Pinch points affecting the food supply chain
FO0451
November 2013

This report was prepared by:

David Parson

Cranfield University

THIS PROJECT HAS BEEN FUNDED BY DEFRA. HOWEVER, THE CONTENT AND ANY RECOMMENDATIONS CONTAINED WITHIN THIS REPORT DO NOT NECESSARILY REFLECT DEFRA’S VIEWS

General Enquiries on the form should be made to:
Defra, Procurements and Commercial Function (Evidence Procurement Team)
E-mail: research.competitions@defra.gsi.gov.uk
In line with the Freedom of Information Act 2000, Defra aims to place the results of its completed research projects in the public domain wherever possible. The Evidence Project Final Report is designed to capture the information on the results and outputs of Defra-funded research in a format that is easily publishable through the Defra website. An Evidence Project Final Report must be completed for all projects.

- This form is in Word format and the boxes may be expanded, as appropriate.

### ACCESS TO INFORMATION

The information collected on this form will be stored electronically and may be sent to any part of Defra, to individual researchers or organisations outside Defra for the purposes of reviewing the project. Defra may also disclose the information to any outside organisation acting as an agent authorised by Defra to process final research reports on its behalf. Defra intends to publish this form on its website, unless there are strong reasons not to, which fully comply with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

Defra may be required to release information, including personal data and commercial information, on request under the Environmental Information Regulations or the Freedom of Information Act 2000. However, Defra will not permit any unwarranted breach of confidentiality or act in contravention of its obligations under the Data Protection Act 1998. Defra or its appointed agents may use the name, address or other details on your form to contact you in connection with occasional customer research aimed at improving the processes through which Defra works with its contractors.

### Project identification

1. Defra Project code  
   FO0451

2. Project title  
   Research into pinch points affecting the food supply chain

3. Contractor organisation(s)
   Cranfield University
   Cranfield
   Bedford
   MK43 0AL

4. Total Defra project costs
   £ 27852
   (agreed fixed price)

5. Project: start date ...............  
   4/3/2013

   end date ...............  
   30/4/2013
6. It is Defra’s intention to publish this form.

Please confirm your agreement to do so..............................................................YES □ NO □

(a) When preparing Evidence Project Final Reports contractors should bear in mind that Defra intends that they be made public. They should be written in a clear and concise manner and represent a full account of the research project which someone not closely associated with the project can follow. Defra recognises that in a small minority of cases there may be information, such as intellectual property or commercially confidential data, used in or generated by the research project, which should not be disclosed. In these cases, such information should be detailed in a separate annex (not to be published) so that the Evidence Project Final Report can be placed in the public domain. Where it is impossible to complete the Final Report without including references to any sensitive or confidential data, the information should be included and section (b) completed. NB: only in exceptional circumstances will Defra expect contractors to give a "No" answer.

In all cases, reasons for withholding information must be fully in line with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

(b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.
Aims
The aim of this project was to understand more about the impact of fuel supply disruption on the UK food supply chain and how these impacts are mitigated. It was envisaged that this would set the basis for building the evidence base by mapping what evidence is currently available and identifying knowledge gaps for further research.

Background and objectives
The UK has a highly effective and secure food supply chain, providing wide consumer choice. Food retailers are expected to have robust business continuity plans to deal with threats to disruptions to food supply and Defra works closely with industry to ensure that Government support is provided in the event of part of the industry requiring support.

The UK sources food from a diverse range of domestic and international suppliers, which helps maintain resilience of supply and keep prices stable. The efficiency of short “Just in Time” (JIT) supply chains is a major strength in keeping costs down. However this approach may lower UK resilience to fuel disruption due to the limited supply of residual food stocks and a heavy reliance on transporting foods by retailers to meet consumer demand. While major food industry players – retailers and distributors are expected to have good bunkered fuel stocks, there is an assumption (based on anecdotal evidence) that many SMEs don’t have the space or financial resources to hold fuel.

The most extensive recent disruption was caused by the protests in 2000 by fuel users, which included a blockade of oil facilities. Subsequent protests in 2005 and 2007 did not include effective blockades, but have kept the possibility of disruption in view.

In the light of the issues raised above, this study set out to review the academic and other evidence, then collate and synthesise information to:

1. Identify the key pinch points in the food supply chain that are sensitive to fuel disruption.
2. Identify those stakeholders and geographical areas most affected by fuel disruption.
3. Identify the mechanisms by which they are affected.
4. Identify the impact (economic, social, and environmental) of fuel supply disruption.

Approach
For the purpose of the review, it was assumed that the typical scenario was a five day protest, blockade or strike causing seven days of disruption to fuel supplies. A pinch point was taken to mean a step in the chain where such disruption could cause a serious reduction in the supply of food to consumers.

Evidence was gathered by reviewing the academic literature (journals and conference proceedings) and available reports from the public and private sectors, using a planned systematic approach. Additional current information was drawn from the web sites of trade bodies and individual companies. The review focused on information from the UK, but included other sources where there was sufficient similarity with the UK supply chain.

The reviews covered meat (beef, sheep, pig and chicken), fruit and vegetables (strawberries and potatoes, taken as extreme cases), milk, eggs, bread, fish and prepared meals. These were chosen to include the main food groups, exemplified by the eatwell plate and to cover a diverse range of supply chain characteristics, including ambient, chilled and frozen, different shelf lives, multiple routes to market, and both home-produced and imported goods.

There has been little academic study of the robustness of UK food supply chains; most research has focused on improving the efficiency of value chains, reflecting a trend towards leaner operations by most of the big providers. Consequently, this review relied on diverse sources of information, including official statistics, reports for public and private sectors, and publicly-accessible company information. Although the individual information sources may not all have been subject to independent review, multiple sources and cross-verification were used to support the robustness of the conclusions, albeit with some imprecision and uncertainty about specific details.

The information was used to map the supply chains for the products being reviewed and to try to estimate the stocks flows and lead times in each stage. These were used to explore the points within each chain where disruption to fuel supplies could propagate to consumers within one week. They also helped to identify the links that could have an impact on large volumes of food supplies.

In addition to considering the supply chains for home consumption, three types of institutions that feed vulnerable groups were considered: schools, hospitals and prisons. Although schools are not the only food providers for children, they are a significant component, especially in economically deprived areas. Hospitals and prisons are both the sole providers to their residents.

The literature review was supplemented by a set of six semi-structured, explorative interviews with stakeholders in the supply chain. Experts with an overview of the whole supply chain, as well as those with
process-specific expertise were selected, to include three trade bodies/associations, a food safety organisation, one generic third-party logistics supplier, and one logistics company dealing with supply to a vulnerable group. Other organisations (to include a supermarket and a food service chain) were invited to participate, but did not respond. Interviews were transcribed in full and analysed using an inductive reasoning approach, in the qualitative data analysis tool NVivo. Although insufficient to provide a representative sample of industry views, they were very useful in highlighting areas of concern and uncertainty within the industry, which were in many cases not highlighted in the literature. The most common recurring themes are discussed below, alongside the results of the literature review.

Results and conclusions

The results of the research are described below in three key sections, related to the objectives: (1) identification of pinch points, (2) identification of stakeholders and the mechanisms by which they are affected, and (3) the impact of a disruption to the economy, society and environment.

(1) Identification of pinch points

The supply chains maps typically identified four main location types or handling points with transport between them. These were the farms where raw food was produced or ports where it was imported, processors or packaging stations (including dairies, abattoirs, millers and bakers), regional distribution centres or warehouses, and retailers or food-service outlets. Some food types might pass through more than one processor (e.g. miller then baker), and some handling points could be co-located (e.g. on-farm packaging of vegetables or dockside packaging of fish). Pinch points were viewed as disrupting transport into these locations, but could also have consequences at the upstream point, as goods could not be removed, so would cause storage problems and potentially generate waste.

Table 1 is a summary of the locations, the issues identified and the food types affected by each. It highlights eight issues affecting multiple supply chains at multiple points. Four of these were supported by evidence from both the literature review and the interviews (highlighted in dark orange); the other four arose from the interviews only. A further seven issues were specific to fewer locations or food types.

Table 1. Summary of possible causes and locations of pinch points across multiple food chains in the event of a 7 day fuel disruption.

Letters are used to denote the foods affected: meat (M), sea fish (S), vegetables (V), dairy (D), eggs (E), fruit (F), bread (B) and pre-prepared food (P), or all types. Brackets indicate that only some companies or some foods within a given type would be affected. Issues highlighted in dark orange are those where evidence was found in both the literature and interviews to suggest that a large number of food supply chains could be affected for 3 or more stages in the supply chains. Issues highlighted in light orange are those where one type of evidence was found to suggest that a large number of food supply chains could be affected for 3 or more stages in the supply chains. Other issues affected fewer food types or had more localised effects.

