Workshop on Identifying Catalysts for Innovation in Smart Systems
Workshop on Shaping Digitisation Across Industrial Sectors: Identifying Catalysts and Overcoming Barriers

Report Road2CPS Workshop,
21st October 2016 Newcastle upon Tyne, UK

www.road2cps.eu

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<td>Confidential, only for members of the consortium, workshop participants, and members of the Road2CPS experts group</td>
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The Road2CPS project is co-funded by the European Community's Horizon 2020 Programme under grant agreement n° 644164.

\[1 \text{R}=\text{Report, DEC}=\text{Websites, patents filling, etc., O}=\text{Other} \]
\[2 \text{PU}=\text{Public, CO}=\text{Confidential, only for members of the consortium (including the Commission Services)} \]
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Executive Summary
The Road2CPS Workshop on Innovation in Smart Systems was held October 21st 2016 in Newcastle upon Tyne (UK), with 15 participants from a range of large and small business. Participants were industrial practitioners, drawn from a wide range of sectors but all interested in application of “smart” digital technologies (including Cyber-Physical Systems (CPS) and/or Internet of Things (IoT)).

The workshop was designed to validate initial findings from the previous 18 months of the Road2CPS project. Initial findings were presented to the participants, and interactive sessions then allowed the participants to discuss the suggestions, consider how they relate to their own sector, and make comments or raise additional recommendations. The overall focus of the day was on barriers to adoption of digitisation technologies and possible solutions to help overcome those barriers.

Workshop aims
The workshop aims were as follows:

• Identify future needs for cyber-physical system (CPS), digitization and smart systems.
• Identify opportunities and barriers in adopting digitisation.
• Generate some recommendations for initiatives and work that could help organisations overcome these barriers.

Recommendations
The finding and suggestions of the workshop generally supported findings of the Road2CPS project to date whilst also providing some new suggestions and emphasising others. Below are some specific points that emerged from the day’s discussions:

• Lack of shared data models is a significant barrier to interoperability. When considering digitisation, integrating services and/or devices from different suppliers/sources is a very real challenge, and this is particularly the case when legacy components were involved. Domain-specific standardised or open data models are needed (this type of work should continue in fields where already under development). Industry-led initiatives are preferable here, in order to ensure industrial adoption and support.
• There was a strong emphasis through the discussions on the difficulty of building a business case or calculating return of investment (ROI) for new digital technologies. There is also difficulty establishing clear communications between the technology and business side of an organisation. Underlying causes include lack of information – for example, about how other organisations have adopted digitisation/CPS/IoT, and the benefits that they experienced as result. It’s difficult to communicate expected business benefits of deploying specific technologies, because in many sectors these are not well understood. The EU could address this issue by funding work to develop published case studies, or by incentivising organisations to share information. Modelling and simulation tools could help, by allowing engineers to simulate and benchmark the performance of the digitised, connected systems that they are planning.
• Skills gaps and lack of effective training is a significant problem, particularly for SMEs.
• Cross-domain regional strategies are important to ensure that businesses in specific regions have the eco-systems and support they need to exploit digital technologies.
• Business models are changing, and businesses (particularly SMEs) need to be able to consider business models that leverage long-term system maintenance or performance as well as selling technology.
Introduction and Scope of Meeting

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The workshop was designed to validate interim findings from the previous 18 months of the Road2CPS project. Interim findings were presented to the participants, and interactive sessions then allowed the participants to discuss the suggestions, consider how they relate to their own sector, and make comments or raise additional recommendations. The overall focus of the day was on barriers to adoption of digitisation technologies and possible solutions to help overcome those barriers.

Workshop aims

- Identify future needs for cyber-physical system (CPS), digitization and smart systems.
- Identify opportunities and barriers in adopting digitisation.
- Generate some recommendations for initiatives and work that could help organisations overcome these barriers.

Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>10:00</td>
<td>Welcome and Introduction</td>
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<tr>
<td></td>
<td>Introducing our project, participant interests and workshop objectives</td>
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<tr>
<td>11:00</td>
<td>Road2CPS provisional findings</td>
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<td></td>
<td>Preview of major technology &amp; research recommendations – the interim findings collected from practitioners and researchers across Europe by Road2CPS over the last 18 months</td>
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<tr>
<td>11:30</td>
<td>Coffee</td>
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<tr>
<td>11:45</td>
<td>Digitisation: Opportunities &amp; Challenges</td>
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<tr>
<td></td>
<td>Interactive session: discussion and brainstorming to identify the opportunities offered by increasing digitisation of existing and new systems, and innovation barriers we need to overcome for the future</td>
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<tr>
<td>13:00</td>
<td>Lunch</td>
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<tr>
<td>14:00</td>
<td>Digitisation: Developing Solutions</td>
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<td>Interactive session: opportunities to discuss issues identified during the morning session. Propose some possible solutions to help businesses exploit these technologies and adopt digital technologies in their own sector</td>
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<tr>
<td>15:45</td>
<td>Coffee</td>
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<tr>
<td>16:00</td>
<td>Plenary discussions</td>
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<td>Discuss proposed solutions in plenary, and gather any final recommendations</td>
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<td>18:00</td>
<td>Close of the workshop</td>
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Presentation: Road2CPS interim findings
An initial presentation by Claire Ingram from Newcastle University summarised for the workshop participants the key outputs already identified by the Road2CPS project over the previous 18 months. The main points of this presentation are included below.

Technology areas
Workshops held during 2015 and 2016 have identified 6 key technology areas for Road2CPS to address:

- Safety, Security & Privacy
- Modelling & Simulation
- Big Data
- Human Machine Interaction
- Autonomy
- Platforms & Interoperability

Some key findings on the current status and challenges for each of these technology areas affecting European industry are presented below.

Security & Privacy
- Significant data about persons/organisations could potentially be collected
- CPSs must consider hybrid threats, that e.g., exploit software vulnerabilities to attack hardware (or vice versa). A systems approach is needed.
- Traditional techniques for analysing safety & security need to be extended to consider aspects of working with hardware and software
- Few tools & techniques exist to support modelling of dynamic or evolving systems
- Mechanisms for deploying updates, patches, etc., must be associated with security policies and technologies and ensure they can’t be exploited for malicious use
- Frameworks are needed to make it transparent to end users when data about them is being collected and/or shared

Safety
- Safety is important for many CPS domains, because CPS systems, by definition, interact with the physical world
- We need to consider safety at the systems level, not just at level of single device or single software service
- Challenges regarding safety in CPS domains:
  - We can’t simply connect components which are certified “safe” to make a system which behaves in a safe way
  - Separate components that we rely on in a single system may use different fault-tolerant strategies, we need CPS systems which can readily support this type of mixed-mode fault tolerance
  - Assessing system safety, checking adherence & certification is time-consuming & expensive; it’s difficult to leverage the opportunities CPS offers for flexible systems with dynamic reconfiguration and also meet certification requirements if each reconfiguration has to be separately certified
  - CPSs typically have real time requirements, since they involve working with hardware components - but some of the fault tolerance strategies employed software-intensive systems have a performance overhead and may not be suitable
Modelling & Simulation
- It’s difficult to model & analyse global CPS behaviour using existing techniques, because:
  - The different disciplines involved in creating advanced hardware and advanced software have different notations and concepts that cannot be readily integrated
  - CPSs often cross organisational boundaries, with multiple businesses or partners contributing towards a single system – we may not have complete information about all components
- We need to be able to link the concepts between collections of diverse models that make up one CPS system
- Tools are needed to help us analyse global behavior, especially for systems which make use of evolution and dynamic reconfiguration to deliver flexibility
- Stochastic/probabilistic modelling techniques are needed for analysis of unpredictable human behavior, faults

Platforms & Interoperability
The concept of a Reference Architecture is now well-established. This is a template of existing solutions, defining agreed-upon interfaces & reference implementations, endorsing standards
Examples of reference architectures which are widely-recognised include: AUTOSAR, SGAM, RAMI+IIRA, ANDROID
Platforms:
- We need to move beyond vertical, domain-centered platforms, towards horizontal, value-chain/ecosystem wide platforms
- Sustainability of platforms needs to be considered. Few of the major platforms currently in use are developed in Europe
- Training needs must be addressed: moving from platform end-users to platform developers
Interoperability:
- There is a need for a consolidation of international norms and standards e.g. EU-US interoperability roadmap (eHealth etc.)
- Mapping is required of relevant standards and protocols for domain specific open platforms and reference architectures

