisational design, operations, personal roles, workable policies, people and wisdom.

H2020 and its preceding programmes have accomplished much in this area that should be applauded; webs of expertise exist, and knowledge-enhancing facilities are widespread. This could be a key resource for the EU28 into many future decades.

12. Three other Gaps make frequent appearances in these plots, all concerned with the integrity of CPS, both for design and for operations. It is important that these are resourced, since a failure to close these Gaps will have an impact on the lives of many, if not most, EU citizens:

- Gap 9 ‘Evaluation methods for IoT’
- Gap 11 ‘Fall-back plans’
- Gap 12 ‘Engineering governance’

It is difficult to see that these could be addressed by stand-alone projects, implying that future project Calls should include these aspects specifically within their scope.

13. Gap 16, ‘Single European Area’ occurs in many of the Gap analyses. It is encouraging that this is a specific goal of the EU and the EC, and, in the context of these plots, it remains a very important goal with regard to standards, the removal of economic barriers to trade, and the efficient operation of CPS.

14. At all the workshops conducted by the Road2CPS project, problems being experienced by SMEs were highlighted. Their problems are threefold:

1) they are faced with skills gaps and a lack of effective training; they do not have the resources to provide this themselves and must look to regional sources to provide this
2) business models are changing fast (e.g. ‘X-as-a-service’), particularly in relation to CPS, and SMEs are finding it difficult to obtain the expertise and capital both to plan the appropriate model for their company and then to fund the development.
3) Cross-domain regional strategies are widely seen as necessary to ensure that businesses within a given region are provided with the eco-systems and support that is needed to exploit their digital technologies. This would alleviate the first two points.

15. Finally, it is recommended that the European Commission should resource a project similar to Road2CPS, but on a much larger scale, as an ongoing feedback mechanism for the Commission and to assist in the planning for future investments in R&I to ensure that maximum impact is obtained.

2.8.2 Recommendations for platforms, architectures, interoperability and standards

- Increase the reliability of CPS systems – this opens the door to the certification of secure systems, the creation of validation methodologies and the impact of these activities into the different standardization bodies. Figures 3 to 7 above indicates the range of Gaps that must be addressed to accomplish this.

- Develop implementations of full CPS systems in different domains – currently there are very good solutions for individual parts of systems like smart grids, but there is a lack of full deployments allowing the validation of whole CPS ecosystems. The provision of such facilities in this and other environments will strengthen the position of Europe and its technology providers.

- Sustain the evolution of reference architectures and platforms - currently, much research and innovation has been carried out regarding interoperability; the focus for the near future should be to consolidate and integrate platforms and frameworks w.r.t data semantics and promote their access to a wide audience of companies.

- To promote this current synergy in the long run, we need to integrate reference architectures and platforms into the educational curricula of engineers and technicians, and encourage a change of mind-set in traditional slow-paced industries towards more agility which one assigns generally to digital industries. This could be accomplished by the cross-domain regional strategies mentioned in point 14 in the recommendations for the Commissions, above.

- Improvements and additions to the body of standards are required; there is a compelling requirement for standards for every Gap in Figures 1 above.

2.8.3 Recommendations for modelling and simulation

- Academia-industry collaborations should produce tool support for heterogeneous modelling techniques, including model management and traceability support, including the ability to consider models of different levels of granularity and abstraction in appropriate relationships to each other. In the longer-term, as these techniques mature, they can be extended to support other useful types of modelling paradigm to capture, e.g., human behaviour. Figures 3 and 6 above indicate the scope of this effort.

- Also in the medium term, academic-industry collaborations can also focus on combining formal verification and simulation technology, to produce system-wide simulation techniques that aid in detecting emergent behaviour and in system optimisation. In the longer-term, these can be extended to cater to systems that experience long-term evolution or short-term dynamic reconfiguration. In this effort it is important that the contract
network that binds the CPS and its participating companies to the world of business is included in the modelling and simulation.

2.8.4 Recommendations for safety, security and privacy protection

- Academic-industrial collaborations should build on existing modelling techniques for fault tolerance or security aspects of dynamic or evolving systems, including the processes for achieving certification of such systems.
- Encourage and support industry initiatives to extend or develop frameworks and tools that support reasoning about security at the systems level. It is acknowledged that such work is already under way and has been for some time; nevertheless, there is a pressing need for this work to extend to the world of CPS.
- Industry-academic coalitions to study and implement the role of the human operator in the CPS architecture. The state of current research is sparse and aspect-specific, and is in great need of expansion, especially to produce comprehensive models. ‘Operator’ here implies firstly lay people, to whom authority may be delegated to accomplish their purposes through a managed interface; secondly co-workers within a CPS ecosystem who are daily interoperators in the CPS, and thirdly CPS ‘gurus’, the resource of last resort in understanding CPS performance.
- Provision of education and training schemes to develop shared concepts of security between human, cyber and physical sides, development of systems approaches, and training for engineers with different backgrounds and domains.

2.8.5 Recommendations for Big Data

- The provision of stable and scalable solutions for the data ‘6Cs’; clipping, classification, condensation, confusion, confounding and non-cancellation.
- From a European perspective: decentralisation leads to disparate policies; a push is required to embrace innovation in some traditional sectors and to create stronger synergies between large companies and innovative SMEs.
- From a market and business perspective, there is a lack of access to real Big Data infrastructures, and corresponding eco-systems are still in fledgling stages. Additionally, boost in Big Data is particularly hindered by issue of data sharing and access rights, IPR and regulations. These are legal issues best addressed by the EC.
- Technical challenges are caused by insufficient interoperability, lack of common standards for data and that no linked data are available for pre-processing. There is a need to address these issues as research issues.
- Other factors determining the success and speedy adoption of Big Data solutions are the development of professional profiles, the readiness of for users to change their behaviour within the data driven society, and the assurance of the safety and security of processes involving the use of data at all levels of the value chain.

More specifically, the recommendations above include:

- Development of Innovation spaces, cross-organisational and cross-sectorial environments that will allow addressing challenges in an interdisciplinary way.
- Development of policies and harmonisation of regulation that support technological opportunities offered by Big Data and Real time analytics.
Promotion of new educational programs addressing the professional skills gaps that emerging technologies are creating

Promotion of programs that work on the development of common data ontologies that facilitates the integration of big data solutions and the replicability of the tools

Data Processing Architecture represents a key challenge for the upcoming scenario of widespread Big data utilisation; on the one hand, it is required to reduce the cost per bit; on the other hand it is important to identify valuable data to be stored in the cloud and how edge computing modifies current approaches

Co-alignment of Real time analytics requirements demands improvements in algorithms and processes that must be demonstrated and assessed through different use cases and in different sectors and exploiting computation capacity currently available

Security is a major aspect to be investigated, as discussed above. Firstly, it is important to assure the integrity of the data collected, secondly that the architecture should be prepared for dealing with advanced communication scenarios implementing E2E encryption and robust architectures. Here the key aspects are reliability, security and safety.

Moving data-based services and visualisations from abstract processing algorithms towards services exploiting the full potential of Big Data requires the development of visualisation techniques that help to understand potential and value of solutions. There is a strong need to move from data floods to comprehensible information streams.

2.8.6 Recommendations for Autonomy

Develop the theoretical underpinnings of safe, legal and ethical behaviour by autonomous agents as a cross-disciplinary, on-going study, involving disciplines such as engineering, IT, anthropology, metaphysics, human factors, the law (aquis) and psychology.

Develop a full understanding of the technologies and the support required in order to guarantee reliable, ethical, trustworthy behaviour by autonomous CPS

Develop ‘situation awareness’ for CPS that contain autonomous decision-making components; for both the state of internal operations of the CPS and for the CPS operational environment

Develop techniques for run-time verification and validation to ensure that autonomous CPS are safe and reliable. This applies both to system components and to the whole CPS, given that the final configuration of the CPS may not be known until run-time

Develop standards, protocols and APIs for autonomous agents within the CPS including their interconnections

Enhance modelling and simulation tools for autonomous agents both for their design and operation, and for the agents to use

The main non-technical enabler for fast progress in autonomous operations is the generation of regulatory environment, and business and insurance models to enable real-world testing of progress. The main barrier to progress is the lack of a well-educated, skilled, widespread workforce to carry out the necessary R&D&I&M that this area needs.
2.8.7 Recommendations for HMI

- Develop a platform for improved models for job design & a trade space to minimise human variability, maximise performance and ensure safe, legal and ethical behaviour
- Develop a full understanding of trustworthy behaviour for human-machine interaction, including the effects of cultures on trust and performance expectations and outcomes
- Improve interface technology for multi-channel, distributed interfaces for team performance, adaptable for different human skill levels and confidence
- Enhance modelling & simulation tools and techniques to enable verification and validation of human decisions and actions prior to execution
- Develop standards, protocols and interface specifications to extend human interaction with advanced, autonomous CPS
- Enhance modelling and simulation tools to make available human avatars for use in design and operations

The main non-technical enabler for fast progress in autonomous operations is a strong commitment to address the technology of human-machine interaction. One key barrier to progress is the lack of a well-educated, skilled, widespread workforce able to adapt to and carry out the range of roles involved in the lifecycle of a CPS from research to retirement that is needed.

2.8.8 Conclusions

- There is a fundamental shortage of professional people in the world of CPS in all flavours of engineering; especially electronics, hardware, IT and systems engineering that are able to bring to fruition good services for the people of the EU. But it is not just engineers that are needed; because CPS will pervade society very deeply, there is a need for other classes of professionals as well, including those from the social sciences.

- Many of the sections above allude to the need for more standards, particularly in connection with ontologies, to enable CPS to interoperate to form CPSoS, and to interoperate with human society. These ontologies should ensure coverage across all interoperability layers, from physical interconnection up to strategy and business. Absent these, and we may expect operational failures of steadily greater significance as the failures occur up the interoperability hierarchy.

- The capability to carry out comprehensive modelling and simulation is a sine qua non for the lifecycles of CPS. There is a dearth of tools, architectures, languages, aggregated modelling techniques and capable people to carry out this work. A fundamental barrier in this area that is being addressed but not yet overcome is that the IT industry has worked with discrete time, whereas other engineers have worked with continuous time.

