ROADMAP

Rethinking of antimicrobial decision-systems in the management of animal production

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Report on desired outcomes for interventions of the key stakeholders, associated data, and data collection protocols

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DELIVERABLE D5.2

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About the ROADMAP research project

The overall aim of ROADMAP is to **foster transitions towards prudent use of antimicrobials (AMs) in animal production in different contexts to manage antimicrobial resistance (AMR). Prudent antimicrobial use (AMU) will be achieved by enhancing antimicrobial decision-systems along the food and drug supply chains.** ROADMAP will focus on supporting animal health and welfare through prevention and health promotion actions.

AMR is recognized as a significant threat to global public health and food security. Overuse and improper use of AMs in many parts of the world contribute to the emergence and spread of AMR. Although human and animal health require AMs, it has been estimated that two thirds of the future AMU growth worldwide will be in animal production. Improving the management of AMU in farm animals is therefore a critical component of dealing with AMR and optimizing production in the livestock sector. Nevertheless, the variety of contexts of AMU in the livestock sector is a major challenge to managing AMR. **There is no "one-size-fits-all" solution to improve AMU and strategies must be contextually developed** (for instance, strategies used in the Danish pig industry are difficult to adapt and adopt in the French free-range poultry farming). Successful solutions must be combined and tailored to the production systems and the social and economic context in which they operate.

ROADMAP will meet three general objectives, in line with the EU AMR Action plan: i) **Rethink AM decision-systems and animal health management**; ii) **Develop options for encouraging prudent AMU in animal production**; iii) **Engage all actors in the food and drug supply chains in fostering a more prudent use of AMs.**

Project consortium

Part. N°	Participant organisation name (acronym)	Country
1	Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE) **	France
2	Association de coordination technique agricole (ACTA) ***	France
3	Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) **	France
4	University of Liverpool (ULIV) *	United Kingdom
5	Cardiff University (CU) *	United Kingdom
6	James Hutton Institute (HUT) **	United Kingdom
7	Alma Mater Studiorum - Università di Bologna (UNIBO) *	Italy
8	Aarhus Universitet (AU) *	Denmark
9	Eigen Vermogen van het Instituut voor Landbouw en Visserijonderzoek (EV-ILVO) **	Belgium
10	Research Institute of Organic Agriculture (FiBL) **	Switzerland
11	Stichting Wageningen Research (WR) *	Netherlands
12	Swedish University of Agricultural Sciences (SLU) *	Sweden
13	Southern Agriculture and Horticulture Organization (ZLTO) ***	Netherlands
14	European Forum of Farm Animal Breeders (EFFAB) ****	Netherlands
15	Fundacion Empresa Universidad Gallega (FEUGA) ****	Spain
16	Dierengezondheidszorg Vlaanderen (DGZ) ***	Belgium
17	INRAE Transfert (IT) ****	France

** Universities/veterinary schools*
*** Research institutes specialized in both fundamental and applied agricultural and veterinary sciences*
**** Public and private advisory services Organisations*
***** Knowledge transfer and Innovation organisations*

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List of acronyms and abbreviations

AB – Antibiotics

AHDA - Animal Health Distributors' Association

AHE – Animal Health Europe

AHWBE - Animal Health and Welfare Board for England

AM – Antimicrobial

AMEG - Antimicrobial Advice ad hoc Expert Group

AMR – Antimicrobial Resistance

AMU – Antimicrobial Use

ANMV - Agence Nationale du Médicament Vétérinaire

ANSES - Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail

CEA – Cost Effectiveness Analysis

CIA – Critically Important Antibiotics

CS – Case Study

CVMP - Committee for Veterinary Medicinal Products

DAH - Department of Animal Health

Defra - Department for Environment, Food & Rural Affairs

DGAL - Ministère de l'Agriculture et de l'Alimentation

DLP - Department of Livestock Production

EC – European Commission

EFSA - European Food Standards Agency

EGGVP - European Group for Generic Veterinary Products

EMA - European Medicines Agency

ESVAC - European Surveillance of Veterinary Antimicrobial Consumption

EU – European Union

FAO - Food and Agricultural Organisation of the United Nations

FVO – Food and Veterinary Office

GMP - Good Manufacturing Practice

ISS - Istituto Superiore di Sanità

IZS – Experimental Zoo-prophylactic Institutes

LHU – Local Health Unit

LL – Living Labs

MOH – Ministry of Health

NOAH – National Office of Animal Health

OIE - World Organisation for Animal Health

RCVS – Royal College of Veterinary Surgeons

RESAPATH

RUMA - Responsible Use of Antimicrobials in Animals Alliance

RVS – Regional Veterinary Service

SIMV - French association for animal health industry

VP – Veterinary Pharmaceuticals

WHO – World Health Organisation

1. Summary

The ROADMAP project aims at developing interventions/solutions for encouraging prudent antimicrobial use (AMU) in animal production. The objective of activities conducted under WP5 is to determine the costs of implementation and the impact on the critical outcomes required by the stakeholders across the food and drug supply chain using data collected by other work packages. The aim of this deliverable "D5.2" was to **determine the desired outcomes for interventions of the key stakeholders, associated data, and data collection protocols.** The Deliverable D5.2 is based on the impact assessment literature review (D6.1) and the case studies (D6.2) conducted in WP6.