<table>
<thead>
<tr>
<th>Evidence (I= interview, L= literature review, or B= both)</th>
<th>Issue (possible cause of pinch point)</th>
<th>Location of pinch point</th>
<th>Distribution from farm/import</th>
<th>Process/packaging</th>
<th>RDC/wholesale</th>
<th>Retail/service</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Low food stock</td>
<td></td>
<td>M, S, V, D, E, F, P</td>
<td>All</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Reliance on third party logistics</td>
<td></td>
<td>V, E, (B)</td>
<td>All</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Staff fuel shortages</td>
<td></td>
<td>All</td>
<td>All</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Other food safety issues (fraud/reduction in quality checking)</td>
<td></td>
<td>All (mostly M/S)</td>
<td>All (mostly M/S)</td>
<td>All (mostly M/S)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Possibly insufficient bunkerated fuel stocks</td>
<td></td>
<td>All</td>
<td>All</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Fuel prioritisation concerns (unclear operational plans, lack of</td>
<td></td>
<td>All</td>
<td>All</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>
From this analysis, it is possible to see that the following issues may contribute to the development of new pinch points, or exacerbate existing vulnerabilities in the supply chain.

- **Low food stock levels throughout the chain**
  The picture that emerged from the literature review on food processors, distributors and retailers clearly confirmed the trend towards very low stock levels throughout supply chains. For fresh and perishable goods, the stocks held by retailers were less than one day in some cases (e.g. milk), relying on frequent deliveries, and at most 3 days.

  The largest bulk stocks of most UK-produced foods are on farms or upstream of the processors (e.g. grain merchants). Other than these, there is possibly more food stored by the public than at and other point in the supply chain. Consumers often buy sufficient stocks of most product types for a week or more of normal consumption. However, these will often be run down before restocking, so the average stock level is lower and the timing of disruption relative to purchase will be significant.

  There were many gaps in the available information, particularly on stock levels, although some of these could be inferred from information of the frequency of deliveries. The estimated stock levels at retailers are 0.5–7 days of normal demand depending on the products. For most fresh and perishable foods the levels are at the lower end of this range. Stock levels at distribution centres are probably very low (less than 1 day for many products), and 0.5–4 days at processors, except for a few storable commodities, such as potatoes.

- **Reliance on logistics service providers**
  As a result of the above, the UK population is dependent on transport, principally road transport, to maintain continuity of the food supply. A large proportion of this is handled by logistics service providers, rather than food companies. In many cases, interruptions to transport of supplies to processors or at any point downstream would cause shortages within one week.

- **Staff fuel shortages**
  Given the manual nature of much of the work in the food industry, there is a heavy reliance in staff availability. Processing plants are often situated in rural locations which may not be well-serviced by public transport, and distribution centres require staff to reach work to ensure logistics are maintained. Some organisations had considered contingency plans (e.g. staff buses) following previous fuel disruptions, but it is unclear whether they would be equipped to deliver these during a period of disruption.

- **Temperature control requirements and associated food safety concerns**

<table>
<thead>
<tr>
<th></th>
<th>cover for non-food supply areas/ small bus.</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Need for waste removal</td>
<td>(?)</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td>B</td>
<td>Low packaging and non-food stocks</td>
<td>All</td>
<td>(?)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>High frequency of delivery</td>
<td></td>
<td>F, V, B, S, D</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Susceptibility to shocks due to harvest schedule/ seasonality</td>
<td>(V)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Low holding capacity for live animals</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Centralisation of production</td>
<td>B, M, (D), (P)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Reliance on imports</td>
<td>F, S, V, (M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Lack of contingency in small businesses</td>
<td>All (D, B to a lesser extent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indicative count (each food = 1 and letters in brackets = 0.5)</td>
<td>31.5</td>
<td>67</td>
<td>61.5</td>
</tr>
</tbody>
</table>
Highly perishable products are particularly vulnerable to transport disruption, because it is impossible to hold significant stocks at any point. Milk, fresh fruit and fresh fish are all examples of this: even a short interruption to chilled transport would render them unfit for consumption, causing the supply to fail and generating waste, with attendant disposal problems. For milk in particular, there is no way to stop the supply and few environmentally benign disposal methods.

- **Other food safety issues (e.g. fraud or reduction in quality checking)**
  Given the economic losses that some producers, processors, retailers or food outlets may experience form waste, there may be a rise in fraudulent or lower quality produce being sold. However, impacts are likely to be confined to high value, perishable goods such as meat and fish.

- **Possibly insufficient bunkered fuel stocks**
  The final transport step to the large supermarkets is essential for bulk food supplies to most of the population: these stores supply about 90% of many commodities. The retailers and their logistics service providers are aware of this dependence and have contingency plans, including fuel bunkering. However, some doubts were expressed about the adequacy of these fuel stocks in the interviews.

- **Fuel prioritisation concerns (unclear operational plans, small businesses, lack of cover for delivery of non-food supplies)**
  There was a recognition that food transport might be given priority in a crisis, but uncertainty about how this would operate. It was questioned whether small businesses, including producers, local processors and ‘corner shops’, which might operate single vehicles, would be included. Additional concern was raised about whether essential non-food components, such as labelling, packaging, inert gases and cleaning materials would receive the same priority.

- **The need for waste removal to be maintained for health, safety and environmental reasons**
  Normal waste arisings include food waste in processing plants, especially abattoirs, and empty packaging, particularly at retailers. If waste collections were disrupted this would accumulate. During interviews, participants noted that waste in retail stores may build up to the point where no further food stock could be accepted for safety and space reasons. An inability to remove food waste from processors or other sites might lead to environmental or health concerns.

- **Low packaging and non-food stocks**
  Most food products require non-food supplies, such as packaging, inert gases and cleaning supplies, as well as minor ingredients including required additives and preservatives. There was little information on the stocks of most of these, but some evidence that stocks of packaging at processors are generally very low. Failure to deliver these could disrupt food supplies even if raw food ingredients were available as normal.

- **High frequency of delivery**
  Due to the low stock levels throughout the supply chain, deliveries are frequent for each chain. This places increasing reliance on the availability of fuel.

- **Susceptibility to shocks due to harvest schedules and seasonality**
  Some vegetable and fruit products might be more severely affected if disruption occurred during the harvest season.

- **Low holding capacity for live animals**
  There is little capacity to hold livestock within the meat supply chain, given animal welfare regulations. This issue is particularly prominent for chicken due to the very rapid growth cycle.

- **Centralisation of production**
  Some processing, such as baking and production of some meat products, is highly centralised, meaning that food supply is reliant on long-distance transport, which could be more vulnerable to disruption.

- **Reliance on imports**
  Almost half (47% by raw food value) of the food consumed in the United Kingdom is imported, mainly from the EU, which supplies 28% of the food consumed. All imported goods and landed fish enter through a limited number of ports, which are remote from most of the population. Disruption of transport from ports could, therefore, have a significant impact of food supplies, especially for fresh fruit, of which 85% is imported and vegetables and processed pork.

- **Lack of contingency planning in small businesses**
Small farmers and retailers were thought to be most likely to have inadequate contingency plans, and thus most likely to be able to maintain supplies in the event of disruption.

(2) Identification of stakeholders and the mechanisms by which they are affected

Multiple retailers are likely to be impacted, given that very little stock is held in the stores or distribution centres. This near-stockless supply chain necessitates regular, reliable transport operations, which are often provided by third-party logistics companies. Depending on the reliability of these providers (and their contingency plans), retailers may be susceptible to fuel shocks. However, they are likely to have priority access to fuel. Retailers also rely on the ability of their staff to travel to work. Further problems would arise if waste collections were disrupted, causing the accumulation of packaging and food waste. In the worst cases, the volume of waste could prevent deliveries of stock, and food waste could present a health hazard.

Other food retailers (including markets, local traders, small supermarkets and convenience stores) may be more reliant on small, local suppliers, who may be less prepared. These retailers may see an initial increase in sales, provided they could maintain stock. However, they would be fragile if supply routes failed. Some small traders rely on their own transport to collect stock, but might be unable to obtain fuel.

Food service businesses account for one third of expenditure on meals and these businesses would be sensitive to interruptions to their food supply, and the ability of consumers to travel to them. During the 2000 fuel protests, some businesses reported reduced demand.

Third party logistics companies are relied upon heavily and will feel strain during disruptions. There is an expectation that they will have up-to-date contingency plans and sufficient bunkered fuel to cover 7 days of disruption. They also rely on staff being able to travel to work.

Processors and distributors hold low food and non-food stocks (1–3 days cover for perishables). As intermediaries, they are susceptible to both upstream and downstream disruptions – either being unable to receive materials to produce goods, or not being able to move their goods off site (causing waste arisings). Some smaller businesses might be unable to survive even a short disruption.

Farmers and growers, while outside the scope of this study, are clearly inputs to the supply chain who would suffer economically – particularly as many are paid on delivery. They may be left with unsaleable, and possibly unsafe, goods to dispose of. Crops may be ploughed in on some farms, or opened for grazing, but disruptions to milk, egg or meat supply would create environmental hazards from waste. Some farmers could delay harvest, but some (e.g. pea farmers) could not. Potato, cereal, and root vegetable farmers with storage may not be affected. Lost sales for seasonal goods might be higher if the disruption occurred in-season.