- A particular area of concern for the future is the explosion of data that will be created continuously as CPS and their associated networks of sensors are instantiated in society. This flood may come to threaten the provision of communications, computing and storage capacity to utilise the data to create knowledge and value. This problem exists from the network technologies upwards to people who query the data and interpret the resulting visualisations.

- Taking all these issues together, it seems evident that the near future, we may expect not just disruption to the external environment of business models, consumer habits, established procedures, and legal concepts; there will also be disruptions within the CPS that in theory will deliver a bright new world. With all the simultaneous development that will be happening in so
many complementary areas, we may expect “failures to be the norm in CPS”. It seems evident that resilience will become a much-sought-after capability within society in the near future.

Given the inter-related aspects of the points above, it may be beneficial for future funding of the expected developments to be oriented towards the Smart Community concept, since this embraces all of the points above. In other words, in future ‘No Call stands alone’; any project must show some commitment to the Smart Community concept, and rather than looking inwards, should look outwards to co-operation with other projects. It will also ensure that each project will have to consider the humans who may be beneficiaries and victims of the project.
3 Recommendations for Innovation Strategies

The work we have carried out for this particular part of the document is not something new. However, this does not mean that it is not important or needed. Europe has devoted a lot of time and effort to think about the way Innovation could be pushed forward and the way a well-defined strategy could have a direct impact on our growth and competitiveness. A proof of such efforts is the definition of H2020, where research and development are secondary words in front of the concept of Innovation. Nevertheless, we are still struggling with Innovation. And that is why, as we have stated, this work is so important. Road2CPS provides an important technological background, but perhaps - and this is a solid impression based on the work we have developed in the last years- without applying some of the recommendations we suggest here, the results Europe wants to achieve will never be reached. For this reason, dear reader, give it a thought.

What do we want to achieve in concrete terms? The main aim is that Europe becomes a global pro-innovation actor; that we succeed in bringing European ideas to market; that we understand what the regulatory and support framework should look like to ensure that innovation has an impact on value, both in terms of global competitiveness of EU industry and in the ability for Europe to face societal challenges. These are the goals that have guided an important work commanded by the President of the European Commission from within the European Political Strategy Center. Its title is “Opportunity now: Europe’s mission to Innovate” [1]. The extensive report provides four key messages that are reflected in the development of this chapter and we have tried to adapt to the specific context of ICT in general and CPS in particular.

- **Innovation is complicated:** understanding the dynamics of innovation ecosystems is not a straightforward topic. Sometimes decisions are taken without having such understanding, which includes the trend to work on a linear pipeline, while innovation should be more open, based on collaboration and inclusion of all stakeholders.

- **Everyone must own the revolution:** Europe can make the choice of experiencing innovation or owning it. The sense of ownership should make us be more responsible and action-oriented.

- **Focus on people, places and processes:** Europe should capitalize all its assets. Innovation is not only about money and research; it is also about upskilling Europe’s people, using local strengths to underpin local innovation and transforming public processes.

- **The Opportunity can be seized now:** some recommendations can start being implemented already in 2017. It is more a political will than any other thing and lies on the second key message of “owning” such innovation revolution or giving Europe the role of “follower”.

The report also gives a sense of urgency. By no means should this lead Europe to be guided by improvisation and spontaneity in an attempt to do tomorrow what we did not do so far; rather than that, we should understand where we are and where we want to be and have a credible plan to go from one point to the next one, still leaving place for changes if corrective actions need to be applied. But let’s face the reality; the time to react is now, and Europe cannot afford missing this train. And dear reader, this may well happen.

Road2CPS brings a very small stone to this endeavor, but with many stones we can create a building. Our stone is putting in bold letters important messages that are often forgotten or left aside for others to react even though it is also our responsibility to drive them forward. Our stone is to formulate recommendations that can be easily understood. Our stone is trying to operationalize those messages and recommendations so that they become “alive”.

When reading this document, please, bring your stone too.
In order to avoid a too long document, we have decided to focus on some concrete areas that we consider especially valuable for a successful Innovation strategy. We start this section with a brief overview of where we stay in terms of Innovation, i.e. what is the performance of the EU as a whole and its Member States. Then, we jump directly into the main building blocks where Road2CPS provides recommendations, including the coordination between the EU, national and regional initiatives, the challenge of skills, the relevance of a suitable Innovation Governance and pro-innovation regulation and very concrete recommendations for funding programmes. Even though this last point belongs to the area of Innovation policy, we have devoted a concrete sub-section to emphasize the relevance of the recommendations for funding entities and particularly for the European Commission.

3.1 Innovation in the EU: where are we?

Some years ago the situation of the EU with respect to our traditional competitors US and Japan was quite critical. However, performance differences with these two countries have decreased. Still, the EU continues to be less innovative than those ones as well as South Korea. Based on the indicators used by the European Innovation Scoreboard 2016\(^\text{11}\) (which includes 25 in many different areas), the EU has reasonable performance with respect to other countries, including China, which is catching up, with a performance growth rate five times that of the EU. That is why we cannot afford being passive if we want the EU to be a competitive player in the years to come.

If we look within the EU at the performance of its Member States we realize about big differences in terms of Innovation. These differences have led to the classification of the MS in four groups, namely innovation leaders, strong innovators, moderate innovators and modest innovators. In the last 8 years, performance has been improving for the EU as a whole, and for as many as 21 Member States, with growth having been highest for Latvia and Malta. However, for seven Member States, long-term performance growth has been negative, with the most negative growth rate observed for Romania. The overall situation as of today is reflected in the following graphic.

![Figure 8 EU MS Innovation performance (source: European Innovation Scoreboard 2016)](image

For the first time, the European Innovation Scoreboard includes a forward-looking analysis of EU innovation performance discussing more recent developments, trends, and expected changes. That analysis forecasts that in 2 years, the EU innovation performance is expected to increase by about 2.5%. This may be the result of several years investing in a strong innovation framework (for example, H2020 has a clear focus on Innovation in comparison to its predecessors).

---

It is worth highlighting that research is compatible with innovation. Furthermore, both of them should coexist, being intimately related. However, the main concern we have in the EU has to do with the lack of ability to bring some of the research results to the market, therefore, failing in creating real impact. As stated in the definition of Wiebe Bijker: “While a new idea is a thought about something new or unique, and making that idea real is an invention, innovation is an invention that has a socio-economic effect. Innovation changes the way people live”. We should aim at creating impact of both economic and societal nature. The definition of the societal challenges in the H2020 programme reflects that objective very well.

Why has Europe failed so far or at least has not reached the expected results?

As suggested by [1], “Europe has looked at innovation as an over-simplified pipeline with measurable supply inputs and intermediate outputs of publications and patents, with no systematic account for demand, adoption or real-world outcomes”. This has generated a technology-push approach where technologies have been generated without a clear demand for them. The speed at which technologies evolve has made the rest, leaving all those results as a set of obsolete pieces of a technological museum. But Europe faces other kinds of challenges if compared with other global players, notably US. Almost two-thirds of US innovation, for example, comes from companies employing over 500 employees (Nager, Hart, Ezell and Atkinson, 2016); Europe still needs a share of that: strong EU-based and EU-invested corporates moving from new to big ideas, and from big to global scale.

We will see later on how important the ability to set up innovation ecosystems is, going towards a model where innovation does not happen in a linear process, as mentioned before, but on a networked environment, with the involvement of many stakeholders –reflected by the quadruple helix approach-. In this context the role of enablers and intermediaries is very important, in order to create the necessary connections and synergies. Because of the well-known agility of small players, SMEs and startups are key in putting new innovative products and services on the market, and that is why supporting measures have been intensified in the last years. However, more should be done, going beyond pure economic support (which is the very important) and facilitating partnerships between them and other established players. This point is particularly difficult for incumbents. Furthermore, we tend to include all these companies under the same “label” applying the same measures and instruments to all of them even though they may be very different in nature and may require different kinds of support. In [1] the reader can find a good number of articles and cases where many of these challenges are discussed, but also concrete suggestions are provided. For example, it points out the need to focus on innovation while keeping basic research in some areas; more specifically it declares that Europe must make a portfolio of higher-risk bets in support of speculative and even disruptive insights, but must also watch the radar screen for innovation promise emerging out of more academic work, and must be ready with the tools to help investigators become innovators, creating marketable Intellectual Property from the research and finding a market for it, in Europe and beyond. It reflects on the role of the different stakeholders in the Innovation ecosystem. For example, Public Administration should predict with the example and bet for innovative solutions in its own environment. A more intensive use of Public procurement in that direction would help in this matter. Involvement of users and citizens in the loop can be essential in some cases too. So far, they have been pure “receptors” or “consumers” of innovations, but many technologies are seen with suspicion, and this could cause rejection or a slowing down of their deployment.

Some of the elements depicted here add to many others that could have an impact on the performance of our EU innovation system and thus, on the competitiveness of European Industries in the coming years. These reflections warm up the debate that continues in the next sections in a more structured way around the pillars of geographical coordination, development of skills, policy and regulation and Funding programmes. These are for sure important challenges the EU has to face in an effective and efficient way, but obviously not the only ones to take into consideration.
3.2 The Geographical aspect: coordination at European, national and regional levels

We have decided to include this challenge as one very important topic the EU has to address because we can undoubtedly state that:

a) The European Commission and other EU institutions do not have unlimited resources to do everything that is needed (furthermore these institutions are not the best positioned to implement policies at local level due to the lack of knowledge on local conditions, but that is a different debate), which leads to the need of aggregating different funding sources to increase the overall potential impact; and

b) There is evidence of lack of coordination when it comes to execute and implement plans at EU, national and regional level, leading to fragmentation of efforts and weaker results.