Within WP1, stakeholder mapping was conducted and the key decision makers in the supply and use of veterinary pharmaceuticals in Europe, with particular reference to antimicrobials, were identified. Within WP6, "Literature review of impact assessment applied to changes in antimicrobial use initiatives" and "Impact assessment case studies selected and documented" were conducted. The data were collected from searches of the peer reviewed, grey literature, and supplemented by the case studies conducted by the ROADMAP partners. In this regard, the activity has been a collaborative, team effort. Data and information collected were summarised by the Liverpool and ENVT teams and the report produced will be the basis for multi-author and interdisciplinary publication.

The report describes the desired outcomes for interventions of the key stakeholders in different production systems and under different regulations. Different actors have expressed different desires and sometimes contradictions. When discussing reduction of AMU, farmers are concerned about animal welfare but at the same time, they are looking for premium price for AB free products. Farmers in some countries, where AMU is low, are not concerned about reducing AMU and AMR. Veterinarians in general are concerned about animal welfare. In countries where veterinarians allowed selling and prescribing AB they are concerned about the reduction of their income. These outcomes need to be reflected in an economic and social analysis of change in order to understand the economic feasibility and social acceptability of interventions. Such information should be useful in policy assessments.

2. Introduction

The aim of the ROADMAP project is to develop interventions/solutions for encouraging prudent antimicrobial use (AMU) in animal production. The objective of WP5 is to determine the costs of implementation and the impact on the critical outcomes required by the stakeholders across the food and drug supply chain. The objective of this deliverable "D5.2" is to determine the desired outcomes for interventions of the key stakeholders, associated data, and data collection protocols.

Information on desired outcomes among key stakeholders is necessary for development of the conceptual and analytic models for cost-effectiveness analysis (Rushton et al., 2016). To this end, WP5 aims to develop a CEA framework using stakeholder desired outcomes identified in WP2 (online survey and interview with farmers and veterinarians), WP3 and 4 (living labs), and WP6 (intervention impact assessment).

As the risk of AMR has the potential to be transmitted along the supply chain of animal products to the consumer, interventions aimed at risk mitigation should be inclusive of the different stakeholders involved in that process. Such a systems perspective takes into account how the behaviours of different people in the chain affect the supply and use of antimicrobials, and how they are affected by any proposed intervention. In addition, people from across the chain should be included in the process of risk assessment, mitigation and communication (Taylor and Rushton, 2011).

Within ROADMAP, synergies between Work Package 5 and Work Package 1 exist in the domain of stakeholder mapping. While Work Package 1 takes a holistic approach to the mapping of stakeholders, Work Package 5 complements this analysis with a focus on the supply side, identifying key decision makers in the supply of antimicrobials into livestock systems. This serves to purposes, firstly as part of investigating the functioning of the market, and secondly to later elicit preferences on potential interventions and outcomes. These results are to be included in a cost-effectiveness analysis (CEA) in the second half of the project. The user of CEA is able to define which measure of effectiveness is most suited to answering the question of interest. In the case of Roadmap, where the perspectives of different stakeholders are being given due consideration, CEA will allow effectiveness metrics to be chosen which reflect these different perspectives. It will therefore be possible to compare the economic incentives offered to stakeholders at different stages of the stakeholder chain by each different intervention proposed.

A summary of the CEA method is presented in Figure 1, illustrating how defining the determination of acceptable outcomes and perspective is a critical step in the analytical process. A framework for mapping antimicrobial users and decision makers across livestock systems is needed so that influential stakeholders can be identified, and desirable outcomes and appropriate metrics for effectiveness can be determined.