Importers and sea fish suppliers depend on longer distribution from ports to the next steps in the chain. Stock may build up at ports if imports continue to arrive but distribution stops,

Consumers and vulnerable communities are considered under ‘societal impacts’ in below.

(3) Impact of a disruption on society, the economy and the environment

Dwellers in rural areas generally maintain larger stocks of food than those in urban areas, and those in very remote areas subject to extreme weather are often well-provisioned. They are likely to be less quickly affected than urban dwellers. The groups with the lowest stocks are typically low income groups in urban areas, who are also likely to have limited flexibility in the use of alternative channels.

Although large supermarkets supply most of the retail food in the UK, smaller stores have an important role, both for top-ups between bulk shopping and for consumers unable to travel to large stores for several reasons, including lack of mobility, poverty and remoteness. It is uncertain whether these have the same level of contingency planning.

Most hospitals and prisons are supplied with food through national contracts with large producers and processors using third-party logistics services, so they depend on their contingency planning.

Supplies to schools are generally organised at the level of local authorities or individual schools, with sources ranging from large companies to smaller local suppliers, which may be vulnerable to disruption if small suppliers do not have good plans in place.

Interruption of the cold chain for perishable foods could pose a health risk unless strict controls remained in place. Disruption of imports could reduce the variety of fresh fruit and vegetables available, but would be unlikely to have a serious health impact within a week. Individuals with restricted diets for any reason might be more affected by a reduction in choice.

There is insufficient evidence to make a reliable estimate of the potential economic impact. Clearly there is a potential loss of turnover around any of the pinch points identified. During the 2000 fuel protests, most retailers continued to receive supplies and some reported increased turnover. Conversely, many food-service enterprises reported a decrease in business. At any time, some companies will be fragile and
vulnerable to a temporary loss of business.

Any disruption to distribution of perishable products would generate waste upstream, with attendant disposal problems. For milk in particular there is no way to stop the supply and few environmentally benign disposal methods.

When operating normally, waste arises at several points in the supply chain, notably at food processing plants, especially abattoirs, and packaging waste at retailers. Disposal of these wastes relies on road transport. A prolonged disruption of waste removal would halt operations and could present an environmental or health hazard.

Implications and further research needs

- Concern was expressed in some of the interviews about how the Government’s priority fuel allocation scheme, which is intended to minimise the impact of a fuel crisis on essential services, would operate in practice. It is important that this information is clearly communicated to the industry before a crisis, so that it can be integrated into their contingency planning. This will be important in avoiding complacency.

- A related issue is the status of small companies, such as individual farmers and retailers. Interviews and anecdotal information suggest that they ‘have to queue at the pumps with everyone else.’ This should be reviewed.

- Companies need to review their contingency plans regularly, because they may become out of date as businesses develop.

- It may be useful to liaise with the Departments for Education and Health, the NHS, and the Ministry of Justice to understand the contingency plans in place for schools, hospitals and prisons. This review did not have access to this information, yet it is likely to be important in the protection of vulnerable communities.

- The security of supplies to institutions when they opt out of central contracts needs to be reviewed. If they use local contracts for staple foods, they need to ensure that adequate contingency plans are in place to guarantee continuity in the event of transport disruption.

- Although the large supermarkets are responsible for the majority of food supplies to consumers, the important social role of smaller retailers, especially for vulnerable groups, should not be overlooked in contingency planning.

- More research is needed to fill in the multiple evidence gaps on stock cover, delivery distances, and delivery frequency that were identified in this study. It is likely that a targeted questionnaire to industry professionals would be most helpful in rapidly generating data of this nature.

- Little evidence was available on stocks of non-food materials such as packaging, gases, yeast or additives. More investigation is needed in this area.

- The other major uncertainty was the level of fuel stocks held by smaller operators, including company fleets, producers, wholesalers and retailers, where large logistics service providers were not used. Given the large number of small companies involved, this would require a survey of a representative sample of companies to estimate the position across the industry.

- Many of the unique issues identified in the interviews may require additional research to validate these opinions. In particular, concerns around food safety and food fraud, contingency planning, fuel bunkering and waste removal may require further investigation.

- More interviews with industry experts (at both a strategic and operational level) are likely to be beneficial. The small sample size in this study cannot be considered to be representative or wholly inclusive. However, despite this the interviews yielded information on numerous pinch points which were not discussed in the literature. Additional interviews may highlight new pinch points, offer new data on typical stock levels, or confirm/ reject those gathered in this study.

- In particular, it would be important to interview supermarkets and small retailers in future studies, as they represent an important part in the supply chain, but were unable to be interviewed during this project.

- The study demonstrated that the food supply chain is highly interdependent. Future work may wish to model the system as a whole in a quantitative manner, to understand the real impact of shocks on the system. With sufficient time and access to data, it would be possible to gain a much clearer picture of exactly how fuel disruptions would impact access to food.

- Little concrete evidence was found on the impacts of a fuel disruption to consumer behaviour or panic buying. Similarly, little evidence was available on the environmental, social or economic impacts. It may be necessary to commission this research during/ immediately after future events, in order to inform future planning. Alternatively, quantitate modelling of the system may yield some
information to contribute to this understanding.

---

**Project Report to Defra**

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;
- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Exchange).
1. Introduction

1.1 Background
Defra has Lead Responsibility for the Government response to emergencies disrupting food and drink manufacturing and wholesale or retail food distribution in England. While there are no specific risks in the National Risk Assessment directly affecting food, many of the risks have significant consequences for food supply.

The UK has a highly effective and secure food supply chain, providing wide consumer choice. Food retailers are expected to have robust business continuity plans to deal with threats to disruptions to food supply and Defra works closely with industry to ensure that Government support is provided in the event of part of the industry requiring support.

The UK sources food from a diverse range of domestic and international suppliers, which helps maintain resilience of supply and keep prices stable. The efficiency of short “Just in Time” (JIT) supply chains is a major strength in keeping costs down. However this approach may lower UK resilience to fuel disruption due to the limited supply of residual food stocks and a heavy reliance on transporting foods by retailers to meet consumer demand. While major food industry players – retailers and distributors are expected to have good bunkerized fuel stocks, there is an assumption (based on anecdotal evidence) that many SMEs don’t have the space or financial resources to hold fuel.

The most extensive recent disruption was caused by the protests in 2000 by fuel users, which included a blockade of oil facilities. Subsequent protests in 2005 and 2007 did not include effective blockades, but have kept the possibility of disruption in view.

In the light of recent severe weather problems and threatened industrial action by fuel tanker drivers in 2012, a deeper understanding of the impacts of fuel disruption on the supply chain was needed. This will ensure that government and industry are informed and prepared for potential disruptions, able to help mitigate negative impacts and maintain resilience of supply where possible.

1.2 Objectives
In the light of the issues raised above, this study set out to review the academic and other evidence, then collate and synthesise information to:

1. Identify the key pinch points in the food supply chain that are sensitive to fuel disruption.
2. Identify those stakeholders and geographical areas most affected by fuel disruption.
3. Identify the mechanisms by which they are affected.
4. Identify the impact (economic, social, and environmental) of fuel supply disruption.

In addition, if time permitted, evidence on the best ways to improve resilience during emergency situations would be included.

For the purpose of the review, it was assumed that the typical scenario was a five day protest, blockade or strike causing seven days of disruption to fuel supplies. A pinch point was taken to mean a step in the chain where such disruption could cause a serious reduction in the supply of food to consumers.

1.3 Achievement of objectives

1. Identify the key pinch points in the food chain that are sensitive to fuel disruption
There was very little direct evidence from the academic literature on the effects of fuel disruption on food supply chains. The available evidence from all sources was used to create supply chain maps and quantify stocks and flows as far as possible given the limited data available. This showed that supplies to most consumers are vulnerable to disruption in most stages of the supply chain for all products except storable vegetables, frozen foods and possibly eggs. The one stage that is common to a very high proportion of the food supplied, and therefore an important vulnerability, is the final delivery from distribution centres to major supermarkets.

2. Identify those stakeholders and geographical areas most affected by fuel disruption
Limited evidence was found on differences between urban and rural areas and between socio-economic groups. Some vulnerable groups were self-evident or were identified early in the review and interviews, so evidence was sought as the review progressed. These were people who were housebound or had low mobility, for which very little evidence was found, and people relying partly or wholly on large institutions and having little self-determination (schoolchildren, hospital patients and prisoners), for which there was
more substantial information.

3. Identify the mechanisms by which they are affected

In our discussion of the key stakeholders, we have included a description of the mechanisms by which they may be affected. Thus, objectives 2 and 3 are presented together in this report.

4. Identify the impact (economic, social, and environmental) of fuel supply disruption

The limited evidence available was combined with inferences from the effects on stakeholders to identify some of the potential impacts.

2. Methods

The main aim of the study was to review the available evidence on pinch points in the food supply chain during fuel disruption, and understand their potential impacts. As such, a literature review (focussed on the academic and non-academic literature, but including trade association and company web sites) was conducted. In order to define the focus of the literature review, a half-day scoping workshop (involving all Cranfield researchers involved in the project) was held to identify key food chains for consideration and search terms for the literature review.