Human-Machine Interaction
- Improved sensing is possible and useful (e.g. motion, posture-sensing) at the human-machine interface, to improve safety and efficiency
- Analytics & visualisation tools can help improve human understanding of big data patterns
- Improvements to interfaces, tools and support software can result in better situation awareness for autonomous systems
- Job design, training & education are needed, to ensure trained people work at human-machine interfaces
- Multi-disciplinary tools, methods & platforms are needed, to design jobs that deliver long sequences of good decisions, best leveraging of human intelligence
- All research projects in CPS areas should include consideration of HMI

Big Data
Big data challenges:
- Market – data persistence & lack of available facilities
- Technical – interoperability challenges between technology solutions
• Data and content – regulation does not facilitate data availability
• Education & skills – there’s a need for trained data analysts
• Policy, legal and security – there is a fragmented regulatory framework in Europe
• Usage & culture – we need confidence to embrace innovation

Big data recommendations:
• Cross-sectorial environments are needed
• We should raise awareness of opportunities & value of data-driven applications for different services, incubate data-driven ecosystems
• Co-operation & co-ordination projects are needed, to coordinate activities in different sectors and different European regions
• Work towards homogenization of regulatory frameworks

Autonomy
• Autonomous systems must be safe, trustworthy, secure, behaving ethically - cross-disciplinary work is required to achieve this
• Effective techniques are needed for effective run-time verification and validation
• Legal aspects must be considered: authority, responsibility, liability
• Resilience is important: autonomous systems need capability to cope with faults
• All large RD&I projects should consider implications of autonomy
• Industry projects (e.g., led by industrial associations such as ARTEMIS) & community-type projects could increase TRLs, aiming to
  – Develop technologies for safe, secure interoperation
  – Lift societal aspects of autonomous systems to higher TRLs

Application sectors
Road2CPS is also studying CPS requirements currently visible in five selected sectors:
• Smart Energy
• Smart Transport
• Smart Health
• Smart Manufacturing
• Smart Cities

Interim findings in these sectors are described briefly in this section.
## Smart Energy

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Barriers</th>
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<tbody>
<tr>
<td>• Aging infrastructure – upgrades needed for efficiency, capacity &amp; resilience</td>
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<tr>
<td>• Changes in energy demand</td>
<td>• Oil &amp; gas: many proprietary tools &amp; platforms for automated extraction, data collection &amp; decision-making - impedes adoption</td>
</tr>
<tr>
<td>• Less controllable renewable generation techniques</td>
<td>• Stakeholders must benefit from investments</td>
</tr>
<tr>
<td>• Many small producers/consumers</td>
<td>• Electricity: Difficult to access a system-wide view of current conditions, difficult to react</td>
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<tr>
<td>• Flexible markets needed to support dynamic pricing, incentives</td>
<td>• Electricity: regional variations in market roles/structure &amp; data standards</td>
</tr>
<tr>
<td>• Hydrocarbon extraction sites more challenging &amp; variable in quality</td>
<td>• Industrial scale energy &amp; heat storage is immature. Research not well co-ordinated</td>
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## Smart Transport

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Barriers</th>
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<tbody>
<tr>
<td>• CPS is enabling autonomy in vehicles</td>
<td>• Safety &amp; regulatory issues still to be solved</td>
</tr>
<tr>
<td>• Sustainability</td>
<td>• Slow change of alternative power infrastructure</td>
</tr>
<tr>
<td>• Potential benefits in information, quality, performance</td>
<td>• Emergent, disruptive effects because of sensitivity of transport to changes in other sectors</td>
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<tr>
<td>• Willingness of governing bodies to create validation environments despite legal constraints</td>
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## Smart Health

Key technologies already in place are:
- Stock monitoring using electronic tracking
- Asset monitoring
- Remote patient monitoring. An early stage of this supported by wearables

<table>
<thead>
<tr>
<th>Drivers</th>
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<tbody>
<tr>
<td>• Reduction in cost</td>
<td>• Security and privacy for dealing with sensitive data</td>
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<tr>
<td>• Development of cloud technologies (storage + processing)</td>
<td>• Patient acceptance of disruptive applications</td>
</tr>
<tr>
<td>• Commoditization of Augmented Reality and Virtual Reality techniques</td>
<td>• Heterogeneous health systems and regulations across Europe</td>
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<tr>
<td>• NFC technology deployment</td>
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</table>
**Smart Manufacturing**
- Communication/Networking (HaLow, 5G)
- Embedded Computing (Mobile/Portable Devices/Sensors)
- Cloud Computing / Edge Computing (Shift towards Cloud Services)
- Leaps in Machine Learning (Big Data, data driven control, ...)
- New business models (products + services = cyberphysical producs)