It is not by chance that the Communication from the Commission to the EP, the council, the Economic and social committee and the Committee of the Regions on “Digitising European Industry: Reaping the full benefits of a Digital Single Market” (April 2016) proposes a framework for coordination of initiatives for digitising industry. In the first half of 2016, the Commission, together with Member States and industry, set up a governance framework to (1) facilitate the coordination of EU and national initiatives on digitisation, (2) mobilise stakeholders, and resources across the value chain, on actions towards the achievement of a Digital Single Market, building upon existing multi-stakeholders dialogues, and (3) exchange best practices. In fact there are currently more than 30 national and regional initiatives for digitising industry across Europe. With value chains increasingly distributed across Europe, the further digitisation of industry brings challenges that can only be resolved through a collective EU-wide effort. It is at EU level that the pooling of public resources can rapidly reach the critical mass needed to attract the right level of private investment. Elements like standardization and definition of the suitable regulation need to be defined at EU level with the cooperation of all the stakeholders, and have to be implemented in a coherent way if Europe wants to realize the Digital Single Market (DSM).

Figure 9 Diversity of efforts across Europe (source: European Commission, DG Connect)
The problem of lack of coordination and hence lack of coherence in execution of European goals add to the serious disparity of regions when it comes to the use of ICT in general and CPS in particular. There is a serious risk of creating a new digital divide, with regions that go full speed in their digitization strategies, while others lag behind.

According to the Atlas of ICT activity in Europe produced by the European ICT Poles of Excellence (EIPE) study, only a very small number of EU regions demonstrate intensive ICT activity. Furthermore, those regions are themselves concentrated in a small number of countries. According to this source, most of Europe’s ICT activity takes place in 34 regions. Only twelve EU Member States (Germany, the UK, France, Sweden, Finland, the Netherlands, Belgium, Italy, Ireland, Denmark, Austria and Spain) host all of the top 34 regions. The top locations include München, London and Paris. With the exception of Trento, the list of the EIPE includes all the EIT digital Knowledge Innovation Communities.

Creation of hubs or poles (or something similar to the concepts expressed by these different terminologies) is an important effort the EU has to undertake. One of the reasons is that factors such as the spatial proximity of similar and related firms and industries and the general tendency of people and economic activity to locate in large cities and economic core regions all lead to agglomeration. The agglomeration of R&D, innovation and business activity facilitates local knowledge spill overs and fosters the local business system.

Then, besides fostering the creation of such hubs, the networking effects should be exploited. This is an area where Europe is just starting despite the high potential impact it could have for different regions and countries, and as a consequence for the overall innovation indicators of the EU.

Horizontal transfer of policies between regions or between countries is part of this discussion. Some good examples already exist. [3] provides details of Urban Eco Map (http://urbanecomap.org), which is a global collective awareness platform aimed at creating people’s awareness to take eco-conscious decisions at local level by providing them with suggestions for concrete actions to take in order to reduce their carbon footprint. The European Clusters and Regions for Eco-Innovation; Network Plus (ECREIN+) builds on the results of the ECREIN project, which focuses on increasing the awareness of existing financial instruments at the European, national and regional levels with the ultimate aim of becoming the main network for regional support of eco-innovation. Another example is the European Service Innovation Centre which develops practice in supporting regions with large scale demonstrators concerning service innovation, and to diffuse the models and lessons from the demonstrator regions to other regions.

The Smart Specialization Platform (the S3 Platform)

The reality nowadays is that most of the innovation activities carried out at European level are disconnected from the local and regional development strategies. During the analysis performed by this project to understand better how different innovation mechanisms and instruments work we have identified many stakeholders that would be grateful to use structural funds to deploy their solutions at local level and in line with the priorities set up by EU regions. However, this does not seem an easy task. It could be due to the lack of experience of this author in those funding opportunities, or maybe because the communication and coordination with other funding entities and programmes has not worked as it should be expected. Despite that, Smart Specialization Strategies and the Smart Specialization Platform seem an opportunity for regions to understand where to invest and connect those investments to other activities that are happening at the EU level, such as the creation of networked Digital Hubs. The objective is not only to develop competencies in a region, but to do that in a coherent way that results not only in better performance for the particular region, but that also creates synergies with other regions, leading to an upgrade of European performance as a whole.

The S3 Platform assists EU countries and regions to develop, implement and review their Research and Innovation Strategies for Smart Specialisation (RIS3). Open to regional and national
administrations of EU, candidate and neighbouring countries, it provides information, methodologies, expertise and advice to national and regional policy makers, as well as promote mutual learning, trans-national co-operation and contribute to academic debates around the concept of smart specialisation. It is composed by three parts: A project management and research team at the IPTS, a Steering Team gathering representatives of several Commission Services, and a Mirror Group composed of leading academics and experts in the fields of innovation and regional development, as well as representatives of networks such as EURADA, ERRIN, EBN, OECD, European Cluster Observatory and European Cluster Alliance.

What it is interesting to see is that selection of proposals with a focus on specific regions in EU R&D programmes are not so well aligned with the specialization strategy of the targeted regions. This is a comment that should not be generalized, but there is in any case an impression of disconnection between some of the funding instruments. A more aligned approach would provide means for further deployment, scaling and sustainability of innovation solutions developed, for example, in the context of H2020. Last summer, the JRC launched the ICT Monitoring tool as part of the S3 Platform. This tool provides a very easy interface to search for Planned ICT Investments under ESIF, therefore giving access to essential knowledge not only on the strategic plans but also on the budgets and timing associated to the implementation plans. For example, if we go to such a tool and select the areas of smart grids and smart cities (two of the sectors included in the Road2CPS roadmap as areas of high potential for CPS penetration), we would get the following map of planned investments in the different MS. More sophisticated searches are possible combining different criteria.

Figure 10 Planned ICT investments under ESIF in the areas of Smart Grids and Smart Cities (source: ICT Monitoring Tool of the Smart Specialisation Platform S3)

---

12 IPTS stands for Institute for Prospective Technological Studies
**Acknowledgement of diverse realities in the EU**

We want to take advantage of this report to highlight the massive effort the EC, among others, has made to qualify and quantify the EU economy from different angles, including the degree of development of different technologies and essentially their potential impact in the coming years. This vast amount of knowledge should also be considered when defining research and investments plans in conjunction with other sources, such as the synergies with regional and local efforts, as pointed out by Smart Specialization Strategies. For example, does it matter the place where a Digital Innovation Hub on a specific technology is set up? Probably yes. There is a good basis to understand where the impact could be maximized besides particular interest of stakeholders involved in such activity. As mentioned before, most units in DG CONNECT (it we refer to the particular DG where the Road2CPS project is funded) have funded studies and reports that provide forecasts and in some cases evidence of the potential impact of specific technologies per sector and per region or country.

We have selected one particular example to illustrate how powerful this can be when planning investments, but many others exist. The European Data Market Monitoring Tool[^13], a study led by IDC and Open Evidence funded by DG CONNECT, reflects the current situation of all countries regarding data markets. It includes indicators such as Data market value, data market share, data companies, data users, share of data companies, share of data users, data companies’ revenues and impacts of the data economy. These indicators have been assessed for 2014, 2015 and then forecasts are provided for 2020 in three different scenarios (that depend on the fulfilment of specific conditions that are clearly described in the study). Users of the tool can play with the years and indicators and get the European landscape for those parameters. This helps very much in understanding the diversity of Member States and assessing what measures and policies should be applied based on the current situation and in order to reach specific outcomes. Reaching those outcomes should obviously be a joint task between the national initiatives/policies and European ones.


3.2.1 Recommendations

As it has been elaborated in this section, more coordination is needed between EU, national and regional initiatives. The power of combining different funding sources could be huge if well aligned. This could greatly help in processes related to standardization, deployment or testing of new solutions, especially when there are cross-border issues. Strategies developed by regions based on their needs and priorities and reflected in the Smart Specialization Strategies should be combined with EU actions in order to maximize their potential impact.

By no means all regions have to invest in the same things and reinvent the wheel 28 times (as many times as MS we have now in the EU). On the contrary, mechanisms that allow regions and MS to learn from others and understand both successful elements and challenges would help Europe to save money and time. This coherence has to be worked out by all the stakeholders in a joint manner.

In concrete terms we think the instrument of Digital Innovation Hubs can be promising because of its capacity to scale and bring different elements of the innovation ecosystem together (ex. Development of skills, infrastructures and facilities to test solutions, etc). In this particular case it is important to ensure that a wide umbrella of technologies are covered and that there is an access (even if virtual) to such facilities by all MS, so that we avoid a “divide” among geographical areas of the EU. As said in the beginning, coordination is important, and that is why attention should be paid to the different networks of hubs that have coined themselves differently, but where synergies are inherent (ex. Nodes created by the EIT through the KIC instrument, competitiveness poles, centers of excellence...).

Additional recommendations include the setting up of performance mechanisms that provide knowledge on their profile, dynamics, and progress of indicators; give them resources for networking purposes, establish special conditions that allow them to ease experimentation or for example, that help SMEs to get favourable conditions to access human resources. Finally, communication is important and there should be a public acknowledgement of their activities and achievements.

3.3 The challenge of Skills

According to [2], the demand for ICT practitioners, with a growth of around 4% per year, is outstripping supply resulting in 500,000 unfilled jobs in 2015 compared to 274,000 in 2014. The deficit of ICT professional skills is forecasted to reach 900,000 by 2020. Numbers and stats may vary from one source to another, but it is clear the EU is facing a lack of skilled people to develop the jobs of the future, but also to have informed and skilled consumers that help to create markets for new technological innovations. This problem affects the whole ICT sector in general. According to the European Data market Monitoring Tool (IDC, 2015), the data workers’ skills gap is of 7.5% of the total demand. In 2014, it accounted for more than 500K professionals. And this kind of worries greatly affects the market of CPS, which is dependent on a wide range of technologies and expertise that include skills on big data, embedded systems, cybersecurity or IoT, to name a few.

This is a problem that cannot be solved in the short term, but the action has to start now! It requires combining long term approaches in the context of educational institutions (for example, evolution of programmes at the University to be better aligned with the reality of the market and industrial needs) and at the same time actions that can provide a faster response to this critical issue. In this category we recommend a closer cooperation between Industry and Academia. References of ongoing programmes in that direction are: Estonian MEKTORY programme or the Irish Webigate, or through the creation of dedicated platforms like the German PELIT or the British GO ON UK.