The information gathered from the literature review was used to build maps to help to visualise and analyse the supply chains. In particular, it was considered important to understand typical inventory levels and transport times between each point in the supply chain. In doing so, we are better able to identify points less able to maintain supply during fuel disruption.

The literature review was supplemented by six interviews with stakeholders in the supply chain. Experts with an overview of the whole supply chain, as well as those with process-specific expertise were selected, to include: three trade bodies/ associations, a food safety organisation, one generic third-party logistics supplier, and one logistics company dealing with supply to a vulnerable group. Other organisations (to include a supermarket and a food service chain) were invited to participate, but did not respond. These contributed information that helped to guide the literature, for example by identifying some of the key supply routes to institutions, and also supplemented the review with information about contingency plans, such as fuel bunkering, and issues of concern to the stakeholders. The scoping, literature review and interview processes are described in more detail below.

2.1 Scoping

Nine researchers with expertise spanning agriculture, food security, food modelling, life cycle assessment, food safety, risk, horizon scanning, supply chain management and operational research were assembled to identify the key food chains for consideration in this research, taking account of the guidance received from Defra at and after the project initiation meeting. It was decided that food chains should be selected to represent the groups in the eatwell plate in order that the main dietary requirements were covered. In addition, it was deemed important to cover the following supply chain characteristics, in order that a range of chain-specific weak points might be identified:

- a range of ambient, chilled and frozen products
- different lengths of supply chains with different stock levels
- range of channels to market
- products with varying levels of demand predictability
- imported and home-grown produce

The resulting food types were red meat, poultry, fish, milk, eggs, bread, fruit, vegetables and prepared or convenience foods, and were thus taken forward for consideration in the literature review and interviews.

2.2 Literature review

The review of the academic literature, including conference proceedings, was conducted using the SciVerse Scopus database. One set of searches was repeated on the ISI Web of Knowledge database to confirm that there was minimal difference in coverage of the relevant material.

The search terms for the food types and subject areas were agreed at the initial workshop, revised after testing for one food type and then used for all the searches to ensure consistent results. A 'snowball' strategy was applied, by following citations by and of the useful papers found. Papers were rejected if they were found to be not relevant, insufficiently robust from a methodological perspective, or qualitatively deficient for some other reason. The first of these was the most common reason for rejection. (Further details are given in Appendix A.)

The main steps in each supply chain were normally identified from the academic literature and reports.
However, information was often too abstract to provide the practical detail required. It was clear at an early stage that the evidence available in the formal literature (particularly on inventory levels, pinch points, or impacts) was sparse, and that the review would have to rely to a greater extent on public and private sector reports and material provided by trade associations and companies.

The results were supplemented by use of Google Scholar. Although criticised for use in systematic reviews (Vine, 2006), it has the advantage of searching the full text of many sources, including university repositories, which often contain reports that were not published in journals. Further reports for government departments and other public bodies were found using popular search engines.

The quality of evidence was a key concern in drawing information from these non-academic sources. However, we found that many reports to government departments, agencies and trade bodies were subject to a degree of review, sometimes peer review, and generally provided references to their sources. As such, we considered them to be sufficiently reliable for this purpose. Whilst trade association and company web sites were not usually subject to independent review, they were the best source for detailed, current information. Where possible, data from these was cross-checked (e.g. trade associations for millers and bakers both provided data on UK flour production). In general, descriptive information about the structure of supply chains and business data (e.g. turnover) were assumed to be reasonably reliable, and used to build up a picture of the supply chains. Commentary (‘we are the biggest supplier of ….’) might be quoted, but was treated more sceptically, as it was subject to imprecise definition (biggest by which measure) and differences of interpretation. The use of diverse sources and cross-verification helped to maintain the robustness of the results, although some variability and uncertainty remained.

Within this report, references published sources (journals, books, reports and conferences) are given in the usual academic style; web sites and documents found only on the web are given as numbered endnotes, because it is not usually possible to give authors and dates for these. The web-based resources include official statistics, so should not automatically be assumed to be less reliable than published sources.

### 2.3 Mapping and pinch points

It was considered important to first understand the normal operation of food supply chains operated. Using information on typical inventory levels, different supply routes, and the frequency of delivery, it would be possible to explore where the pinch points might be in each of the food chains, and which chains overall might be most affected. Each researcher was allocated specific food chains to map, based on their prior expertise, using a consistent conceptual framework. There are various standard tools for considering and mapping supply chains. In general, a map consists of ‘nodes’, presented graphically as shapes (circles, boxes, pictograms, etc.), which are connected by arrows. The nodes represent sites in the chain, such as producers, processors, distribution centres and retailers. The arrows represent transport between these. Data such as transport times, lead times and stock levels may be added to the map, so that it can be used to analyse the performance of the supply chain.

When considering a single well-defined product, such as a pint of milk on the shelves of a supermarket, the supply chain may be linear or a simple tree with its base at the consumer and a limited number of branches for the milk, the bottle and the label. When all the routes by which milk is supplied to consumers are considered, the map becomes a network or web of interconnections.

Qualitative maps were constructed for the products in the study, usually starting from maps found in the literature, or in some cases from prior knowledge of the commodities. The maps found in the survey were of two types: detailed value chain maps for specific companies and products from industry sources or simplified generic maps for product categories from public sector reports. Irrelevant details were removed from the industry maps to form a basis for development. Both types were then expanded to incorporate alternative supply routes found during the review.

The resulting maps, which are presented for each product, are intended to summarise the multiple routes from producers to consumers found in the review. Information about the typical transport, holding and processing times was added as a timeline at the bottom of each map. Ideally this would be a full inventory pipeline map, showing both times and inventory levels, from which it would be possible to analyse the effects of disruption, such as the time until retail stocks were exhausted if any of the transport links was interrupted. Unfortunately, data on inventory levels was rarely available.

Pinch points could be defined as steps in the supply chain where disruption would have an impact on a high proportion of supplies to consumers within 7 days. In the absence of inventory level data, these cannot be determined precisely, but the timeline together with the generally low stock levels in most supply chains indicate where they might be. Disruption to the high-volume supply routes would have the biggest total impact.
2.4 Interviews

During the scoping stages of the literature review, it was recognised that there were likely to be numerous data gaps and inconsistencies in the evidence relating to the location of pinch points, industry contingency plans, and food or fuel stocks. As such, primary data was gathered from key stakeholders with the capacity to offer practical and operational insights to support the analysis.

Thirteen key stakeholders were identified through discussion between Defra and Cranfield University. Many stakeholders were identified based on their involvement with Defra’s Food Chain Resilience Group and expert knowledge of supply chain operations and vulnerabilities. The members of this are typically trade associations or other industry representatives, so individual companies with direct experience of the food supply chain were also included. The initial set of stakeholders also had expertise spanning chilled foods, packaging, third party logistics, healthcare supply, grocery and retail.

Given the short timescales available for analysis, it was agreed that between six and eight interviews would be conducted to supplement the literature review. Interview invitations were sent in two tranches to avoid over-subscription. The first tranche invited individuals from three trade bodies/associations, a food safety organisation, one generic third-party logistics supplier, one logistics company dealing with supply to a vulnerable group, a supermarket and a food service chain. These individuals were intentionally selected to elicit information from experts with an overview of the whole supply chain, as well as those with process-specific expertise. These initial invitations achieved a 75% successful response rate (with failed response from the supermarket and food service chain), thus fulfilling the specification. Whilst additional interviews were sought, no additional responses were received in time for project completion.

The interview research employed a semi-structured, explorative, and inductive reasoning approach (see Appendix B). The questions were designed in line with the overall objectives of the study, i.e. to understand the key pinch points in the supply chain that are sensitive to fuel disruption, the likely impact of that disruption, and the mechanisms by which stakeholders might be affected. However, given that little up-to-date evidence was available in the literature on contingency planning in the industry, questions were also designed to investigate current measures employed by participants. A full list of questions is given in Appendix B. The researcher first covered those points highlighted in italics, and then further explored novel issues or insights arising in the interview to complement the evidence base. The interviews were conducted by telephone and lasted 30–45 minutes each. They were recorded and transcribed in full.

The transcribed text was subsequently analysed using a qualitative data analysis tool (NVivo). Reading through the transcripts, the researcher “coded” all important insights using NVivo software. Here ‘coding’ refers to a process of ‘highlighting’ key quotes and assigning a meaning to that quote. For example, the following quote describes how fuel disruptions may cause waste build-ups at processing or other sites:

“Well one thing is that if you don’t have fuel you can’t move waste off your site, and that can become a food or health and safety problem.”

