RODIN

Robotics Digital Innovation Network

Robotics and European Networks of Digital Innovation Hubs Supporting European Resilience

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Robotics and European Networks of Digital Innovation Hubs Supporting European Resilience
Output of the RODIN Resilience Working Group
Part 1 Resilient Recovery from COVID-19 Disruption

1 Overview

Robotics is a technology that, at its heart, is intrinsically about flexibility and adaptability. One of the key reasons for purchasing a robot over another form of machine is that, for a range of applications, an existing robot can be purchased and readily adapted to that particular application rather than a specific machine having to be designed and built. And yet there are limits to much current robot adaptability. These limitations arise from:

- The frequent need for application specific tooling and jigging to cope with the demands of a new application
- The need to re-program a robot for even a small change in the product or process
- Geometry, mass or power restrictions associated with the robot

More recent “intelligent” robots can utilise comprehensive sensor suites and flexible programming to overcome several of the first two issues. Although intelligent robots have been around in research labs for over 50 years, increases in both computer and sensor performance mean that cost-effective robots can be produced that are both competent and adaptable. In terms of the third issue, the ability to deal with a wider range of physical constraints of a task has increased due to progress in terms of materials, drives and the computing power needed for more sophisticated control methods, although progress in these areas has, arguably, been slower. In all these areas significant, further progress can be expected provided the funding of broad, general research and innovation in robotics technologies continues.

Resilience in society requires, amongst other things, adaptation and quick responses to changed situations, particularly in emergency situations. In theory, robots should be ideally placed to help mitigate the effects of a major incident by being re-purposed to meet the changed requirements. However, recent history has shown that when emergency situations arise, robots have been ill-adapted or unable to be deployed rapidly to meet the needs of the

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situation. An oft-quoted example of this was the relatively poor ability for robots to be deployed to help in the aftermath of the Fukushima disaster, despite much effort being put on building resilience with robots following Chenobyl. It is now well-known that part of the problem was an institutional one, where robots were not seen as part of a standard response to an urgent situation, but there was a, perhaps, bigger contribution to the intermittent nature of the support for emergency response robots, both in terms of funding and in terms of the safeguarding of knowledge and expertise. Despite previous work, much of it in Japan, on developing emergency response capability, the lack of incidents then led to a curtailment of funding and an eventual mothballing of equipment and loss of detailed knowledge and expertise that had been built up on how to respond. To learn from the past is to learn that developing robots that can help with resilience cannot rely on ad-hoc mobilisations but must be built up and maintained over time.

Recently, Europe and the world has been hit by the COVID-19 epidemic which has put strains on health services around the world, as well as restricting the supply of people to perform both their normal jobs and to respond to the extra demands of the pandemic. Robots should be ideally placed to help respond to the changed circumstances and extra demands.

This paper addresses the role robots can play in addressing resilience issues across the 4 Priority Application Areas represented by the Networks of DIHs, namely:

- Agile manufacturing
- Agri-food
- Healthcare
- Inspection & maintenance

The aim of this paper is to give an overview of the situation in the 4 Priority Application Areas, particularly with respect to the capability of robotics to assist with overcoming problems. The paper also addresses the Challenges faced by the Networks of DIHs and the way these networks could be, or have been, used to channel recovery actions. Finally, some overall conclusions are drawn.

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2 The situation in Priority Application Areas

This section addresses the problems encountered with the COVID-19 pandemic as it affected each of the four areas represented by the Networks.

2.1 Agile Manufacturing

The major issue with manufacturing worldwide has been the disruption of supply chains. This has hit both European manufacturers but also the availability of commodities and products of items entirely manufactured outside of Europe.

2.1.1 Disruptions

For European manufacturers, this supply chain disruption (caused in large part by disfunction of sea-going container backlogs) can be sub-classified in 2 similar, but subtly different impacts:

- Impact 1: For all manufacturers, but particularly for smaller manufacturers, there have been significant disruption caused by major delays in the supply of components and commodities. This, in turn, has led to price rises for in-demand components or just complete lack of availability for significant periods of time. In many cases this has caused production lines to have to close for periods of time.