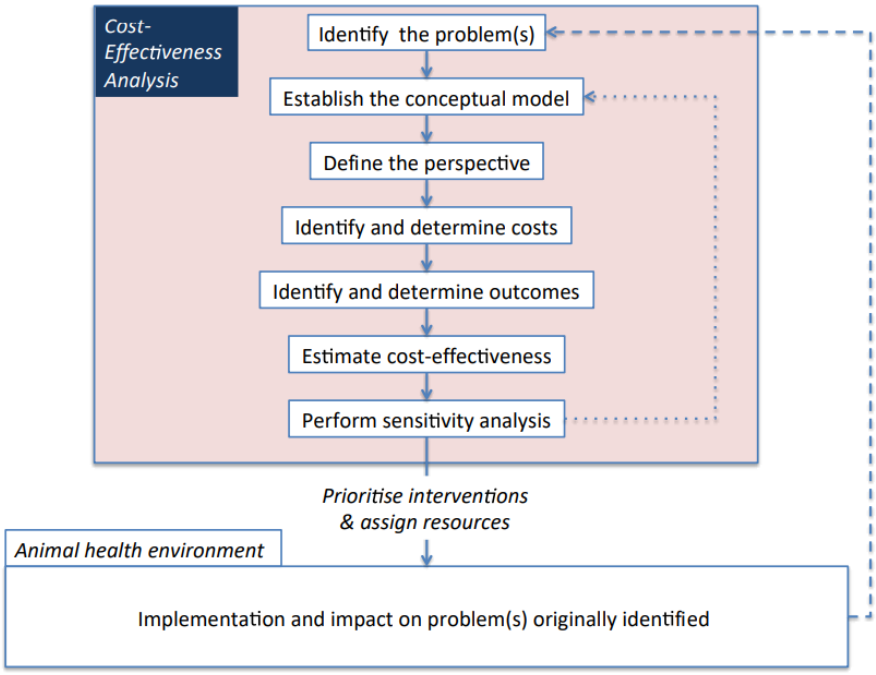

Figure 1. Method of application for cost-effectiveness analysis.

3. Method

For the determination of the desired outcomes of the critical decision makers, ULIV in collaboration with other ROADMAP partners (INRA, ACTA, CIRAD, HUT, UNIBO, AU, EV-ILVO, FiBL, WR, ZLTO, DGZ) have conducted semi-structured interviews to investigative the management and monitoring of antimicrobial manufacture, distribution and use across the livestock production systems of interest. For WP5, D5.2, the focus of the analysis was to summarise data on the desired outcomes of key stakeholders and organisations require on interventions for AMU, T5.3. Data from other WPs: WP1, WP2, WP6 / Links with Case Studies: CS 1, 2, 3 and Living Labs were used.

In WP1, University of Cardiff and the James Hutton Institute have conducted 12 and 16 online interviews with different stakeholders, respectively. Stakeholders were identified by scanning grey literature, pre-existing researcher knowledge and interviews conducted as part of WP2 (see below). The stakeholders were from the following categories: academic (veterinary sciences), agri-consultant, agri-tech entrepreneur, feed company rep (youngstock specialist), drug company rep (veterinary advisor), milk company rep (farm advisor), agri-tech entrepreneur, agricultural advisory board, nutritional company rep (youngstock specialist), veterinary consultant, agri-consultant/ farmer support group founder, vet, farmer organisation employee, and government employee. Outputs from WP6 particularly the impact assessment of CS and LL will be also utilised.

3.1 COVID-19 contingency

Many CS leaders anticipated difficulty in carrying out normal activities with COVID-19 causing restrictions on travel, meetings and interactions with stakeholders. As people and organisations have adjusted to the new circumstances, alternative arrangements are being made to resume the planned work. Given the timetable of the project however, CS leaders have been encouraged to submit data when it becomes available. Further information has been gathered by literature review, and a search of grey literature including government and commercial reports.

4. Results

4.1. Selection of Case Studies/LL for greater detail (See D6.2)

For the previous deliverable (D5.1) on stakeholder mapping, we looked at systems in France, Italy, and the UK as those case studies provided the most complete data via discussions in WP1.

While full ex-ante impact assessment will be conducted in WP6 for French and Italian productions systems as described in D6.2, there will only be a short ex-ante impact assessment done for the UK's marginal cattle production system. No other cattle production system will be fully assessed, and the only marginal system being fully assessed is the Vietnam marginal poultry system. We will therefore be short on data for the UK cattle system (unless we switch to the Vietnam poultry system) and will only be able to assess stakeholder desired outcomes. Note that the UK study is focused on calf-rearing, which is not the main source of AMU in the UK cattle system. Full ex-ante impact assessments will include stakeholder participation in mapping outcomes and producing impact pathways and impact indicators, which will all aid in providing a more complete, accurate CBA/CEA.

Country	**Production System**	**Impact Assessment**	**Living Lab?**
UK	Marginal Cattle	Short	Y – Calf-rearers
France	Conventional Pig	Long	Y
France	Conventional Poultry	Long	Y
Italy	Conventional/Label Pig	Long	Y
Italy	Conventional Poultry	Long	Y
Vietnam (tentative)*	Marginal Poultry	Long	

*The Vietnamese case study will not be identifying desired impacts until July-December 2021 (due to CoVid delays), so it likely isn't one we can use

**Note that the Danish Living Labs are furthest along and may be worth looking into to conduct CEA/CBA on conventional and/or organic systems of cattle and pig production

4.2. Key outcomes for decision makers

Desired impacts of AMU initiatives in the literature and across all case studies generally revolve around economic margins. Without understanding the exact intervention or targeted point in the production system for each case study, it is difficult to state desired impacts/outcomes and required data for assessment. We herein summarize the state of understanding of stakeholders and their motivations regarding AMU.

4.3. Overview of desired outcomes and actual outcomes of AMU initiatives in literature

Expected and actual outcomes and long-term impacts reported in D6.1, Boxes 2 and 3 as part of a literature review of AMU initiatives identified many outcomes related to knowledge, awareness, and behavior, but reported fewer quantifiable farm-level outcomes or impacts related to AMU or economic output. **These expected outcomes include decreased AMU and AM prescribing and increased use of AM alternatives.** Expected impacts include maintaining herd productivity levels, improving animal health, and improving surveillance of AMU. Despite limited mention of economic impacts among expected outcomes and impacts, the authors of D6.1 note that many initiatives attempted to quantify economic impact but were unable to accurately manage the complexities of such analysis.