Given the context of the study, the researcher might allocate a “waste removal” code, to record this issue as a possible pinch point. Should other waste removal issues be mentioned again in other interviews, the

---

**Figure 1. Key to symbols used on supply chain maps**

- **Source**, usually farm or port for food, external supplier for other materials
- **Processor or trader**
- **Sub-process**, normally co-located with a main process
- **Storage**, including warehouses and distribution centres
- **Consumer**
- **Transport**
- **Transport**, showing highest volume supply chain (if it can be determined)
researcher would “code” these quotes in the same way. This process allows the researcher to organise the evidence and count the number of times a particular issue was raised across the interviews, and infer a level of importance based on its frequency.

Given the explorative nature of the study, the interviews were initially coded as “free nodes” i.e. with no hierarchy or clustering of themes. Following a review and cross-checking process, coded information was organised into five key areas: food type, pinch points, impacts, general supply chain issues and key knowledge gaps. The results report key insights in each of these areas. Key issues were identified by considering the number of times the issue was coded, the number of interviews it was coded within, in addition to the interviewer’s interpretation of the importance of the theme. Codes and themes were validated by colleagues who had not attended the interviews. Validators were presented with quotes coded under themes and asked to interpret the quotes and provide a name for the theme. These interpretations were cross-referenced with the analyst’s conclusions.

3. Literature review results

The general structure of the commodity-specific reviews below is a brief comment on the sources found for that commodity, an overview and map of the supply chain and a discussion of the potential vulnerability to disruption of fuel supplies. Most of the information about supplies to large institutions has been combined in a separate section to reduce repetition. These are preceded by a discussion of some previous studies of disruption of the food supply chain.

3.1 General supply chain studies

The most comprehensive assessments of food supply chain resilience in the England are contained in two reports for Defra by Dr Helen Peck from Cranfield University. The first considered the retail food supply chain, using interviews with 61 managers from businesses throughout the supply chain to gather qualitative information on business continuity management in these organisations (Peck, 2006). The second followed a similar approach with 41 managers from the food service industry (Peck, 2009, p. 200). Both studies considered a wide range of potential disruptions; shortage of fuel for a limited period formed only a small part of the study. However, many of the interviewees referred specifically to the protests in 2000. The main findings about the consequences of the protest for the retail supply chain were (Peck, 2006):

- The retailers had weathered the crisis well. The larger ones had used their own forecourts to maintain supplies to stores, whilst the small independent retailers had continued to be supplied by their wholesalers. The crisis changed demand patterns at the small independents who experienced increased local trade, unless the store operated a forecourt, in which case food sales dropped.
- Problems with the government’s priority user scheme for fuel were evident, with confusion over its administration within organisations, local government and at point of sale.
- There is evidence to suggest that the large supermarkets implemented their own priority user supply agreements during the fuel crisis, by making fuel available to suppliers of key product lines and service suppliers as well as their own vehicle fleets.

The food service sector tended to give less emphasis to the loss of fuel supplies (Peck, 2009):

> A shortage of fuel for road transport was something everyone was aware could be a problem, although the food service companies reported very little disruption to their activities during the 2000 shortage and had tended not to dwell on the likely implications of another major event.

It thus appears that the industry at the time of the surveys was fairly confident of its ability to function during a similar period of disruption. However, there is a shortage of readily available evidence to show whether this confidence is well-founded over a decade later, during which there has been a continuing trend towards leaner supply chains.

The theoretical ‘Life without lorries’ study (McKinnon, 2006, 2004), considered the effects of a complete shut-down of road haulage in the UK for one week, which is far more extreme than a one-week reduction in fuel supplies. The author noted that the protest in 2000 only reduced lorry traffic in the UK by 10–12% (Hathaway, 2000), but “by the end of it serious food shortages were developing”. In the theoretical study, there was insufficient time for major retailers to switch from centralised systems to local sources of supply, so rationing of some foods was necessary after three days. It also found that supplies to many NHS hospitals would break down within one day (McKinnon, 2006).

Increasing uncertainty and turbulence have led some authors to argue that there is a need for a departure from current thinking to build greater structural flexibility into supply chains generally, to enable them to cope with volatility (Christopher and Holweg, 2011). Whilst much of this work is focused outside of food
supply, there has been a considerable effort in recent years to advance practice globally. Reports from the FAO (FAO, 2011) and the Scottish Government (Weir, 2009) have all sought to identify potential risks to food chain resilience. FAO (2011) predominantly describes the actions required to achieve disaster risk reduction for the FAO Food and Nutrition Security Framework programme at a global scale. Whilst the range of risks posed is diverse and largely focussed on the impacts of natural disasters of food supply and nutrition security, there are some key points to note. First, the report highlights the importance of international institutions in ‘enabling’ appropriate policy, legislation and regulation. Second, it notes the criticality of communicating early warnings to stakeholders, applying preventative measures, and encouraging the agricultural sector (in particular) to prepare to respond to disruption. Whilst constructed in a different context, the report highlights possible pinch points around institutional support, communication, and contingency planning.

More closely related to this study, Weir (2009) demonstrated that the Scottish food supply system is vulnerable to demonstrations and industrial action. An impact analysis of an on-shore refinery explosion was also conducted considering both current and advisable controls. The impact of such an event was noted to be ‘catastrophic’ with current controls, and ‘moderate’ with additional controls (use of passenger ferries and planes to send urgent ration to the islands’ airstrips within 36 hours). Island communities were found to be particularly vulnerable to disruption in their food supplies. However, the report noted that anecdotal evidence suggests that populations in such areas routinely hold greater supplies of food at home, thus mitigating this vulnerability; this is supported by the findings of other studies (Byrom et al., 2001a; Byrom et al., 2001b).

A study from Finland considered transport vulnerabilities of critical industries, including food, looking specifically at the impact of port closures due to a 12-day strike in 2010 (Yliskylä-Peurulahti et al., 2011). Interviewees noted that trade via Finland’s land borders is limited, so it is reliant on ports for most of its imports, like the UK. In comparison with the scenario considered in this report, the strike was of longer duration and more rapid onset than the effect of fuel disruption on transport, although limited international trade was still possible through some private ports, and it was confined to the start of the supply chain. Despite the differences, it provides some points of comparison with the information found for the UK. It was estimated that production of milk and some other products could only continue for 2–3 days after disruption, whereas production of meat and meat products could continue for 2–3 weeks (having adopted mitigation measures) and grain for several months. These differences are presumably the results of differing perishability and consequent stocks in the supply chain. It suggested that food suppliers may adopt flexible strategies to adapt to difficult conditions. For example, they may “raise their inventory levels before the disruption, re-schedule or postpone deliveries, shift customer orders between production plants among their company’s production network or in extreme cases buy finished products from their competitors to fulfil customer orders” (p. 235). The study also suggested that supermarkets ran out of perishable foods during the 2010 strike.

3.2 Meat

3.2.1 Sources

The literature search revealed 992 articles, of which 133 appeared relevant following a review of the abstract and scan of the full article. After further examination, 29 were used in producing the literature review.

3.2.2 Supply chain overview

The meat supply chain is highly vertically integrated: several large producers incorporate numerous stages of the supply chain from farm to processor (Arason et al., 2010). The supply chain is largely dependent on scheduling, handling of raw materials and logistics. The steps from farm to consumer, may be grouped into three main categories: industrial processing (primary processing, secondary or further processing and final manufacturing), distribution (wholesale, retail and food services) and consumption (household purchasing, storage and use) (Yakovleva and Flynn, 2004). The maps for poultry, beef, sheep and pig meat (Figure 2 and Figure 3) show typical stages of the supply chain.
A summary of lead times from abattoir to retailer or consumer is provided in Table 2. In most instances, lead times between abattoir and retailer is short (less than 7 days) for all meat types and may be considered vulnerable to disruptions that last an estimated 7 days. Poultry and pig meat (and possibly processed meat) are also vulnerable from abattoir to consumer as lead times could be less than 7 days and stock levels are uncertain. Generic data on lead times for fresh meat suggests an average of 3 days from processor (supplier) to retailer (McKinnon, 2006). These times are slightly shorter than the 2–3 weeks found in the study of a strike at ports in Finland (Yliskylä-Peuralahti et al., 2011).
Table 2. Lead times between key nodes of the meat supply chain

<table>
<thead>
<tr>
<th>Type of meat</th>
<th>Abattoir to retailer</th>
<th>Abattoir to consumer</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig</td>
<td>2 – 2.5 days</td>
<td>6 days</td>
<td>Taylor (2006)</td>
</tr>
<tr>
<td>&quot;Beef&quot;</td>
<td>2 – 8 days</td>
<td>14 – 15 days</td>
<td>Francis et al. (2008); Safefood (2008a)</td>
</tr>
<tr>
<td>Poultry</td>
<td>Unknown</td>
<td>7 – 12 days</td>
<td>Safefood (2005)</td>
</tr>
<tr>
<td>Processed meat (not poultry)</td>
<td>6 days</td>
<td>Unknown</td>
<td>Safefood (2008a)</td>
</tr>
</tbody>
</table>

*UK beef has a use from date of 21 days and a use by date of 42 days from slaughter, providing 14 days of code life (Francis et al., 2008).

**Industrial processing**

Primary processing of meat involves several distinct stages from stunning/slaughtering to portioning, packing and labelling (Yakovleva and Flynn, 2004). Secondary processors include food service distributors, butchers and meat product manufacturers. Secondary or further processing of poultry and pig meat involves adding value such as pre-cooking the meat, adding spices, etc. Some small processing companies slaughter animals only, while larger companies are involved in processing, portioning and packaging operations to provide both primal cuts and finished products to the retail sector (Safefood, 2008a).

Final manufacturing produces high quantities of a wide variety of meat products and is indicative of the amount of further or secondary processing that occurs. About 80% of pig meat (pork and bacon) in the UK is handled by a secondary processor. For some pig meat products (e.g. pork sausages), additives such as salt, herbs and flavour enhancers are added (Safefood, 2008b). Poultry is manufactured as the main ingredient for chilled food preparation, such as ready meals, sandwiches and soups (Flynn et al., 2003). An analysis of the processed food chain in Wales (Banks and Bristow, 1999) suggested that secondary processing companies that sell their products to retailers and food services are under constant pressure to ensure consistency and availability in supplies that guarantee continuity for consumers. Thus local sourcing of supplies is often not an option, because the costs related to regulation, accreditation and presentation of product quality in combination with problems with processing and freezing facilities, restricted processors from guaranteeing regular supplies to retailers and continuity for consumers. As a result, processed meat retailers are highly dependent on imported supplies and long-distance transport.

Fresh meat carcasses, cuts and finished products are typically vacuum packed in gas-impermeable bags or wraps to increase shelf-life at low temperatures (Safefood, 2008a). A wide range of packaging systems are used, including overwrap packaging for short-term chilled storage and/or retail display, specified modified atmosphere packaging for long-term chilled storage and vacuum packaging, bulk-gas flushing or modified atmosphere packaging systems that use 100% carbon dioxide for long-term chilled storage (Kerry et al., 2006).

**Distribution**

The retail distribution of meat is dominated by multiple retailers (Table 3). Thus the role of independent wholesalers in the meat industry is declining as wholesale and distribution functions are being integrated into large enterprises such as slaughtering companies or large retail chains (Safefood, 2008a). There are high levels of centralisation of distribution as multiple retailers buy directly from meat processors via central distribution centres (Cox et al., 2007). This excludes the food service sector, which also handles substantial volumes. For example, McDonald’s claims to be one of the UK’s largest purchasers of beef, all of which passes through its processing centre in Scunthorpe, resulting in long transport links before and after processing."

<table>
<thead>
<tr>
<th>Types of meat</th>
<th>Multiple retailers</th>
<th>Butchers</th>
<th>Independent grocers and other retailers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry</td>
<td>85</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Pig meat (pork)</td>
<td>84</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Beef</td>
<td>84</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Sheep meat (lamb and mutton)</td>
<td>79</td>
<td>13</td>
<td>8</td>
</tr>
</tbody>
</table>

Abattoirs and processors distribute animal cuts to local and specialist butchers, wholesalers and food services. Further processing, cutting and packing of meat occur at the butchers and sold to consumers. Food services provide an additional market for UK meat products where, for example, beef products are cut and vacuum packed into specified cuts for food services (individual 8oz sirloin steaks) and transported by a processor-owned vehicle to the food service distribution centre, where they are then consolidated with other products for delivery to restaurants (Francis et al., 2008). Other meat products are stored and transported, frozen or chilled to wholesale, retail and food service distribution centres for ultimate sale to consumers (Safefood, 2008b).

Meat and finished products must be stored and transported at low temperatures (0 to 4–7°C depending on product), even over short distances (Dabbene et al., 2008). Microbial spoilage of meat is of great concern, particularly for poultry and minced meat that have the shortest shelf-life (2 days at 4°C) (Greater Pittsburgh Community Food Bank, 2012). A study of the influence of cold chain disruptions on the shelf-life of fresh pork and poultry suggests that a shift to abusive temperatures of 7°C and 15°C for less than 5% of the total storage time (in the first 60 hours of storage) resulted in shelf life reductions of approximately 11% and 20% respectively (Bruckner et al., 2012). Freezing poultry extends shelf life to 12–18 months. Chilled (and frozen) products should be transferred in a continuous flow (i.e. no stopping or delays) between temperature controlled areas; from delivery trucks to holding areas and storage areas to retail display units (George, 2000).

Most retailers run on a just-in-time system, with products supplied on demand. Orders are usually placed 1–2 hours before the dispatch deadline for the suppliers’ vehicles, which means meat products are usually supplied from available stocks of finished products or based on estimates of daily orders (McKinnon, 2006; Taylor, 2006). On-shelf availability data and back-of-store materials handling were identified as areas in need of improvement in most large supermarkets. Consequently, there is a lack of data from which to estimate the duration of stock cover in retailers. However, the trends in systems of operation and the short shelf lives imply that it will often be low and therefore vulnerable to disruption.

Consumption

Poultry and pig meat are in constant demand, but demand for beef fluctuates and demand for sheep meat (lamb and mutton) is partially seasonal with irregularities (Cox et al., 2007; Whitehead et al., 2011). Data on demand management across six of the large UK supermarkets chains (Taylor, 2006) suggests consumer demand peaks towards the end of the week, usually on Fridays and Saturdays with lower level sales recorded on Sundays and Mondays. Suppliers operating five days a week tend to overproduce earlier in the week to increase stock levels toward the end of the week, where consumer demand is high. However, this is not always well aligned to orders placed by retailers operating seven days a week that have the highest peak in orders on Mondays.

3.2.3 Possible pinch points

The meat industry is highly reliant on road transport and has a number of possible pinch points inherent in the supply chain. These include:

- **Holding capacity.** Live animal transport is sensitive to disruptions to journey frequency, because farms have no holding capacity for some species (e.g. chickens), and duration, because of animal welfare considerations. However, no data on the frequency of journeys was found, meaning it is currently unclear how quickly a lack of holding capacity might impact the supply chain.

- **Low stock levels.** Whilst no data was found on in-store inventory levels, it is likely that given industry trends that this is low.

- **Centralisation.** The centralisation of production in the UK has resulted in meat travelling relatively
long distances (2–6 hours for pig meat) in large quantities from abattoirs to retailers. Transport links, and thus daily deliveries of raw materials or finished products, could be disrupted if fuel stocks provided inadequate cover for the frequency of trips needed (McKinnon, 2006). Studies on temporary disruption of road freight transport on the national economy (McKinnon, 2006; Peck, 2006) suggest that fresh meat stocks in supermarkets would deplete rapidly without road transport.

- **Temperature control.** The need to control temperature during transport of fresh meat and meat products means that there is less flexibility to substitute vehicles than there could be with ambient foodstuffs. Poultry and minced meat are particularly vulnerable given their short shelf life.

- **Timing.** Whilst not expected to be a major pinch point, some seasonal disruptions may have a larger impact for beef and sheep meat at certain times of the year. Disruptions to supermarkets towards the end of the week (Fridays/Saturdays) are also likely to have a higher impact on consumers for all products.

- **Packaging and additives.** Similar disruptions to continuous processes, such as meat packaging and supplies of additives (e.g. salt, herbs and flavour enhancers) may result in delays or failure of production, especially for chicken, where 40% of sales are processed cuts and cooked products. Over 95% of fresh meat sold by multiple retailers is produced pre-packed, with further packaging, usually in heat sealed foils, added at the retailer for safe transportation by consumers (Vo and Thiel, 2011, 2008). No data was found on the stocks of packaging and added ingredients held by processors and retailers.

### 3.2.4 Uncertainties and future research needs

As the UK is largely self-sufficient in meat and meat products, with the exception of processed pig meat, a seven-day fuel supply disruption would not cause a serious national shortage. However, little quantitative data on geographical factors, the distances travelled by meat and meat products and the risk to the cold chain of transport disruption was available (Nychas et al., 2008). Similarly, neither data on the on-shelf availability data and back-of-store materials handling, nor the frequency of trips made between abattoir and retailers or consumers was found.

### 3.3 Fruit and vegetables

#### 3.3.1 Sources

General information is available to map the flow of some of these products along the supply chain. Sources range from government agencies reports to company websites. There was very little usable evidence in the formal academic literature. Because of the heterogeneity of the products, very little evidence exists regarding the robustness of the chain in terms of stock levels, which are highly variable. No evidence was found on fuel contingency plans for fruit and vegetables.

#### 3.3.2 Supply chain overview
The fruit and vegetable supply chain in the UK differs from many of those considered in this survey, because it relies on the import of 85% of fruit and 45% of vegetables, so transport from a limited number of ports is a large component, which makes it especially vulnerable to transport disruption.

The enormous diversity of offered products, the variability within them (e.g. different varieties of the same fruit or vegetable) and the complexity of retail operations hinders the building of a single generic supply chain model; there are, in fact, many different supply chains. Some of the main supply chains are illustrated in Figure 4.