We have seen in some reports that results from closer cooperation between educators and employers could come by the midterm, but for the immediate term, EU companies should get facilities to gain access to talent irrespective of origin and location, i.e., the conditions to hire employees from within the EU (any MS) and outside the EU should be improved. As it can be seen,
different measures and instruments can be put in place to ensure that we have a credible response to the challenge of skills. It was last year in the 2016 edition of the Open Innovation 2.0 Conference held in Amsterdam when Angelica Kohlmann, from Kohlmann & Co, made a comparison of the strategy behind innovation in the EU and US in order to highlight the most relevant differences. She mentioned the entrepreneurship spirit and conditions, investments and finally, education. It was surprising to see that only 6 Universities in Europe are among the top 20 world Universities. Furthermore, and with Brexit in people’s minds she pointed out that without UK, Europe would position just 2, which basically means zero if we restrict to the EU, since the 2 top universities in the ranking are based in Switzerland.

Figure 12 Results of the survey on skills and mobility performed by COBECOE Evolving Europe Report

The Business Innovation Observatory highlights some ongoing initiatives that should be taken into consideration as reference, such as The Grand Coalition for Digital Jobs, launched in March 2013, which is a partnership bringing together stakeholders from the education and employment world with the ICT industry, in order to tackle the lack of digital skills in Europe and the several hundred thousand unfilled ICT-related vacancies. Other relevant EU initiatives include “Opening up education”, the eSkills Campaign, the European Coding Initiative, the Startup Europe Roadshow, and the EU Code Week.

As it has been pointed out before, many technological areas have requested studies to analyse the current offering and demand in strategic sectors so that we are more aware of what the gap is and react accordingly. The IDC report on Big Data is just an example followed by many others. This has led to intensify the resources from R&D programmes (ex. H2020) devoted to skills-related aspects in the last years, even though this is absolutely insufficient. Looking at current discussions on the upcoming WP2018-20 we even realize about the lack of this kind of activities apart from the training concepts associated to the instrument of Digital Innovation Hubs.

Coming back to some of the existing examples that can serve as reference to inspire others, in the field of Big Data technologies, the European Data Science Academy project (EDSA) designs curricula for data science training and data science education across the European Union (EU). EDSA establishes a virtuous learning production cycle whereby they: a) analyse the required sector specific skillsets for data scientists across the main industrial sectors in Europe; b) develop modular and adaptable data science curricula to meet industry expectations; and c) deliver data science training supported by multi-platform and multilingual learning resources. The curricula and learning resources are continuously evaluated by pedagogical and data science experts during both development and deployment. Building on top of EDSA results as well as those of EDISON, the recently launched Big Data Value ecosystem (BDVe) project, a CSA giving support to the implementation of the so called Big Data Value PPP, involves industry to further align curricula to
their needs. This is complemented by the support to the Network of Big Data Centers of Excellence in Europe, an initiative to foster cooperation among academic institutions in research and training all over Europe. This kind of initiatives has to be supported in the context of new framework programmes. It is not by chance that skills have been repeatedly mentioned by experts in all the workshops organized by the Road2CPS project as one of the major challenges for the future of CPS adoption.

![Estimated number of Big Data Scientists](image)

Figure 13 Estimated numbers of supply and demand of data scientists (Data market Monitoring Tool, IDC 2015)

### 3.3.1 Recommendations

The CPS area is encouraged to increase investment in educational aspects with a focus on alignment with industrial needs and requirements. This can be supported through specific instruments or integrated with other industry-led initiatives, such as Large Scale Pilots. Synergies and cooperation with instruments funded by different institutions should be encouraged, for example through the combination of H2020 projects with Marie-Curie actions and educational activities carried out by KICs and in the particular case of ICT, by EIT Digital, which also combines entrepreneurial innovation and education.

Since advances in automation, robotics and smart systems are increasingly transforming the nature of work, not only for repetitive tasks but also for sophisticated tasks in administrative, legal or supervisory functions, the EU strategy should be defined taking into account different technologies and skills and avoiding fragmentation. For example, as aforementioned, there are ongoing initiatives funded by DG CONNECT on skills development; however, they focus on particular areas and there is little cross-fertilization between actions. Awareness around ongoing activities and achievements should be promoted to increase the potential impact of such actions and avoid silos.

On a general basis we recommend connecting industry and research organisations to the national and EU Grand Coalitions, and stimulate commitment from industry to take action.

On a more concrete level, immediate actions include the engagement of digital innovation hubs in skills for mid-caps and SMEs and the identification of areas in H2020 where educational actions like the ones described above do not exist yet so that gaps can be addressed. All this, as highlighted in a reiterative way through this document, should be done in coordination with MS and national actions. Complementary to this, and as a powerful tool to overcome the urgent shortfall of skilled professionals, the EU should push for recognition of Massive Open Online Courses (MOOCs) as an effective way of teaching that contributes to the development of specialised skills.
3.4 Innovation Governance and Policy challenges

“The regulatory environment is more and more a critical driver for the success of innovation in Europe, and at the same time, the breath-taking pace of innovation also puts the regulatory framework and process under pressure”

Commissionaire Moedas

Regulation is another challenge that inevitably appears every time Road2CPS consults experts on the future of CPS. Based on our experience this can be extrapolated to almost any sector. The EC is fully conscious of that and this is precisely the reason why a better Regulation package was launched less than 2 years ago (COM(2015) 215 final of 19 May 2015); “This Juncker package is a detailed box of tools with which to refine ex ante checks, to see and avoid regulatory double jeopardy, to weigh more fully the benefits of innovation as well as the risks of intervention, and vice versa. This promises faster and more easily adjustable rules to frame activities that may not be easy targets for full legal rule-making. The package makes notable references to building a Digital Single Market. And that is good indeed if it gets materialized, because companies in the EU face a clearly fragmented market with different regulations depending on the Member State of operation”. Furthermore, this situation, besides avoiding companies to benefit from economies of scale, creates barriers to implement cross-border services. When looking at the MS situation as such in terms of regulation (talking in general terms) we also find big differences, with some MS that promote or facilitate innovation while others have a regulation that acts as inhibitor.

When looking at the regulatory environment we should think about different components: a regulatory framework that supports and enhances innovation, regulations in ICT, but also regulations in the particular sector where the product or service operates. We have seen many examples where main barriers to carry out an experiment were not related to pure ICT regulations, but to the constraints of the sector as such (this happens in highly regulated domains such as energy).
For the purpose of emerging sectors and activities, such as the case of the autonomous cars, more experimentation is needed. This is sometimes blocked by existing regulations. Some studies suggest a new social contract, allowing innovators out of the laboratory and into the streets, and giving them the benefit of the doubt, at least if they on their side subscribe to open and responsible innovation norms. In operational and commercial environments one of the most visible barriers, as mentioned before, is the lack of a real Digital Single Market. In this respect different policies are currently under study and subject to open consultations. The Digital Single Market Strategy includes the following chapters: Digitizing European Industry, Cloud, Inclusive Digital Economy and society, e-government, standardization and interoperability, digital skills and Data economy. The last one is one of the especially active chapters in terms of policy making. For example, as of May 2018, there will be one single pan-European set of rules for the protection of personal data where any transfer of personal data outside the EU will be subject to the same level of protection and all data subjects will have a right to personal data portability.

Attention should be paid not just to the handling of personal data protection but also to matters related to industrial data protection. This means setting clear rules and regulations for the various elements of the new smart value chains (workers, robots, smart tools, Cyber-Physical Systems, connected cars, and advanced tracking systems) to gather and exchange data and information safely and effectively. That is why the EC is currently working on the following policy barriers: (1) Free flow of data (removing data localisation restrictions except if they are required for national security and similar objectives); (2) Data access and transfer (making machine-generated data more accessible for businesses to boost innovation and the digital economy); (3) Data portability, interoperability and standards; (4) Liability in the context of IoT and autonomous systems and (5) Experimentation and testing. All these elements will have a high impact on CPS development and adoption.

According to [1] a positive, but not lax, framework for innovation would require a two-way deal with several building blocks:

- "Responsible Innovation", including strong citizen engagement with both science and innovation
• Legal basis for regulatory discretion to allow and control piloting, and to adjust standards in light of technological development and new data,
• Scope for insurance-innovator-regulator conversations to ensure that the market for insurable innovation risk is taking as much of the burden as possible,
• Innovator-regulator cooperation and information sharing,
• A positive duty to remove existing burdens as they prove unnecessary, and to regulate with a view to supporting growth,
• The designation of a single local regulator as the 'primary authority' for applying a law, so that operators have a single interpreter of their duties, on whom other regulators can also rely,
• Regulatory sand-boxes, especially for FinTech, allowing regulators and innovators to get to know each other upstream of requests for product approval, and close involvement of start-ups and venture capitalists in advisory boards of regulatory authorities
• regulator-regulator cooperation,
• a safeguard mechanism,
• periodic evaluation.

Even though it seems like if all work was still to be done, the document recognizes some progress, and specifically points out the outcomes of the Dutch EU Presidency, where two concepts related to innovation challenges have been brought forward: Innovation Principle and Innovation Deals. The first one should lead to “find the most efficient way of dealing with public policy goals not just today but also for the years to come, and not just enable the innovation of today's incumbent players but also – particularly – that of the challengers of tomorrow”. Innovation Deals, on the other hand aim to “address regulatory uncertainties identified by innovators, which can hinder innovation within the existing legal framework”.

Some additional challenges in the field of regulation where policy intervention would be needed according to the Business Innovation Observatory include:

• Remove existing barriers to the uptake of innovative products (like the regulatory fragmentation that limits market integration);
• Ensure favourable framework conditions (including education, funding and networking opportunities), tailored to the needs of the different actors;
• Promote the development of open innovation ecosystems, which do not function autonomously but need new management processes and a new role of orchestrators to address complex problems and be successful;
• Encourage networks that foster collaboration between EU SMEs and ensure openness, neutrality and fairness in value chains.

When coming to developing a smart regulation approach based on open and collaborative innovation ecosystems, the same source points out some additional aspects where we see room for recommendations from the Road2CPS perspective:

• Develop an integrated and systemic approach to standardisation in order to ensure a higher degree of certainty and clarity for the introduction of innovative services and products
• Harmonise and specify European regulations on minimum requirements for privacy provisions in new technologies such as connected cars, connected devices, advanced tracking systems
Carefully harmonise electronic health records initiatives while addressing privacy considerations.