<table>
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<tbody>
<tr>
<td>• Reduction in cost</td>
<td>• Legacy equipment which needs to be adapted/retrofitted</td>
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<tr>
<td>• Development of cloud technologies (storage + processing)</td>
<td>• Connected equipment increases need for trust &amp; security concepts and solutions</td>
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<tr>
<td>• Deployment of new wireless communication technologies</td>
<td>• Increased interoperability requirements for connected equipment</td>
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<tr>
<td>• Increasing computing capability of embedded devices</td>
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**Smart Cities & Tourism**
- Smart Cities are wide-scale CPS
- Generates “big data” due to the use of CPS
- Challenge of reducing impact on daily activities of citizens while improving the way city behaves
- Lot of open challenges (citizen participation, security, privacy...)

<table>
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<tr>
<th>Drivers</th>
<th>Barriers</th>
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<tbody>
<tr>
<td>• Development of city ecosystems – requirements, providers &amp; solutions are all local</td>
<td>• Security and privacy for dealing with sensitive data</td>
</tr>
<tr>
<td>• Development of cloud technologies (storage + processing) and big data application</td>
<td>• Digital divide + citizen engagement</td>
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<tr>
<td>• Interoperability providers</td>
<td>• Heterogeneous regulations across Europe</td>
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<td></td>
<td>• Different context &amp; laws for each city – difficult to port applications between cities/regions</td>
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</table>

**General Barriers Identified**
- Concerns regarding **security, safety and privacy**: current systems often have not been designed and built with cyber security in mind
- Lack of **interoperability**, standards and a reference architecture
- High **implementation costs**: Cost is too high to be adapted broadly by SMEs
- Unclear economic benefits, concerns regarding multiple ownership, missing **business model** development
- **Conservativism** of decision makers, resistance to change, risk aversion
- **Social acceptance** of pervasive IT systems
Interactive Session

After a presentation of Road2CPS findings to date, an interactive session asked for participants’ contributions: suggestions of opportunities and barriers they perceived as they sought to adopt digital and smart technologies in their respective fields. The discussion took place in plenary. In this section we summarise the major points generated during this discussion, collected into categories.

Regional development strategies

Regional development strategies are needed to ensure businesses have the local support network they need to adopt and exploit new technologies. Some participants at the workshop reflected on their experiences of regional strategies deployed in the north east of England. Regional strategies like this can tackle challenges specific to the region.

Communications

There are many different groups involved in adopting a new technology for a business – including technologists, engineers, innovators, policy and decision makers. In addition, CPS and IoT technologies cross many domains. There are many different communication channels and terminologies; establishing clear and unambiguous communications that all parties understand is challenging.

- We need simpler, easier to understand terminology – there are many overlapping terms from different domains (e.g., IoT, CPS, IIoT, Industrie 4.0, IR4...)
- Business + IT teams often talk in different languages
- “Translators” are needed, to fill the gap between technology, software experts, developers, engineers and users in manufacturing. We need to ensure the developer speaks same language as the end-user.
- Keeping up to date is difficult. Finding out what/when/why developments are going on, and ensuring that we are included in (or updated with) new initiatives is challenging.

Partner eco-systems

Appropriate local eco-systems are needed, to ensure that businesses can locate the partners they need with appropriate skillsets.

- Today’s solutions requires many integrations, and this requires partnerships, so it’s complex to set up the appropriate, effective solution. Partner eco-systems are needed.

Everything as a service

Business models are changing, and businesses should think carefully about the business models they should/can adopt. SMEs risk falling behind here – this limits ability to capitalise on their innovative ideas.

