Government Office for Science

Foresight

Foresight Report: Detection and Identification of Infectious Diseases

Mid-Term Review

May 2007 to March 2011

Foresight, Government Office for Science

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Project background

The Detection and Identification of Infectious Diseases Project: preparing for the future (the Project) takes an innovative approach to identifying future risks from infectious diseases and evaluating the research and technology which might reduce such risks. Published in 2006 and sponsored by the Department for Environment, Food and Rural Affairs (Defra), it looked up to 25 years ahead to provide an extensive international review of infectious disease risks across three sectors (human, animal and plants).

This Mid-term Review (the Review) highlights the longer-term impact of the Project on a range of sectors, as identified by expert stakeholders. Sectors considered include government departments, the international community, the academic and research community, research councils and business. It recognises that while some outcomes can easily be measured and attributed, in other cases the Project's influence is less direct and is likely to be one of many factors. This Review follows the 2007 One-year Review which outlined the actions catalysed by the Project in the year after its publication. This mid-term Review marks the final phase in the Project's formal life cycle.

Overview of impacts

The Project attempted a grand challenge; to identify future risks from infectious diseases across three continents and across three disciplines and, thereafter, evaluate the research and technology that might reduce such risks. The conclusions of the Project and the One-year Review have been published. This Mid-term Review shows that further and, in some cases, impressive progress has been made in affecting change and influencing policy in Governments, their departments and agencies, and funding organisations. It would appear that the principal finding of the original Report, that there is a continual emergence of diseases and that the majority of new human diseases are zoonotic, has proved accurate thus far. The Report has remained an enduring point of reference for the 'One Health' Agenda.

In the UK Government a notable outcome was Defra's funding of a bio-security chip that detects 1132 different viruses from 40 viral families, which followed one of the Project's proposals. Since the Project's publication there has also been greater government commitment to research connected to the detection and identification of infectious diseases (DIID). Defra and the Scottish Government, for instance, are now funding projects designed to improve the design of disease surveillance systems. Similar projects are also operating in the EU and USA.

The Project's emphasis on the importance of detecting disease and promoting a joined-up 'One Health' approach is reflected in the creation of some new collaborative networks. Since 2006, the UK has established an Inter-Departmental Government Coordination Group for High Containment Facilities as well as leading an EU programme to develop an EU and global approach to the procurement of evidence for animal disease.

A major success for the project was stimulating the development of the Technology Strategy Board's (TSB) "Detection and Identification of Infectious Agents (DIIA) Innovation Platform" in 2008. The TSB launched this innovation platform with a view to

investing up to £50 million in activities over five years together with additional funding from government departments, particularly the Department of Health (DH) which will invest up to £5m, and the research councils. The TSB states how the "broad consensus that the work [of the Project] should be taken forward led to the development of this innovation platform".

In research and academia, the Project has helped to bring diagnostic and surveillance issues much higher up the research agenda, with the area explored in at least seven national and international research projects, reports and funding initiatives since 2006. The Project also highlighted the importance of social sciences to DIID; it has been credited by stakeholders with leading to greater acceptance of the need to integrate natural and social sciences in disease –related work. Five research projects at the London School of Economics explicitly continue to explore this link. A number of the experts that worked on the Project have continued to research the issues raised during the Project and help lead initiatives and organisations that work on associated areas. The Project's research is still used and its work still widely referred to five years on.

The Report informed and influenced governments at the highest level and promoted global discussions across continents. The Project was highlighted at the 2006 and 2007 G8 Conferences, helped frame the 2006 G8 priorities and declarations in the area of infectious diseases, and informed the long-term strategies of major European and multi-national organisations. It has also helped catalyse other national foresight programmes in the DIID area, including in China, Canada and Thailand.

The Project has also been credited with highlighting that issues concerning the emergence of diseases in Africa should be seen as a global public good. The extension of the Project into Africa was a novel and previously unexplored idea, which in turn led to the support and creation of the Southern African Centre for Infectious Disease Surveillance (SACID), directed by former Project team member Professor Mark Rweyemamu.

Indeed, since 2006, a number of international initiatives and organisations have been created or established with the Project as an acknowledged reference. As well as SACIDS, they include the London International Development Centre and the Leverhulme Centre for Integrative Research on Agriculture and Health.

The Project did receive some criticism. Some thought that predicting 25 years ahead was unlikely to be accurate. There were questions about whether the Project made the best use of the large amount of information it assembled. In addition, while social science was a novel element of the Project, more social scientists could have been included and more use made of their contributions.

The Project's aim to break across barriers of human, animal and plants government agencies has had less long-term impact than hoped, impeded in part by limited funding. There does not appear to be substantial movements between departments to break barriers that existed before the Project. Similarly, the aspiration to incorporate plants into cross-sectoral collaboration has occurred only in a limited way.

Despite these limitations, the Project's principal finding – that there will be continual emergence of diseases and that the majority of new human diseases are zoonotic – remains the case. Its work continues to provide a sound basis and to influence research, networks and institutions to take forward its ideas on detecting and identifying infectious diseases.

1. Introduction

The Foresight Programme was recast in 2002 as a rolling series of major in-depth studies which use the latest scientific and other evidence combined with futures analysis to tackle complex issues and help policy makers think more systematically about the decisions affecting our future.

The '***Detection and Identification of Infectious Disease***' (DIID) project (the Project) was the seventh Foresight study and was the first to have a major international dimension from the outset. Infectious diseases are constantly present and often rapidly evolving; their incidence can be either local or global and their transmission as rapid as the aeroplanes that can carry them. For these and other reasons, the DIID project widened its focus to include the UK, sub-Saharan Africa and China. It considered the impact on societies of human, animal and/or plant diseases along with many of the new technologies and scientific advances which have the potential to mitigate their damage. To complicate matters, there is a constant emergence of new diseases through mutation or by 'jumping' from one species to another. The most evident of these are those from animals to humans (zoonoses) thereby accounting for the vast majority of novel human diseases (e.g. SARS) or variants of existing diseases (e.g. 'swine 'flu').

The Project published its findings as the '***Infectious Diseases: preparing for the future***' report (the Report) on 26 April 2006. The Report provided an independent and international review of the infectious disease risks over the ensuing 25 years. (https://www.gov.uk/government/collections/detection-and-identification-of-infectious-diseases). The scale, diversity and complexity of the project was ambitious. There are 61 written review papers reflecting the commissioned science reviews, risk analysis, modelling, sub-Saharan Africa, China, future disease control, and cultural/governance issues (all available on the website above). The Report informed and influenced governments at the highest level and promoted global discussions across continents. The Project developed a novel risk analysis in order to attribute importance to the plethora of risks associated with infectious diseases in the different hosts (in some cases, up to 35 countries) that experts had highlighted. Of the many identified by the analysis, 'new and emerging diseases' were consistently considered one of the most important global risks.