The last point can surely be extrapolated to specific challenges in other sectors; let’s think for example about the diversity of data models used in different cities in Europe that prevents the EU to consolidate a digital single market for smart cities.

3.4.1 Recommendations

Looking at the previous background we would like to focus this section on three particular points. This by no means implies that there are no other areas of work, but we consider that efforts specifically in the context of DG CONNECT should concentrate on:

- **Standardization**

As pointed out by literature and proved by experience, standards can facilitate interoperability between the different elements and actors involved; they constitute a codification of common terminology, development methods and measurement techniques; they ease the diffusion of information about technology, notably in the case of quality certification and consumer safety rules that are important in shaping demand; they can reduce risks and transactions costs for producers and consumers.

In April of 2016, the EC published a communication on ICT Standardization Priorities for the Digital Single Market. In such communication it is stated that common standards are essential to ensure interoperability of digital technologies. It highlights that “effective interoperability guarantees that connected devices such as cars, phones, appliances and industrial equipment can communicate seamlessly with each other, regardless of manufacturer, operating system, or other technical components” and furthermore gives relevance to the concept of Open Standards “to foster innovation and low market entry barriers in the Digital Single Market, including for access to media, cultural and educational content” and advises that “differing national standards may significantly slow down innovation and put European businesses at a disadvantage vis-à-vis the rest of the world”.

The Commission has identified five priority areas that are considered essential technology building blocks of the Digital Single Market: 5G communications, cloud computing, the internet of things (IoT), (big) data technologies and cybersecurity. Areas like eHealth, smart energy, intelligent transport systems and connected and automated vehicles, including trains, advanced manufacturing, smart homes and cities would be direct beneficiaries of this work, since they rely on the so called building blocks. The EC is progressing on those areas and many meetings and activities have taken place since this communication was launched. However, and based on the experience of the Road2CPS consortium and experts that have gone through the roadmaps and workshops in the context of this project, the current situation is not enough. Most projects are asked to assign resources to standardization, but it is difficult to see a coherent strategy behind that approach. While some projects have been relatively successful in their standardization efforts (for example ETSI, the European Telecommunications Standards Institute, has announced the creation of a new Industry Specification Group on cross-sector Context Information Management (ISG CIM) for IoT-enabled Smart Cities and also other verticals including Smart Industry and Smart Agriculture as a result of the efforts made by FIWARE on NGSI14), others have not made any impact in this respect. Furthermore, it seems like if some approaches were conflicting because of belonging to different initiatives supported by the EC (the former example on smart cities is an interesting one, where some work has been done in the context of the FIWARE project15 that was disconnected and sometimes was even competing with the approaches of the EIP on Smart Cities and Communities). The EC and in particular DG CONNECT should push forward a more coherent and convergent strategy in terms of

---


15 FIWARE is the cornerstone Project of the Future Internet PPP
standardization and point out, together with the relevant stakeholders, which directions would be beneficial for the EU. The adoption of CPS will greatly depend on these decisions. The full implementation of CPS, as the enabling technologies that lie at the heart of the radical transformation from a linear value chain to a non-linear value network, raises a number of technical challenges, such as broadband infrastructure and interoperability (for ex. to date, there is no software application that can manage the data from millions or more connected devices); in order to cope with the complexity of CPS it will be necessary to have such an overarching software infrastructure. The working group on Digital Platforms could be a good vehicle to agree on standards, but still, projects should get the mandate to work in concrete directions that reflect the strategy of the EU. De facto approaches are also welcome as a way to establish markets in a fast way. Good examples can be seen in automation, where car manufacturers have agreed on interoperability standards for the benefit of the industry (even though they are competitors).

- **Cross-fertilization between technological areas and sectors avoiding work in “silos”**

The second point has to do with the first one, but affects a wider range of elements. It refers to the poor cooperation that exists nowadays between different technological initiatives. Technical PPPs set up by DG CONNECT focus on their domains, but the reality is that boundaries between technologies are blurred. Therefore it is not by chance that the Big Data Value PPP is working on standards for data-related aspects, but that is also a major aspect in the case of the AIOTI alliance\(^{16}\) and the related work of the recently launched IoT Large Scale Pilots. The lack of common work is reflected in recommendations provided to the EC, sometimes by the same companies, but different teams working in the related organizations. This needs to be overcome and cooperation procedures have to be defined and promoted to take maximum advantage of all available resources.

Another example where cooperation is needed is security. Data storage, data privacy and liability are key areas of concern for the development of wearable technologies, connected cars, CPS, and Smart Health. Security aspects of CPS namely data security, security of data flows, as well as the protection of intellectual property rights; represent the biggest barrier to the uptake of remote service solutions. Here again we find extensive work happening in the context of the Big data Value PPP as well as AIOTI, but benefits could be derived from a closer cooperation with the PPP on Cybersecurity. A suitable legal framework regarding security and privacy is needed to ensure innovation. Attention should be paid not just to the handling of personal data protection but also to matters related to industrial data protection. This means setting clear rules and regulations for the various elements of the new smart value chains (workers, robots, smart tools, CPS, connected cars, and advanced tracking systems) to gather and exchange data and information safely and effectively.

These silos created by technical areas are not the only ones. When it comes to sectors or application domains, it happens the same. IoT, for example, is an enabler for digital transformation in many different domains, but a lot of work is being repeated because projects in different sectors work isolated from other domains. Again, the EC is pushing forward this cooperation (we have mentioned before the efforts in the working group of Digital Platforms under the DEI Strategy, where different DGs are coming together), but this is still insufficient.

The project Synchronicity, one of the IoT Large Scale Pilots launched in January 2017 aims at creating a Digital Single Market for Smart Cities by promoting the implementation of four simple principles stated by the vision of the Open and Agile Smart Cities Alliance (OASC)\(^{17}\). These principles include the use of specific standards such as CKAN or NGSI as well as the definition of common data models. Synchronicity has already established relationship with projects under initiatives like the EIP on SCC\(^{18}\) but the EC should encourage, even more, such relationships and provide clear guidance on how to exploit in a joint manner good results. This is compatible with funding competing initiatives that may

\(^{16}\) [http://www.aioti.org/](http://www.aioti.org/)

\(^{17}\) [http://www.oascities.org/](http://www.oascities.org/)

explore on different solutions, but the strategy on what needs to be achieve should be clear from the beginning if we do not want to end up with an umbrella of incompatible, non-interoperable and still competing solutions, standards and platforms. This particular example applies to almost any sector and as it was described in the previous point, also to different technologies.

Again, as in the case of standardization this may entail the definition of concrete instruments or ways to carry out such cooperation, since day-to-day management of projects prevents sometimes them to dedicate resources to such objectives. The EC has successfully worked on other measures that help to improve the way the work is done. For example, in the past recommendations\textsuperscript{19} suggested that some improvements could be introduced in standardisation policy by ensuring that SMEs would be more involved in defining standards. One of the reasons why this was not happening was that a direct participation of SMEs in the process represents a high investment in terms of time and cost. That is why the EC has provisioned some funds that will be devoted precisely to the involvement of particular SMEs in different standardization activities.

This reasoning should jump to other areas and help to create cooperation between areas and technologies. An immediate area where this could be tested would be the implementation of the so-called Large Scale Pilots in different initiatives, where further exploitation of testing environments and infrastructures could be achieved.

Initiatives like the Smart Data Innovation Lab (SDIL)\textsuperscript{20} supported by Germany could be replicated at wider scale and with a stronger focus on integration of technologies (at this stage SDIL focuses essentially on big data), maybe through instruments like the Digital Innovation Hubs.

- Extend the use of pre-commercial procurement or procurement of innovation so that public authorities predict with the example

This should include the EC as potential customer of some of the innovations supported in the context of H2020 and future Framework Programmes. In order to convince others to adopt innovative solutions it is important to give good examples that reflect credibility in such solutions. There is still a long path to go through in this regard. Complementary to this, additional measures that help Public Administrations to improve Public Procurement processes would help a lot. The EC has already some references of projects working in that direction, for example, showing the way Open ICT Standards can be included in these processes to promote interoperability and avoid vendor lock-in. In this respect there is already an EU catalogue of ICT standards as well as national catalogues. Projects like PICSE focused on particular domains\textsuperscript{21} (in this case on procurement of innovation for cloud services).

However, more dissemination is needed.

3.5 Research & Innovation Programmes

This section overlaps slightly with the previous ones, since many recommendations that affect current funding mechanisms and programmes have already been provided (for ex. In Section 1). Therefore, some of the statements are repeated on purpose for the sake of insistence. Since we understand the audience of this document has a strong background on this topic we go directly to the areas where intervention or improvements are clear in some cases with a short introduction of the challenge.

\textsuperscript{19} According to the companies interviewed in a case study on standards and certification, the standard definition process is currently mainly addressed to and engaged with large companies and public institutions, in spite of the dispositions of Regulation (EU) No 1025/201245.

\textsuperscript{20} http://www.sdil.de/en/

\textsuperscript{21} http://www.picse.eu/
Foster cooperation

In the previous chapter of innovation governance we pointed out the existence of silos across technologies and sectors, but this also affects the way funds are used. Barriers between and within programmes and institutions should be broken down. This could directly impact activities in EIT networks, H2020, national research programmes, Joint Research Centre expert analysis and the Smart Specialisation process. While all of them are of high value, they work on parallel tracks with few if any interactions. Bringing them together would significantly improve policy impact and financial efficiency. Experience in JPF and Eureka programmes could help to shape joint initiatives learning from mistakes.