Actual outcomes and impacts include those expected outcomes, as well as farm-level shifts towards a focus on biosecurity and use of technical innovation, higher economic performance, increased net profit, positive or neutral impacts on animal production, and positive or neutral impact on animal health. Negative outcomes reported include increase in mortality and disease, increase in therapeutic AMU to control disease, and increase in injectable and water-soluble AMU. Not all outcomes were experienced across all studies, and further details are provided in D6.1.

4.4. Stakeholder reported motivators and desired impacts per case study (including potential interventions)

Data from stakeholder mapping in WP1 (UK only), interviews on possible solutions in WP4, and impact assessment in WP6 is used here to summarize potential action points, influences, interventions, and outcomes among key case studies for farm-level CEA/CBA.

Reported solutions from D4.2 (from Italy, the UK, France)

4.4.1. UK marginal cattle

The UK case study has a narrow focus on calf-rearing within marginal cattle systems, which limits the impact of any intervention but may make construction of a model simpler. WP1 researchers identified motivators among key actors in this system. **Calf-rearers** may be motivated by animal welfare and emotive concerns, and have little overall influence in the system, but may influence the farmer on AMU. **Calf-rearing companies** are driven by a desire to maintain free movement and management of

calves and will likely not support AMU regulations that may alter their management strategies. **Veterinarians**, another group with high interest and influence in AMU, may be influenced by a need to generate income (via AM prescription) as well as a need to maintain legitimacy.

Calf-rearers, while having less influence, *do* make choices about daily calf rearing and recognize the importance in reducing AMU. They therefore may be able to reduce AMU where possible in their sphere of influence.

Sociotechnical solutions reported in D4.2 that could be implemented at farm-level:

1) Adaptation to calf pens that has been shown to be easier to clean, reducing mortality rates and the need for medical treatments.
2) Support programme offered by the Welsh government to provide business support to dairy farmers looking to reduce AMU.

Existing data from work in WP1 (T1.2) indicates that there are around 900 dairy farms in Scotland with an average of 200 cows each, and 7000 beef farms with an average of 23 cows. Farms in Scotland are typically family owned. In Wales, there are 2600 dairy farms with an average herd size of 95 cows. Once case study farmers are recruited, data will be collected at farm level on volume of annual livestock production, value of annual livestock production, number of livestock per farm and per working unit, the size of farmland, herd management systems, feeding systems, manure management systems, and information on animal lodging.

4.4.2. France

The single French Living Lab aim to use problem trees to explore alternatives to AMs and tools for AMU monitoring. Only one of these topics, chosen by participants, will be pursued to identify desired impacts.

Sociotechnical solutions reported in D4.2 that could be implemented at farm-level largely consist of voluntary awareness and accreditation campaigns. No programmes to provide business, technological, or economic support farmers or other stakeholders in reducing AMU were listed (though this does not mean they don't exist).

Conventional pig production: Key stakeholders (producers, vets, farmers, processors, retailers) representing 55% of French pork production have been interviewed regarding desired impacts, but these data and analyses have not been released yet from WP1 and WP2.

Conventional poultry: 15 stakeholders across the production and supply chain have been interviewed. **Farmers** view AMU as a way to minimize production loss risks, and are largely driven by cost/benefit ratios when deciding on AMU. **Technical advisors** have a balanced interest for the use of antibiotics. Their goal is to both satisfy PO's productive plans and to ensure that they keep a good legitimate influence over farmers to do so. **Veterinarians** are reliant on drug sales as a source of income, and may need to recover any loss of income associated with reduced AMU to support new initiatives to reduce AMU. **Producer organizations (PO)** can have strong coercive influence on AMU, but are also motivated by maximizing economic profitability. Again, reducing production risks associated with minimal AMU is key to getting POs on board. **The regulatory organization, French general directorate of food, (DGAL)** has interest in setting regulations that minimize AMU, but enforcement of these regulations is often slow or incomplete. **Pharmaceutical companies** are reportedly losing interest in AMs, but will still need to sell pharmaceutical products of some kind, such as vaccines.

4.4.3. Italy

Conventional pig: The Italian pig sector is highly fragmented, making implementation of new AMU practices difficult. The majority of AMU occurs during the weaning phase, which may be a key time point to target. COVID-19 has also increased interest in biosecurity measures. This interest could be used to spur action on reducing AMU as well.

Conventional poultry: The highly integrated Italian poultry sector recently (2017) drastically reduced AMU, which has led to a concurrent rise in the use of vaccines, prebiotics, probiotics, and organic acids. Further reduction of AMU faces constraints in that biosecurity measures cannot be implemented in some existing windowless infrastructure, and that AMU or currently given in feed and water, increasing environmental contamination and making it impossible to isolate and treat sick chickens apart from healthy chickens.