- Impact 2: For larger manufacturers, who have placed part, or all, of their manufacturing capacity abroad, the supply chain delays extend to whole sub-assemblies or even full products.

The supply chain disruption has largely masked, or at least demoted to a second order disruption, an additional disruption due to personnel availability. This, nevertheless, would have had a significant effect of manufacturing output during the height of the pandemic even in the absence of supply chain issues.

The other significant disruption for European manufacturers has been changing supply demands, meaning openings for new products to be supplied at relatively short notice whereas demand for existing products may have declined.

2.1.2 Response required and the capability of robots to support

The "simple" answer to this disruption is the construction of shorter supply chains with most of the manufacturing carried out within Europe's borders. However, this is neither a short-term fix nor necessarily an economic one. It takes a long time to build factories and (re-)acquire the expertise to operate them. And in the case of commodities, it is often an

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infeasible option to relocate them. Nevertheless, where cost of local manufacture is a critical issue, introducing more robotics and automation can both lower costs and increase quality.

However, one thing that can be done is to improve the holding of critical stocks. While lean manufacturing has driven manufacturers to adopt Just In Time supply chains, the pandemic has shown that such a policy can be very fragile. In terms of robotics, the main support measure for this is in keeping the cost of larger stock holdings to a minimum which, in turn, depends upon the efficient operation of warehouses and other storage facilities where, of course, automation and robotics can make significant contributions.

The availability of production personal can be partially alleviated by greater automation & robotics although, again, this is not a quick fix and, at least in the manufacturing sector, has not led to a noticeable increased demand for automation & robotics.

Where some DIHs have noticed an increase in demand for automation and robotics in general, and agile manufacturing in particular, has been in the need for greater flexibility in order to cater for changing patterns in demand from both large industries and from government sources. This increased demand is primarily originating in smaller manufacturers and second and third tier supply chain companies.

2.1.3 Current Status of Products and Service

Although the development of many agile manufacturing techniques and products are still ongoing, there are sufficient current automation and robotic products which support the principles but the knowledge about how to apply them in an agile way to be cost effective is not widespread, particularly among manufacturing SMEs and adoption is generally low. This is where case study material, pilot installations and the knowledge being built up within the networks of DIHs can be helpful in encouraging manufacturing companies to begin the journey of increased agility.

2.1.4 Support Required

As mentioned above the main support required comes in 3 main forms:

- Awareness: Both DIHs have raised the awareness of agile manufacturing techniques through workshops, seminars and the provision of informational material
- Examples and case studies: Real-world implementations provide strong communication of both the benefits and cautions of adopting new technologies, particularly if they arise from sources that are seen to be non-biased, i.e. not from the suppliers that are trying to sell the equipment or services. Such information is particularly relevant to manufacturers who may be aware of some of the benefits of agile manufacturing but need reassurances regarding the practicalities, pitfalls to avoid and the resulting cost-benefits. The networks of DIHs have provided both

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written case study material as well as direct support to projects implementing agile manufacturing transformation of existing production processes.

- Direct support: Direct support to agile manufacturing change management can come in the form of direct consultancy or more direct collaboration in the implementation process. Direct support from the DIHs and their networks came in the form of direct support to both equipment manufacturers and to end users through the Funding Support to Third Parties (FSTP) mechanism. For the former these projects allows manufacturers to understand the market requirements and to tailor their market offering, while for the end users they can reduce the risks of an initial implementation of agile manufacturing. Additional direct support from the DIH networks is also available in terms of consultancy and advice services.

2.1.5 Coordinating the Response

For both the DIH² and Trinity projects their core mission was to accelerate the introduction of an Agile Manufacturing approach within the European Union manufacturing base. Therefore, the response required during the pandemic was essentially to carry on as normal, albeit with changed working practices that the pandemic introduced.

2.2 Agri-Food

The major issue faced by the Agri-food sector as a result of the COVID pandemic, as reported by the agROBOfood Network of DIHs, has been caused by difficulties in labour supply, although food manufacturers have also been affected by supply chain issues, particularly where long-distance supplies or particularly complex supply chains have been involved.