Success does not only depend on research

Research is not the only driver of the system of innovation. According to [1] “it is one of ten or so key success factors identified in innovation literature. And at corporate level, for example, only 17% of innovation spending is on Research and Development, with the bulk going on other components of Knowledge-Based Capital (design and data, skills and software, organisation and marketing)”. This means that the programming exercise should look at instruments that cover some of those areas that are considered as essential pillars to promote the adoption of technology innovations. One may argue that there are other programmes to do so (for example, Marie-Curie actions focus on skills, so why to add more actions that address skills development?). Either better cooperation between actions is sought or no impact whatsoever will be obtained. There is no value in creating a wide amount of platforms, protocols, algorithms, solutions that will never be used by industry and will become obsolete in few years. Instead, we should think about the right combination of work that needs to be done to maximize the probability of success of the EU investments. And this could well entail more support to areas like marketing or transition towards new ways of working (including adaptation of work spaces, setting up testing infrastructures, and development of certain skill sets...). Some good results have already been shown by the FIWARE initiative within the Future Internet PPP, where a relevant percentage of resources has been devoted to marketing and communication activities, helping the solution to be seen as a market-ready product in expert communities because of the convincing implementation of the marketing strategy. However, this does not mean that fundamental research should not be supported. Excellence research is an indispensable driver of innovation, and this includes research not only in science, but also in Humanities. [1] suggests incentives for systematic companion research in both the hard and the social sciences (including game theory) into the changes that flow from innovation breakthroughs. How to cover everything? The answer should be in a well-planned long-term strategy with a combined portfolio of academic research focused on some priorities for the future of the EU and more innovation-oriented actions for the short and medium terms.

Work further on the demand side

Research programmes have been driven by technology-push approaches so far. It is just in H2020 that we have started to see the word “ecosystem” in a more prominent position, acknowledging the need to bring supply and demand together. Feeding the demand is essential to ensure real testing of the solutions in operational conditions and go through the difficult gap that separates a research solution and a market-ready one. As stated by [1] Un-locking the potential of the analysed trends depends to a large extent on ways to promote the wider up-take of the solutions and scaling up the use of the new models. The major barrier is on the demand-side, in the form of conservatism, scepticism, and a lack of understanding the trend, the technologies and the benefits among potential clients. These clients are mainly other companies, but also public procurement officers, or consumers (which might for instance be hesitant to shop on-line). Many companies fear for disruptive changes and unknown consequences of adopting new business and production models.

That is why actions like raising awareness, promoting diffusion and absorption, behavioural change, involvement of end users, societal transformation processes, and promoting the up-take of new
business, organisational and production models are very much needed. But the support for business innovation activities can happen in different ways. Some alternative, yet complementary methods, include: not only subsidising R&D for product innovation, but also allow funds to be used for adopting new business models and for diffusing and ‘marketing’ of societal innovations; therefore besides product innovation we should think about supporting process innovation (implementing Advanced Manufacturing Technologies), organisational innovations (changing the business model, implementing disruptive solutions), and market-innovations (adapting solutions to other sectors or for internationalisation). Some of these angles have been explored in former CIP projects, now in SME instrument and others, but work is still to be done. For example, sometimes we create solutions waiting for the right regulatory changes to happen and hoping that they could be implemented in a timeframe of several years, but this does not guarantee the feasibility of adopting new production processes and business models. These challenges should be explored hand-in-hand with the development of technologies (let’s think for example about autonomous cars and their associated regulatory, policy and business challenges). This is expected by the so called Large Scale Pilots defined in the H2020 work programme but more emphasis should be put on this in upcoming programmes. Other opportunities could be the assignment of grants to companies to cover the costs of installing initial production or technology centre (in order to avoid distortion of competition some measures such as the need for a public company could be considered); provide tax benefits for clients who buy existing solutions for advanced manufacturing to make best use of existing R&D findings; launch a credit system for the customer to generate efficiency gains at the beginning of the investment (this cost neutral scheme -not a subsidy- would allow companies that buy and use new process technology get up-front the money for the investment that would be saved and paid back, e.g. from a reduced energy bill).

Feeding the demand does not only refer to private demand. As it has been anticipated, Public Authorities can also become users of innovative solutions and promote their usage to generate traction in private demand environments. For this, public procurement as first customer should be used more widely.

- **Support entrance of new actors in the innovation ecosystem**

This includes SMEs, not because they have not been involved in research programmes so far, but because of the difficulty they still have in getting involved in innovation programmes like H2020. Instruments like the SME one and others have improved the situation, but the reality is that SMEs still call for the simplification of rules and conditions. Experiences like I4MS should be encouraged.

In addition to SMEs, and thanks to the adverse employment conditions in many countries because of the economic crisis and the opportunities that emerge from new technologies, we see every time more momentum around entrepreneurship-. Startups have been supported in the last years with big initiatives like Startup Europe, the set-up of specific incubation and acceleration instruments in the framework of KICs (like EIT Digital) and also in H2020 (good examples are the acceleration programmes promoted by FIWARE and the extensive use of cascading funds in many topics, including Large Scale Pilots). They are important actors in this new innovation ecosystem and as such, their participation should still be supported. Other mechanisms that could be explored are: use of emerging alternative financing mechanisms such as crowdfunding or coupling financial aid with advisory services, as offered by the EIF InnovFin fund.

Other intermediaries could also be important. We have mentioned here actors like incubators and accelerators, but other proxies to different organizations may also add value in this context (let’s think for example about user associations).

- **Open data, Open APIs…towards openness**

In order to foster interoperability and create critical mass, as it has been explained before, open standards and open APIs could play an important role. However, this does not mean that absolutely everything has to be open. We envisage models where open data will be combined with closed data.
The EC should have a clear strategy on which interfaces and parts of the system have to remain open and which ones can be led to private industry to decide. This is part of a responsible role in the innovation ecosystem that gives opportunities to all stakeholders in a fair way through enabling completely new business models, while still allowing for competition.

In this context, ongoing initiatives of Digital Innovation Hubs or Digital Platforms may be refined adopting some of these practices, but they are already a good basis, since they are considered as environments open to different stakeholders and where access to different technologies and expertise can help to test fast, learn fast, and fail fast (since this also happens).

As final comments out of this classification of areas we would like to emphasize once again the relevance of putting in place a coherent and strategic standardization strategy (including also promotion of de-facto standards); defining a portfolio of added-value areas where Europe should react (in combination with Member States) and taking into consideration findings by National programmes, Smart Specialization Strategies or outcomes of instruments like the Innovation Radar. This would give coherence to the programming exercise. Finally, credibility and future decisions should come from a serious assessment process. Different instruments and initiatives should be measured against KPIs to understand where reaction is needed. This should also apply to the performance of policies put in place by policy makers (see existing references such as the Innovation growth Lab by Nesta). In this respect, we would welcome more transparency on the results of the assessments, which should be public when funded with public money.

Figure 16 Demand-side Innovation Policy (source: Business Innovation Observatory)

22 In the course of this Project we have tried to gather information to understand good innovation ecosystems from the Innovation Radar initiative of the EC, but we did not find any public outcome apart from the prices awarded. On the other hand we have visited some projects that could be useful in understanding good innovation practices and therefore could help us to recommend future actions, such as the Industrial Innovation in Transition (http://www.iit-project.eu/); despite contacting them to get some insights we did not get any reply.
4 Business Opportunities

It would be too presumptuous from the Road2CPS side stating in a categorical way which are the emerging opportunities enabled by new technologies, assuming a pro-innovation environment is in place. We do not even dare to assess business models and judge which ones will work and which ones will fail. Instead of that we would like to use this section to inspire readers about potential business opportunities that can be materialized thanks to the development of specific technologies.

We have captured examples that fall directly into areas of application of CPS and that complement the information already provided in the sectorial roadmaps elaborated by Road2CPS. The second part of this section reflects about new business models and the elements that make them possible. Materialization of these business opportunities through existing or emerging business models requires in some cases additional challenges to be solved such as changes in regulatory and legal frameworks. Some recommendations arise from these particular examples that contribute to validate recommendations already suggested in previous chapters of this document.

4.1 Disruptions leading to market opportunities

We have selected three particular disruptions analyzed by the Business Innovation Observatory (BIO) that show in a very clear way how the potential adoption of CPS could lead to new smart value chains in the respective domains. In all cases we can see the market opportunity accompanied by the challenges that have to be faced, including those that call for actions by policy makers. This exercise helps to figure out how the recommendations proposed in Section 3 could affect the development of a specific business sector. In other documents released by Road2CPS we have pointed out the trend of linear value chains becoming value networks. CPS are precisely at the core of this transformation towards a network-based economy.

Example 1: Health: as it is highlighted in the diagram below, the market behind eHealth is a multi-billion one. Population is ageing and the cost associated to Public Health Systems is not sustainable anymore.

![Image: Disruption of body monitoring and Global mobile health industry market size projection from 2012 to 2020 (in EUR billions)](source: Business Innovation Observatory; Statista)
The future seems to be a combination of public and private institutions that will cope with basic services but also with more personalized treatments. IoT devices, permanent connectivity and the wide use of mobile devices by most of the population will make possible the reduction of cost and personalization of health services, including a more prominent focus on prevention. Even though a lot of challenges still need to be addressed, as reflected in the table, new stakeholders will enter the value network, including solution developers, service providers, integrators, network providers and even authorities that may be responsible for keeping the privacy of data or intermediaries that may help users to manage their “personal data spaces”.

**Example 2: Robots.** BIO suggests that robots will disrupt different markets creating new business opportunities that will have to be combined with the expected loss of “traditional” jobs. Besides manufacturing, where application of robots seems straightforward, we can think about myriads of sectors where robots will change dramatically the way of providing services. Some examples already exist: robots that play the role of waiters in restaurants in Japan or receptionist welcoming people to hotels or companies, but also assistants for elderly people. Challenges in areas like safety or standardization are still open, even though the most difficult aspect seems to be the relationship with human beings and the cultural impact this may take. From a business point of view opportunities are undeniable if such barriers are properly addressed.