Across both pig and poultry sectors, Italian AMU is monitored with an online system that traces AM from production to administration. The high level of integration means that farmers have little choice over AMU, and the integrated companies are the ones who will determine (with the input of the company vet) when and how to use AMs.

Sociotechnical solutions reported in D4.2 that could be implemented at farm-level largely include education programs:

1) Education of farmers and veterinarians on animal welfare and prevention of aggressive behaviour. Includes topics such as tail cutting in pigs, evaluation of welfare and biosecurity in cattle, and feeding and welfare of pregnant sows.
2) Technological innovation in poultry farming to improve animal welfare and reduce AMU

Two living labs (one per production system) are in preparation, but it is unclear who will attend or what details on desired impacts will be collected.

4.4.4. Mozambique

The objective of the Roadmap Mozambican case study is to support the implementation of the NAP-AMR in the poultry sector, in collaboration with the association of the poultry farmers of the Province of Maputo (ADAM) and the Dinav (the veterinary national authority). Currently, there is no technical innovations to reduce AMU (no organic or AM free poultry). Innovations are related to the policy and regulatory process (revision in progress). In addition, the topic of AMR is being progressively included in the training of the veterinarians and zootechnicians.

Most activities of the Mozambique case study have focused on the analysis of the organisation of the veterinary drugs supply chain in general. Interviews with stakeholders of the veterinary drug market chain have been conducted (with importers, wholesalers and retailers, clinic etc.). Interviews with stakeholders of the public sector are in progress. The main impacts expected from the Roadmap project by these partners are: for Dinav, a support in implementing the National action plan, and more particularly in better quantifying veterinary AMU in Mozambique; for the ADAM members, a support in animal health through exchanges on a better use of veterinary drugs (beyond AMU).

4.4.5. Switzerland

Veterinarians were identified as relevant stakeholders in 2 case studies. They acting as a source of information for farmers and extension and as the governmental authority. They prescribe and sell AM's

directly to farmers, certain AM's can also be sold on stock to farmers (BLV, 2019a). For the latter case, the farmer and the veterinarian sign an agreement called "Tierarzneimittelvereinbarung" (TAM-V), which obliges the veterinarian to check the health status of the animals regularly and the farmer to use the pharmaceutical properly (BLV, 2019b). The profit margin of AM sales constitutes a considerable source of income for veterinarians. According to a study by Pont et al. (2020), veterinarians who support calf and veal fattening farms in Switzerland generate 82% of their profits from pharmaceutical sales. Moreover, the study revealed that 54% of these profits originate from AM sales. The study concludes that under the current system, a reduction of AMU in animal production would seriously decrease income in Switzerland's veterinarian practices. Pharmacies in Switzerland play only a minor role in AM dispensing. Even though pharmacies are allowed to sell AM to farmers, almost all veterinary pharmaceuticals are only available on prescription. Therefore, the share of pharmacies in AM sales in veterinary medicine is negligible (A. Maeschli, personal communication, 8 September).

For both case studies, the **organic farmers association** is relevant as a market actor and based on their impact on policy-making. The association funds research projects targeted on the needs of organic farmers and makes sure that farmers are involved in developing and executing such studies. Also relevant is the collaboration between farmers. In the case of organic pork, there is a weak collaboration between pig fatteners and pig breeders, and in the case of organic beef/veal there is no existing collaboration between milk producers and veal/beef producers. Contact between farmers is mediated by an animal trader. Contact between a farmer and his/her traders is often very close and trustful. In the case study on organic beef/veal, the focus lies on providing targeted extension services to farmers and improving the collaboration between farmers and veterinarians.

4.4.6. The Netherlands

Nine key informants were interviewed by telephone of which 2 turkey farmers, 1 farmer and veterinarian, 2 veterinarians, 1 employee of a German turkey integration, 1 person of a Dutch breeder company and 2 experts from Wageningen University and Research center. As part of WP6 tasks, a short online survey for participants to Living Labs (WP3) was conducted to gain insight in the desired outcomes. Interview of 8 participants as a part of WP3 LL activity (4 veterinarians, 1 farmer, 1 employee farmers organisation, 1 researcher, 1 feed advisor). Results are summarised in Annex 3 (D6.2.) Summary of survey desired impacts results for the turkey case study in the Netherlands. Participants were asked to respond to the following open questions:

Consider possible impacts in relation to AMU in the livestock sector in the coming 5-10 years. State how important you find the following impacts by giving them a score from 0 to 3 (0 no importance, 1 low importance, 2 average importance, 3 high importance). List other highly important impacts if they are not listed.

Farmers (1 participant): No additional highly important impact listed

Veterinarians and others (7 participants):

Other highly important desired impacts:

- Focus more on preventative instead of curative care

- Don’t focus on alternative treatment, more on preventing treatment

- Awareness of the effect of antibiotic treatment in the development of AMR and risk factors - Better communication that animal husbandry only has a small role in AMR development

- Steps in the production chain before primary farm and information about origin

Farmers (1 participant):

Impact	Importance			
	None	Low	Average	High
Consolidation of relationships between farmers and veterinarians			1	
Decreased antimicrobial use			1	
Improved access to information/training on alternatives to AM treatments				1
Improved awareness of farmers on the antimicrobial resistance issue			1	
Improved credibility and visibility of antimicrobial-free animal food products		1		
Improved farmers' income				1
Improved offer of antimicrobial use advisory services		1		
Improved perception of animal farming by the civil society				1
Improved state help for investments into alternatives to AM treatments		1		
Increased economic value of antimicrobial-free animal products			1	
Maintained good health of animals				1
Prevented increase of farmers' workload		1		
Prevented increase of the costs for maintaining animals healthy		1		

No additional highly important impact listed

Veterinarians and others (7 participants):

Impact	Importance			
	None	Low	Average	High
Consolidation of relationships between farmers and veterinarians			2	5
Decreased antimicrobial use		1	1	5
Improved access to information/training on alternatives to AM treatments	1	3	3	
Improved awareness of farmers on the antimicrobial resistance issue		2	5	
Improved credibility and visibility of AM-free animal food products	2	1	4	
Improved offer of antimicrobial use advisory services		4	3	
Improved perception of animal farming by the civil society		1	5	1
Improved state help for investments into alternatives to AM treatments	3	2	1	1
Increased economic value of antimicrobial-free animal products	1	2	2	2
Increased recognition of the role of veterinarians in the response to AMR	1	1	2	3
Maintained good health of animals				7
Prevented decrease of veterinarians' income	2	3		2
Prevented increase of veterinarians' workload	3	2		2
Prevented increase of the costs for maintaining animals healthy	2	2	2	1

4.4.7. Belgium

There is a delay in WP2 and WP1 activities due to Covid-19. Data from these activities could be used for identifying stakeholders' behaviours, practices, knowledge and motivations.

Data from literature:

• In Belgium, the highest consumption of AM is in the pig sector (Fillippitzi et al., 2014), with the main Factors for use are digestive disorders and streptococcal infections in piglets, as well as respiratory problems during the second half of the battery period (Callens et al., 2012).

• Pig farmers in Belgium often perceive their own antimicrobial usage as being lower than their peers in the same country, and lower than or comparable to similar farmers in other countries. Further, pig farmers in Belgium showed little concern over AMU and AMR (Visschers et al., 2015). Veterinarians in Flanders (main pork production region in Belgium), indicated that suboptimal climate conditions, poor biosecurity and farmers mentality were among the main reasons for high AMU in pig production (Postma et al., 2016).

• Veterinarians are more optimistic about possibilities for reducing AMU than farmers, and farmers intentions to reduce AMU were mainly associated with the feasibility of reducing AMU (Visschers et al., 2016a).

• Farmers reported AMU is associated with their perceived risks related to AMR. However, in general they perceive many benefits from AMU and only few risks (Visschers et al., 2016b).

• A systemic analysis of AMU in pig production revealed several systemic obstacles such as the provision of 'free' advice by feed mills and the fact that the business model of veterinarian was largely focused on the sales of AM (Rojo Gimeno et al., 2018).

4.4.8. Denmark

Pigs

In Denmark, AMU in livestock is primarily driven by pigs, 75% of antibiotic active compounds are used for pigs. Weaners is the age group receiving the majority of AB in pig farms for the treatment of diarrhoea (68% of doses), leg- and central nervous system-related disease (21% of doses) and respiratory disease (10% of doses). Since 2017, "Pure Pork" or "Pigs raised without antibiotics" or OUA pigs started but reared in the same pens with other pigs so there is a risk of transmission of resistance. Farmers hoping for the premium price but it doesn't work as expected. Many farmers produce around 70% of their pigs without AB. They desire to keep a premium price for these label pigs – the premium has decreased over time due to problems with selling the meat. It would be of no advantage to these farmers if the general consumption of AB in Danish pig production was reduced – because it would be more difficult to differentiate and thereby earn a premium.

Farmers producing "traditional" conventional pigs

There is no motivation for these farmers to lower AMU (as long as it stays below the Yellow Card limit and stays as cheap). Vaccines and other measures to reduce AMU are always more expensive and more complicated to integrate. From a broader perspective, marketing point of view, Danish farmers have the advantage of being known abroad for having a low AMU. Farmers are generally concerned that reducing AMU will compromise welfare in terms of avoiding treating sick animals. Farmers believe that they produce what consumers want (to pay for). In addition, most farmers have worked in large industrialized conventional systems, and have been supported by colleagues, advisors, veterinarians and industry partners in their understanding of efficient and profitable pig production, so they have not been aiming at changing things fundamentally.

Practising vets: In Denmark, veterinarians do not earn money on medicine, as it is forbidden. As part of the national legislations, they do regular (approximately monthly) visits to farms for advice during which they prescribe medicine that dispensed by the pharmacy.

Farmers and veterinarians are generally concerned about the welfare of pigs when discussing a future with less AB-use in animals. Some of them see problems in the way the Yellow card system functions – because they think it makes some farmers use too little, and thereby compromise welfare.

Farming consultancies: Their role is more or less the same as the veterinarians' – except that they do not prescribe medicine and their advice for farmers is not enforced by law. They are also concerned about compromising welfare if the usage of AB is restricted even more. As for veterinarians, some seem to think that Denmark has reached the limit for reduction.

Seges (Research and Development within the industry): Seges is a part of Danish Agriculture and Food Council – a farmers' organisation. Seges aims to prepare Danish farming for the future and therefore has an interest in holding on to License to produce and constantly reducing the usage of AB. Welfare

concerns are the same as described for veterinarians and consultants and farmers. Being a farmers' organisation, Seges is generally working to protect and defend farmers' rights and immediate interests.

Danish Crown – Abattoir: Danish Crown started up the label production of Pure Pork by request from the United States of America. The vast majority of pigs slaughtered at Danish Crown, however, are standard pigs. Most of all, Danish Crown desires to keep their customers (farmers and retailers) and keep their customers happy. Therefore, it is difficult for them to promote a specialized type of label as farmers producing standard pigs could be offended. From a broad perspective, Danish Crown probably gains from selling meat from a country with such a good reputation concerning food safety and with low consumption of AB. It is not straightforward, that they would benefit from Denmark having a lower AB usage. Pure Pork, as it is now, does not seem to be a financial success – because of the relatively low demand from customers and because much of the carcass has to be sold as traditional meat.

Danish Agriculture & Food Council (focus on the export of meat): Everything that could increase consumers' interest in Danish pig meat is a benefit. This includes a high focus on food safety and low use of AB.

Consumers (represented by a professor in consumer behaviour): Consumers have many different agendas when buying meat. Animal welfare is a high priority (when asked – not necessarily when buying). Danish consumers generally – though not all -seem to trust that AB residues are not an issue in Danish meat. The fact that Pure Pork does not sell well might indicate that consumers are not concerned about the use of AB in animals. However, some surveys indicate that low usage of AB is a high priority when consuming meat.

The case study on organic dairy cows and calves

The Danish case study focuses on organic dairy herds

The Living Lab with focus on dairy cows and calves

The case study is focused on organic dairy production, but the Living Lab covers both organic and conventional dairy cows and calves.

Private practising vets and veterinary companies (LVK): Veterinarians don't sell medicine, their main concern of reducing AMU is animal welfare. Organic farmers are reluctant to use AB and demand for "more natural system" and alternative products.

Other stakeholders were described but no impact assessment yet.

4.4.9. Vietnam

More than 20 stakeholders were identified and their links have been conducted between July and November 2020. This included private sector: feed, drug, alternative products companies, food chain including chicken companies and retailers (sell products with no AB residues or organic). For Practitioners: technicians/veterinarians working for the private sector and government. For researchers: Universities and national research centre, international researcher in the framework of ongoing project about AMU reduction. For policy-makers and administration: Vietnamese government (Ministry of Agriculture and Rural Development with the Department of Livestock Production (DLP) and Department of Animal Health (DAH). For multipliers: PGS Vietnamese Network, Vietnam Organic Organization (that are working in the development of organic production mainly in vegetables but start slowly to develop it for livestock production), cooperatives of farmers.

The stakeholders' desired impact assessment will be conducted between July and December 2021.

4.5. Data requirements for CEA/CBA

The interventions to be discussed or deployed per case study have yet to be determined. Until those decisions are made, we cannot provide exact details on the data and indicators required to perform CEA/CBA. We therefore will summarize key data and indicators reported in the literature for monitoring AMU/AMR at farm-level, as described in D6.1, Box 1. Please note, these indicators are largely from studies of cattle and comparable indicators for poultry and pig production will be used as appropriate.

AMU on Farm: Use of CIAs, AM and feed consumption, treatment incidence, number of treatments

Technical performance (production data): Mortality, reproduction, average daily gain, feed conversion rate, milk yield and average lactation number

Animal health data: Welfare, disease incidence, clinical mastitis incidence, foodborne disease incidence, milk somatic cell score

Economic Indicators: Economic value of changes in technical performance (costs due to disease and productivity; reduced costs in antimicrobials), changes in net profit margins associated with feed costs, net cost of intervention, and change in antimicrobial expenditure

Bacterial isolates, food or faecal samples: Residues and occurrence of AMR in indicator bacteria, zoonotic bacteria, and pathogenic bacteria from animals and food

Quality of the intervention: Implementation fidelity, level of compliance

4.6. Data collection protocols and methodology (for CEA/CBA analysis)

We are reliant on WPs running case studies and living labs. Data will be collected as described in LL protocols. We are collaborating with the active CS and LL to collect relevant data for CEA/CBA and are searching for existing data sets with other partners that could be usable for CEA/CBA (eg. Data from Italy for pig and poultry production systems, antibiotic free versus conventional production). Once, our partners have a permission to share data, we will review the data and develop a protocol for CEA/CBA. We are also in communication with LL leaders for the possibility of collecting supporting data for CEA/CBA.

In addition, the WP5 team are directly contacting producers' organisations and veterinarians to collect datasets enabling to conduct empirical research, using the outcomes of interventions as variables of economic modelling. France, Italy and Belgium groups have or will in the near future (autumn 2021) give access to datasets that will allow researches of WP5 to complete the deliverables.

Outcomes from the 2nd annual meeting with WPs leaders on 21st April 2021 *"WP5: Assessment of intervention costs and impact: how to apply to CS and LL"*

Participants discussed the access data required for a cost-effectiveness analysis (CEA) when working with the CS or LL of the Roadmap project:

1. There was some uncertainty as to whether sufficient data exists for the analysis:

There could be difficulties with estimating the cost-benefit interactions that would allow the separation of interventions. For instance there are potential synergies between vaccination, breed, nutrition and management which needs to be explored for both the short and long term benefits and impacts of change. Management/AMR could have implications on selective breeding/fitness which is

turn could lead to changes in management/AMR. To reveal the causal pathways within a production system where different breeds are used for ex (fast, premium and slow growing) would need to have access to real data, use of AM, real costs. The WP5 team are managing these problems with a dataset from French chicken broiler systems and are working with WP1 colleagues on access to datasets on pig production.

2. Discussions and knowledge of peer review publications indicate that testing of discrete AMU interventions at livestock level are rare and what tends to be implemented "smart combination of interventions".

Such combinations could be analysed in terms of cost-effectiveness or even cost-benefit analysis, but to disaggregate the incremental value of each intervention would need data and statistical analysis this is likely to be beyond the scope of the ROADMAP project. However WP5 will look to make recommendations on the need for design of validation, and where this cannot be done the type of monitoring, data capture and analysis to help disaggregate the incremental value of individual interventions.

Previous research has shown that the impact on farm profitability changes were largely the result of net changes in production ("indirect cost" changes from improvements in mortality, feed conversion, average daily growth), and less due to "direct cost" changes relating to costs of vaccines, disinfection products and veterinary services. Reliable data on these technical parameters is often even more difficult to get and would need a way to find a control group.

Discussions with the WP3 leaders explored how to work with LL to assess the economics of these "smart combination of interventions" with the participants. This could be done in a qualitative manner. In additions discussions are underway to combine data from CS with LL work leading to greater integration of WP5 with the LL.

3. The level of the analysis:

The level of analysis should take another level and not only farm intervention an example is the case of the environment. It would be interesting if we could do something on the relative cost-effectiveness of more "high-level" interventions such as extension versus tax on antimicrobials versus ban on (certain) antimicrobials versus "AM-free" labels.

4. Other points:

The so-called AM free value chain is also complex. Broiler production in France, the problem is that producing AM-free flocks for Labels or specific clients doesn't lead to AM-free production at the system level. In France, according to the 18 interviews carried out, pig farmers involved in an antibiotic-free labels have a variable proportion of their pigs marketed in the line, between 25% and 100%. They therefore perceive the added value on this part of their production while investments in buildings, work, and alternatives to antibiotics are made for the entire production.

5. Discussion

Deliverable "D5.2" summarises the data and information available at this stage of ROADMAP on the **desired outcomes for AMU/AMR interventions of the key stakeholders.** It has drawn on the impact assessment literature review (D6.1) and the case studies (D6.2) conducted in WP6. The desired outcomes for interventions of the key stakeholders in different production systems and under different regulations were summarised. The data showed that different actors have expressed different desires from their involvement in AMU changes and in some cases there are contradictions and potential

conflicts. For example when discussing reduction of AMU, farmers are concerned about animal welfare but at the same time, they are looking for premium price for AB free products. Farmers in some countries, where AMU is low, are not concerned with reducing AMU further and do not see any further action on AMR from their perspective. Veterinarians are in general concerned about animal welfare, yet there are many countries where veterinarians depend on the sale and prescription of AB for their income and are concerned that AMU changes will reduce their income. These conflicts and contradictions need to be considered and are dependent on the rules and enforcement of different jurisdictions and in some cases the private standards in different value chains.

There is no single data source for the future cost-effectiveness analyses albeit many datasets exists. These data need agreements with private companies and the WP5 team are working with WP1 and LL to on access to data. Contact is being made with producers' organisations and veterinarians to collect datasets enabling to conduct empirical research, using the outcomes of interventions as variables of economic modelling. France, Italy and Belgium groups have or will in the near future (fall 2021) give access to datasets that will allow researches of WP5 to complete the deliverables.

6. Conclusion

Work is progressing in development of CEA/CBA models, and we are confident in the ability to assess interventions in 3-4 case studies across France, Italy, the UK, and/or Vietnam. Work is contingent on the continued good work of collaborators in Living Labs and Case Studies in WP 1, 2, 3, 4, and 6. Ambitions on the development of marginal abatement cost curves (MACC – Moran, 2019) may be limited to outline how these can use the CEA approach and how important this could be use in helping to shape policy. This will draw on the extensive literature and application of MACC for environment and climate change intervention – an area similar to the management of AMR.

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8. Delays

Covid delayed some outputs and more specific data on outcomes and available data, as well as progress in some CS and LLs, but this has been overcome by selection of more active Cs and LL.

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