2.2.1 Disruptions

Within the food industry the effects of the COVID pandemic came from three main sources, namely difficulties with labour supply, changes in the demand pattern for food and, to a lesser extent, supply chain issues, as detailed below:

- Labour supply: Labour supply problems during COVID arose from a number of sources. First, there was the straightforward issue of workers isolating leading to higher absences than normal. Second, at the start of the pandemic many migrant workers either returned home or were not available for seasonal work. Third, the need for greater controls in the workplace made achieving previous levels of throughput more difficult, particularly with respect to food manufacturer. For agriculture, these supply problems mainly manifested themselves during the harvest period, particularly in fruit picking which, in Europe, traditionally relies on migrant labour. Within the food manufacturing supply chain, labour supply problems generally hit small manufacturers (who supply about 50% of Europe's food) quite hard as these firms

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tend to have low levels of automation and rely on relatively large numbers of unskilled and semi-skilled staff. It was this latter aspect of relatively large staff numbers that also impacted upon smaller food manufacturers when trying to implement health policies involving greater distancing. However, these difficulties in implementing health policies were also noted in areas of agriculture and primary food preparation that are reliant on high numbers of staff working in relatively small areas such as glasshouses and slaughterhouses.

- Changed patterns of food demand: The COVID pandemic also caused changes in the demand pattern for certain foods as a large proportion of society self isolated and worked from home. This was again more of an issue for the food manufacture and retail sector rather than directly impacting upon the agricultural sector but required more agility in meeting the demand.

- Supply chain disruption: So far, supply chain disruption as a result of COVID has not been observed to have significant consequences on the agriculture sector but some problems have been observed in the food manufacture and retail sectors that have resulted in reduced number of food lines and relied on the flexibility within the food manufacturing sector. Traditionally, this flexibility arises from the preponderance of manual operations in the smaller food manufacturers, but this has been stressed by the labour supply issues mentioned above.

2.2.2 Response required and the capability of robots to support

For all sectors of the Agri-food industry, greater automation and robotics could help with increased flexibility to cope with disruption, such as occurred with the COVID pandemic. With regard to labour supply problems, harvesting and picking robots can perform the tasks that currently are usually performed by seasonal labour. In food manufacture, agile robots can support many of the routine assembly tasks performed by assembly line staff. Agile robots can also help address the changes in food production to meet the changed patterns of demand in the food supply chain and also alleviate some of the effects of supply chain disruption.

2.2.3 Current Status of Products and Service

Agricultural robots are not yet widely adopted with most agricultural robots that are available are being manufactured by SMEs and most of these are new market entrants. The arguable exception is with drones that are generally used for detailed inspection to increase crop yields, although their range of application is growing. To become more mainstream needs further investment and although venture capitalists are showing increased interest in the

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sector, the business case remains a challenge and the investment timescale is too long to respond to the opportunities by a short-term disruption. So far the large agricultural machinery firms, whilst showing interest in robotic technologies and solutions, are not showing commitment to implement robotics systems in a widespread manner but are rather incorporating associated technologies into existing machines in order to implement, for instance, precision farming.

One agricultural area where robots are starting to be used more is in glasshouse tasks such as fruit tending and picking, particularly among larger growers. However, general outdoor robotic fruit pickers are not yet widespread despite there being several small companies offering products in this area.

For food manufacture, the situation differs according to the different types of manufacturers. Large scale manufacturers, generally have long, stable runs of branded products and automation is widely adopted, although this tends to be hard automation (i.e. systems specifically designed for the process and product) which is more cost effective for high-volume, long-life products. For small and medium manufacturers, again automation is fairly widespread for liquids and piped products and robotics is becoming more widespread for easier to handle products such as end of line packaging and palletising as well as some goods-inward bulk materials handling. However, food assembly tasks are where large numbers of staff are routinely utilised, mainly on assembly lines. These tasks tend to be routine and, in principle easier to automate, with the exception that many food products are difficult to handle and require specialised end effectors. Also, the batch quantities are often quite small requiring frequent changes of product per day. Nevertheless, systems have been demonstrated that can operate with the required flexibility and speed and which can be cost-effective, particularly when introduced to multi-shift production environments. Again, several companies are offering products in this area, but awareness and uptake is not significant, given the size of the sector.