<table>
<thead>
<tr>
<th>Disruption</th>
<th>Robots bring (back), change and destroy jobs and value chains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenges</td>
<td>Integration in society, Safety, Fears among potential users, Improve awareness and understanding through demonstrations and pilot projects</td>
</tr>
<tr>
<td>Market opportunity</td>
<td>Multi-billion EUR market, Across manufacturing and service industries</td>
</tr>
<tr>
<td>Policy challenges</td>
<td>Promote investment, experiments and usage in Europe, Promote demand for robots, Promote standards for safety, Address skill-gap and regulation gap</td>
</tr>
</tbody>
</table>

Figure 18 Left: Disruption of human-robot collaboration (source: Business Innovation Observatory); Right: e-vigilante is a surveillance robot for monitoring warehouses and other industrial sites (source: http://www.eos-innovation.eu/Produit/EVigilanteFr.sls)

**Example 3: Autonomous driving.** According to the European Roadmap: “Smart Systems for Automated Driving” (EPoSS 2015), in few years the degree of automation in roads and vehicles will be very high. This means that the car industry will be drastically transformed. Cars will not be the same than before, but customers or users of cars will also play a different role. The traditional product of a car that we know today will not suffer an evolution but a revolution. It is not just personalization that will be feasible thanks to innovative technologies; it is also the fact that performance of a car will be a data-driven business. As such, the most important assets will not be the machines that produce high-quality cars but those companies that get access to the highest-quality data. Data together with pervasive communications (with other cars, infrastructure, etc) will make possible the autonomous car. And that is why we see data and internet companies entering this market (ex. Google, Apple). They will be the competitors of the traditional car manufacturers like Volkswagen, Volvo or Renault, to name a few. Understanding this future is essential to be competitive, since all traditional companies will have to experiment a transition towards a data-driven business. Some European car manufacturers have already created alliances to compete against those incumbents. This has made possible the emergence of new companies, like HERE, a Nokia-
based company that transform information from devices, vehicles, infrastructure and other sources into real-time location services. If we jump now to the role of the driver we can realize that the person will not be a driver anymore, but a user of a transportation service. As such, these users will have time to consume other services, and here again is where lots of potential business opportunities arise. As in the previous case, technologies will destroy some traditional jobs, but at the same time new ones will be created. We can imagine this user consuming media while on his way (music, movies, newspaper, books) or using apps for different purposes, including professional ones.

At the same time, the car may be sending data to the manufacturer or the maintenance service so that it is continuously monitored (for predictive maintenance or just to report a problem and get the right and fastest solution), it could report problems on the road and help in dynamic traffic management or reporting deficiencies in infrastructure thanks to cameras and other sensors integrated in the car. The umbrella of services with a business or a social objective provided by private or public entities is never-ending. As it was aforementioned, the three examples provided here have been taken from a previous analysis carried out by the Business Innovation Observatory because on the one hand they illustrate the impact that technology disruptions will create on the markets, the stakeholders and business models around them, and on the other hand they involve a high number of CPS.

![Image of disruption of autonomous cars]

**Figure 19 Disruption of autonomous cars: opportunities & challenges (source: Business Innovation Observatory)**

We want to finish this section pointing out again the business opportunities that may arise from the real implementation of the Digital Single Market. As it has been repeated along the last sections, the lack of a digital single market creates fragmentation and avoids companies to enjoy the benefits of economies of scale. Furthermore, having different regulations in all Member States leads to diverse interpretation of European law, sometimes creating inconsistencies. The cost of adapting services to each operational and legal environment is very high and plays against the EU interest. Issues such as liability, free flow of data, data portability will intrinsically affect the future of sectors like automotive industry, health, and so on and so forth. And this, the realization of the DSM (or the lack of it) will also affect future business models.
4.2 Emerging business models

As we have seen in the previous chapter, one of the effects of applying new technologies is the "servizitation" of many industries. Availability of massive amounts of data enables the creation of very innovative services around the product that sometimes generate more benefits than the core product. Let’s think for example about a mobile phone. Many operators distribute devices for free as a way to charge users for other added-value services. Coming back to the case of cars that we have extensively used in this document because it is very easy to understand, forecasts say that in the future we will not pay for the car but we will pay for the time we use it, or the number of Kms driven with it; all this is possible thanks to the inherent intelligence of the systems and the capacity to control parameters almost in real time. Pay per use was precisely one of the business models that created more disruption with the advent of the Internet and it is nowadays highly exploited by emerging organizations that use the virtual world (digital platforms) to commercialize both products and services in the real word. That is the case of Uber in the personal transport/taxi domain or Airb&b in the accommodation segment. The novelty here is that none of these companies own those assets, but technologies help them to exploit the community effect, creating new business models. Disruption introduced in the respective markets is so huge that has led regulators to intervene to protect traditional players. What should be the EU position in this regard? We think that markets should be kept open ("contestable" as a key enabler of innovation), i.e. innovating firms should be able to gain profitable sales in competition with established firms by providing better or cheaper products or services to customers using new business models (such as the cases previously described) provided competition is fair. So, our recommendation is not to over-regulate and adapt to the evolution of the markets in an agile way after testing different models. In that sense, a pro-innovation regulatory environment for experimentation and testing has already been recommended in the section of this document devoted to Innovation regulation and governance.

The effect of new business models in transforming industries does not only have to do with the distribution channel (for example, listening to music in Youtube instead of buying a CD); in this particular case Youtube gives you access to music for free. This is what google has been doing from the very beginning and this has also been the norm on the web. Monetization happens through different means and not anymore as a consequence of the basic transaction. Publicity models with freemium versions are enabled by data. And it is also data the engine for many other changes in completely different business areas. See the following example in the field of the Smart Cities.

**Reduction of Energy and costs in a “smart” city**

*This project began with a city government seeking to achieve a significant reduction in its energy bills. To do that, the best available option was to replace the existing conventional street lighting with new generation LED technology, which requires only 30% of the energy now being spent on lighting the city. Unfortunately, the city had no way of paying for such an ambitious project from its own current income, so it approached a leading technology company, headquartered in the city and proposed a joint venture approach. The result has evolved to become a true multi-sided solution, in which the new LED lighting also includes sensors that can be used to measure traffic flows at specific points in the city in real time. This data is then monetized in a number of ways.*

*Source: Smart City Economics ("A multi-sided approach to financing the Smart City"); Atos position paper*

That example represents another phenomenon related to the exploitation of network effects, which is the one of multi-sided markets and enabling platforms. In those ones partners, customers and suppliers share data asset platforms to be used by the participating players.
The economy of data behind gives all players access to a larger market, where the different sides are (within limits) mutually reinforcing i.e. growth in one side of the market can drive additional insights that enable growth in the other. Increased profitability is enabled by market operating costs being shared between the participating members (not necessarily equitably) and the potential to command higher prices because of perceived increased value of services enriched by the shared data insights. Ecosystems like Android or Apple benefit from the same concept. The higher the number of applications is, the more attractive it will be for the user that will buy an iphone or a mobile device with android OS respectively. At the same time, an application developer will work just for the platforms that have a massive amount of potential customers behind. So, this mutual reinforcing effect is clearly visible here. How does it translate into concrete recommendations?

- The first element is that platforms will become commercially viable if they maximize network effects and benefit from economies of scale. As we have seen, this requires reaching a critical mass of users, and that is why we encourage the support of platforms that enable multi-sided markets. Nevertheless, there are many strategies to create critical mass. One of them is granting access to the platform at very low or zero cost to drive adoption. That is the model that many EU-funded projects focused on platforms are following, such as FIWARE\(^{23}\). The main challenge is that it has to keep the benefits for all parties involved and requires a solid sustainability plan to raise business margins.

- The second element where recommendations can be derived has to do with the fact that more attention should be paid to challenges associated to new data-driven businesses. The following list describes some of them:
  - Cost – There are close to zero marginal costs associated with creating, storing and distributing data; whereas producing goods and services can be very expensive
  - Rights over ownership – It is much more difficult to identify and preserve digital rights, meaning that once a data set has been sold to a customer, it can very easily be sold on to multiple third parties
  - Privacy – There are huge grey areas to contend with over data security legislation, not least because countries have different rules and regulations over how information is governed, stored and accessed. This issue has recently come to light again, after the European Court of Justice ruled that the transatlantic Safe Harbour agreement is invalid. The agreement lets American tech companies, such as Facebook and Twitter, use a single standard for consumer privacy and data storage in both the US and Europe. The repercussions could be huge, forcing US organisations to transfer their European user data to Europe and follow 20 or more different sets of national data-privacy regulations

\(^{23}\) https://www.fiware.org/
Growth – Data businesses have the tendency to develop much faster than traditional goods or services organisations, expanding into monopoly or oligopoly structures.

Access to data: incentives need to be created so that organizations are willing to share data under certain conditions with players that can generate value on top of them. This requires secured environments and a suitable legal environment that favours trusted relationships between data providers and data owners.

(Free) flow to data: a “Shengen of data” is needed to allow data flows in Europe as a means to scale businesses.

Data integration: breaking data silos means cultural/mindset change, but also the need to work on common/harmonized/standard/shared data models.

4.2.1 Trends in Organizational, Production and Business models

The content of this section could have been perfectly placed under section 4.1; however, the fact that it includes not only technologies but other types of components has led us to finally include it here. It adds in any case elements to reflect on those innovation trends that have proved to have a relevant impact on organizational, production and business models. This is the way it is referred to by the Business Innovation Observatory, from which we have picked up this information directly. We include five innovation trends and we elaborate some of the business innovation areas that have been found. In the original report the description of all companies and business cases can be accessed.

- **Advanced Manufacturing Technology**: Advanced Manufacturing is defined as comprising production systems and associated services, processes, plants and equipment, including automation, robotics, measurement systems, cognitive information processing, signal processing and production control by high-speed information and communication systems.

- **Environmentally friendly technologies and energy efficiency**: The rise of environmentally friendly technologies is closely linked to the resource-conscious mindset that has emerged since the global oil crisis of the 1970s. Forty years on, Europe continues to face similar environmental issues, whether it be resource depletion, climate change or pollution. However Europe’s cultural mindset has changed and sustainable growth is key priority in the Europe 2020 strategy. In achieving the strategy’s sustainable growth objectives, environmentally friendly technologies and energy efficiency will be key, as they apply cutting edge knowledge and non-technological innovations to improve existing products, processes and business models.

- **New Manufacturing Engineering**: Manufacturing’s increasingly competitive environment presents Europe with an opportune moment to further the transition from traditional to advanced manufacturing. To do so, Europe ought not to solely focus on product innovation but must also identify the processes that provide manufacturing with the means to create the products of tomorrow at an industrial scale. New Manufacturing Engineering (NME) has the potential to contribute to such an agenda, as the trend draws on the know-how of highly skilled engineers to develop advanced processes enabling the manufacturing of high-tech products.