The Project, sponsored by the Department for Environment, Food and Rural Affairs (Defra), provided a robust evidence base which has informed policy making, strategic thinking, research and investment in technology development to address the challenges it raised. In order to help projects achieve such impact, Foresight has set aside resource to disseminate reports and their findings and to catalyse action. This 'Follow-up Team' works with government and other stakeholders to help ensure that projects are used to inform their activities, particularly in the year following publication, and also to capitalise on specific opportunities that arise in the longer term.

Foresight routinely undertakes a formal review of projects' impact during the year following their launch, in this case published as the 'One-Year Review' (OYR) in 2007. However, as with many projects, it has become increasingly apparent that the impact of many of Foresight's major projects occurs over a longer time scale. Therefore, Foresight is conducting a series of mid-term (3- to 5-year) reviews of which this is one, to explore these impacts.

Foresight commissioned Professor Joe Brownlie, Royal Veterinary College, to undertake this mid-term review (the Review). Using a combination of questionnaires and one-to-one interviews, members of the Project's High Level Stakeholder Group, Lead Expert Group and other key individuals and organisations were invited to comment on the Report's impact. The responses have been drawn together to form the main body of the Review.

This Review is a record of some of those longer-term impacts. It provides an overview of the Project (chapter two), and a summary of the OYR (chapter three). It sets out the Project's impact by sector, in particular within the academic and research communities and to a lesser extent in government departments and business, together with its conclusions (chapters four and five). It is not intended to be comprehensive as impact will often be indirect or intangible and not clearly attributable to the Report.

The Review marks the final phase in the Project's formal life-cycle.

2. Project overview

This international project delivered an inter-sectoral and multi-disciplinary analysis in the field of infectious diseases and brought together stakeholders from government and over 400 leading experts from over 30 countries. Contributions from all relevant social and natural scientific disciplines were made from areas as diverse as risk perception and data fusion to epidemiology and earth observation.

This Defra-sponsored study involved a wide range of UK and international stakeholders from government, the research community, business and civil society. It produced a challenging and long-term vision for the detection and identification of infectious diseases in plants, animals and humans which took account of the evolving risk of diseases; changing user requirements for detection and identification; and cutting-edge science. The Project was intended to inform policy at a national and international level.

The Project considered international as well as UK issues and looked up to 25 years into the future in developing its findings. It built upon the best published work as well as commissioning novel analyses. In particular, the study assessed the evolving risks of infectious diseases, the factors driving them and how these future threats might best be managed. By taking a broad view, the Project successfully stimulated new and enduring connections between hitherto poorly linked fields of science. It also explored new technologies for detection and identification and the societal and governance implications of using such technologies, for example the ethical, legal and institutional aspects of their development and deployment.

In summary, the Report provided a framework for how future science and technology might be developed and deployed to mitigate the future threats to health, the economy and the environment posed by infectious diseases.

3. Summary of one-year review

In 2007, the Project's initial impacts were reviewed and reported in the DIID One-Year Review (https://www.gov.uk/government/publications/infectious-diseases-preparing-for-the-future-1-year-review).

Within a year of its launch, the Project promoted the development of innovative evidence-based approaches to policies and provided a framework for developing multidisciplinary scientific analysis and technologies to overcome cross-sectoral barriers. The analysis also offered a fresh and innovative holistic perspective to support cross-government strategy to manage the long-term risks associated with the evolving threats of infectious diseases in the UK at a central and local level.

The Report helped frame the 2006 G8 priorities and declarations in the area of infectious diseases; in particular, by linking the consideration and analysis of animal and human infectious diseases and the role of surveillance and monitoring systems in improving preparedness. The study also informed the long-term policy and strategy setting of key European and major multinational organisations such as the European Centre for Disease Control, the World Health Organisation and the Food and Agriculture Organization; in particular, in the areas of human and animal health, novel technologies and systems, and by strengthening understanding of the impacts of infectious diseases on ecosystems.

The Report developed and promulgated a high-level proposal for a pan-African network, which would aim to deliver a step change in capacity to manage the future infectious diseases of humans, animals and plants. It also set out the key role that south-north links, so-called, 'smart partnerships' and other international collaborations will play in delivering capacity and regional and global solutions to these future threats. One of the most important Project outcomes was the creation the Southern African Centre for Infectious Disease Surveillance (SACIDS) which was founded on these principles. This initiative, which has attracted multiple donor support, is both stand alone centre and potentially the first regional node of the proposed continental network.

The Project identified funding gaps and informed major public and private sector strategies for investment in the research and development of converging technologies for detection, identification and monitoring (DIM) systems for infectious diseases. The analysis also provided a framework for future public and private sector technology development through the development of a suite of novel roadmaps. These roadmaps set out how the four key strands of technology and systems identified by the study might develop over the next 25 years to meet the needs of future user communities.

In summary, in the year following publication, the project has catalysed action in the UK and abroad in policy development, research and investment in novel technologies. Furthermore, in doing so, the ground for deeper and wide ranging impact has been prepared.

4. Impact by sector

This chapter has been developed directly from the contributions from stakeholder organisations.

4.1 UK Government

There continues to be a substantial uptake by relevant Government departments of the proposals, as set out in the Project Action Plan, 2006. Some were identified in the One-year Review whilst others have since developed over time. Clearly a driver for this has been the continued incursion of infectious diseases across the three sectors (human, animal and plant). These include avian and now H1N1 (so-called swine 'flu) in humans; bluetongue in ruminants; equine infectious anaemia in horses; colony collapse in bees, as well as Sudden Oak Death and horse chestnut tree bleeding canker. Clearly the project was timely and has provided a platform of informed scientific expertise to which government departments are able to refer. It has been from this platform that some further studies, networks and policies have been launched. Possibly the most novel aspect of the project has been proposed for a better 'joined-up' approach to the 'One Health' Agenda across government departments. This has promoted links between both Defra and DH Departments whilst the international dimension of emerging diseases has sought further collaborative links with DfID.

Department for the Environment, Food and Rural Affairs (Defra)

Defra was the governmental Department that both commissioned and took ministerial ownership of the project. Since the one-year DIID review, the Department has recognised the importance of continued collaborative networks relating to infectious diseases, many that could be attributable to the DIID project. These include a new Inter-Departmental Government Co-ordination Group for high containment facilities, a UK (Defra) led EU programme (ERA-NET) to develop an EU and Global approach to Evidence Procurement for animal disease, a refocusing of the UK Zoonosis and Animal Disease/Infections Group around 'One Health', more social sciences research on attitudes of Vets, particularly with regard to the delivery of disease control and other Defra-funded research programmes to facilitate the adoption of new technologies, including a Defra/ESRC Fellowship.

The Chief Veterinary Officer/Deputy Chief Veterinary Officer (CVO/DCVO) Team has continued to focus on how best to ensure the systematic assessment of disease risks taking account of the characteristics of the disease agent, animal population dynamics, husbandry practices and available control measures. A risk-based and tailored approach to surveillance has been critical to some notable successes in disease management (e.g. the reducing prevalence of salmonella in UK poultry and the management of an incursion of Blue Tongue virus disease, with the subsequent and official recognition of UK's 'low risk' status).

Much of the DIID science evidence-base is still considered relevant although recent scientific advances have been made, particularly in molecular diagnostics, which have impacts on the quality of diagnostic assays. What has become increasingly important is the addition of greater 'social science evidence base' research and an increasing requirement for 'cost-benefit' evidence as a driver for disease interventions.

Whilst the overall level of the infectious disease threat has not appreciably changed in the relatively short time-scale since the Project launch, certain individual diseases have posed greater threats to the UK since 2006 e.g. 'swine 'flu and Equine Infectious Anaemia, and several new conditions have been recognized (e.g. Bovine Neonatal Pancytopenia and a new form of a transmissible psoroptic mange in cattle). However, considerable effort has been given to identifying the 'risk pathways' by which diseases might enter the UK and policy attention has been paid to ensuring that such pathways are 'closed down' whenever possible.

Defra funded – Bio-security Chip

One of the major impacts of the Project was the recognition that the new molecular sciences had the potential to deliver rapid and highly sensitive diagnostic assays. The retrospective modeling following the Foot-and-Mouth outbreak 2001 has clearly shown that reducing the time for correct diagnosis (i.e. from several days to a few hours) could reduce substantially the size and scale of an outbreak. The Bio-security Chip was funded directly following the recommendations of the DIID project.

Defra – Bio-security Diagnostic Chip (BioChip)

The Defra funded bio-security chip (BioChip) is a pan-viral microarray, enables the detection of 1132 different viruses from 40 viral families in a single test. Furthermore the project consortium has developed a full suite of protocols and bio-informatic analysis tools to enable deployment of the technique. The work has shown that a pan viral array can be effectively used for the detection of viruses in animals, humans, plants and insects, often where other methods fail to generate a definitive diagnostic result.

One of the strengths of the BioChip project has been the unique collaboration across Defra and other government agencies to deliver a technological solution. The benefits of this have been the increased speed by which the tools have been developed, and a resultant synergy in cross agency diagnostic capability. This concerted working is relevant to emergency preparedness as there is now a pool of trained scientists across the agencies able to deliver the technique to meet a government contingency response.

The microarray is one of the cutting edge technologies used to investigate emerging, exotic and endemic diseases and as such its value can hardly be underestimated. The ability to detect emerging pathogens is an important feature to ensure food safety and security on the background of increasing international trade and climate change. The methodology of the array was deliberately chosen and developed to allow for the detection and typing of evolving variants of both endemic and exotic viruses. The BioChip is of direct use for both exotic and emerging policy teams, where the results of our work inform risk assessments and management. It is also used to investigate cases of exotic diseases thus informing exotic disease policy regarding emerging threats for example on import controls. As a pan-virus specific technology, the array includes all viruses crossing species barriers including zoonotic diseases and is thus also of wider benefit for the protection of humans health targeting diseases.

This work addresses several of the policies described in the Defra document "Animal Health and Welfare Strategy Implementation Plan for England", released in December 2003 as a 10-year plan. These include New Initiatives for Veterinary Surveillance Strategies. This is common to other areas of Defra policy in which a broad screening technique could potentially provide an alternative approach to efficient surveillance and inspection for regulated pathogens, to provide baselines for the occurrence of endemic pathogens, against which changes might be detected concurrently with surveillance of exotic, regulated or emerging diseases.

Department of Health (DH)

For the DH, there was little doubt that the Project and its Report, in such an accessible format, was effective in raising awareness of the importance of detection of new and emerging infectious diseases in the wider medical audience. This facilitated the collaborations that lead to the publication in 2008 of '***Health is Global: the UK Government's Strategy 2008-13***' which followed the Department's 2007 report on the same topic and linked with the Health Protection Agency's '***Migrant Health: Infectious diseases in non-UK populations'*** report published in 2006.

An example of the direct consequences of the Project is the establishment of the Technology Strategy Board's **Detection and Identification of Infectious Agents (DIIA) Innovation Platform** to which the DH is providing funding of £1 million per year over the five-year life of this £55 million project.

The above initiatives show the strong resonance that the Project had, and continues to have, with the Department's work and its evidence base remains relevant and continues to inform their work on infectious diseases.

Infectious diseases continue to pose a risk and the threat of a new influenza pandemic remains; the present winter of 2010/11 clearly shows the potential for this to occur. The Department maintains vigilance for new and emerging diseases with a **National Expert Panel on New and Emerging Infections (NEPNEI)** to have oversight of the risks to public health from such infections and consider their capability to detect and identify new infections. The panel takes a 'One Health' approach in such risk assessments.

4.2 Research Councils

Biotechnology and Biological Research Council (BBSRC)

The DIID report is now one of the many background documents and reports that underpin the development of BBSRC's priorities in the areas of food security, animal disease and one health. Since the Project ended, BBSRC has taken an increasingly global perspective in its research priorities on infectious diseases and health. It has developed a strategic priority in global food security and joint initiatives have been launched, with a number of funders, which address the priority. Much of this relates to the activities detailed in the DIID action plan. A significant component of the Report concerned the risks posed by new and emerging infectious organisms to plant, animal and human health in sub-Saharan Africa. BBSRC has run a joint initiative with DFID and the Scottish Government that is relevant to this area. It is also developing a '***One Health***' strategy that recognizes the importance of an integrated approach to human and animal health.

The Biotechnology and Biological Sciences Research Council has continued to work with Defra in delivering **the Institute for Animal Health - Pirbright Site Redevelopment Programme**. BBSRC has encouraged networking within its community in the area of exotic and emerging diseases through a workshop involving scientists from its '**Combating Viral Diseases of Livestock**', involving Defra and Scottish Executive Environment and Rural Affairs Department (SEERAD) support and '**Combating Avian Influenza**' programmes. Obviously genomic sequencing methods have moved on apace, and there is a clear recognition that we need to make influenza vaccine using modern methods that do not involve eggs. Scientists funded through MRC's pandemic influenza initiative also contributed.

The Animal Sciences Research Committee discussed the Report in the context of its Control of Infectious Disease (CID) Programme, which covered most of the relevant issues. The Agri-Food Committee and Plant and Microbial Sciences Committee also discussed the report. Systems biology approaches to study the animal or plant host response to infection were considered valuable and to be encouraged. The Studentships and Fellowships Panel will discuss implementation of the recommendations for multidisciplinary training later in 2007.

Animal disease research was made a priority area in awards for 2006 Travelling Fellowships. BBSRC is investing £10.15m in a **Combating Endemic Diseases of Farmed Animals for Sustainability Initiative**, with additional funding from industry, Defra and, possibly, SEERAD. The last round of the Rural Economy & Land Use (RELU) initiative, primarily funded by BBSRC, ESRC and NERC with contributions from Defra and SEERAD, focused on animal and plant disease research and policy advisors from relevant Government Departments were involved in the project selection process. Talks are underway between Research Councils on funding multidisciplinary research of relevance to global security, including plant and animal disease. These will all be informed by the Report.

In recent years, there has been an increasing recognition of the threats to human and animal health posed by new and emerging diseases. We recognise the importance of reducing the threats from infectious disease to address global health, and outbreaks from SARS in 2003, avian flu in 2006 and more recently pandemic H1N1 in 2009 has demonstrated how quickly a new disease can spread and threaten global health and economy. The Blue Tongue Virus episodes that we avoided in 2007/8 are a clear reflection of changes in vectors and their geographical ranges, caused in this case by climate change.

4.3 Business and industry - Technology Strategy Board

Technology Strategy Board (Dr Penny Wilson, member of the Project's Expert Advisory Group)

The Technology Strategy Board (TSB) was established by the UK government in 2006 and has invested more than £1 billion in innovative research projects for UK science, in knowledge transfer networks and partnerships and has co-ordinated pan-European initiatives (presently the 7th Framework Programme 2007-2013).

The TSB launched the Detection and Identification of Infectious Agents (DIIA) Innovation Platform in October 2008 and with a view to investing up to £50 million in activities over five years together with additional funding from government departments, particularly the Department of Health (DH) which will invest up to £5m, and the research councils. There was a *"broad consensus that the work [of the Project] should be taken forward, led to the development of this innovation platform".*

Foresight played a pivotal role in the establishment of this platform by bringing together the TSB and the diagnostic business community and supporting the development of the proposal. The Platform is soundly based on some of the outcomes from the Project which is highlighted in the associated brochure under the heading 'Background to the DIIA Innovation Platform"
http://webarchive.nationalarchives.gov.uk/20130221185318/www.innovateuk.org/_assets/pdf/corporate-publications/tsb_detectionidentificationinfectiousagentsinnovationplat.pdf

(http://www.innovateuk.org/_assets/pdf/corporate-publications/tsb_detectionidentificationinfectiousagentsinnovationplat.pdf)

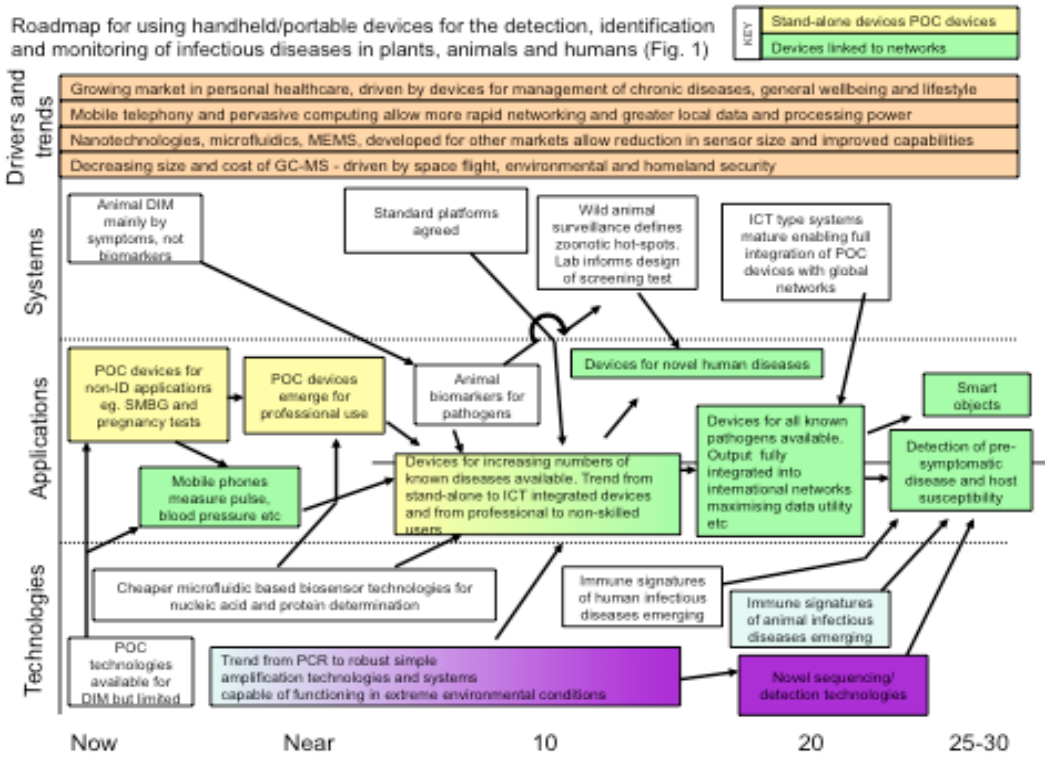
The DIIA Innovation Platform aims to encourage the development, uptake and adoption of clinically useful, commercially viable diagnostics for the detection and identification of infectious agents in humans and animals.

More rapid and accurate diagnosis of infectious diseases can lead to targeted and more efficient treatments with improved outcomes that will reduce the social and economic impact of infectious agents and create opportunity and wealth for UK industry.

In the first competition, 26 feasibility studies were supported for technology approaches to investigate the diagnostic potential of biomarkers (including volatile organics), immunodiagnostics, molecular diagnostics, microfluidics, biosensors, multiplexing capability, systems integration and wireless technology, with many of the technologies supported being equally applicable for the detection of human, animal and plant pathogens. The greater focus has been on point-of-care/near patient/penside tests (identified in the Project in User Challenge “UC3”).

The TSB's DIIA programme has valued the roadmaps produced for the Foresight DIID.

Figure: Roadmap for using handheld/portable devices for the detection, identification and monitoring of infectious diseases in plants and humans



4.4 Academia

The Innogen Centre & ISSTI. University of Edinburgh (Professor Joyce Tait)

The vast amount of data that were generated from the expert consultation on the infectious diseases of humans, animals and plants from the three different continents (Europe [UK], sub-Saharan Africa and Asia [China]) revealed complex roadmaps which required a novel approach to risk assessment.

This analysis was undertaken by Professor Joyce Tait and her team at the Innogen Centre in Edinburgh. Since the launch of the project, Professor Tait has presented her risk analysis to a number of relevant meetings. A most significant outcome has been a major research project, jointly funded by ESRC and Dept of Health.

University of Edinburgh (Professor Mark Woolhouse, member of the Project's Lead Expert Group)

The Project was an enormously valuable exercise catalysing an important change in the field, with greater commitment to both research and policy on issues connected with DIID. The Report is widely refereed to at infectious disease meetings of all kinds, and this continues almost five years later. The specific issue of the emergence of new infectious diseases or novel variants is considerably better researched and better understood than it was in 2006. None of that work suggests other than that emerging infectious diseases continue to be a significant, but inherently unpredictable, threat to human, animal and plant health.

In epidemiology, the next few years will see considerable progress with 'smart surveillance' in a variety of infectious disease contexts; this was a direct impact from the Report.

The main impact of the Report on the research community was to bring the topics of diagnostics and surveillance much higher up the academic research agenda than previously. In the past, these topics were simply not 'sexy'; now there is greater recognition of their importance and relevance with several research projects now designed to improve the design of disease surveillance systems (for human influenza [funded by the Scottish Government], foot-and-mouth disease [DEFRA] and bovine TB [Scottish Government]) and this work will continue.

The US National Academies report 'Sustaining Global Surveillance and Response to Emerging Zoonotic Diseases' published in 2009 also picked up many of the themes from the Report. Several major funding initiatives, including the USAID PREDICT programme and the EU EMPERIE programme, reflect a greatly increased recognition of the importance of DIID in public health, especially in the context of emerging diseases. Disease surveillance is also a major theme of the EU EPIZONE initiative on animal health.

The very wide engagement of the scientific, public health and policy-making communities did a lot to guarantee 'buy in' from those communities. The political impact was also very helpful (e.g. Moscow G8 summit) in focusing attention on the importance of the report.

University of London, Department of Social Policy, London School of Hygiene & Tropical Medicine (Professor Tony Barnett, member of the Project's Expert Advisory Group)

Professor Tony Barnett was the leading social scientist on the DIID project.

Whilst the sciences directly related to detection and identification of infectious diseases (e.g. microbiology, virology, molecular biology and epidemiology) was strongly represented within the Project, this was less apparent for **the social sciences**. Their importance became clearly evident when aspects of sample taking, vaccine administration, and the acceptance, delivery and surveillance of disease control programmes were proposed. For instance, taking blood samples in certain African countries were tantamount to restricting male potency whilst vaccination was likened to giving life-threatening infections.

The Project brought the social sciences into the debate. It has subsequently, since its launch in 2006, broadened and expanded the research efforts at LSE with a large project on avian influenza and also work on TB. In addition, led to recruitment of three doctoral students currently pursuing work on: a) local level studies of wet markets and poultry in Indonesia (b) the role of conspiracy theories in understanding HIV transmission in South Africa (c) the potential of the England and Wales coroners' service in communicable disease and London International Development Centre (LIDC) on the social sciences of infectious diseases. The details of these are available on the LSEAIDS and LIDC websites.

From this series has flowed a successful grant application to NERC ESEI programme (Environmental & Social Ecology of Human Infectious Diseases) to prepare a study of zoonotic niches in pig and poultry production in the Mekong Basin. This is led from London School of Hygiene & Tropical Medicine and is a large co-operative effort between LSE, LIDC, LSHTM, Sussex and RVC.

The Project has had a longer term and continuing impact on the social science/infectious diseases debate. Furthermore, the work on the mathematic modelling of infectious diseases has produced an entirely novel and important manner of interrogating the sociology of mathematical modelling (see Erika Mansnerus, http://www.lse.ac.uk/collections/CARR/aboutUs/staff/mansnerus.htm).

Royal Veterinary College (Professor Joe Brownlie, member of the Project's Lead Expert Group)

A distinct outcome of the Project was highlighting the high risk of new and emerging diseases and understanding that a high percentage of these had animal origins and reservoirs. This inevitably has examined the linkage between medical and veterinary research and surveillance. To some degree, this is overseen by **National Expert Panel on New and Emerging Infections (NEPNEI)**, on to which a number of veterinarians, including Defra staff, have been appointed. Moreover, the veterinary schools have made progress in the "One Health' agenda with a number of recent initiatives to strengthen their impact.

The Royal Veterinary College (RVC) is a co-applicant of the Wellcome Trust **Southern African Centre for Infectious Disease Surveillance (SACIDS)** programme in Southern African and has been influential in developing SACIDS new 'One Health' teaching modules for African Universities. The London School of Hygiene and tropical Medicine (LSHTM) and the RVC are partners to the Rockefeller Foundation Project grant to

support efforts by the SACIDS to map health system resources and their potential for mobilisation in response to pandemic influenza and other emerging infectious diseases in the human and animal sectors of two African countries, to inform efforts in the border region of Southern and East Africa.

The College is also developing its contribution to the One Health debate, recently creating a new position of Professor of Wildlife Health and Emerging Diseases with particular regard to Africa. The Professor will have some leadership for the development of the '**Wildlife Health Bridge**' which links UK, East Africa and India and is part of the new '**Emerging Pandemic Threats**' Initiative, particularly its RESPOND programme, which is funded by the $480M USAID programme.

A collaborative project aimed at developing risk management strategies for avian influenza in selected South-East Asian and African countries was conducted a number of international organisations (International Livestock Research Institute, International Food Policy Research Institute FAO and University of Berkeley) including the Royal Veterinary College. The project was funded by UK DfID with a total ward of US$6 million.

The threat associated with the continued spread of African Swine Fever for European pig producers has lead to the '**ASFrisk project**' which is aimed at developing improved diagnostic and risk management tools for this important and emerging (in a geographical dimension) disease.

The EU funded **EPIZONE** network of excellence, aimed at enhancing collaboration between EU research institutions involved in infectious disease research and external partners, supports and aims to improve countries' preparedness for dealing with infectious disease outbreaks. Professor Dirk Pfeiffer (RVC) is a member of the external advisory board. Furthermore, the RVC now conducts a systematic review for DfID into wildlife/domestic livestock interactions in context of zoonotic disease risk.

4.5 International

What distinguished this Project from previous Foresight studies was its international dimension. This was inevitable considering the global nature of infectious diseases and the constant risk of their introduction into the UK from overseas. In retrospect, the Project could not have been more timely. The appearance of avian 'flu during the project and subsequently, the arrival of Bluetongue, swine 'flu and sudden oak death, have all clearly illustrated its importance. The vision to encompass human, animal and plant health was empowering, thereby permitting the project the distinction to link a larger scientific and political audience not attempted before. The focus on sub-Saharan Africa was unique amongst international disease future projects and, as a result, was able to influence and benefit the developing world in a way not achieved by previous programmes. Two of the notable impacts either directly, or certainly catalysed by, the Project have been LIDC and SACIDS.

Beyond the establishments of LIDC and SACIDS, the project has been a benchmark for other national Foresight or programmes, most notably Canada and Southern Asia.

At the highest political level, the Project influenced the need for global awareness of the risks of infectious diseases and the need for co-ordinated action. This was highlighted at two G8 conferences (Moscow 2006 & Germany 2007) and has also by several International organisations (WHO, FAO and WOAH).

G8 – St Petersberg Communiqué, Russia 2006

Fight Against Infectious Diseases

We are aware of the heavy toll taken by infectious diseases on societies and economies around the world. In our statement we underlined principles and proposed actions to halt the spread of epidemics. We addressed a range of challenges including limited access to prevention and treatment, inadequate capacity of health care systems, resource constraints and the shortage and significant outflow of qualified health workers, especially in developing countries.

We will seek to enhance international capacities to monitor and respond to outbreaks of infectious diseases through establishment of new laboratories and strengthening WHO Global Outbreak Alert and Response Network.

Aware of the threat posed by avian influenza, we will cooperate closely with each other and with relevant international organizations and other partners in preparing for a possible human influenza pandemic. We called on donors to honor commitments made at the International Pledging Conference on Avian and Human Pandemic Influenza. The G8 members also welcomed the Russian Presidency's proposal to establish the WHO Collaborating Centre on Influenza for Eurasia and Central Asia to enhance international capacity to counter the spread of the viruses recognises the importance of strong coordination between human and animal health services … a need to strengthen animal health services and laboratories, encourage better monitoring of the wild life animal population, enhance virus detection and research, improve inspection and support outbreak containment plans through the teaching of good farming practices. (HTTP://en.g8russia.ru/docs/10.htm)

G8 – Heiligemdamm, Germany 2007

Fight against Infectious Diseases

“A further set of measures is thus to be introduced to promote sustainable development in Africa. The leading industrialised nations have made the following commitment: "We will focus on promoting growth and investments in order to combat poverty and hunger, to foster peace and security, good governance and the strengthening of health systems, and to assist the fight against infectious diseases."

US$60 billion to combat infectious diseases

“Over the coming years the G8 will be making a total of US$60 billion (around €44 billion) available to combat HIV/AIDS, malaria and tuberculosis. This is to be used to safeguard universal access to comprehensive HIV/AIDS prevention programmes, treatment and care, and to develop health systems at local level. Particular attention in the fight against infectious diseases is to be paid to the needs of adolescent girls, women and children.” Germany will be providing €4 billion to support efforts to combat these illnesses.

London International Disease Centre (LIDC) (Professor Jeff Waage, member of the Project’s Lead Expert Group)

The LIDC was initiated by London School of Hygiene and Tropical Medicine and launched in 2007. Its first Director is Professor Jeff Waage, who was one of the four co-ordinating scientific advisers (“lead experts) to the DIID programme. The road-maps that emerged from the Project with its strong recommendation for an integrative approach to

future problems of emerging diseases by linkage across the silos of human, animal and plant sciences have influenced the direction of LIDC. LIDC has pulled together the skills of six London academic establishments by:

- developing interdisciplinary research and training programmes to address complex international development challenges. Addressing these challenges effectively often requires working across sectors, such as education and health, or between disciplines, such as sociology and economics. With partner institutions in low and middle-income countries, LIDC builds initiatives on such subjects as climate change, HIV/AIDS, migration, and emerging diseases.

- LIDC's constituent Colleges are Birkbeck, Institute of Education, London School of Hygiene and Tropical Medicine, Royal Veterinary College, School of Oriental and African Studies, and The School of Pharmacy. Collectively, these specialist Colleges have enormous depth of development-related research and training in education, health, agriculture, environment, law and business sectors, with disciplinary expertise ranging from clinical and veterinary medicine to economics, anthropology, sociology and history. LIDC was established in 2007 with a grant of £3.7m from the Higher Education Funding Council for England (HEFCE), and it now has more than 1,000 staff, students and alumni members from its constituent Colleges.

The impact of the Project has continued to grow, as has the impact of LIDC. Researchers, policy makers and development professionals consider that the Foresight project has contributed three key 'new' ideas: (1) the acceptance, due to the report, of the importance of integrating natural and social science in work on disease futures, (2) the need to address disease emergence issues in Africa as a global public good and (3) the acceptance that a 'one health' approach was the rule, not the exception (particularly amongst non-experts)

The project has influenced the development of LIDC, also new initiatives like the Leverhulme Centre for Integrative Research on Agriculture and Health, and SACIDS. Also LIDC has seen substantial changes in the way research on infectious disease is viewed more broadly (across scientific disciplines and between natural and social science) in the UK research councils, Wellcome Trust and DFID. But attribution becomes difficult after time, and the Foresight impact is hard to separate from recent general trends towards inter-disciplinarity, one-health thinking, new diagnostic platforms and more and more-out-of-box work on pandemic disease threats.

Africa

Possibly one of the most important impacts of the Project has been within sub-Saharan Africa. The extension of this Foresight programme into Africa (https://www.gov.uk/government/publications/infectious-diseases-preparing-for-the-future-africa) was both novel and unexplored. To develop any substantial and sustainable impact was always going to be a challenge; to champion a multi-national Centre within Africa was not even on the horizon when the project started in 2004! However, it did become one of the Project suggested outcomes in 2006, if only as a network. In the years since the launch, a great deal of negotiating skill and effort has been directed at capitalising on the DIID African Risk assessment to persuade both the African organisations (particularly one of the premier organisation in Africa – **the African Union** [AU]) and the international funding agencies (most notably the **Wellcome Trust** and the **Rockefeller Foundation**) to support such an initiative. The LSHTM and the RVC are partners to the Rockefeller Foundation Project grant to support efforts by the SACIDS to

map health system resources and their potential for mobilization in response to pandemic influenza and other emerging infectious diseases in the human and animal sectors of two African countries, to inform efforts in the border region of Southern and East Africa.

From this partnership, the SACIDS was both conceived and delivered. Without the resolve and support of the Foresight team and the extra-ordinary leadership of one of the African DIID team members (Professor Mark Rweyemamu), it is unlikely that such an outcome would have been possible. Professor Mark Rweyemamu has now become the first Director of SACIDS.

Southern African Centre for Infectious Diseases (SACIDS) (Professor Mark Rweyemamu)

The Director of SACIDS considers that five years after the Report, its findings remain a key point of reference. The report influenced thinking about infectious diseases in both developed and developing countries. In Southern and Eastern Africa the concept of inter-sectoral collaboration between public and animal health sectors became better debated among scientists far more than within official national and regional organisations. The greatest difference between the present and previous African initiatives (not Foresight) is that Project provided the scientific rationale and risk assessment to provide the basis for an African-lead proposal that would be driven by African leaders.

The Centre has already been the catalysed to increase collaboration between the public and animal health sectors thereby increasing attention to infectious disease issues in Africa. ‘One Health’ goals continues to gain momentum

The formation in January 2008 of the **SACIDS**, which links academic and research institutions involved with infectious diseases of humans and animal and the ‘smart linkage’ with Colleges of the University of London that form the London International Development Centre has stemmed directly from the recommendations of the Foresight report of infectious diseases.

A similar approach is being developed in Eastern Africa with the formation of the **Eastern African Centre for Infectious Disease Surveillance (EACIDS)**. After four years of debate within the African Union, the Science and Technology Research Commission of the AU has now tabled a proposal to the AU Commission for the formation of the **African Centre for Infectious Disease Surveillance**. One of the key objectives of such a centre will be to stimulate the formation of regional networks along the lines of the SACIDS.

In the 2010/2011 academic year the SACIDS launched the **first molecular biology ‘One Health’ MSc in Africa**. The **second ‘One Health’ MSc** to be launched in 2011-2012 will focus on **epidemiology**.

Funding agencies are increasingly paying attention to infectious diseases across public and animal health sectors and addressing disease at source in Africa. The ‘One Health’ movement is largely across human and animal health and the environment more than directly with plant health. There is little evidence of enhanced attention to plant pathology or interaction between studies on infectious disease of plants with those of humans and animals. Philanthropic funding agencies have more readily taken the challenge of cross-sector funding and targeting institutions in the endemic settings of developing countries than official governmental funding agencies.

Global response where there is infectious disease risk to OECD countries has improved; however, the developing capacity in the endemic settings of developing countries is still slow.

Canada

In January 2009, a workshop was held in Ottawa, under the aegis of the Canadian Food Inspection Agency, to form a Foresight Initiative to apply 'foresight to managing future challenges' to Canadian Animal Health. This programme - Fore-Can (http://forecan-precan.ca/content/fore-can-strategic-alignment-foresight-action) - was 'to help Canada better anticipate, prepare for and respond to future risks to animal health'. It is to be a three-year programme that has already started with the workshop in January 2009. The Project was an important reference point for this programme and its co-ordination team were invited to give keynote lectures (Professor Joe Brownlie & Dr Penny Wilson) to the meeting. It was considered that this has greatly helped and influenced the For-Can programme, which now continues to make good progress.

Southern Asia (Bangladesh)

The impact of the Project has certainly helped catalyse other national foresight programmes. One of the exciting developments has been in southern Asia. In March 2008, a national meeting was held entitled '**One World, One Health – Bangladesh Initiative**'. It was acknowledged that the Project had been a primary stimulus for this programme and, at the March meeting in Chittagong; the Project was presented (Professor Joe Brownlie) and debated in full. Since that time, the programme has widened to six countries in Southern Asia (including Bangladesh, India, Pakistan, Nepal and Sri Lanka) and been re-titled '**One Health Alliance for Southern Asia (OHASA)**'. In April 2010, a meeting was held in Dhaka for all Chief Medical Officers and Chief Veterinary Officers in these countries to discuss an 'EcoHealth Alliance'. The programme is actively supported by *EcoHealth Alliance USA*, formerly *Wildlife Trust* (http://www.ecohealthalliance.org/health/28-predict_program).

Thailand

In 2006, the Asia-Pacific Economic Cooperation Centre for Technology Foresight (APEC CFT) proposed a foresight study on those new technologies and approaches needed to combat the threats of human and animal diseases. The proposed time horizon was to 2017, i.e. about a 10-year forward look. In 2008, an extensive Report of the project was produced entitled "Roadmapping Converging Technologies To Combat Emerging Infectious Diseases" by the APEC CFT and the National Science and Development Technology Agency in Bangkok, Thailand (www.apecforesight.org). Dr Penny Wilson from the Project was invited to be a collaborator and advisor on the project.

The conclusions of this project were highly redolent of those of the Project and with a review of an identical series of 8 categories of diseases considered (with new diseases as the first mentioned threat). The APEC CFT project took their review further into diagnostics, tracking and treatments (particularly vaccines) than the Project.

4.6 Impact-limiting factors

When considering the expert opinion invited for the Review, it is valuable to keep in context the scope and ambitions of Foresight projects. They are not empowered either to make policy or to award funding for initiatives or research. The ambition is to look forward to identify risks to the UK, evaluate the importance of those risks, look across

science/technology disciplines to identify potential solutions and hope to influence stakeholders to take some 'ownership' of the outcome of their review. There is sometimes a mismatch between influence and ownership. The views expressed here are those of some of the stakeholders who contributed to this Review

The 'forward look' and the speed of science

The Project was asked to look forward up to 25 years ahead. In the intervening years since the project launch in 2006, the risks have not diminished and give added weight to the conclusions that new and emerging (sometimes a geographical new emergence) diseases continue apace. It might be said that the global integration of surveillance has diminished the risk of transmission of diseases more widely but their emergence continues. It is encouraging that, since 2006, a number of international Initiatives and Organisations have been created or established (e.g. SACIDS, EPIZONE and LIDC). The Project is an acknowledged reference for these initiatives.

The science and technology identified in the Project has moved rapidly. The Report did not predict just how fast some of the molecular technologies would advance and, just as relevant, how affordable they would become: multiplex PCR and high throughput sequencing being two examples. It remains to be seen how quickly these will be incorporated into routine diagnostic practice. The first line of surveillance, for many diseases, remains clinical assessment (increasingly by remote services such as NHS Direct), and that seems unlikely to change in the near future.

The user challenges outcome had predicted the advance of mobile telephonic technology into the field of disease data capture, which has happened and has the potential to play an important part in the disease surveillance in the developing world.

Risk and roadmaps

The risks of emergence of new diseases remains but possibly the public perception of that risk may have increased. However, it might be arguable that the risk of wider transmission of new diseases into epidemics, or even pandemics, may have decreased because of coordinated monitoring and control measures, as swine 'flu has shown.

The novel and extensive roadmaps, constructed during the project, have attracted much attention and been utilised internationally as a resource base. However, it would have been valuable to have interrogated them more completely. They remain a strong point on which to focus in the future.

Cross-sector collaboration

The ambition, clearly outlined in the Project's conclusions, to break across the sectoral barriers of medical, veterinary and plant agencies ('silo-busting') has had less long-term impact than hoped. The closer integration, since 2006, of human and animal disease surveillance and research can be demonstrated in several aspects of the 'One Health' Agenda and the cross-cutting research programmes developed by Defra, BBSRC and funding agencies such as Wellcome Trust. However, there is as yet relatively limited funding which directly targets cross-sector collaboration. There is also limited funding which targets directly institutions in the endemic settings of developing countries. Both of these could impede the rate of development of effective partnerships across the health sectors (human and animal) and between developing and developed countries.

International agencies such as the WHO, FAO, OIE appear to have been slow in setting up an inter-agency body for coordinating issues of infectious diseases.

The intention of the Project to incorporate plants into the cross-sectoral collaboration on infectious disease detection, identification and surveillance has occurred only in a limited fashion, most notably the Defra 'BioChip' project. It is to be regretted that the sciences, particularly the molecular sciences, that are evidently shared by all three sectors (human, animal and plants) have not encouraged a greater cross-fertilisation of discussion and thinking by both their protagonists and their funders. It has been stated that "there is an inertia for uptake of new diagnostic systems and a resistance to change and innovation (largely because many organisation are publically funded and managed by state institutions)."

International uptake of DIID outcomes

The international impact of the Project was excellent, if not 'spectacular'.

The impact on other countries can be seen in the wide uptake and reference to the Report and, in several cases, undertaking their own Foresight exercise on infectious diseases (USA, Canada, Asia-Pacific countries and the Indian sub-continental countries).

The most important long-term benefit may be the establishment of the SACIDS funded by the Wellcome Trust. It is yet to be seen whether this Centre is able to generate sufficient funds and collaborations to provide a long-term sustainability. Its recognition by the AU as a new key institution in Africa is promising.

UK uptake of DIID outcomes

To some degree, the communication of the Foresight projects relies on advocacy. After their public launch, the uptake of the content and outcomes is encouraged by dissemination activities, and follow up initiatives. This takes time but should diminish their longer-term importance. It does, however, make the evaluation of impact more difficult to access.

If there was some criticism, it would not be from lack of imaginative and innovative but whether the project made best of the very large amount of information assembled. It would be useful to know whether and what were the results of each stream and work package. This was not always clear and final communication with the large number of contributors was diffuse. Inclusion of a very small number of social scientists was valuable but more might have been included and more made of such contributions. There was no opportunity to interrogate the status and methods of mathematical modelling.

The recent constraints of public spending imposed through the current Comprehensive Spending Review settlement could be said to make collaboration and innovation in DIID more important than ever, with an added need to deliver ever better value for money and priorities where resources are applied. The essential infrastructure that supports the facilities for disease surveillance i.e. the biosecure containment facilities for medical (Porton Down) and veterinary (Institute for Animal Research, Pirbright) need to be securely funded and strategic partnerships across the sectors need to provide a joined-up and cost-benefit approach to emerging zoonotic diseases.

DIID and the social issues

The delivery and take-up of novel diagnostic and surveillance technology relies to some extent on community 'buy-in'. The failure to understand the social impact of this renders the delivery of new technology less successful or significant. The Project, although advised by prominent social scientists, possibly needed to explain and share more fully

the advanced technology relating to disease detection and surveillance and better engage with the wider social science community “albeit one with which it is difficult to create common intellectual links”.

What about border control and trade?

The global nature of infectious diseases means that international cooperation and agreed overarching governance is key to decreasing the spread and impact of infectious agents. This was not sufficiently highlighted with regard to border control and trade; the implication here is that if one had had more manpower and better applied technology, more disease control could be undertaken, particularly through non-invasive means. There could have been a stronger impact following the UC4 challenge.

5. Conclusions

The Project attempted a grand challenge; to identify future risks from infectious diseases across three continents and across three disciplines and, thereafter, evaluate the research and technology that might reduce such risks. The conclusions of the Project and the One-year Review have been published. This mid-term review shows that further and, in some cases, impressive progress has been made in affecting change and influencing policy in Governments, their departments and funding organisations. It would appear that the principal finding of the original Report, that there is a continual emergence of diseases and that the majority of new human diseases are zoonotic, has proved accurate thus far. The Report has remained an enduring point of reference for the 'One Health' Agenda.

The deep analyses of the pathways, drivers and outcomes of infectious diseases have had an influence at the International level (with impact on two G8 summits). Further similar Foresight programmes by other nations have valued this Report as a formative source of information. To date, this would include Canada, USA, the Indian sub-continent and a number of sub-Saharan countries. Possibly the greatest measurable success has been in the sub-Saharan countries.

The establishment of the SACIDS was a direct consequence of the inclusion of sub-Saharan countries into the initial Foresight programme and the dedicated follow–on support from the Foresight Team for workshops and meetings with African stakeholders and appropriate funders. The present funding is provided by both the Wellcome Trust and the Rockefeller Foundation. It is clear that the SACIDS Initiative has, in turn, now influenced the further development of an East African country consortium to establish an East African Infectious Disease Centre; this has the potential to widen further across sub-Saharan Africa.

At the national level, both Defra and MH Government Departments have accepted the Report as a valued reference to engage with the One Health Agenda. A limited number of funding opportunities have been created.

For such an ambitious project, it is to be expected that impact would be limited in some defined areas. It was clear that the importance of the social sciences in both the uptake and delivery of new technologies was not adequate. To some extent, this is an under-resourced area of science with regard to infectious disease and reference data is not substantial. More research is needed to facilitate better uptake of relevant new technologies, whether diagnostics, vaccines or screening systems.

Some technologies moved faster than predicted in the Report, particularly the molecular sciences and telephony, where the recent possibility of combining both to provide immediate, and yet distant, surveillance is a striking technological advance.

The ambition to provide a platform for cross-cutting approaches ('silo-busting') to disease research, technology and surveillance has had limited success. The advantages of such collaborations seem obviously beneficial, as stated in the Report, but there is appears to be little substantial movement between departments to realise such advantages.

Many stakeholders and experts consider that looking ahead some 25 ahead in such an unpredictable and dynamic subject as emerging infectious diseases is unlikely to be

accurate. A more fruitful approach might be to review again within a shorter time interval the progress of both the new technologies and the new diseases.

The intention to more closely link the medical/veterinary disease research with that of plant disease research did not materialise to any lasting extent. This largely reflects the close relationship between the human/animal pathogens and the lack of related plant pathogens, even though the technologies have much in common.

Finally, if Foresight is a ‘process (which) involves intense iterative periods of open reflection, networking, consultation and discussion, leading to the joint refining of future visions and the common ownership of strategies’, then the Project has been visionary and has strongly encouraged ministerial ownership.

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