2.2.4 Support Required

Similar to agile manufacturing, the support required is mainly in the 3 main areas of awareness, examples and case studies, and direct project support. The agROBOfood network has been providing support in the former 2 areas areas through workshops, seminars and case study material and direct project support using the FSTP mechanism.

Additionally, more near market financial support is required to help small agri-food robot developers develop these new markets and to encourage robotics take up by small agricultural organisations and in SME food manufacturers (who produce 50% of all food products in Europe). The former, while difficult, can be accomplished through a combination of (national) near-market grants and the involvement of private capital (such as venture

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capitalist). The latter could be assisted with a mixture of pilot plants (both food factories and field test-beds) combined with specific financial incentives such as highly targeted capital allowances.

2.2.5 Coordinating the Response

Again, for agROBOfood the core mission was to accelerate the introduction of greater flexible automation throughout the European Union food production supply chain. Therefore, the response required during the pandemic was essentially to carry on as normal, albeit with changed working practices that the pandemic introduced.

2.3 Healthcare

Healthcare was front and centre of the COVID pandemic and health organisations around the world were severely challenged in dealing with the resulting disruptions. The HERO project played a central role in organising robotics aspects of the European response.

2.3.1 Disruptions

The healthcare organisations in Europe were directly and severely challenged by the effects of the pandemic. The main disruptions can be classified in four broad, but overlapping, areas namely:

- Dealing with a novel, widespread infection: As in well known, the COVID infection was both novel and widespread. This meant that both effective interventions and new vaccines had to be developed. The development of new interventions requires extensive healthcare knowledge combined with clinical trials and is generally beyond the scope of current robotic systems. That said, the use of AI systems both in diagnostic areas and to help identify promising interventions is an area of active application and development.
- Labour supply: With healthcare staff exposed to high levels of COVID infection, staff levels were severely depleted due to the number of staff at any one time that were isolating due to COVID infection. This led to severely depleted staff levels.
- Backlogs in non-COVID care. As the demand for COVID care support rose, other medical procedures had to be put back which resulted in a high backlog of urgent and important procedures being delayed. Given the lack of margin in most European healthcare system, this has led to a dramatic increase in the waiting lists for routine procedures which, using conventional procedures, will take years to clear.
- High demand for high-dependency care. High-dependency care is a critical and expensive part of all countries healthcare systems. The rapid rise in COVID related high-dependency care has further impacted on the number of non-COVID procedures

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that can be carried out and therefore further increased then wait lists for non-COVID procedures.

- Infection control. The novel nature of the COVID infection meant that special measures needed to be undertaken to ensure that areas within a hospital were kept as sterile as possible.
- Demand for medical equipment. The demand for protective equipment and clothing rose significantly during the COVID outbreak leading to supply shortfalls.

2.3.2 Response required and the capability of robots to support

Robotics could potentially answer many of the challenges of the COVID pandemic. In particular robots could undertake many of the routine tasks that take up a significant proportion of hospital staff activities including the delivery of medications and meals, laundry duties and infection control. Undertaking such tasks with robots would save considerable staff effort which would free them up for direct support of intensive care procedures.

2.3.3 Current Status of Products and Service

Currently the focus of medical robotics has largely been on surgical and rehabilitation robots. While there have been some systems developed for general hospital support activities such as drug and food delivery, these have not had widespread uptake.

One healthcare area where robots are emerging is in the area of infection control with several prototype systems being developed based upon either the spraying of disinfectant or the irradiation of areas with UV-C light. However, prior to the COVID pandemic few of these systems had been taken up by healthcare authorities.

2.3.4 Support Required

Unlike the other Priority Application Areas (PAAs) the EC made the decision to boost the healthcare area by specifically providing €1m additional funding for a COVID-19 dedicated “Response and Deployment” call. This call was aimed at accelerating the use of robotic applications within healthcare settings which specifically revolved around COVID-19 response, recovery and support in daily challenges as well as post COVID-19 challenges.