- **Mass customisation**: The impact of mass customisation is transversal, as it is not a trend devoted to a specific sector. More importantly, it requires an appropriate adaptation of existing manufacturing processes to be successful. The degree to which MC should be used to answer clients’ needs depends on the level of

---

24 Some interesting experiences can be seen through the SDIL (Smart Data Innovation Lab), a German initiative focused on data-driven innovation.
customisation required by the client and enabled by the technology. In other words, some products require sophisticated customisation while others only require cosmetic changes to better fit client expectations. This array of possibilities have shaped mass customisation’s current environment, which provides an opportunity for developing market niches but also raises barriers to entry and difficulties in raising funds.

- **Measurement Technologies & Robotics:** In our age of globalisation, European manufacturers are relocating their businesses to emerging markets so as to remain competitive. These emerging markets offer wider profit margins as a result of lower infrastructure and labour costs. Manufacturers that remain in developed countries are placing even greater importance on the use of automation solutions to differentiate, develop a competitive advantage and finally remain competitive. As such, the application of automation through measurement technologies and robotics is an important tool in the sustainability of many manufacturing businesses in the European Union as it enables them to compete more successfully in the global market.

- **Smart Value Chains:** The advanced manufacturing market is rapidly changing. While in the semiconductor industry we see increasingly more buzz on the next manufacturing technology, i.e. 450mm production, we also see radical changes in other high-tech manufacturing markets. Recent research suggests that the market is moving towards an increasingly automated world that will continue to rely less on labour-intensive mechanical processes and more on sophisticated information-technology-intensive processes. This trend is likely to accelerate as advances in manufacturing are implemented.

- **Public Private Partnerships:** Also known as PPPs have taken different forms in the last years, going beyond traditional infrastructure PPP to PPP for technology demonstration, for testing robustness of large scale solutions, to fix a societal problem or to initiate a new market.

- **Large-Scale Demonstrators & Small-Scale Testing Units:** Business innovations have the potential to tackle the societal challenges of today and become key contributors to the achievement of the European Union’s 2020 objectives. Yet to realise the potential of their innovations, businesses require real-life settings in which their technologies can be assessed, and facilities in which their prototypes can be industrialised. The establishing of such settings and facilities is typically costly and risky, and may call for public support, often in the form of public private partnership (PPP). Europe is increasingly deploying large-scale demonstrators and small-scale testing units that adopt a PPP approach. These demonstrators and testing units meet the validation and industrialisation needs of businesses, and may lead to Europe realising a number of socio-economic benefits, including the tackling of societal challenges, job creation and economic growth.

- **Public Procurement of Innovation:** In recent years demand-side policy measures have taken the form of product market regulation and standardisation as well as public procurement for innovation. Especially in the current economic climate, it is hard to acquire funding and customers for (radical) innovations. Both capital investors and firms prefer to invest their funds in products, processes and services that have a relatively short return on investment. Therefore, in such a context, public procurement could be a valuable instrument to maintain innovative capacity in an economy. This however also forms a paradox, as most governments also have their funds limited as a results of declining economic growth.
Road2CPS

D4.1 Recommendations for future Research Priorities, Business Opportunities and Innovation Strategies

- **Big Data** (definition skipped due to the extensive attention paid by Road2CPS to this technology field)
  - **Analytics and Decision Making**: The big data market is at a nascent stage and is expected to develop as organisations seek to enhance their competitive advantage. In doing so, firms seek to better understand the ever-growing amounts of data, through analytic and decision making solutions. Employing this software may involve a variety of techniques, technologies and visualisation tools.
  - **Artificial Intelligence**: Artificial intelligence offers the technology and methodology to do so, and the market for artificial intelligence-based tools and applications is growing rapidly. Uptake of this trend can benefit European companies as well as the EU-economy and labour market, as the development and management of artificial intelligence requires highly skilled workers in a multitude of fields.

- **Workplace innovation**:
  - **Solutions for enhancing workplace productivity**: Enhancing workplace productivity entails improvements to the efficiency of production by any organisation employing personnel. It is about new ideas that facilitate the daily office work and increase productivity, such as coherently coordinating appointments, the reliable management of office documentation or enhancing workplace environment by moving away from common workplace convention. This trend study deals with enhancing workplace productivity through business innovation driven by technology and ICT and enabling a more flexible work force.
  - **Novel Organisational Setups and Management Practices**: Novel organisational setups and management practices refer to the organisational innovations that facilitate company interaction with its environment. Currently there is a clear trend in organisational setups towards collaborative roles, stakeholder involvement and openness. This can take the form of either: an outside-in perspective, with companies that display high degrees of stakeholder involvement; an inside-out approach, in the form of external exploitation of company ideas in different markets; or a coupled process, linking both approaches by creating partnerships with complementary stakeholders with a high degree of collaboration.

- **The Sharing Economy** (as it can be seen it refers to the same servitisation concept that initiated this chapter on business models and where we pointed out the trend of paying per usage instead of paying for “owning”)
  - **Accessibility Based Business Models for Peer-to-Peer Markets**: As a result of the economic crisis, available technology and decreased consumer trust in the corporate world, consumers have become more receptive to peer-to-peer business models which are centred on consumer needs, both as a supplier and buyer. In order to capitalise on this, companies emerge that host online marketplaces for matchmaking between consumers. The manner in which these companies generate revenue and impact the economy depend on their commercial interest. For all of these business models, however, community building and creating social relevance is crucial.
5 Conclusions

Cyber Physical Systems are at the core of a revolution, the one associated to the Digitization of European Industry, where Industry refers to almost any sector we can think about. New technologies do not only mean better performance of a specific operation; they also bring disruptions at the level of changing business processes and business models, and this is not a trivial thing, since it will mean that some areas of work that seem well established today will disappear. Sectors and their value networks will see new incumbents. That is why it is so important for Europe to understand where the focus should be so that organizations working in different sectors and technologies are well prepared for this transition.

This document provides a critical view of the existing Research & Innovation Framework with the intention of identifying areas that require further or different work in upcoming work programmes, but we are sure that readers that do not belong to the group of policy makers will also see inspiring ideas on the way they should proceed in their own innovation environments.

The focus of the Road2CPS project has been essentially on the technology itself. Previous deliverables released by us give good account of the roadmapping exercises already carried out by this consortium - in many occasions in connection with previous and ongoing roadmaps and initiatives - (for the sake of coordination and more efficient and effective use of resources). However, these documents show clear deficiencies in the coverage of elements that may greatly impact the future of CPS adoption and are not of technical nature (such as skills development, adoption of different business models, suitable communication campaigns and awareness strategies, to name a few). But successful adoption by the market is precisely what we want to achieve, and not the creation of thousands of solutions and platforms that sometimes overlap and in general do not even interact with each other. That is why reports generated by Road2CPS point out those challenges too, even in the case of reports that were expected to be “only” technical. This vision is shared by external experts to the project, who have highlighted many non-technical elements at each occasion where they had the opportunity to share their views (see different reports produced by Road2CPS as a result of the series of workshops organized since the beginning of the project).

This deliverable has given us the opportunity to reflect in a deeper way on all those elements and put them together, as we think the EU strategy should work on the different aspects in a coordinated way. In fact, it may well happen that we are not aware of developments in some of the areas pointed out by this document, but this would mean precisely that the connections between different kinds of activities (technical development, regulation, skills, standardization) is not working properly. Then, silos should be removed.

D4.1 Recommendations for future Research Priorities, Business Opportunities and Innovation Strategies synthetizes previous work done by the project (through technological and sectorial roadmaps, workshop reports, etc) and presents it in the context of a wider strategy that should serve the interests of the EU in the context of CPS, even though many ideas could be used in other ICT environments. For this we have tried to provide a comprehensive picture of the landscape as it is today in the different areas and then we have worked out a set of recommendations.

We have gone through three main chapters or areas of work:

- Recommendations for Future research Priorities. This chapter includes both technical and non-technical priorities. Its main baseline is the deep analysis performed by Road2CPS on projects funded in the CPS area. As it has been pointed out, it includes elements that have been permanently raised by experts and that projects should account for even though they do not fall under purely technical development aspects. It also complements this part with very concrete recommendations in areas like platforms, architectures, interoperability and
standards; modelling and simulation; safety, security and privacy protection; Big Data; Autonomy and HMI

- **Recommendations for Innovation Strategies.** This chapter elaborates on the elements of successful innovation environments. To set up the scene it provides a summarized picture of the performance of the EU when it comes to innovation. From there we go to the following areas where recommendations are suggested: coordination between European, national and local initiatives and efforts; skills development; Innovation Governance and finally, we insist on the particular area of R&I programming, capitalizing on some of the ideas previously exposed in Chapter 1.

- **Business Opportunities.** In this chapter we make an analysis of changes that are being triggered by new technologies, showing the disruption that these technologies can create in existing and well established business sectors. We provide examples extracted by the Business Innovation Observatory that illustrate business opportunities for CPS in a clear way, together with their associated challenges. Finally, we reflect on emerging business models, expecting that this work can inspire researchers on how to create impact out of their work either from a business point of view or from a societal perspective. Because this is what we call Innovation.
References

Chapter 1

[1] Road2CPS - D1.1 - State of the Art and current impact report
[3] Road2CPS - D2.2 - Report on market requirements and socio-economical needs
[6] Road4Fame project Website - http://road4fame.eu
[22] http://www.knowledgegrid.net/~h.zhuge/CPS.htm
[29] FIWARE website - https://www.fiware.org/
Chapters 2-4


[2] Disruptive innovations and forward-looking policies towards smart value chains (Business Innovation Observatory; European Union, May 2015)

[3] Un-locking the potential of business and societal innovation; how to scale-up successful new business and production models? (Business Innovation Observatory; European Union, September 2013)

http://www.s3vanguardinitiative.eu/pilotinitiatives
http://blogs.ec.europa.eu/eupolicylab/
http://www.innovationgrowthlab.org/
http://www.iit-project.eu/
https://www.holaportal.com/search/?query=CPS&org_type=corp
https://itif.org/issues/innovation-competitiveness
http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=output
http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards/