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## **Exploration of the fipronil in egg contamination incident in the Netherlands using the Functional Resonance Analysis Method**

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33 Functional Resonance Analysis Method

34 **Abstract**

35 Following the 2017 fipronil egg contamination incident in the European Union, improvements  
36 in safety management continue to be necessary, particularly for regulatory, preventive, and  
37 control activities. Drawing from the Dutch and European legislation, and the use of the  
38 Functional Resonance Analysis Method (FRAM), the aim of the study was to explore the  
39 regulatory framing of the elimination of red mites on poultry farms, the compliance of actual  
40 events in 2017 with these hygiene standards and regulations in order to reconcile actual  
41 practices with policy directives. The study considers the difference between policy  
42 implementation for work-as-imagined and the tasks undertaken in practice i.e., ‘work-as-done’.  
43 This allows for assessment and analysis of the gap between pre-defined hygiene policy and  
44 actual practice and allows for a systemic approach rather than a causal approach to examine  
45 the public health incident. The study concludes that it is important for high level policy makers  
46 to comprehend the challenges and barriers faced by those implementing policy, and how this  
47 could potentially mean that policy in practice is not aligned with what was originally intended.  
48 The presented analysis outlines the potential of the FRAM in assessing complex food systems  
49 to support a public health investigation of incidents, and to design practical and realistic food  
50 safety policies leading to higher levels of stakeholder compliance and improved safety  
51 management.

52  
53 **Key words: fipronil egg contamination; work-as-imagined; work-as-done; policy;**  
54 **FRAM; Netherlands**

## 55 1. Introduction

56 Public policies are the outcomes of government efforts to stimulate behaviour changes at  
57 institutional and societal levels (Howlett & Mukherjee, 2014; Tummers, 2019). They are  
58 adopted by governments to structure relationships and manage behaviour among key  
59 stakeholders in order to achieve collective objectives and purposes (Howlett & Mukherjee,  
60 2014). Additionally, public policies often aim to exert power and motivate individuals to do  
61 things they are reluctant to do on their own (Stone, 1997). At the same time the successful  
62 implementation of public policies requires the availability of resources and a strong  
63 commitment by all stakeholders (Ernie & Collier, 2003; Watt et al., 2005). By itself, the  
64 implementation of new policies and practices consists of introduction and adoption stages,  
65 which are critical in determining the fate and further impact of a given policy directive  
66 (Galstyan & Harutyunyan, 2016). Inadequate translation of knowledge into practice and a  
67 failure to adapt interventions into a local context can lead to erroneous interpretation of policy  
68 directives, and to the presence of a gap between what is planned ('prescribed policy') and what  
69 is implemented in practice ('enacted policy') (Grimshaw et al., 2012).

70 Policy implementation in the food industry is a complex regulatory process that involves a  
71 range of actors at different levels of the system (Babu, 2015). When evidence-based food  
72 policies ('work-as-imagined') are designed and implemented, it means they are better aligned  
73 with the needs of actual practice ('work-as-done'), and therefore are realistic and appropriate  
74 to apply to deliver the desired outcomes (Clay-Williams et al., 2015). In complex adaptive  
75 systems, such as food systems, work-as-done is often more complex and different to work-as-  
76 imagined (Hollnagel, 2012). Multiple barriers influence the implementation of effective policy  
77 in the food industry, and three barriers are of particular interest in this study due to their  
78 applicability in examining non-compliance with policy (Gunn, 1978; Hunter, 2003; Phulkerd  
79 et al., 2017). They are firstly, poor understanding of, and disagreement on the objectives of the

80 intended policy among policy makers, senior managers, and front-line employees; **secondly**,  
81 inadequately and incorrectly prescribed tasks in cleaning schedules or audit requirements as  
82 prescribed by senior and line managers; and **the third barrier is** the inability to obtain perfect  
83 compliance with policies due to changes in policy priorities and poor governance systems  
84 (Phulkerd et al., 2017). Consequently, these factors need to be considered in the design of food  
85 policies within existing governance structures.

86 **The fipronil in eggs contamination incident in the Netherlands was an example of the**  
87 **outcome of implementing flawed national and private policies on red mite elimination,**  
88 **designed by government and senior management personnel, with a poor understanding of the**  
89 **challenges of real-world pre-audit preparation and audit processes.** On the 2<sup>nd</sup> June 2017, a  
90 notification was received by the Belgian Federal Agency for the Safety of the Food Chain  
91 (AFSCA) from an egg-breaking plant of a non-compliant result for fipronil (Manning, 2018a).  
92 An investigation on the suspect egg laying farm led to further investigations and four days later  
93 two potential sources of fipronil were suggested: poultry feed and on farm red mite treatment  
94 with Dega-16, undertaken by a Dutch poultry service company (AFSCA, 2017). Two weeks  
95 later it was suspected that fipronil had been used in the red mite treatment. Four months later,  
96 the economic cost of the incident was estimated as 65-75 million euros. 1.9 million birds were  
97 slaughtered, and 77.4 million eggs were affected (Manning, 2018a; Poultry World, 2018).

98 **The aim of this study was to explore the elimination process of red mites on poultry farms, and**  
99 **the compliance of actual events with the hygiene standards and regulations, drawing from the**  
100 **Dutch and European legislation, and the use of the Functional Resonance Analysis Method**  
101 **(FRAM) in the reconciliation of the actual practices and policy directives. Three research**  
102 **questions were developed:**

103 **RQ1. How red mites were eliminated in poultry farms (work-as-done)?**

104 RQ2. How much 'work-as-done' was aligned with the requirements of the Dutch and European  
105 legislation ('work-as-imagined')?

106 RQ3. How can the FRAM be used for policy development to reconcile the gap between 'work-  
107 as imagined' and 'work-as-done'?

## 108 **2. Poultry hygiene standards and regulations based on Dutch and European** 109 **legislation**

110 Article 9 of Regulation (EC) 852/2004 of the European Parliament and the Council on the  
111 Hygiene of Foodstuff contain requirements and guidance related to good hygiene practices in  
112 pullet rearing and egg laying flocks. According to this Regulation, it is important ensure that  
113 poultry of the same health status are kept on the same premises and constitute a single  
114 epidemiological unit (Regulation (EC) No 852/2004 of the European Parliament and of the  
115 Council, 2004). Article 2 of Reg. 2160/2003 sets a similar mandate for housed poultry sharing  
116 the same airspace (Regulation (EC) No 2160/2003 of the European Parliament and of the  
117 Council, 2003).

118 In 2002, the European Commission Regulation (EC) No 1490/2002 required the European  
119 Food Safety Authority (EFSA) to review the potential for harm by fipronil in food products. In  
120 2006, the then EU Member States concluded that fipronil content below 0.72 mg/kg in eggs  
121 would not pose any food safety concerns (EFSA, 2006). Although fipronil is permitted to be  
122 used as a pest control product, the European Commission set a maximum residue level for  
123 fipronil in eggs and poultry meat at 0.005 mg.kg, while completely banning its use on animals  
124 and animal products meant for consumption (European Commission, 2017).

125 **3. Materials and methods**

126 **3.1. Study Design**

127 To address the first and second research questions literature analysis was performed to  
128 establish supranational and national guidance on treating red mites in poultry farms within the  
129 European Union (EU) **current in** 2017-18, and to gain insight into the events leading to the  
130 contamination of eggs (EUWEP, 2012; Defra, 2018; Ministry of Health Welfare and Sport,  
131 2018a). **A framework with three categories, adapted from Powell et al. (2009), was considered**  
132 **for exploring factors associated with the fipronil egg contamination incident, including content**  
133 **of the incident, context of the incident, and the process of the incident (see Table 1). The focus**  
134 **of this study was limited to the process of eliminating red mites on poultry farms. Since**  
135 **compliance failures in the incident discussed in this paper occurred at the point where poultry**  
136 **farms were being cleaned by cleaning contractors, only one of the themes of the policy,**  
137 ***cleaning and disinfection*, was analysed in detail in to achieve the research aim defined in this**  
138 **study.**

139 **Take in Table 1**

140 To address the third research question of the study the FRAM was utilised for mapping and  
141 modelling 'work-as-done,' a qualitative approach endorsed by safety experts (Stanton et al.,  
142 2013). For detailed information on the FRAM, the authors referred to practical instruction  
143 guides (Hollnagel et al., 2012; Stanton et al., 2013), and prior publications (Clay-Williams et  
144 al., 2015; Damen et al., 2018; Raben et al., 2018). The corresponding author also attended a  
145 workshop on the methodology conducted by Professor Erik Hollnagel and Professor David  
146 Slater, hosted by the University of Oxford in March 2019.

147        **3.2. Research Instrument**

148            An initial model of red mite elimination ‘as-imagined’ was constructed based on an  
149 analysis of the European Union of Wholesale with Eggs, Egg Products and Poultry and Game’s  
150 (EUWEP) European public policy for national agencies within the EU to design their own  
151 national public policies (EUWEP, 2012). The authors developed a framework (Appendix 1)  
152 which guided the document analysis process and subsequent FRAM analyses. The  
153 interrogation of the framework is based on the FRAM method, with minor adaptations made  
154 for the analysed incident (Hollnagel et al., 2014).

155        **3.3. Data Collection and Analysis**

156            Due to the absence of red mite-specific guidance within the EUWEP (2012) policy  
157 document, the authors analysed two additional national red-mite management policy  
158 documents. These were the *Code of practice for the welfare of laying hens and pullets*,  
159 published by the Department for Environment, Food & Rural Affairs (DEFRA) in 2018 (Defra,  
160 2018); and *Advice on the risks in the poultry meat supply chain*, published by the Netherlands  
161 Food and Consumer Product Safety Authority (NVWA) in 2018 (Ministry of Health Welfare  
162 and Sport, 2018a). It should be noted that both of these documents were produced after the  
163 2017 fipronil incident. The authors deemed it relevant to analyse the United Kingdom’s (UK)  
164 national policy despite the incident originating in the Netherlands for two reasons. Firstly, the  
165 UK was an EU-member country at the time of the incident and hence, its policy would be  
166 largely similar to the policy adopted by the Netherlands regarding treating red mites in free-  
167 range egg-laying hens. Secondly, the European Commissioner for Health and Food Safety  
168 reported that 26 of the 28 EU Member Countries (as of 2017-18) were affected by the incident;  
169 of which the UK had imported approximately 700,000 contaminated eggs, but a problem was  
170 not identified on UK farms (Boffey & Connolly, 2017; European Commission, 2017). An  
171 iterative modelling process was applied (Damen et al., 2018) with preliminary models



172 developed after analysing each document, and updated versions developed from subsequent  
173 document analyses.

174 The FRAM model reflecting red mite elimination work-as-done was developed by the  
175 authors based on an analysis of the 2018 Dutch national investigation report (Ministry of Health  
176 Welfare and Sport, 2018b). An iterative modelling process was applied (Damen et al., 2018)  
177 with preliminary models developed after analysing each section of the investigation report, and  
178 updated versions developed from subsequent analyses. The ‘FRAM Model **Visualiser** version  
179 2.1.0’ was used to construct the FRAM models (Hill & Hollnagel, 2018). **Document analysis**  
180 **was** carried out until data saturation (defined as a criterion for discontinuing data collection  
181 once redundancy is identified in the data) was reached for the model (Saunders *et al.*, 2018).

182 Each hexagon within the FRAM was colour coded based on the nature of the function.  
183 Yellow hexagons represent non-cleaning related tasks that should be performed before the  
184 cleaning contractor visited the site. Blue hexagons represent tasks specific to dry cleaning that  
185 poultry farmers needed to perform before the visit by cleaning contractors; and green hexagons  
186 represent tasks that were scheduled to occur during the visit by inspectors and auditors. The  
187 FRAM analyses were performed by the corresponding author. Other authors then reviewed the  
188 analyses as a means of validation. While the corresponding author is a human factors researcher  
189 with experience in analysing food safety incident analysis, the second author has experience in  
190 applying socioeconomic and cultural theory in agri-food supply chains, and the third author  
191 has experience in applying human factors and accident analysis methods in various domains  
192 including food safety culture.

#### 193 **4. Functional Resonance Analysis Method (FRAM)**

194 **The FRAM is an analytical framework to analyse and describe the implementation of work-**  
195 **as-done in complex socio-technical systems (Hollnagel, 2012; Stanton et al., 2013). It allows**

196 exploring of the elements behind the performance variability at individual, technical, and  
197 organisational levels that may result in an adverse outcome, and to discover their  
198 interrelationship (Hollnagel et al., 2008; Hollnagel & Goteman, 2004). While the FRAM is a  
199 new approach in the food industry, it has been applied in different areas such as healthcare  
200 (Hollnagel, 2012), aviation (Hollnagel et al., 2008), railway traffic supervision (Belmonte et  
201 al., 2011), air traffic management (De Carvalho, 2011; Ferreira & Canas, 2019), sustainable  
202 construction (Rosa et al., 2015) and manufacturing (Albery et al., 2016). Based on functions or  
203 tasks, the FRAM is used for the analysis and modelling of complex systems, allowing analysts  
204 to identify and describe functions, characterise the variability of functions, aggregate the  
205 variability of functions, and provide suggestions to manage the variability (Hollnagel, 2012).  
206 A function represents an activity or a range of activities and is characterised with six aspects  
207 (Figure 1) (Damen et al., 2018). In Figure 1, 'Function 1' represents an activity (e.g., power  
208 washing of surfaces) contributing to the safety management (e.g., red mite elimination). Each  
209 function six aspects: (1) input; (2) output; (3) time; (4) control; (5) resource; and (6)  
210 precondition.

211 **Take in Figure 1**

## 212 **5. Results**

213 Table 2 provides a description of the functions modelled in Figures 2 and 3, and highlights  
214 functions unique to the work-as-done scenario.

215 **Take in Table 2**

### 216 **5.1. Work-as-imagined: Policy design and dissemination**

217 The red mite elimination 'work-as-imagined' model reflected recommendations from  
218 the policy and guidance documents developed by the EU (EUWEP, 2012), the Dutch Food  
219 Safety Authority (NVWA, 2018), the Ministry of Health Welfare and Sports (2018a) and the

220 UK government (DEFRA, 2018) for the use of disinfectants to eliminate red mites in poultry  
221 farms by cleaning contractors (Figure 2). The requirements included: (1) having a detailed  
222 understanding of relevant Regulation (EC) 2160/2003 of the European Parliament; (2)  
223 physically auditing relevant and required documentation; (3) verification of disinfectants for  
224 red mite treatment; (4) enforcing a detailed plan (e.g., cancelling a contract with the cleaning  
225 contractor and discarding of disinfectants), if disinfectants were disapproved; (5) defining the  
226 farms' red mite treatment policy; and (6) achieving disinfection competency and ensuring that  
227 documentation has been signed off by private, farm and government auditors. To assess the  
228 variability of FRAM functions, the authors defined criteria to extract data from the three policy  
229 and guidance documents on red mite elimination (European Union of Wholesale with Eggs  
230 Egg Products Poultry and Game, 2012). The EUWEP's 2012 policy on terminal cleaning is a  
231 guidance document designed in accordance with Article 9 of the Regulation (EC) 852/2004 of  
232 the European Parliament, the Council (of 29 April 2004) on the Hygiene of Foodstuff,  
233 Committee of Professional Agricultural Organisations-General Confederation of Agricultural  
234 Cooperatives (COPA-CEGECA), which is a union of two big agricultural umbrella  
235 organisations representing European farmers (European Union of Wholesale with Eggs Egg  
236 Products Poultry and Game, 2012). Regulation (EC) No. 852/2004 and all relevant EC hygiene  
237 legislation on the hygiene of foodstuffs applies to all primary products, including eggs. The  
238 aim of the EUWEP policy document is to provide a framework for the effective application of  
239 Regulation (EC) 2160/2003 of the European Parliament and of the *Council on the control of*  
240 *Salmonella and other specified food-borne zoonotic agents* (European Union of Wholesale  
241 with Eggs Egg Products Poultry and Game, 2012; Union of International Associations, 2003).

242 Information was collated from public policies on treatment for red poultry mites (based  
243 on a work-as-imagined philosophy) (DEFRA, 2018; European Union of Wholesale with Eggs  
244 Egg Products Poultry and Game, 2012; Opperhuizen, 2018). On discovery of red poultry mites,

245 the poultry farmer needs to book an appropriate (and approved) cleaning contractor well in  
246 advance of the depopulation date. The farmer must discuss cleaning and disinfection protocols  
247 with the contractor so that there is a clear understanding by the contractor of the farmers'  
248 requirements, and to ensure compliance with national guidelines and policy on the use of  
249 approved chemicals. Once a consensus has been reached, it is then the farmer's responsibility  
250 to depopulate the poultry house by ensuring any dead birds, waste and/or surplus feed are  
251 removed and appropriately disposed-off. Prior to commencing (wet) cleaning and disinfection,  
252 cleaning contractors are required to dry clean the poultry house and remove any poultry  
253 manure. Following the dry-cleaning step, cleaning contractors are allowed to commence  
254 cleaning with water and disinfectants. It is mandatory for all moveable equipment and floors  
255 to be cleaned and disinfected. Contractors need to treat the poultry house in line with national  
256 pest control protocols and in accordance with national guidelines on approved disinfectants for  
257 red mite, and as per the instructions on the label i.e., correct dilution rates. If there is a large  
258 population of mites in the poultry house, contractors are allowed to use a higher concentration  
259 of the mite disinfectant. In essence, contractors are provided the autonomy and responsibility  
260 to ensure safe and legal use of mite disinfectants. The steps to apply mite disinfectants are as  
261 follows:

262 *Step 1:* Use a high-pressure hose to hose down the poultry house and parts of the poultry house.  
263 While using a "high-pressure" hose is not mandatory, it is recommended as the pressure helps  
264 to clean the parts of the house that are difficult to reach or hidden from plain sight, i.e., parts  
265 of the house where red mites reside. Post cleaning with a hose, the house needs to be left to dry  
266 for 10-15 minutes.

267 *Step 2:* Once the house has dried, it is advised to repeat Step 1 as it is common for red mites to  
268 crawl out of hiding once disturbed during Step 1. Step 1 needs to be repeated until there are

269 very few red mites left in the house. A decision on the number of repetitions of this step is left  
270 up to the discretion of the contractor.

271 The process of red mite elimination is complete once no more red mites can be detected  
272 on physical inspection of the environment. It is also key to note that red mites can be persistent  
273 and hence, regular pest management is essential to manage the issue. Farmers must apply a red  
274 mite powder at regular intervals in the house (including to perches) as a proactive measure to  
275 prevent hens from getting infested with red mites. [Table 3](#) briefly summarises the topics  
276 covered by the policy document. Figure 2 illustrates through a FRAM analysis the steps needed  
277 to be undertaken by the farm and the cleaning contractor to disinfect the environment against  
278 red mites.

### 279 **Take in Table 3 and Figure 2**

280 The FRAM diagram in Figure 2 highlights all the steps required to take place  
281 immediately before, during and after the elimination of red mites from poultry farms. The  
282 FRAM functions labelled 1.1 to 1.10 (in yellow) highlight tasks supposed to take place on  
283 poultry farms before cleaning contractors visited the site. These tasks revolve around  
284 depopulating poultry houses to get the site ready for cleaning. The FRAM functions labelled  
285 2.1 to 2.4 and 2.8 (in blue) highlight dry cleaning activities that poultry farms needed to carry  
286 out before being visited by the cleaning contractor. These were largely primary cleaning  
287 functions which did not require specialist cleaners. Functions 2.5 to 2.7 (in blue) highlight  
288 cleaning activities that were meant to be carried out by the cleaning contractor.

289 The FRAM functions labelled 3.1 to 3.27 (in green) are activities designed to take place  
290 during the inspections and audits by private and independent third-party auditors. An  
291 independent third-party auditor was supposed to visit the poultry farm to ensure that required  
292 inspection documents were in place, and to verify the quality of private inspections. Inspections

293 of the cleaning contractor (performed by the private auditor/auditing team) were designed to  
294 include mandatory assessments of the safety and regulatory compliance of chemicals used to  
295 eliminate red mites. Additional checks on the adequacy of manpower equipment were also  
296 designed to be carried out before cleaning contractors could commence their work. In total, 24  
297 checks were explicitly stated in policy documents to ensure that all essential inspections were  
298 carried out before cleaning contractors applied chemicals. **Aspects relevant to each function**  
299 **have been listed in Appendix 2.**

## 300 **5.2. Work-as-done: The 2017 fipronil in eggs incident**

301 Fipronil in concentrations above permitted levels was detected in Belgian table eggs in 2017  
302 (Ministry of Health Welfare and Sport, 2018b). The use of fipronil to control pests in  
303 agriculture and food producing animals is banned by the EU as fipronil is classified as  
304 moderately hazardous for human consumption (Commission Implementing Regulation (EU)  
305 No. 781/2013 of 14 August 2013, 2013). Reg. (EU) 2016/2035, Reg. (EU) No. 540/2011 and  
306 Reg. (EU) No. 781/2013 state that eggs containing fipronil concentration  $>0.005$  mg/kg should  
307 be identified and noted. The regulations further state that eggs and egg-products containing  
308 fipronil concentrations  $>0.72$  mg/kg could pose as potential health risks for humans.  
309 Investigations by the Ministry of Health Welfare and Sport (2018) established that a Dutch  
310 poultry farm cleaning company had knowingly and without notification used Dega-16, a  
311 chemical containing fipronil, on poultry farms to eliminate red mites. As a result of non-  
312 compliance by the cleaning company, the NVWA blocked approximately 258 farms from  
313 trading more eggs, instructed them to recall all their eggs from the market, and prevented  
314 farmers in specific geographies from allowing hens and manure to leave the premises (Ministry  
315 of Health Welfare and Sport, 2018b). Instructions provided by the NVWA led to disruption in  
316 the agri-food supply chain and uncertainty among consumers. This consequently had an impact  
317 on the financial stability of poultry farms and other stakeholders within the egg supply chain,

318 as in addition to the recalls and product destructions ordered by the NVWA, there was also a  
319 decline in the sales of Dutch eggs across the EU (Ministry of Health Welfare and Sport, 2018c).  
320 In the 2018 Ministry of Health Welfare and Sport's report, large portions of the investigation  
321 lean towards finding organisations to blame. The following subsections of this paper are based  
322 on the findings from the FRAM analysis (Figure 3) and the 2018 report evaluating events  
323 leading up to and immediately after the egg contamination incident.

### 324 **Take in Figure 3**

325 Figure 3 highlights tasks that were supposed to be performed as per organisational and  
326 national policy, but were not. The FRAM diagram in Figure 3 highlights all the activities that  
327 took place immediately before, during and after the visit by cleaning contractors. The colour  
328 coding used is the same as used in Figure 2. An additional colour coding has been used in  
329 Figure 3. The FRAM functions in red are those activities where there was non-compliance.  
330 Discrepancies in cleaning procedures largely occurred within the blue (cleaning contractor)  
331 and green (audits and inspections) functions leading to the fipronil contamination. Auditors  
332 (government and third-party) did not perform the activities prescribed to them in a robust  
333 manner. For instance, multiple government auditors arrived at the site at the same time leading  
334 to confusion on the farm. This, in addition to factors such as a poor understanding of regulations  
335 led to inadequate audits of farm inspection methods and records. A lack of robustness in audits  
336 led to instances of non-compliances such as incomplete paperwork at the farm level going  
337 undetected. These points of failure can be seen in the functions with a red circle around the  
338 *Control* and *Input* aspects in the FRAM diagram in Figure 3. Unlike Figure 2, Figure 3 has two  
339 functions without an input activity (i.e., these are points where critical non-compliances  
340 occurred leading to incorrectly performed functions) and three functions with inadequate  
341 control measures. Although 24 *audit and inspection* mandatory checks were stated in policy  
342 documents and regulations (and highlighted in Figure 2), only sixteen of these checks were

343 carried out in practice. These non-compliances along the entire process enabled the cleaning  
344 contractors to use an illegal chemical during the process of red mite elimination.

345 **This section has considered and addressed RQ1. How red mites were eliminated in poultry**  
346 **farms (work-as-done)?**

347 On conducting a thorough investigation and establishing the extent of the damage caused,  
348 the NVWA classified the case as an *incident* and formed an incident investigation team on the  
349 18<sup>th</sup> of July 2017. The NVWA further blocked 258 farms from trading eggs, chicken, and  
350 manure to protect public health (Ministry of Health Welfare and Sport, 2018a). Despite all  
351 these actions taken by the NVWA, the investigation commission concluded that the NVWA  
352 was ill-prepared for a food safety incident due to: (1) the poor communication of its standards  
353 with poultry farmers; and (2) poor enforcement action leading to doubts over its credibility to  
354 take decisive action in a proactive manner (Ministry of Health Welfare and Sport, 2018a).  
355 **Aspects relevant to each function have been listed in Appendix 3.**

356 **6. Discussion**

357 The responsibility for food safety lies primarily with food businesses, i.e., companies  
358 producing, distributing, processing, and marketing food must actively ensure that they do not  
359 introduce products into the market that do not comply with statutory regulations. Inadequate  
360 knowledge of relevant policies and regulations meant that the safeguards implemented by egg  
361 supply stakeholders were insufficient (Ministry of Health Welfare and Sport, 2018a). Findings  
362 also highlighted limited food safety-related risk assessments being implemented by farmers.  
363 The Commission concluded that despite stakeholders being aware of the impact (on public  
364 health and finances) of using banned chemicals to treat red mites, the risks were either ignored  
365 or inadequately assessed by all stakeholders (Ministry of Health Welfare and Sport, 2018a).  
366 The aim of this study has been to assess the differences between the criteria defined by



367 European and Dutch national standards for poultry farmers on the elimination of red mites on  
368 poultry farms through policies and the actual events that took place that led to the 2017 fipronil  
369 egg contamination incident. The differences between what was envisaged by policy makes and  
370 actual practices extended beyond activities at farm level to poultry service companies and the  
371 degree to which system standards and regulatory requirements were upheld, the agility of  
372 responding to intelligence regarding non-compliance within the sector, and the inability to  
373 enact a policy framework that was too complex to work in practice.

374 **This next section addresses RQ2. How much 'work-as-done' was aligned with the requirements**  
375 **of the Dutch and European legislation ('work-as-imagined')?**

376 The system standard adopted by Dutch poultry service companies, IKB Ei (Integrated  
377 Chain Management Egg), failed to ensure adherence to points mentioned in its policy. Being a  
378 voluntary measure, the system was used to assess the quality of eggs and egg-containing  
379 products rather than as a verification system to ensure business compliance with national policy  
380 standards and regulatory requirements (Ministry of Health Welfare and Sport, 2018a). The  
381 scheme was also found to be lacking in terms of its ability and desire to ensure food safety as  
382 IKB PSB, the quality system for poultry service companies, did not impose food safety  
383 requirements on participating farms. Additionally, neither IKB Ei nor IKB PSB made  
384 improvements to their system standards even after the publication of a report containing critical  
385 assessments of these existing systems. The investigation also highlighted that in addition to  
386 farm service companies, poultry farms were poorly equipped to deal with food safety incidents  
387 (Ministry of Health Welfare and Sport, 2018a). Farms struggled to recall their contaminated  
388 eggs from the market as the stakeholders' primary goal was to limit financial impact.

389 Public monitoring of food safety is the NVWA's responsibility in the Netherlands  
390 (Ministry of Health Welfare and Sport, 2018a). The authority, an agency in the Ministry of

391 Agriculture, Nature and Food Quality (LNV) has its own Intelligence and Investigation  
392 Services (IOD). The IOD is responsible for conducting criminal investigations with support  
393 from the Public Prosecution Services, in the Netherlands (Ministry of Health Welfare and  
394 Sport, 2018a). The NVWA comprises of an independent scientific advisor, and the Bureau for  
395 Risk Analysis and Research (BuRO). The BuRO is tasked with assessing food safety hazards,  
396 product safety, and animal welfare. Despite a detailed structure with delegated powers, multiple  
397 limitations were identified by the Commission at this regulatory level (Ministry of Health  
398 Welfare and Sport, 2018a). A key investigation finding was that although the contamination of  
399 eggs was officially declared in 2017, the NVWA had received three tip-offs from whistle-  
400 blowers, and through IOD investigations as early as November 2016, regarding the illegal use  
401 of fipronil by a farm cleaning company to combat red mites in poultry farms (Ministry of Health  
402 Welfare and Sport, 2018a). However, through to 2018, inspectors and standard owners had  
403 been unsuccessful in preventing fipronil contaminated eggs repeatedly penetrating the market.  
404 Since preliminary investigations and media trials scrutinised farm practices, farmers often  
405 questioned existing regulatory structures, standards and national NVWA policies. Pressure  
406 increased on consumer trust of national standards and the credibility of NVWA actions was  
407 questioned (Ministry of Health Welfare and Sport, 2018a). Although the NVWA is  
408 commissioned to ensure food safety in the Netherlands by the Public Health Wellbeing and  
409 Sports (VWS) and the Agriculture, Nature and Food Quality (LNV) departments of the  
410 government, public supervision of egg safety is commissioned in practice to a private  
411 organization. This organization, the Dutch Control Authority for Eggs (NCAE), is a part of a  
412 privately managed, independent administrative body, the Central Body for Quality Issues in  
413 Dairy (COKZ) (Food and Veterinary Office, 2013). It is also important to note that the  
414 production, distribution and sale of organic eggs and their compliance with EU Regulations is  
415 monitored by another supervisory authority, Foundation Skal Biocontrole, under the guidance

416 of the LNV department (Ministry of Health Welfare and Sport, 2018b). A finding in the 2018  
417 report highlighted that the system (food safety legislation, policies, and guidance documents)  
418 designed to guarantee the safety of eggs was complex and unclear (Ministry of Health Welfare  
419 and Sport, 2018a). The complex structure of Dutch regulatory agencies, as illustrated in Figure  
420 3 and in the 2018 report, provides an insight into why farmers and the investigation commission  
421 felt that the Dutch egg safety system was poorly design and too complex to navigate.

422         Once the fipronil incident was declared, it was the NVWA's responsibility to ensure  
423 consumer safety (Opperhuizen, 2018). Despite receiving tip-offs in 2017, the BuRO within the  
424 NVWA failed to follow protocol and perform a risk assessment. If a risk assessment had been  
425 carried out, the NVWA would have been able to pursue enforcement action based on the Plant  
426 Protection Products and Biocides Act (Wgb). However, it would be crucial in this scenario for  
427 the NVWA to identify which stakeholder to prosecute, the farm(s) or the poultry cleaning  
428 company. Failure to clearly identify the non-compliant stakeholders led to financial losses for  
429 multiple stakeholders across the egg supply chain as farmers were largely portrayed in a  
430 negative light by media publications (e.g., BBC News, 2017; Cook, 2017). A poorly defined  
431 regulatory system led to delays in egg safety investigations and communication of this  
432 information to importing countries (Reuters Staff, 2017).

433         Post the incident, there was widespread confusion among consumers about the extent  
434 of exposure to fipronil through contaminated eggs (Ministry of Health Welfare and Sport,  
435 2018b). The confusion stemmed from the government agency level. In January 2017, the BuRO  
436 provided an oral assessment of the extent of consumer exposure to fipronil based on inadequate  
437 information (Ministry of Health Welfare and Sport, 2018b). A similar incomplete investigation  
438 was carried out in April 2017 by the IOD and the Public Prosecution Services (Ministry of  
439 Health Welfare and Sport, 2018b). Further, inadequate resources and a lack of collaboration  
440 between the IOD and the supervisory divisions within the NVWA lead to investigations not

441 commencing until June 2017 (Ministry of Health Welfare and Sport, 2018b). The lack of  
442 collaboration was a consequence of a lack of clarity regarding the restrictions on sharing  
443 information (such as investigation proceedings) between divisions and departments. This led  
444 to decisions being inadequately documented and responsibilities being poorly defined (Cook,  
445 2017; Ministry of Health Welfare and Sport, 2018b; Reuters Staff, 2017). All these failures at  
446 the enforcement agency level contributed to the widespread distribution of contaminated eggs  
447 across global egg supply chains.

448         Variability and interdependence between the two FRAM models are apparent in the  
449 functions around regulatory controls, as auditors (both private and government) were required  
450 to have a detailed understanding of relevant regulations and policies prior to auditing  
451 documents and verifying regulatory compliance regarding the disinfectants used. In an ideal  
452 scenario (i.e., Figure 2) regulations and policies provided outputs that served as important  
453 control measures for several downstream functions. However, as illustrated in Figure 3, most  
454 of the functions were left incomplete (i.e., red) due to an inadequate understanding of the  
455 regulatory and policy requirements by key stakeholders. This subsequently led to failure in  
456 discarding illegal/unapproved disinfectants from storage units and inadequate control over  
457 other functions such as carrying out surface spraying, approving mite disinfectants, auditing  
458 cleaning contractor supplies and engaging a compliant cleaning contractor.

459         Interdependence was particularly apparent for the function “to audit documents” since  
460 as many as six downstream functions were associated with it and were severely impacted  
461 leading to several other non-compliances across the system. It can also be argued that there  
462 was an over-reliance on documentation checks as seen in Figure 2. Multiple stakeholders were  
463 tasked with verifying completion of documents, while there were minimal checks physically  
464 inspecting disinfectants, and no checks to ensure stakeholders had robust understanding of what  
465 were approved or unapproved disinfectants. Indeed, the poultry cleaning contractor was able

466 to commit fraud, renaming the fipronil-based disinfectant, without identification by other  
467 stakeholders. Functions that represent farmers cancelling cleaning contracts seemed to have no  
468 robust control structure in place leading to an over-reliance on farmers' autonomy and an  
469 insecure assumption of the degree of their understanding of regulations regarding cleaning and  
470 disinfection of poultry farms.

471         Although farmers received multiple inspection reports (through private and government  
472 inspections) they relied on cleaning contractors to adhere to the national regulations and  
473 policies on eliminating red mites from poultry houses (Ministry of Health Welfare and Sport,  
474 2018b). However, regulations and policies did not account for downstream functions that  
475 controlled upstream functions. For example, existing policies failed to ensure that a final check  
476 of disinfectants was carried out by farmers before being used by cleaning (Cook, 2017;  
477 Ministry of Health Welfare and Sport, 2018b). Additionally, although auditors were trained to  
478 carry out inspections, their understanding of regulations and policies was not evaluated  
479 (Ministry of Health Welfare and Sport, 2018b). There was also no mechanism in place to  
480 educate auditors and cleaning contractors about the importance of various regulations and  
481 policies.

482         There was an over-reliance on regulations and checks based on policies designed by  
483 policymakers higher up the hierarchical chain to ensure that banned disinfectants and chemicals  
484 were not used to clean poultry houses (Ministry of Health Welfare and Sport, 2018b). Future  
485 policies and governance structures must focus on improving the *underpinning and core*  
486 *cultures* (Manning, 2018b) within farms and associated organisation (e.g., specialist farm  
487 cleaning companies). The intention of policies which aim to improve *underpinning cultures*  
488 would be to improve organisations' espoused and unspoken values which often guide employee  
489 behaviour and attitudes towards legislation and standard operating procedures. These policies  
490 also play a critical role in defining the depth of an audit/inspection of service providers to the

491 food organisation (poultry farms in this case study). Improving *core cultures* requires an initial  
492 understanding of assumptions made by employees about their role within in the agri-food  
493 system. These assumptions are often misunderstood or misrepresented (Manning, 2018b).  
494 Going forward, policy makers need to allow for more of an *active input* from all relevant  
495 stakeholders. Modern information technology systems may allow for greater ease of provision  
496 of such input. National food safety governance bodies might also consider limiting the number  
497 of information sources that they currently use as this would also reduce the amount of and  
498 possibility for conflicting information. Farmers could rely on simple written  
499 instructions/reminders instead of lengthy checklists and policies to follow on a day-to-day  
500 basis. Negative incidents are often the outcome of a chain reaction of technical and social  
501 barriers such as lengthy and complex policies and protocols, confusion among staff and time-  
502 related stressors (Brown et al., 2000). This phenomenon can be observed in Figures 2 and 3  
503 where despite detailed policies (Figure 2), the actions performed in the real-world (Figure 3)  
504 did not comply with the required protocol.

505         Investigating *work-as-done* offers a new dimension to food safety, regulatory design,  
506 compliance and policy design rather than focusing policy design and redesign primarily on  
507 avoiding previous food safety incidents which although important, are very specific in their  
508 nature (Soon et al., 2020). When designing robust food safety policies it is important to  
509 consider potential outcomes arising from everyday routine performance; exceptionally good  
510 performance; as well as near-misses and food safety incidents (Eurocontrol, 2013, p. 25).

511 **RQ3 asked “How can the FRAM be used for policy development to reconcile the gap between**  
512 **'work-as imagined' and 'work-as-done'?”** The FRAM can be used proactively as a tool for  
513 incident analysis as it helps to establish *emergent themes* based on work-as-done rather than  
514 solely comparing negative events with expectations of a process (Hounsgaard, 2016). Thus,  
515 adopting such an approach helps to improve supply chain resilience (de Sá et al., 2019; Faour-

516 Klingbeil et al., 2015; Lord et al., 2017; Nayak & Waterson, 2017, 2019; Thatcher et al., 2019).  
517 The 2017 fipronil incident clearly shows the dangers at multiple levels of a practice gap in the  
518 implementation of public health policies between work-as-imagined and work-as-done.

## 519 **7. Conclusion**

520 This study has considered the activities before and during the 2017 fipronil incident showing a  
521 clear difference between how red mites were eliminated on poultry farms in practice ‘work as  
522 done’ and ‘work as imagined’ in predefined public hygiene policies. There were failures in  
523 ‘work as done’ at all hierarchical levels of food safety governance from farmers through to  
524 supply chain stakeholders and the regulators themselves. Within the imagined scenario, there  
525 were assumptions of what would happen and what would be achieved, and this failed to be  
526 enacted in practice.

527 The use of FRAM allowed an exploration of the conditions and interactions between  
528 various functions and their outputs in the case study example, and helped to assess the  
529 limitations of current food safety policies and regulations designed solely by policy and  
530 lawmakers. This approach to policy design does not reflect the lived experience of those who  
531 take part in day-to-day activities especially if high-level policy makers do not fully comprehend  
532 the challenges and barriers faced by individuals implementing policy and the methods they  
533 might use to overcome these challenges. This study has shown how the FRAM can be used for  
534 policy design and redesign to reconcile the gap between work-as imagined and work-as-done.  
535 The ability to establish interdependence and variability between functions informs the  
536 identification of opportunities for improvement in current practices and policies especially in  
537 the event of a food safety incident where multiple factors are of influence. One of the  
538 limitations of this study was that the authors were unable to carry out ethnographic observations  
539 and incorporate observed behaviours and actions within the models. **Consequently, the authors**  
540 **were also unable to determine high-priority functions in the process of elimination of red mites**

541 **from poultry farms.** In future studies, the FRAM approach could be used to develop  
542 mechanisms to improve existing practices within agri-food supply chains. Whilst the FRAM  
543 has been used to perform a reflective desk-review in this study, it also has a role in supporting  
544 multi-stakeholder activity to design evidence-based food policies that are less complex and  
545 with a greater likelihood of being complied with in practice.

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1 **Table 1: Factors that undermined policy implementation in the egg trading industry**

2 Adapted from Powell *et al.*, 2009.

<b>Theme</b>	<b>Issue</b>
Content of the incident: what are safety improvement measures and why have them in place?	Lack of agreement that safety improvement was necessary Lack of clarity about the nature of the incident and how the proposed new improvements fitted with existing and related practice
Context of the incident: what are the features of the local environment?	Poor fit with local organisational priorities. Poor fit with local organizational structures (e.g. departments). Adverse effects of previous organizational improvements (e.g. reorganizations) Lack of direct and indirect resources to support the improvement
Process of the incident: how safety improvements challenge professional roles and identities?	Divergent views among food professionals about responsibility for various aspects of safety improvement Conflict with longstanding professional boundaries and norms.

3

4 **Table 2: Description of the FRAM functions**

<b>Functions</b>	<b>Descriptions</b>	<b>Location of Functions</b>
To complete cleaning and disinfection of coop	Successful disinfection and cleaning of chicken farms (storage plants).	Fig 2
Power Washing of coop	Thorough cleaning of chicken coop at least once every 12 months using water-jets and approves soap.	Fig 2 and 3
To carry out surface spraying	Spraying surfaces with low-pressure disinfectants to remove fine dust and soften stuck-on manure.	Fig 2 and 3
Prewash of surfaces	Cleaning of surfaces prior to the visit by a professional (third-party) cleaning company.	Fig 2 and 3
Steam cleaning of the site	Process used to clean difficult equipment such as cages.	Fig 2 and 3
To wipe surfaces with cloth	Process used to clean difficult equipment such as cages.	Fig 2 and 3
To dry surfaces	Surfaces should be allowed to dry before disinfection.	Fig 2 and 3
To book cleaning contractor	On completion of the <i>prewash</i> stage, trained and certified external cleaning contractors must be booked for treating the red mite infestation problem.	Fig 2 and 3
To define farm's mite disinfection standards	Identify and establish legally compliant farm's disinfection standards.	Fig 2 and 3
To depopulate poultry house	Catching, carrying, and crating of laying hens at the end-of-lay period.	Fig 2 and 3
To carry out primary cleaning	First stage of cleaning of the environment after the depopulation stage.	Fig 2 and 3

<b>Functions</b>	<b>Descriptions</b>	<b>Location of Functions</b>
To dry clean site	Blowing down or vacuuming dust from high fittings and buildings and sweeping floors to remove litter.	Fig 2 and 3
To carry out repairs by the cleaning company	Repairs likely to dislodge hidden litter/dust should be carried out after disinfection and before washing.	Fig 2 and 3
Detection of red mites in coop	Physical inspection at the end or during of an egg-laying cycle.	Fig 2 and 3
To carry out audits & inspections	Routine inspection of all areas by government and private auditors to ensure compliance with cleaning, disinfection and hygiene policies and legislation.	Fig 2 and 3
Multiple government auditors arrive at cleaning company	Arrival of multiple auditors due to poor communication.	Fig 3
Government auditor arrives at cleaning company	Arrival of the auditor to assess degree of compliance.	Fig 2
To take auditor to documentation room	Auditor is taken to the documentation room where they can assess records.	Fig 2 and 3
To audit documents	Physical audit of disinfection, cleaning and hygiene documents.	Fig 2 and 3
To take auditor to disinfectant storage room	Government auditor is taken to the storage room to assess the disinfectants (including name and compliance with EU Regulations).	Fig 2 and 3
Audit of disinfectants	Physical audit of disinfectants.	Fig 2 and 3
To understand relevant regulations	Developing a detailed understanding of regulations related to disinfection, cleaning and hygiene of poultry houses.	Fig 2
To develop audit documentation checklist	Design of checklist to ensure necessary checks are performed.	Fig 2 and 3
To develop permitted disinfectant checklist	Design of a detailed checklist listing permitted disinfectants.	Fig 2 and 3



<b>Functions</b>	<b>Descriptions</b>	<b>Location of Functions</b>
To discard disinfectant from storage	Discarding disapproved disinfectants from storage units to prevent their wrongful use.	Fig 2 and 3
To warn or take legal action against cleaning company	Take enforcement action in the event of misuse of chemicals by cleaning company.	Fig 2 and 3
To catch hens	Catching hens to depopulate the environment.	Fig 2 and 3
To ensure training to catch hens	Providing adequate training to ensure animal welfare during the catching process.	Fig 2
To ensure clean PPE is available	Provision of clean protective personal equipment as per EU Regulations to ensure biosecurity.	Fig 2 and 3
To ready transport equipment	Ensuring licensed or authorised vehicles have been organised prior to loading hens and equipment.	Fig 2 and 3
To load hens onto trucks	Loading hens without causing them harm and in a manner which ensures biosecurity.	Fig 2 and 3
To take hens to loading area	Hens taken to loading area to complete depopulation phase.	Fig 2 and 3
To take farm auditor to documentation room	Farm auditor is taken to the storage room to assess the disinfectants (including name and compliance with EU Regulations).	Fig 2 and 3
To define farm's mite monitoring standards	Definition of private standards using the EU Regulations as a baseline.	Fig 2 and 3
To develop farm audit checklist	Design of a checklist to ensure compliance during internal audit.	Fig 2 and 3
To book re-audit date	To carry out a repeat audit in the event of serious non-compliance	Fig 2 and 3
Farm auditor arrives at disinfection company	Arrival of farm auditor to inspect the contracted cleaning company.	Fig 2
Farm cleaning contract cancellation	Contract cancellation with cleaning company in the event of non-compliance.	Fig 2

<b>Functions</b>	<b>Descriptions</b>	<b>Location of Functions</b>
To audit adequacy of manpower	Auditors evaluating availability of skilled/trained labour to perform the disinfection processes.	Fig 2 and 3
To audit adequacy of disinfecting equipment	Auditors evaluating availability and readiness of disinfecting equipment.	Fig 2 and 3
To approve or disapprove adequacy of manpower	Decision on availability and readiness of personnel to deliver the disinfection service.	Fig 2 and 3
To approve or disapprove adequacy of equipment	Decision on availability and readiness of equipment to perform the disinfection service.	Fig 2 and 3
To develop equipment removal and drycleaning checklist	Checklist to ensure all equipment is removed and all areas are dry cleaned prior to the disinfection stage.	Fig 2
To take auditor to mite disinfectant storage room	Government auditor is taken to the storage room where mite disinfectants are stored for an audit of chemicals used.	Fig 2 and 3
Audit of mite disinfectants	Government auditor performs an inspection of the chemicals used and their compliance with EU Regulations.	Fig 2 and 3
To approve or disapprove mite disinfectant	Decision based on compliance of chemicals with EU Regulations.	Fig 2
To audit cleaning contractor supplies	Internal audit of chemicals by the farm auditor.	Fig 2 and 3
To ensure least financial losses	Potential egoistic approach to ensure financial sustainability at the expense of public health and environmental sustainability.	Fig 3
To approve mite disinfectant	Approval regardless of compliance with EU Regulations	Fig 3

6 **Table 3: EUWEP policy on good hygiene practices in pullet rearing and egg laying**  
 7 **flocks**

8 Adapted from European Union of Wholesale with Eggs Egg Products Poultry and Game, 2012, pp. III–IV.

<b>Process</b>	<b>Theme</b>	<b>Topic</b>	
On the farm	Risk Management Measures	Location	
		Site	
		Buildings	
		Equipment	
		Vermin, feral animals and insect control	
		Domestic animals on site	
		Feed	
		Water	
		Litter supply (for non-caged birds)	
		Veterinary products	
	Management	Record keeping	
		Routing hygiene and husbandry	
		Personnel and visitors	
		Livestock management	
		Egg management	
		Cleaning and disinfection	Forward planning
			Removal of equipment and dry cleaning
			Used litter/manure
			Water system
			Washing
Disinfection			
Assemble and checking of equipment			
Microbiological monitoring of cleaning and disinfection			
Specific measures after detection of <i>Salmonella</i>			
Depopulation and transport of hens	Catching and loading of hens		
	Transport of hens	Hygiene during transport Vehicles	

10 **Appendix 1: Topic list used during document analyses to identify aspects and coupling**  
 11 **of FRAM functions**

12 Adapted from Damen et al., 2018.

<b>Aspects</b>	<b>Questions</b>
<b>Input</b>	What starts the function? What does the function change?
<b>Output</b>	What is the outcome of the function? Does the EUWEP, DEFRA or the NVWA policy document need to be used? Does anything need auditing or checking? Who is the recipient of the output? Who will use what is produced?
<b>Precondition</b>	What needs to be in place so that the function can be completed as planned? What happens if the preconditions are not available?
<b>Resource</b>	What resources are needed to perform the function? What happens if the resources are not available?
<b>Control</b>	Specific goals for the function (e.g., to carry out an activity within certain legal frameworks) What is the purpose of this function? Why is it done? Are there formal procedures controlling the function? Are there assigned people who control the function (e.g., private auditors)? Do unofficial work practices or culture control the function? Are there constraints (e.g., resources)?
<b>Time</b>	Is there a time element <b>related</b> to the function? Is there a delay in performing the function? What are the consequences of delays? Time has four options: (1) too early; (2) on time; (3) too late; and (4) function did not occur.

**Appendix 2: Aspect labels for each function in Figure 2.**

Name of function	2.7. To complete cleaning and disinfection of coop
Aspect	Description of Aspect
Precondition	As few mites as possible
Control	Physical monitoring of cleaning & disinfection
Name of function	2.6. Power Washing of coop
Aspect	Description of Aspect
Input	Spray surfaces to saturation point
Output	As few mites as possible
Precondition	Spraying hard to reach surfaces
	Use approved mite disinfectant
Resource	Power washer
Control	Repaired equipment
	Approved disinfectants
	Approved manpower adequacy
	Approved equipment adequacy
Name of function	2.5. To carry out surface spraying
Aspect	Description of Aspect
Input	Washed inside and outside of house
	Dried inside and outside of house
Output	Spray surfaces to saturation point
	Spraying hard to reach surfaces
	Use approved mite disinfectant
Control	Repaired equipment
	Approved disinfectants
	Approved manpower adequacy
	Approved equipment adequacy
Name of function	2.1. Prewash of surfaces

Aspect	Description of Aspect
Input	Dry cleaned shed
Output	Loosened adherent dirt
Precondition	Verified cleaning contractor hired
Name of function	2.2. Steam cleaning of the site
Aspect	Description of Aspect
Input	Loosened adherent dirt
Output	Clean equipment
Precondition	Pressure steamer
Name of function	2.3. To wipe surfaces with cloth
Aspect	Description of Aspect
Input	Clean equipment
Output	Clean fittings

Name of function	2.4. To dry surfaces
Aspect	Description of Aspect
Input	Clean fittings
Output	Washed inside and outside of house
	Dried inside and outside of house
Name of function	2.8. To book cleaning contractor
Aspect	Description of Aspect
Input	Cleaning contractor supplies rigorously
Output	Verified cleaning contractor hired
Control	Approved disinfectants
	Approved manpower adequacy
	Approved equipment adequacy
Name of function	3.1. To define farm's mite disinfection standards
Aspect	Description of Aspect
Output	Pressure steamer
	Disinfection protocols defined

	Dry cleaning equipment
	Power washer
Control	Understanding of Regulation (EC) 2160/2003 of the European Parliament

Name of function	1.9. To depopulate poultry house
Aspect	Description of Aspect
Input	Hens loaded
Output	Poultry house depopulated
Precondition	Ensure removal of dead birds
	Ensure removal of rubbish
	Ensure removal of surplus feed
	Equipment removal and drycleaning checklist developed
	Clean out the coop - get rid of any bedding

Name of function	To carry out primary cleaning
Aspect	Description of Aspect
Output	Ensure removal of dead birds
	Ensure removal of rubbish
	Ensure removal of surplus feed
	Clean out the coop - get rid of any bedding

Name of function	1.10. To dry clean site
Aspect	Description of Aspect
Input	Poultry house depopulated
Output	Dry cleaned shed
Precondition	Dry cleaning equipment

Name of function	To carry out repairs by the cleaning company
Aspect	Description of Aspect
Output	Repaired equipment
Name of function	1.2. Detection of red mites in coop
Aspect	Description of Aspect

Output	Egg laying cycle ended
Name of function	3.14. To carry out audits & inspections
Aspect	Description of Aspect
Output	Ensure legal compliance
	Ensure compliance with farm standards

Name of function	3.15. Government auditor arrives at cleaning company
Aspect	Description of Aspect
Input	Ensure legal compliance
Output	Government auditor arrives
Name of function	3.16. To take auditor to documentation room
Aspect	Description of Aspect
Input	Government auditor arrives
	Farm auditor arrives
Output	Auditor arrives at documentation room
Name of function	3.18. To audit documents
Aspect	Description of Aspect
Input	Auditor arrives at documentation room
	Farm auditor arrives at documentation room
Output	Paperwork is available and completed
	Paperwork is either unavailable or incomplete
Precondition	Documentation checklist is developed
Control	Understanding of Regulation (EC) 2160/2003 of the European Parliament

Name of function	3.20. To take auditor to disinfectant storage room
Aspect	Description of Aspect
Input	Paperwork is available and completed
Output	Auditor in disinfectant storage room
Name of function	3.21. Audit of disinfectants
Aspect	Description of Aspect



Input	Auditor in disinfectant storage room
Output	Disinfectant audited
Precondition	Disinfectant checklist is developed
Control	Understanding of Regulation (EC) 2160/2003 of the European Parliament
Name of function	3.19. To understand relevant regulations
Aspect	Description of Aspect
Output	Understanding of Regulation (EC) 2160/2003 of the European Parliament

Name of function	3.17. To develop audit documentation checklist
Aspect	Description of Aspect
Output	Documentation checklist is developed
Name of function	3.22. To develop permitted disinfectant checklist
Aspect	Description of Aspect
Output	Disinfectant checklist is developed
Name of function	3.24. To discard disinfectant from storage
Aspect	Description of Aspect
Input	Disapproved disinfectants
Output	Disinfectant discarded

Name of function	To warn or take legal action against cleaning company
Aspect	Description of Aspect
Input	Disinfectant discarded
	Cleaning chemicals discarded
Name of function	1.3. To catch hens
Aspect	Description of Aspect
Output	Hens caught
Precondition	Cleaned and disinfected transport crates
Resource	Clean protective clothing and footwear
Control	Trained farm personnel or contractors
Time	Egg laying cycle ended

Name of function	1.6. To ensure training to catch hens
Aspect	Description of Aspect
Output	Trained farm personnel or contractors

Name of function	1.5. To ensure clean PPE is available
Aspect	Description of Aspect
Output	Clean protective clothing and footwear

Name of function	1.4. To ready transport equipment
Aspect	Description of Aspect
Output	Cleaned and disinfected transport crates
	Cleaned and disinfected transport vehicles

Name of function	1.8. To load hens onto trucks
Aspect	Description of Aspect
Input	Hens in loading area
Output	Hens loaded
Control	Cleaned and disinfected transport vehicles

Name of function	1.7. To take hens to loading area
Aspect	Description of Aspect
Input	Hens caught
Output	Hens in loading area

Name of function	3.5. To take farm auditor to documentation room
Aspect	Description of Aspect
Input	Farm auditor arrives
Output	Farm auditor in documentation room

Name of function	3.7. To define farm's mite monitoring standards
Aspect	Description of Aspect
Input	Farm auditor in documentation room
Output	Physical monitoring of cleaning & disinfection
	Farm auditor arrives at documentation room

Name of function	3.13. To develop farm audit checklist
Aspect	Description of Aspect
Output	Developed farm audit checklist
Name of function	3.23. To book re-audit date
Aspect	Description of Aspect
Input	Paperwork is either unavailable or incomplete
Name of function	3.12. Farm auditor arrives at disinfection company
Aspect	Description of Aspect
Input	Ensure compliance with farm standards
Output	Farm auditor arrives
Precondition	Disinfection protocols defined
	Developed farm audit checklist

Name of function	Farm cleaning contract cancellation
Aspect	Description of Aspect
Input	Paperwork is either unavailable or incomplete
	Disapproved disinfectants
	Cleaning chemicals disapproved
Name of function	3.10. To audit adequacy of manpower
Aspect	Description of Aspect
Input	Paperwork is available and completed
Output	Manpower adequacy audited
Name of function	3.11. To audit adequacy of disinfecting equipment
Aspect	Description of Aspect
Input	Paperwork is available and completed
Output	Equipment adequacy audited

Name of function	3.9. To approve or disapprove adequacy of manpower
Aspect	Description of Aspect

Input	Manpower adequacy audited
Output	Approved manpower adequacy
Name of function	3.8. To approve or disapprove adequacy of equipment
Aspect	Description of Aspect
Input	Equipment adequacy audited
Output	Approved equipment adequacy
Name of function	1.1. To develop equipment removal and drycleaning checklist
Aspect	Description of Aspect
Output	Equipment removal and drycleaning checklist developed

Name of function	3.2. To take auditor to mite disinfectant storage room
Aspect	Description of Aspect
Input	Paperwork is available and completed
Output	Auditor in disinfectant storage room
Name of function	3.3. Audit of mite disinfectants
Aspect	Description of Aspect
Input	Auditor in disinfectant storage room
Output	Disinfectant audited
Name of function	3.4. To approve or disapprove mite disinfectant
Aspect	Description of Aspect
Input	Disinfectant audited
Output	Disapproved disinfectants
	Approved disinfectants

Name of function	3.6. To audit cleaning contractor supplies
Aspect	Description of Aspect
Input	Farm auditor in documentation room
Output	Cleaning contractor supplies rigorously

**Appendix 3: Aspect labels for each function in Figure 3.**

Name of function	2.5. To complete cleaning and disinfection of coop
Aspect	Description of Aspect
Precondition	As few mites as possible
Control	Physical monitoring of cleaning & disinfection
Name of function	4.4. Power Washing of coop
Aspect	Description of Aspect
Input	Spray surfaces to saturation point
Output	As few mites as possible
Precondition	Spraying hard to reach surfaces
	Use approved mite disinfectant
Resource	Power washer
Control	Repaired equipment
	Wrongly approved disinfectants
	Approved manpower adequacy
	Approved equipment adequacy
Name of function	4.3. To carry out surface spraying
Aspect	Description of Aspect
Input	Washed inside and outside of house
	Dried inside and outside of house
Output	Spray surfaces to saturation point
	Spraying hard to reach surfaces
	Use approved mite disinfectant
Control	Repaired equipment
	Wrongly approved disinfectants
	Approved manpower adequacy
	Approved equipment adequacy
Name of function	2.1. Prewash of surfaces

Aspect	Description of Aspect
Input	Dry cleaned shed
Output	Loosened adherent dirt
Precondition	Verified cleaning contractor hired
Name of function	2.2. Steam cleaning of the site
Aspect	Description of Aspect
Input	Loosened adherent dirt
Output	Clean equipment
Precondition	Pressure steamer
Name of function	2.3. To wipe surfaces with cloth
Aspect	Description of Aspect
Input	Clean equipment
Output	Clean fittings

Name of function	2.4. To dry surfaces
Aspect	Description of Aspect
Input	Clean fittings
Output	Washed inside and outside of house
	Dried inside and outside of house
Name of function	4.10. To book cleaning contractor
Description	Book appropriate cleaning contractor by auditing contractor's policies and procedures followed to depopulate and clean.
Aspect	Description of Aspect
Input	Incorrectly audited cleaning contractor supplies
Output	Verified cleaning contractor hired
Control	Approved manpower adequacy
	Approved equipment adequacy
Name of function	3.1. To define farm's mite disinfection standards
Aspect	Description of Aspect
Output	Pressure steamer

	Disinfection protocols defined
	Dry cleaning equipment
	Power washer
Control	Understanding of Regulation (EC) 2160/2003 of the European Parliament

Name of function	1.9. To depopulate poultry house
Aspect	Description of Aspect
Input	Hens loaded
Output	Poultry house depopulated
Precondition	Ensure removal of dead birds
	Ensure removal of rubbish
	Ensure removal of surplus feed
	Quick completion of equipment removal and drycleaning checklist
	Clean out the coop - get rid of any bedding

Name of function	1.10. To carry out primary cleaning
Aspect	Description of Aspect
Output	Ensure removal of dead birds
	Ensure removal of rubbish
	Ensure removal of surplus feed
	Clean out the coop - get rid of any bedding

Name of function	1.11. To dry clean site
Aspect	Description of Aspect
Input	Poultry house depopulated
Output	Dry cleaned shed
Precondition	Dry cleaning equipment

Name of function	2.6. To carry out repairs by the cleaning company
Aspect	Description of Aspect
Output	Repaired equipment
Name of function	1.2. Detection of red mites in coop

Aspect	Description of Aspect
Output	Egg laying cycle ended
Name of function	3.12. To carry out audits & inspections
Aspect	Description of Aspect
Output	Ensure legal compliance
	Ensure compliance with farm standards

Name of function	4.8. Multiple government auditors arrive at cleaning company
Aspect	Description of Aspect
Input	Ensure legal compliance
Output	Auditors arrive
Name of function	3.13. To take auditor to documentation room
Aspect	Description of Aspect
Input	Auditors arrive
Output	Auditor arrives at documentation room
Name of function	3.14. To audit documents
Aspect	Description of Aspect
Input	Auditor arrives at documentation room
	Farm auditor arrives at documentation room
Output	Poor quality audits completed
	Incomplete paperwork detected by chance
Precondition	Documentation checklist is developed
Control	Understanding of Regulation (EC) 2160/2003 of the European Parliament

Name of function	3.15. To take auditor to disinfectant storage room
Aspect	Description of Aspect
Input	Poor quality audits completed
Output	Auditor in disinfectant storage room
Name of function	3.16. To audit disinfectants
Aspect	Description of Aspect



Input	Auditor in disinfectant storage room
Output	Poorly audited disinfectants
Precondition	Disinfectant checklist is developed
Control	Understanding of Regulation (EC) 2160/2003 of the European Parliament
Name of function	3.9. To develop audit documentation checklist
Aspect	Description of Aspect
Output	Documentation checklist is developed

Name of function	3.17. To develop permitted disinfectant checklist
Aspect	Description of Aspect
Output	Disinfectant checklist is developed
Name of function	4.5. To discard disinfectant from storage
Aspect	Description of Aspect
Input	Disapproved disinfectants
Output	Disinfectant discarded
Name of function	4.7. To warn or take legal action against cleaning company
Aspect	Description of Aspect
Input	Disinfectant discarded
	Cleaning chemicals discarded

Name of function	1.3. To catch hens
Aspect	Description of Aspect
Output	Hens caught
Precondition	Cleaned and disinfected transport crates
Resource	Clean protective clothing and footwear
Control	Trained farm personnel or contractors
Time	Egg laying cycle ended
Name of function	1.6. To ensure adequate training to catch hens
Aspect	Description of Aspect
Output	Trained farm personnel or contractors

Name of function	1.5. To ensure clean PPE is available
Aspect	Description of Aspect
Output	Clean protective clothing and footwear

Name of function	1.4. To ready transport equipment
Aspect	Description of Aspect
Output	Cleaned and disinfected transport crates
	Cleaned and disinfected transport vehicles

Name of function	1.8. To load hens onto trucks
Aspect	Description of Aspect
Input	Hens in loading area
Output	Hens loaded
Control	Cleaned and disinfected transport vehicles

Name of function	1.7. To take hens to loading area
Aspect	Description of Aspect
Input	Hens caught
Output	Hens in loading area

Name of function	3.3. To take farm auditor to documentation room
Aspect	Description of Aspect
Input	Farm auditor arrives
Output	Farm auditor in documentation room

Name of function	3.4. To define farm's mite monitoring standards
Aspect	Description of Aspect
Input	Farm auditor in documentation room
Output	Physical monitoring of cleaning & disinfection
	Farm auditor arrives at documentation room

Name of function	3.11. To develop farm audit checklist
Aspect	Description of Aspect
Output	Developed farm audit checklist

Name of function	4.6. To book re-audit date
Aspect	Description of Aspect
Input	Incomplete paperwork detected by chance
Name of function	3.10. Farm auditor arrives at the disinfection company
Aspect	Description of Aspect
Input	Ensure compliance with farm standards
Output	Farm auditor arrives
Precondition	Disinfection protocols defined
	Developed farm audit checklist
Name of function	3.7. To audit adequacy of manpower
Aspect	Description of Aspect
Input	Disapproved disinfectants
	Paperwork is available and completed
	Cleaning chemicals disapproved
Output	Manpower adequacy audited

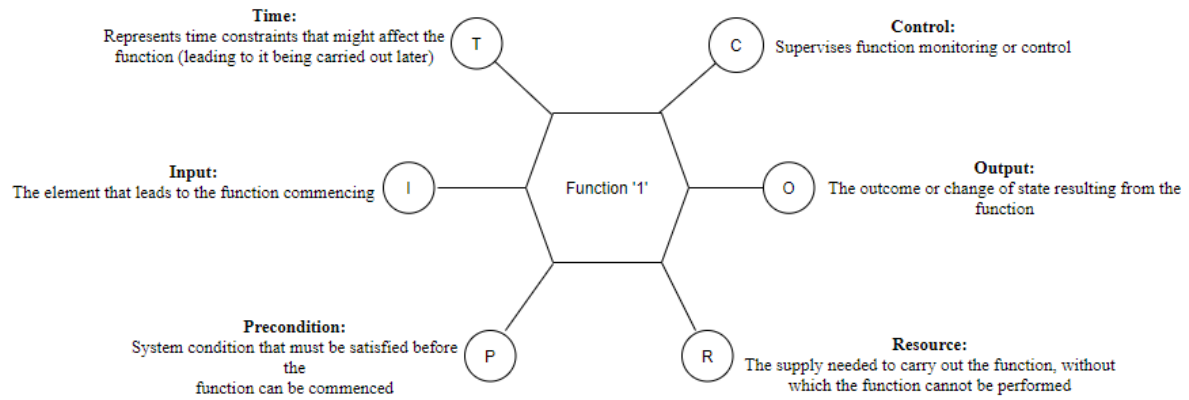
Name of function	3.8. To audit adequacy of disinfecting equipment
Aspect	Description of Aspect
Input	Paperwork is available and completed
Output	Equipment adequacy audited
Name of function	3.6. To approve or disapprove adequacy of manpower
Aspect	Description of Aspect
Input	Manpower adequacy audited
Output	Approved manpower adequacy
Name of function	3.5. To approve or disapprove adequacy of equipment
Aspect	Description of Aspect
Input	Equipment adequacy audited
Output	Approved equipment adequacy

Name of function	1.1. To ensure least financial losses
Aspect	Description of Aspect
Output	Quick completion of equipment removal and drycleaning checklist
Name of function	3.2. To take auditor to mite disinfectant storage room
Aspect	Description of Aspect
Input	Poorly audited disinfectants
Output	Auditor in red mite disinfectant storage room
Name of function	4.1. Audit of mite disinfectants
Aspect	Description of Aspect
Input	Auditor in red mite disinfectant storage room
Output	Incorrect audit of red mites

Name of function	4.2. To approve mite disinfectant
Aspect	Description of Aspect
Input	Incorrect audit of red mites
Output	Wrongly approved disinfectants
Name of function	4.9. To audit cleaning contractor supplies
Aspect	Description of Aspect
Input	Farm auditor in documentation room
Output	Incorrectly audited cleaning contractor supplies

# 1 **Figure 1: An example of a FRAM function hexagon with the six aspects**

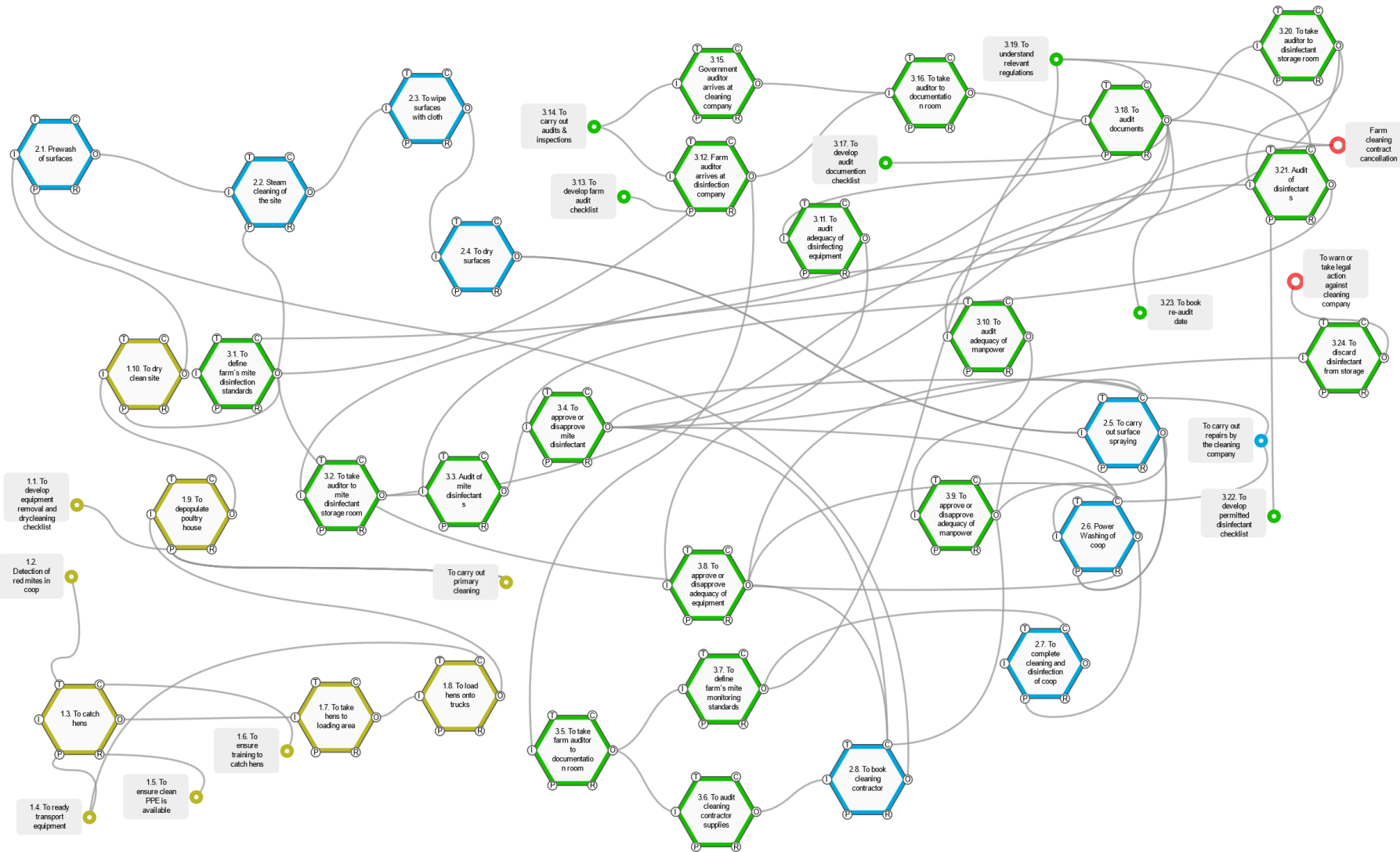
2 Adapted from (Ferreira and Canas, 2019).



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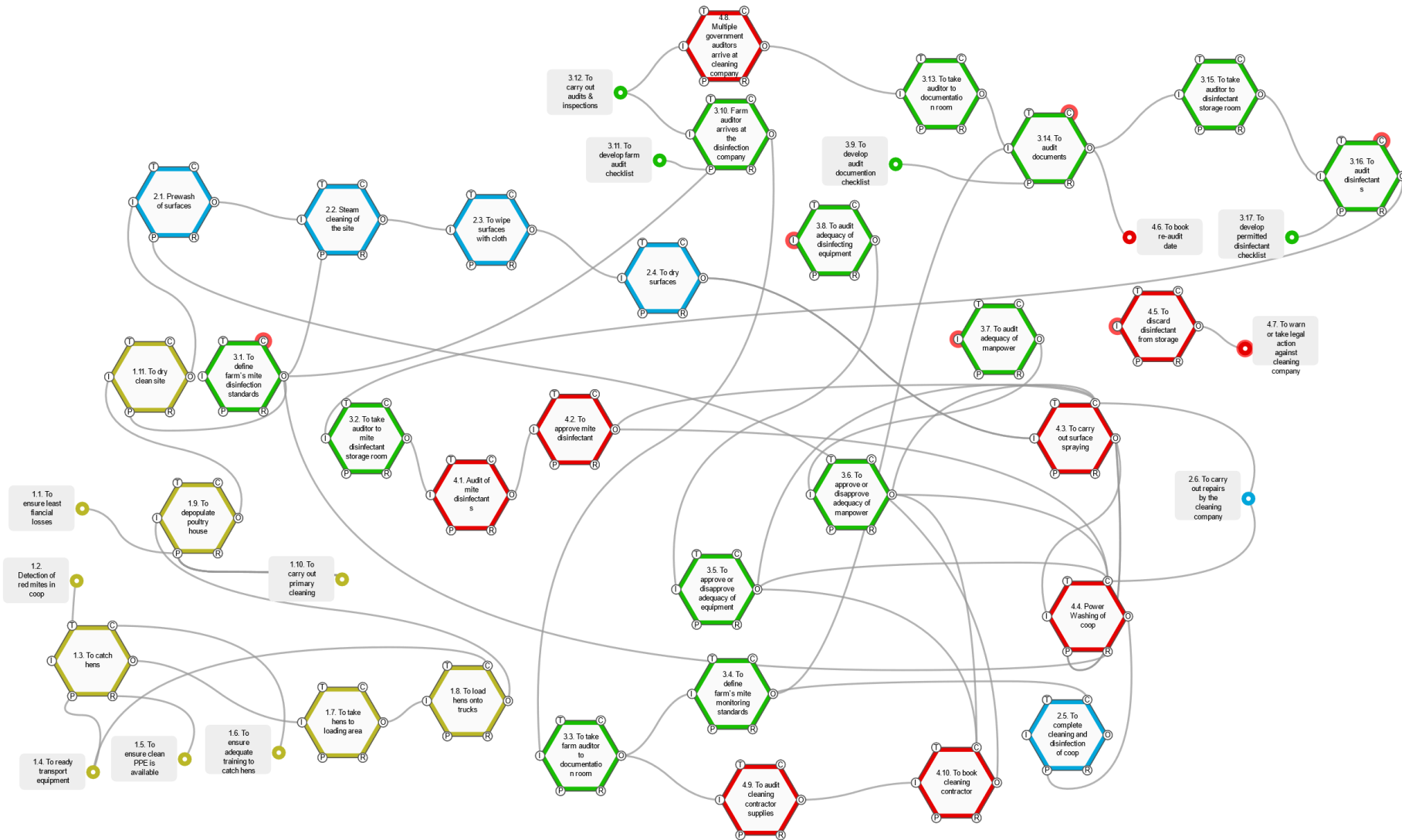
5 **Figure 2: FRAM based on a work-as-imagined philosophy for red mite elimination in poultry farms (eggs)**



7

Key  
I – Input  
O – Output  
R – Resources  
P – Precondition  
C – Control  
T – Time

8 Figure 3: FRAM based on work-as-done for red mite elimination in poultry farms (eggs)





Key  
I - Input  
O - Output  
R - Resources  
P - Precondition  
C - Control  
T - Time



## **Highlights**

- 2017 Fipronil in egg contamination incident in the Netherlands was explored.
- Red mites were eliminated through practices that did not comply with regulations.
- Performance variability in public hygiene policies was a key failure in work as done.
- The use of FRAM was of value in assessing complex food systems.

**Exploration of the fipronil in egg contamination incident in the Netherlands using the Functional Resonance Analysis Method**

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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## CRediT Author Statement

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**Rounaq Nayak:** Conceptualisation, Methodology, Investigation, Formal analysis, Resources, Visualisation, Writing – Original Draft

**Louise Manning:** Validation, Resources, Writing – Review & Editing

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