The call was prepared in short time and had an extremely short submission period of 1 week. Despite this, and because the network of DIHs were leveraged in awareness activities, 146 proposals were received by the deadline. Nine projects were funded ranging from disinfection robots to hospital portage robots and a home-based rehabilitation robot.

With regard to resilience, the key point here is that the network of contacts existing within the HERO network of DIHs, together with the broad base of knowledge contained within the

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network, enabled a fast and effective response to be mounted in a much quicker timescale than the EC working on its own could have achieved. This shows the potential that networks of excellence have for helping the Commission mount rapid responses to quickly emerging societal shocks and destabilising events. In other words, the networks of DIHs have the potential to amplify the Commission's ability to increase societal resilience.

2.3.5 Coordinating the Response

The HERO project's core aim was to pull together a network of DIHs that, together, could help accelerate the uptake of robotics and automation within the healthcare system. However, during the pandemic the project and network took on the additional responsibility of fast-tracking part of the European Commissions COVID response by arranging for a rapid response call specifically aimed at evaluating and demonstrating the use of robots for supporting COVID-related activities in healthcare.

2.4 Inspection & Maintenance

The RIMA (Robotics for Infrastructure Inspection and Maintenance) network and project aims to provide industrial leadership by building and supporting a network of DIHs, together with some associated suppliers and users, involved in the inspection and maintenance of high value capital infrastructure. As such the target vertical sectors were primarily energy related. This network reported the least effects of any network, which largely reflects the constant requirement for, particularly, inspections of capital infrastructure regardless of the usage patterns.

2.4.1 Disruptions

Although this network reported that inspection and maintenance operations did suffer from some of the manpower disruption seen in the other reported sectors, these were less severe than with the others. This itself is probably due to much of the working being in outdoor or large facilities with a low density of workers. The reported effects of this particular disruption was reported as manageable.

One reported effect of the pandemic in this area resulted from the drop in demand for certain products, particularly in the petrochemical industry, which resulted in more storage tanks being full and the period between the emptying of tanks increasing significantly. With statutory requirements to perform inspections on such tanks remaining, this highlighted what had been a growing background demand, namely the desirability of being able to inspect such tanks without emptying the contents. While external inspections can meet some of these needs, the full integrity of many tanks cannot be assured without an internal inspection. Robot inspections for the internals of empty or near-empty tanks is already a growing practice due the dangers, difficulties and costs of putting people inside such structures. However,

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many of these tanks when full contain liquids that may be any combination of explosive, flammable, opaque or viscous, or have other special requirements with regard to non-contamination or hygiene. A solution to this problem would also have benefits for non-pandemic working as it would ease the problem of scheduling inspections.

2.4.2 Response required and the capability of robots to support

In general, there was no special response required in this area.

2.4.3 Current Status of Products and Service

Robots are already extensively used for inspection and maintenance of capital infrastructure, with the take up continuing to rise. The capability of robots in this area continues to improve with a competitive market ensuring new capabilities and functionalities are being delivered to the market at a regular rate.

2.4.4 Support Required

With regard to the capability to inspect tanks when full, no commercial robots with a general capability to do this are known. Given that this is a significant increase in functionality, such a development would require considerable funding (probably beyond that which could be achieved with FSTP funding) but the associated risks of not achieving the goal are significant. This is an area where EC funding could be usefully directed, not only to develop a capability that would be of economic value not just in times of crisis but also in normal operations. Also such a capability, once developed, could bring substantial competitive advantage to any European company able to market such products worldwide.

2.4.5 Coordinating the response

As stated above the impact of the pandemic was not severe in this area so, other to changes in internal working practices, there was no great change in the operation of the network of DIHs in this area.

Again, for agROBOfood the core mission was to accelerate the introduction of greater flexible automation throughout the European Union food production supply chain. Therefore, the response required during the pandemic was essentially to carry on as normal, albeit with changed working practices that the pandemic introduced.

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3 Challenges faced by the Networks of DIHs and their member Hubs during the Pandemic

As with most organisations, the networks of DIHs and their member Hubs faced significant challenges in adapting to carrying out their operations during the pandemic, and this led to great pressures. Yet despite this, most operations were kept going and few major delays resulted directly from the pandemic.

The most significant disruptions to the operation of the networks came from:

- Periods of large numbers of staff working from home. This disrupted the normal communications within organisations, making these communications less efficient and requiring more online meetings, with a greater number of people in each meeting. This, in turn slowed progress within organisations and meant that additional resources had to be deployed to meet deadlines.
- Periods where significant numbers of staff were ill with COVID infections. This, again disrupted the continuity of work and meant that staff less familiar with the task had to be deployed, and thus took longer to complete assignments, or that tasks had to wait until the relevant staff member had recovered.
- Communications with potential users of the Hubs and potential applicants for FTSP actions were disrupted by the inability to hold large face to face information, promotion and dissemination events. This disruption was probably the most significant faced by the networks of DIHs and meant that many more one to one communication channels and meetings had to be be held via telephone and web either as the primary means of communication or as follow up to one to many web conference calls. However, this also showed the effectiveness of the networks of local DIHs having local knowledge and contact details and being able to maintain contact with the potential user base despite not being able to hold public dissemination events.

Overall, none of these issues were specific to the networks of DIHs and their operations. They were shared with most organisations in Europe and across the world as the measures to contain the pandemic were enforced. However, they were still significant disrupters and bare testimony to the resilience of the network of DIHs structure that long term effects on the operation of the networks and the deadlines of the IAs operating the networks were not more apparent.

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Part 2 The Assessment of Resilience following the outbreak of the War in Ukraine

4 Rationale

During the assessment period of the resilience to the pandemic, the Russian invasion of Ukraine started and it became apparent that further disruption to European businesses and society were starting to occur. It was therefore decided to extend the Resilience Working Group activities to examine disruptions caused by the Ukraine war and to examine possible resilient responses from the networks of robotics DIHs.

4.1 Disruption Assessment

The Ukraine war has proven to have 2 significant disruptions to European businesses and society. The first of these has been further disruption of supply chains, particularly in the area of food and agriculture supplies. This disruption has extended the problems resulting from the pandemic and required significant adjustment of supply chains to ameliorate the situation. However, these supply chain problems did not reveal any new resilience issues nor pose any new requirements for solutions over those revealed during the COVID pandemic.

The second major area was on energy supply, particularly with regard to gas supplies and the resulting price rises that introduced shocks across European industry and society. While these energy restrictions were different to those experienced during the COVID pandemic and required significant restructuring of supply lines together with political action to limit the societal effects, the analysis did not identify any significant action that could have been undertaken within the 4 Priority Application Areas represented by the networks of DIHs that could have significantly ameliorated the situation. This is not to say that the application of robotics would not have helped with European resilience following the invasion of Ukraine. It is just that the action required is in other application areas such as Construction, rather in the 4 Priority Application Areas of the networks of robotics DIHs. Also changes to energy supply systems are long term undertaking. Robotics can contribute to making European energy systems much more resilient. This could include increased robotic inspection and maintenance of renewable infrastructure, particularly wind and solar farms, but providing this in the absence of these sources becoming an increased percentage of the European energy mix is meaningless and it will take far longer to increase the production than it will to provide robot systems to carry out the maintenance and repair. Similarly, robots have a potentially significant role to play in the renewal of European energy distribution systems as well as in the operation of new generation nuclear generation but again the timescales of the infrastructure deployment is significantly longer than the development and deployment of support robotics systems.

Therefore, while robotics is still an important element in increasing the resilience of European society to shocks such as the war in Ukraine, there were no significant short term elements that were identified by the Working Group that go beyond those identified to strengthen resilience to the COVID pandemic, at least within the 4 represented Priority Application Areas.

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Part 3 Conclusions and Recommendations

5 Conclusions

The COVID pandemic caused widespread problems across Europe and the world and tested the resilience of many systems. In terms of the major disruptors the common issues amongst the 4 Priority Application Areas (PAAs) were:

- Staff availability. Staff shortages were caused by staff contracting illnesses, staff isolating and difficulties with accessing temporary staff due to movement restrictions.
- Restrictions from changed working practices. The need to maintain increased inter-personal distance in the workplace caused problems for heavily manual production lines and the move to more remote working disrupted existing working practices (both formal and informal) causing increased inefficiency.
- Supply chain disruption caused significant problems in all 4 PAAs, particularly where long and complex supply chains had been built up, mainly in the pursuit of cost savings. These long and complex supply chains proved to be particularly fragile in the face of global disruption factors.

In all 4 PAAs, robots were shown to be (or potentially to be) part of a resilient solution, although often the timescales involved and costs of widespread adoption of robotic solutions were such that the degree to which they could currently be utilised to increase resilience was limited. In other words trying to mount a short-term response to a global disruption using robotics (or probably any other technology) would require massive short term funding and even then would have limited results in some areas unless structural preparations had been undertaken beforehand. For robotics to really help in the creation of a resilient society, preparations need to be taken ahead of the disrupting event. For instance, Agile Manufacturing techniques which include robotics can help increase resilience to supply chain shocks by making it more cost-effective to manufacture a wide range of goods locally, simplifying and shortening the supply chain. However, while agile robotics can be deployed quickly, the simplification of supply chains is a much longer process. Therefore, is greater societal resilience is required, government policy should incentivise more local production and the uptake of agile robotics.

This is not to say that robotics was not helpful in increasing the resilience of parts of industry, and the networks of DIHs were active during the pandemic in helping individual firms seeking more resilient solutions. It is just that widespread resilience requires a strategy that balances and corrects the short-termism of market driven solutions.

The effects of disruption was different in the 4 different PAAs with Healthcare being clearly the most directly effected and Inspection & Maintenance being the least. Nevertheless,

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robotics has been shown ti have a role to play in all 4 PAAs and would, undoubtedly, also have application in increasing resilience in other areas.

All 5 networks of robotics DIHs have been shown to be adept in transforming their working practices such that, despite major disruption and challenges, the work of these networks continued without the introduction of significant deviations or delays.

The special action undertaken by the HERO healthcare project and network of DIHs shows how such networks can be effective in channeling EC resources in a Europe wide response to societal disruption.

The war in Ukraine did not introduce any new disruptions in the 4 PAAs, but did extend the duration of disruption, particularly with respect to supply chain problems.

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6 Recommendations

The assessment of the disruptions caused within the 4 PAAs by the COVID pandemic and the war in Ukraine show 2 main conclusions, namely:

- Robotics has the capability to significantly strengthen societal resilience in Europe by helping to make Europe more self-sufficient in terms of production, support systems and employee utilisation.
- The networks of DIHs have shown to be an effective mobilising resource to help implement Europe-wide strategic action at a local level.

However, for robotics to significantly change the resilience of European society needs long-term government planning. Previous events such as the Fukushima reactor melt-down have shown that even when robotics have been considered as part of the solution to a potential problem, short-termism prevents the necessary support being kept available until it is required. In the case of Fukushima, locally developed robotic systems that had been specifically designed to assist in nuclear disaster scenarios had long been decommissioned and the associated expertise had been lost. Therefore, strategic solutions are required that build greater resilience into European society.

It is therefore recommended that:

Recommendation 1: That future policy on the response to societal disruptions should include consideration of utilising the Networks of Robotics DIHs in the rapid deployment of European Community actions.

Recommendation 2: That consideration be given to setting up Networks of Robotics DIHs in other Application Areas to increase the capability of Europe to build resilience through the application of robotics. Candidate areas would include construction and logistics.

Recommendation 3: That a joint European Commission / robotics community task force be set up on the topic of Resilience through Robotics. This Task Force should, through scenario planning consider a range of societal disruptions that could occur and consult widely within the robotics community as to how robotics and associated technologies could be utilised to strengthen resilience ahead of time together with consideration of long term policy recommendations that would support such resilience building.

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