- SMEs need to give equal weighting to the ongoing support in their planning and business models. Their business models should focus not only on clever technology

Skills Shortages

In general, there is shortage of people with sufficient training in multiple disciplines, including varied engineering disciplines, computer science and commerce. Examples of these can be felt across different sizes of business and in different domains.
• There’s a shortage of electrical/electronics engineers with analogue electronics skills, signal processing and software development
• We need experienced people. However, digital technologies, IoT, CPS (etc.) are new topics, so we have limited experience in-house. We need IT experts, but also engineers, that understand IoT/CPS/Industrial Internet/Industrie 4.0 etc.
• Skills gaps are particularly an issue - across STEM jobs generally. The pace of new technology can make it hard to “keep up”
• Finding people with “technology” knowledge and commercial awareness/understanding is difficult
• Computer scientists mostly have little awareness of the physical environment in which software is deployed, and focus principally on information systems. The exception is industrial developers of embedded software, who understand constraints but often have little knowledge of data security
• We should reverse engineer university degrees so that graduates are capable of instantly contributing to industry & commerce
• Engineering degree courses in UK universities do not include sufficient training in software development

Route to Market

When looking at new digitally-enabled technologies such as CPS, it’s difficult to plan the route into the marketplace, primarily due to lack of information about available partners/solutions.

• There is no access for us to those that have a solution to the current problem – this blocks our route to market
• There is a lack of road-mapping from problem to solution to help us understand the route to market.

Time to implement

• The time to implement a solution is a problem. In fast-moving market sectors the opportunity is sometimes lost before solutions can be built

Underlying technology improvements

• We need low power, low cost, yet powerful processors or SBCs for embedded applications
• We need to invest more in IoT enabled devices for asset tracking and condition monitoring
• We currently experience environmental barriers: i.e., metal interference, battery life, modelling & visualisation
• We’d like to see a quality-assured, “high level” language and operating system combination for embedded applications with networking

Innovation versus regulation

In some fields regulations and certification requirements affect innovation.
Standards (safety) are a barrier to innovation. Standards require a large investment to refactor/rewrite innovation for certification processes. The regulatory framework limits appetite for risk, i.e., solutions must demonstrate/evidence minimum loss and maximum customer benefit.

**Standardisation**

There’s a need to standardise, to increase the possibility of interoperability.

- Standardisation of code and technology and needed.
- There are no shared data models – it’s very difficult to exchange data, intelligence, etc.
- We’d like to see standardised “safe” and secure operating systems for e.g., offshore applications working within “Atex”

**Open source versus IP/enterprise**

There’s a conflict between open data and open solutions – which could help to create a dynamic and innovative marketplace - and a business’s desire to protect its IP.

- Crowd sourcing could help with skills/people availability. However, industries may be against opening up their IP to an open community (gov.uk is breaking this cycle!)

**Big/smart data**

We want to emphasise “smart” data, not necessarily just “big” data. Lots of data alone is not necessarily always useful – we need to understand how to use it and the meaningful messages we can extract.

- Effective data capture & analysis is a barrier. We need to look at interoperability of data from various sources - e.g., how to analyse data from legacy systems and new sensors & facilities & external weather data, etc. We need to cope with big data.
- We run the risk of drowning in data by making multiple measurements. The value is in the interpretation of the data so that useful decisions can be made. Holistic overviews of the challenge are essential. We should emulate the Rolls-Royce jet engine model
- Lack of understanding is a barrier in this area. We should consider big data versus smart data. Predictive analytics versus real-time analytics. It’s not about quantity, it’s about quality – fully smart data is decision-enabling
- There is a skills gap, not enough data analysts available. Experts are needed to understand data usage and what reporting capabilities this provides

**Return on investment/R&D**

It’s difficult to get support for programs to adopt CPS/IoT technologies because the potential return on investment is not well understood.

- Availability of funding (and people power) to spend time in ideation and research is limited by the lack of clarity on building a business case and defining return on investment (ROI)
• We want to understand how to promote investment in terms of time and technology of a roadmap, or a mid-term plan. How to see more POC? Examples: sensors, track & trace, industry 4.0 enabled equipment
• The resources & cost involved of translating opportunities as an SME act as a barrier

Understanding market and risk
There is very little information available at the current time to facilitate building a business case for a new technology.
• There’s a lack of information and awareness in many organisations about how this type of technology could support business goals. There’s a risk that we “talk the talk” but don’t commit to “walk the walk”
• Market confidence. Potential product users are cautious about using new technology – or at least being the first to use new technology
• Market/end-user education is needed. There is poor technical literacy amongst some market end users. The demand for education is shown by the interest level in workshops we operate to fulfil this need
• Risk of the unknown! There’s a reluctance to make changes which are not seen as strictly necessary - “if it works, why change it”. We need simulation/modelling tools to demonstrate clear views of the system to be, and help us gain confidence on risk
• Clients often have poor understanding of what is offered by continuous monitoring. As a result there may be an institutional/budget resistance to adopting technology that can save them money and drive their continuous improvement
• Customers don’t know what is possible and feel threatened on cost, when new innovations are technology/supplier led (risking vendor lock-in). This leads to long cycle
• A roadmap is required. We need gap analysis and prioritisation between the vision of a factory of the future and legacy equipment. What are the big wins to start with and what to prioritise next? We need information for developing a budget.

Integration
Integrating multiple services or devices is a challenge in itself, but in addition many businesses need to integrate new technologies with legacy systems.
• We should think about legacy infrastructure - prioritisation and associated timelines. We need to create a modernisation path, examine the ability to modernise, and think about ability to deliver to current expectations
• Integration with “the old” is a barrier. Old and new mix of technologies and their compatibility - this raises a challenge
• Full system integration is difficult to test, due to many integration technologies & platforms (this is where modelling could be useful). This leads to risks for the system supplier.
• In complex digital ecosystems (enabled by wifi) there are a huge range of end user smart devices (phones, tablets...). Ensuring compatibility really means ensuring that we can deliver content to the lowest/oldest device in circulation
• In defence, organisation costs prohibit rapid updating of digital systems, so we mostly must use *legacy* systems. This has an impact on SMEs, because it’s difficult to sell into defence (and security) organisations

• SMEs should support ESCROW arrangements, to provide stability and reassurance and prevent vendor lock-in

**Comments on application sectors**

*Smart health*

• The UK’s NHS is risk averse & extremely slow to test & adopt new & disruptive technology – this acts as a barrier to innovation
Prioritising the discussion points

Following brainstorming in plenary to identify some major barriers that participants perceived, the group prioritised the different categories. Where appropriate, the suggestions made during the plenary brainstorming were clustered into the categories shown above. Each participant was awarded 5 “votes” to select the categories or individual suggestions that they thought were most important. Results of the voting are shown in Table 1.

Table 1: Results of «voting» exercise to prioritise categories for elaboration

<table>
<thead>
<tr>
<th>Topic</th>
<th>Votes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partner eco-systems</td>
<td>0</td>
</tr>
<tr>
<td>Everything as a service</td>
<td>0</td>
</tr>
<tr>
<td>Route to market</td>
<td>0</td>
</tr>
<tr>
<td>Open source versus IP/enterprise</td>
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<td>Time to implement</td>
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<td>Innovation versus regulation</td>
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<td>Standardisation</td>
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<td>Regional development strategies</td>
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<td>Communications</td>
<td>5</td>
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<tr>
<td>Underlying technology improvements</td>
<td>6</td>
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<tr>
<td>Understanding market &amp; risks</td>
<td>8</td>
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<tr>
<td>Return on investment</td>
<td>9</td>
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<tr>
<td>Skills shortages</td>
<td>10</td>
</tr>
<tr>
<td>Big/smart data</td>
<td>11</td>
</tr>
<tr>
<td>Integration</td>
<td>11</td>
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</tbody>
</table>

Following the prioritisation exercise, four categories were selected for further elaboration. In addition, “Understanding market and risks” and “Return on investment” were merged due to their popularity and overlap. The selected four categories are:

- Skills gap
- Big/smart data
- Integration
- Return on investment/understanding market & risks

Participants divided into small groups of 3-5, each dedicated to one of these challenges. They spent some time in these groups considered the question of what research/development should be funded by a body like the EU to help businesses overcome these barriers?

Figure 1 shows an example of the worksheets used by these small groups, to design a solution to their designated barriers.
**Figure 1** Worksheets used by small groups to design solutions to selected barriers

Detailed solutions to these barriers developed by the participants’ groups are described in this section.
**Big/smart data**

The group addressing this subject developed a flow chart to illustrate a generic process for deploying a “smart data” solution (shown in Figure 2), which captures some of the underlying concepts. The flow charts captures some basic steps involved for a business which is considering the deployment of a big data solution.

![Big data flow chart](image)

The group discussed the process and the steps involved for a business. There’s a need for a structured process like this to be available to businesses, to demonstrate best practices and lessons learned elsewhere. A structured process which is made available to a range of businesses can help them develop more effective smart systems, that deliver real value and can be incrementally achieved. Businesses need to be able to access previous examples and guidelines on best practice; this provides confidence and support for businesses which are deploying and designing bespoke types of solution for the first time. This is relevant for businesses in any sector or domain.

The group expects that it would take 6 months to 1 year for a business to implement a smart data system using an agile process. The necessary process to implement this type of smart data solution should centre on an iterative examination of real-time information followed by redefining. This cycle is needed to deliver results in sufficient time.

After discussing the implementation of this process, the group suggested that research is needed to:
• Bridge the gap between business knowledge and data analysis/measurements.
• Address a skills gap, particularly in the need for cross-functional or multi-disciplinary teams which are likely to be involved in smart data solutions.
• Make available previous examples or best practice guidelines

Skills Shortages

Fundamentally, there is a shortage of staff – including recent graduates – with skills in multiple disciplines that contribute towards CPS and smart solutions. This was expressed by large and small businesses, and by businesses from different application sectors. There were two types of shortfalls expressed:

- Recent graduates lack experience of the business environment and large scale technical challenges. Graduates usually need training in an industrial environment before they can make active contributions
- There are is a lack of experienced staff with the skills in cross-disciplinary areas (engineering, computer science, physics, business/commercialisation)

The group discussed what type of training is required as a minimum for graduates entering the workplace as CPS software developers and programmers, and possible ways to improve experience of undergraduates studying STEM subjects.

There’s a need to improve the pipeline that delivers skilled staff to industry, particularly by e.g., offering teaching and training through structured events that engage all stakeholders in exploring solutions. For example, in many regions in the UK there are challenges ensuring that graduates leaving universities in the region remain stay in the area after graduating rather than moving to London for career development.

The group concluded that we need:

• A curriculum for CPS courses.
• Regional level strategies to attract skilled staff and encourage them to stay, in order to allow regions to benefit economically and continue to grow. Possible strategies could include scholarships to “pay” students through their degree, in exchange for a minimum number of years’ service in a specific region.

Understanding markets and risks

The underlying problem is that engineers, organisations and decision makers have very little information available to them to help them plan out the business case for adopting smart technology. This was expressed by organisations large and small, and in different domains. Many organisations which are interested in this area, or are capable of make significant improvements through digital technologies, are treading new ground, and find it difficult to plan as a result. Business models, risks, potential benefits, and return on investment are not well-understood. There are very few previous case studies or benchmarks available to help with planning, particularly for businesses whose core function and specialism is not based in digital or IoT.

There’s a need therefore for case studies and benchmarking data, based on real-world examples, made available so that others can learn how to evaluate the business case. Projects are needed to examine
real-world examples of businesses in different sectors as they deploy digital technologies, and produce “lessons learned”. This should include examining the technological challenges involved, but also the lessons learned about managing and deploying a project, effects on operators and end users, and business benefits. It’s very difficult to obtain this information currently, because few businesses have developed, and deployed complete solutions, and those that have deployed large solutions have no incentives to share their benchmarking data, ROI and business case. Availability of data or previous case studies will increase confidence. Based on this, standardised guidance, facts and examples can be produced.

There’s a need to educate end user decision makers to be able to talk with Industry 4.0 providers and truly understand what they are offering and what can be achieved. Once the opportunity is conceptually understood, provide a platform or forum where technology can be “elevator-pitched” or demonstrated/showcased. This could include events targeted at non-technology-oriented businesses looking at digitising for the first time, for example.

High quality modelling and simulation tools which allow engineers to produce accurate representations of the likely behaviours of IoT or CPS deployments would be useful. The ability to produce simulations which illustrate potential performance improvements will improve understanding, make it easier to communicate the goals of proposed upgrades to all stakeholders, and provide information for building a business case. Businesses could be more confidence that their proposals will bring benefits.

Economically, improving understanding like this could accelerate purchasing and investment decisions and deliver opportunities for end users faster. This will speed up the development/deployment/benefit cycle. It also reduces the risk of misspecification.

These solutions are not sector-specific and could be applied to multiple sectors. Solutions which are perceived as technically complex might not be.

Multiple approaches are possible for different groups of end users. Some businesses may be incentivised via EU projects to participate and share data; others may be incentivised to attend existing fora such as trade associations (regional) or SME fora, to share lessons learned.

Funding should be made available for research, events, speakers and materials.

Research/development needed:

- Case studies and best practice guidelines
- Events and materials to improve literacy of all stakeholders, particularly business leaders and policy/decision-makers
- Modelling and simulation tools which allow engineers to simulate potential benefits of their proposals for connected smart systems

Integration

The key barriers here are the difficulty of integrating components and parts from different sources – particularly when systems rely heavily on legacy services or components which can no longer be updated. The group’s solution included:

- Domain-specific data models are needed (per application sector)
- Cross-domain reference communication architecture
- Process or guidelines for integrating legacy equipment or systems
The solutions would ideally be open-source and community-contributed (i.e., industry-led). Solutions based on this infrastructure will allow SMEs to deliver services to application sectors while adding to defined standards. They will also allow/encourage innovation, yet allow businesses to retain links and integration to existing and legacy tooling and systems.

To implement this solution, there will need to be an iterative development of models, to leverage a community drawn from across different application sectors. There’s a need for a marketplace for SMEs and large enterprises, and the existence of data models, supported by cross-domain communication architectures and guidelines can facilitate this. It will also provide support and help for in-house teams.

The solution must be open. It would be a candidate for access via tooling such as GitHub.

Research/development is needed:

- Research into data models appropriate for different domains, as well as identifying elements which cross domains. Some domains are further ahead than others; this will allow different domains to share ideas and existing frameworks.
- Different application sectors need to be co-ordinated in an effort to define initial data models.
- Reference implementations (via existing or pilot clients) should be trialled
- Work should be led by working groups for domain-specific “users” and “suppliers” or contributors
Concluding Remarks

The workshop brought together experts, from a varied cross-section of domains, with an interest in digitisation and smart systems, to discuss barriers that they perceive in their industries. Group priorities focussed quickly on cross-cutting problems, some of which are not technology-oriented (i.e., skills gaps, the difficulty of understanding the ROI or business case). Many barriers identified by the group centred on a lack of information – for building convincing business cases, keeping up with technology, educating and training staff, for example.

The findings and suggestions of the workshop generally supported interim findings of the Road2CPS project at this stage, and in some cases provide some new suggestions. Below are key recommendations from the day’s workshop:

- Participants agreed that a lack of shared data models is a significant barrier to interoperability. When considering digitisation, integrating services and/or devices from different suppliers/sources is a very real challenge, and this is particularly the case when legacy components were involved. Experiences of the participants suggested that coping with legacy systems/components was the norm, not an exception. Domain-specific standardised or open data models are needed (this type of work should continue in fields where already under development). Industry-led initiatives are preferable here, in order to ensure industrial adoption and support.

- There was a strong emphasis through the discussions on the difficulty of building a business case or calculating return of investment (ROI) for new digital technologies. There is also difficulty establishing clear communications between the technology and business side of an organisation. Underlying causes include lack of information – for example, about how other organisations have adopted digitisation/CPS/IoT, and the benefits that they experienced as result. It’s difficult to communicate expected business benefits of deploying specific technologies, because in many sectors these are not well understood. The EU could address this issue by funding work to develop published case studies, or by incentivising organisations to share information. Modelling and simulation tools could also help, by allowing engineers to simulate the potential results of their plans for connected, digitised systems.

- Skills gaps and lack of effective training is a significant problem, particularly for SMEs, although this was raised by large and small businesses, and by businesses in different sectors. This issue has been raised at previous workshops run by Road2CPS, but the strong emphasis on this subject at the Newcastle workshop stressed the real-world impact of skills gaps on commercial businesses. There’s a particular shortage of technical staff (engineers, software developers etc.) with skills that span the multiple domains required for designing and deploying “smart”, digitally-enabled systems.

- Some discussion at the workshop touched on experiences of regional development strategies which have been deployed in the UK. Several suggestions emphasised that cross-domain regional strategies are productive and important to ensure that businesses in specific regions have the eco-systems and support they need to exploit digital technologies.

- Business models are changing, and businesses (particularly SMEs) need to be able to consider business models that leverage long-term system maintenance or performance as well as selling technology. Failing to do so limits their ability to capitalise fully on their innovations. Selling systems as long-term services can also help to improve customer confidence, which was identified during the workshop as a barrier to overcome.