UK-produced fruit and vegetables are harvested seasonally. Some, for example apples, onions, root vegetables and potatoes, can be stored for many months, so large stocks exist, but these are usually upstream, remote from the retailers. Highly perishable crops are moved rapidly through the chain from growers to retailers during the harvest season. Imports are used to provide a year-round supply of many fruit and vegetables.

The retailers operate a just-in-time approach, placing orders with suppliers based on demand. In some cases (e.g. salads in summer), short-term forecasts based on weather, public holidays and so on are used.

Most of the available evidence was synthesized in a study for WRAP that constructed fruit and vegetable resource maps to quantify the level of loss and waste of fruit and vegetables through the retail and wholesale supply chain (Terry et al., 2011). The authors interviewed 45 UK fresh produce suppliers and analysed several fruit and vegetable food chains. During the last decade, there has been an increase in the overall level of professionalism among growers and suppliers. This has allowed the sector to meet the technical and commercial demands of the multiple retailers who account for nearly 80% of the market fresh produce. Supply chains have become shorter and exhibit a high degree of customer awareness. There is also considerable vertical integration and consolidation in the sector. Collaborative relations are also well-developed to deliver year round supply.

Following consolidation, the number of commercial growers of fruit and vegetables in Great Britain is around 1,250. Some of these are “producer organisations” under the EU Fruit and Vegetable Aid Scheme (Terry et al., 2011 based on data from the Horticultural Development Company). There are around 500 workplaces for processing and manufacturing fruit and vegetables in UK (accounting for five per cent of all manufacturing workplaces); however, this number declined by 30% between 2000 and 2006. Despite an 8% fall in workforce, the turnover of these remaining fruit and vegetable manufacturers increased by about 19% in this period. Furthermore, there are a large number of fresh produce import/export companies...
operating in UK.

Due to the large number of companies involved in this food chain, it is not highly centralized. There is also high variability between companies. These range from small family businesses taking part in one step of the chain (e.g. a small fruit import company) to large corporations that can perform all phases and even supply directly to the consumer. This adds to the diversity of supply chains in the sector (Figure 4).

As the storage periods and shelf lives of fruit and vegetables vary widely, this review considers two extreme examples. Strawberries are used as an example of highly perishable products with short post-harvest life and short shelf life. Conversely, potatoes are a staple food in the UK and are used to exemplify a product with much longer post-harvest life and shelf life.

**Strawberries**

The UK produces 102 kt/year of strawberry fruit. As with most fruits, to cover demand, the UK needs to import 45 kt/year of strawberry fruit (Defra, 2009). The best period for the consumption of UK-grown strawberries is from March/April to October, with peak production during the summer. Spain is the main exporter of strawberry fruit to the UK. The UK strawberry and raspberry industry is dominated by four key suppliers/marketing companies, making up over 90% market share (Terry et al., 2011).

The post-harvest life for strawberries is typically 4–8 days but tends to be longer for imported fruit (8–14 days), due to varietal differences. The lead times are 12–24 hours and retail stock levels are 1–3 days, but commonly 1–2 days. The shelf-life is 2–11 days (typically 3 days), dependent on adequate and efficient initial cooling and maintenance of the cool chain throughout (Terry et al., 2011).

**Potatoes**

The UK produces approximately 6,000 kt/year of potatoes and imports 200–300 kt/year plus 1200–1400 kt/year of processed potatoes (Potato Council, 2012). Six key suppliers/marketing companies making up over 60% market share dominate the UK potato industry. Consumption is relatively stable over the year, but can increase by 2–50% for new potatoes in good weather and 20–100% for baking potatoes in cold weather (REF?). Typically, more salad-type potatoes are eaten during Easter and the summer than during the winter months.

The post-harvest life is typically 3–270 days (some extended to 365 days), but it depends on variety and storage regime. The mean storage life is 120–160 days and the shelf-life is 1–15 days, but is typically 6–8 days. Lead times are 6–24 hours and retail stock levels are 0.5–6 days, but commonly 0.5–2 days (Terry et al., 2011).

The supply routes to large institutions (schools, hospitals and prisons) are similar to the other food types reviewed.

### 3.3.3 Possible pinch points

Based on the evidence identified for highly perishable (strawberries) and less-perishable goods (potatoes), we consider that the challenges in the fruit and vegetable supply chain between these product types are distinct. The following section describes those pinch points found in highly perishable supply chains:

- **Low stock levels.** Low stock levels are necessary because they have short shelf-life. Large retailers operate just-in-time systems based on (forecast) demand, drawing on several steps in the supply chain. All of the transport steps may be within 7 days of the consumer.

- **Reliance on third party logistics.** Much of the transport relies on third-party logistics companies. Some companies may use their own vehicles, but no evidence on their preparedness for fuel disruption was found.

- **Timing.** For imported crops or those harvested on fixed schedules, any disruption of transport is likely to lead to deterioration and wasted product. In some cases (e.g. lettuce), the use of production on demand means that products are harvested only when needed. This allows some flexibility to delay harvesting and reduce waste if transport is not available, but usually for only a few days.

- **Packaging.** These products use a variety of packaging types (e.g. plastic films and trays), and often rely on other supplies, such as ethylene scavengers and gas mixes for modified atmosphere packaging. No evidence was found on the levels of stocks and contingency plans for these.

- **Reliance on imports.** Heavy reliance on imports for fruit (85%) and vegetables (45%) makes the supply chain vulnerable to disruption of transport from a limited number of ports, which are remote from many population centres.
For less perishable products, the following pinch points may be found in the supply chain:

- **Low stock levels (retail).** The stock levels held by retailers are typically less than 7 days, and stocks are held upstream, close to the producers.
- **Timing.** It is unlikely that supplies of UK-produced crops would be a problem, unless disruption occurred at the start of the harvest season, when stocks were low.
- **Reliance on third party logistics.** Continuity of supply again depends largely on third-party logistics companies, and possibly companies’ own fleets.

Some products in this category are supplied in plastic packaging, on which no evidence was found. However, some, such as potatoes, root vegetables, onions and apples, are often sold loose, having been packed (shortly after harvest) in large bags or boxes. These would be less vulnerable to disruption of packaging supplies.

### 3.4 Dairy

#### 3.4.1 Sources

Sufficient information is available to map the flow of the sole ingredient (raw milk) along the supply chain. Sources range from peer-reviewed papers, articles in magazines to company websites. There was very little usable evidence in formal academic literature. Similarly, very little literature exists regarding the robustness of the chain in terms of stock levels; however, since milk has a short shelf life, only low stock levels are possible at each stage as an efficient flow of product through the supply chain is required to ensure the milk reaches the consumer unspoilt. Discussion in the literature regarding fuel contingency plans is very scarce; only one article was found for a wholesaler. No papers from peer-reviewed journals contained relevant UK milk supply chain information, and only Peck (2006) considered its resilience to a fuel supply disruption.

#### 3.4.2 Supply chain overview

About 90% of fresh milk consumed takes the supply route Dairy farm → Dairy processor → Supermarket → Consumer, represented by the bold arrows in Figure 5 (Boulton et al., 2011). There are 14,500 dairy farmers with 1,800,000 dairy cows in the UK with a total annual yield of 13,300 Ml; only 0.1 Ml/year are imported and 0.4 Ml/year exported. The majority of farms are in the southwest and northwest of England (Dairy UK, 2012). There is a trend towards fewer large dairy farms: 3900 farmers produced 57% of the raw milk in 2009.

Cows are milked two or three times a day, with raw milk stored in chilled tanks on the farm (at 8°C if collected daily, otherwise 6°C (FSA, 2007)). Chilled tankers from the dairy collect the milk daily or on alternate days, with multiple collections per journey, during which the cold chain must be maintained. Raw milk is either delivered direct to a dairy processor, or via a reload point where it is transferred into another.
tanker for transport to the dairy processor\textsuperscript{8}.

About 95\% of raw milk is supplied to the dairy processors\textsuperscript{7}, of which each of the 3 main companies (Robert Wiseman Dairies, Dairy Crest and Arla Foods UK plc) processes over 2,000 Ml raw milk each year, operating from at least 4 factories across England and Wales\textsuperscript{8,9,10}. The raw milk is transferred to silos (around 250,000 litre capacity\textsuperscript{11}). It is pasteurised, then separated into skimmed milk (0.5\% fat) and cream. The processor adds some of this cream back to the skimmed milk to produce semi-skimmed (1.5–1.8\% fat) and whole milk (\geq 3.5\% fat). Any excess cream is used to produce other ‘balance products’, such as butter, cream, cheese, yoghurt\textsuperscript{12}. The fresh milk component of the dairy processors represents roughly half of the total milk production\textsuperscript{7,8}. Arla Foods’ Cravendale\textsuperscript{\textregistered} brand includes a filtration step before pasteurisation to extend the shelf life. Some milk is ultra-heat treated (UHT) to provide a longer shelf life without the need for chilled storage.

Machines can bottle and label up to 40,000 l per hour\textsuperscript{13}. At large dairy processors where the volume is sufficient, the plastic milk bottles are produced on site in an adjacent building, being passed via a ‘hole through the wall’ to be used directly in milk bottle filling, which eliminates a transport step to supply the empty bottles. Small processors receive delivery of the bottles from a central bottle production site\textsuperscript{14}. About 80\% of fresh milk is sold by retailers in plastic containers, the remaining 20\% is sold in glass bottles or cartons (DSCF, 2008).

Filled bottles are loaded onto metal trolleys and held in the dairy processor’s cold store, or transferred to a depot, from which they are loaded onto refrigerated lorries for delivery. For the large multiple retailers, the milk bottles remain on the metal trolleys for display on the shop floor.

Several different contract plans may underlie the same physical supply chain. For example, 70\% of all milk bought in the UK\textsuperscript{15} is the result of ‘integrated supply arrangements’, which are direct contracts with the dairy farmers to supply the raw milk and with processors to collect and process it in the retailer’s own brand bottles. Alternatively, the dairy processors contract the dairy farmers and the processors supply stores with milk under the processor’s brand.

Dairy farms with their own processing facilities can deal direct with retailers to establish a dedicated retail supply chain\textsuperscript{16,17}, however only a few farmers have taken this option\textsuperscript{12}. Dairy farms with a processing dairy on site may also source milk from other, usually local, farms (Cotteswold, Marybelle) and sell their milk in local shops, supermarkets and via milk rounds\textsuperscript{18}.

The average individual fresh milk consumption is 1.5 l/week (Defra, 2011), with organic milks making up 2.81\% of milk sold in 2011 (Dairy UK, 2012). Milk for domestic consumption makes up only around half of the milk sold in the UK; the rest is used in schools, hospitals, coffee shops and restaurants\textsuperscript{19}.

The total times found are consistent with the 2–3 days of continued production following a strike at ports found in Finland (Yliskylä-Peuralahti et al., 2011).

**Doorstep**

Doorstep sales accounted for 4.3\% of the total milk sold for in-household consumption (2012–2013), down by 7.1\% compared to the previous year\textsuperscript{20}. This decline has seen consolidation of the sector, dominated by Dairy Crest operating under their Milk&More brand\textsuperscript{19}. On average there are 475 customers on a milk round, with milkmen delivering 1,000,000 pints of milk every day plus the range of 240 complementary products (Dairy UK, 2012). Large dairy processors supply the depots of national doorstep delivery companies, who may use local milkmen for some deliveries. Regional dairy processors also operate doorstep services, either delivering themselves or via wholesale companies. Milk is delivered in glass bottles which keep the milk fresh for 5 days\textsuperscript{21}, and are, on average, used for 20 deliveries each (Dairy UK, 2012).

**Schools**

Milk to schools is delivered in 1/3 pint cartons for the children to drink as a mid-morning snack. This size carton is made by both the large dairy processors\textsuperscript{22,23} and the regional dairies\textsuperscript{18,24,25}. As with the doorstep service these dairies either deliver these small cartons themselves, supply a wholesale company or use local milkmen. Delivery occurs between daily to twice a week.

**3.4.3 Possible pinch points**

- **Low stock levels.** This chain only contains one food ingredient, raw milk, which has a short shelf life and must be stored below 7°C for the entire length of the supply chain. For this reason, minimal stock is kept at any stage and it is moved quickly (within 2 days) to the next step along the supply chain. The supply of raw milk into the supply chain is relatively fixed (in the short to medium term) with some seasonal variation due to poor grass yields in October–November and peaks following spring calving (Dairy UK, 2012).

Without deliveries, supermarket stocks would run out within one day, and sensitive product...
categories like milk are often susceptible to panic buying (Peck, 2006). Consumers could opt to buy longer lasting fresh milk substitutes, such as UHT and powdered milk. These have a long shelf life, but only limited stocks are held in stores.

- **Capacity to store finished produce (processor).** If transport was not available from the processors to retailers but raw milk supplies continued, space to hold the finished products would be filled within two days (Peck, 2006). In this case, waste milk would be generated either at the processor or the farm, and stored milk would rapidly pass its expiry date.

- **Frequency of delivery (farm - processor).** Processors also rely on daily deliveries of raw milk, unless they are sited on farms. There is some evidence that milk processing companies might join forces when faced with disruption, as some have joint plans in place in case of a severe winter. They could also divert milk from the balance products to provide more fresh milk (Peck, 2006).

- **Staff fuel (processors).** Processing sites also rely on the ability of staff to travel to work. In the case of one company, 99% of staff relied on private vehicles (Appleton, 2013) implying that a 7 day fuel supply disruption could severely impact the attendance of a majority of their staff.

- **Inability to delay production and waste removal (farm).** Farms have limited storage for raw milk on site in their chilled tanks and rely on collections every one or two days by the processors, usually by their own bulk tankers. The farmers cannot stop production, so failure to collect milk would result in large volumes of waste milk within two days. Milk is a potentially serious pollutant of water (high biochemical oxygen demand) and carries a health risk though microbial contamination.

- **Packaging (processor).** Some processors hold some packaging on site but most of the supply chain is stockless, so production would halt if the supply of plastic bottles (or materials) failed, even though there would be supply of caps and labels (Peck, 2006).

The supply chain is thus highly reliant on three transport steps: tanker deliveries, often using the processor’s own tankers, plastics or plastic bottle deliveries, presumably by logistics service providers, and deliveries to retailers. National dairy companies own and operate their own fleets of delivery vehicles, so continuity of supply will depend on their contingency plans of the company. There was little evidence on the contingency transport plans of processing companies, though it could be assumed that companies have examined this critical part of their business.

About half of doorstep deliveries are made using electric milk floats (Dairy UK, 2012), which would be unaffected by disruptions to liquid fuel supplies. No evidence was found on the stocks of fuel for petrol/diesel milk floats.

### 3.5 Eggs

#### 3.5.1 Sources

Sufficient information is available to map the flow of the sole ingredient (shell egg) along the supply chain from sources including reports, articles in magazines and company websites. There was no literature regarding the stability of the chain in terms of stock levels at each stage; only the volumes processed at the packing centre. The literature discussing fuel contingency plans was very scarce. No papers from peer-reviewed journals contained relevant egg supply chain information.

#### 3.5.2 Supply chain overview
The majority of shell eggs eaten (75%-90%) take the route: Farm – Egg packaging site – Supermarket – Consumer, represented by the bold arrows in Figure 6. The remaining 25% are used in the catering industry. No information is available regarding the volume of eggs supplied to the consumer through a doorstop service, although this supply route has been identified.

The UK has 33 million laying hens enabling it to be 82% self-sufficient in eggs and egg products. The volume of shell egg production for human consumption in 2012 was 778 million dozen, from the following farming methods: 48.6% cages; 45.2% free range and 6.2% barn and organic (Defra, 2013). In 2012, 16% of total egg production was used for processing, with eggs being sold as frozen, boiled, liquid and in powdered form, which have extended shelf lives. These products are suitable for retail and foodservice customers such as bakeries, canteens and schools. This review concentrated on shell eggs.

Eggs are collected daily and stored at the farm on trays (of pulp or plastic). If the packing station is not located at the layer farm, the eggs are collected by the packing site van. The frequency of collections may be daily, regularly or twice a week. Shell eggs must be transported and stored at a temperature between 5 and 20°C for the entire supply chain.

Depending on the quality, eggs are required to be packed within 4–10 days of lay. In 2009, around 95% of production passed through a total of 2,165 packing stations, with at least half of the egg throughput being accounted for by 4 major packers, who pack up to 72,000,000 eggs/week. These companies either have one packing centre, 2 packing centres or a number of egg packing machines nationwide.

Some of the major egg packing centres produce all of the eggs to be packed on their own farm. Others produce a proportion on company owned farms with the remainder supplied by numerous contracted egg farm producers throughout Britain (to protect against localised disease outbreaks).

At the packing site the eggs are kept in the ‘ungraded’ store which can hold enough eggs for one day of grading. Large packaging centres operate 7 days a week, 365 days a year and can inspect, grade, pack, label, box and palletise at a rate of 300,000 eggs/hour. Eggs are packed into cardboard or plastic cartons containing 6–18 eggs, which are dated and arranged in retail display cases. Larger units are packed for caterers. The packed eggs are palletised and kept in a cooled store room, until picked and loaded onto refrigerated trucks ready for delivery to the cold stores at the retailers, depots, distribution centres or wholesalers.

Eggs should not be stored at the packing site for more than 3 days and are usually transported to store within a few days (or even hours) of being packed. Some packing sites act as consolidation hubs, in some cases handling over 32,000,000 eggs/week.

Packaging companies own fleets of vehicles or use specialist distribution and may deliver packed eggs and collect eggs for packing in the same journey. Some cover large distances, for example Peeblesshire to Southampton.

Eggs slowly deteriorate in storage hence the statutory E.U. limit of best-before 28 days from date of lay: eggs must be graded, marked, packed and labelled within 10 days of lay and delivered to the consumer.
within 21 days of lay. More than 85% of British eggs are produced to the British Egg Industry Council Lion Brand code of practice, under which eggs have a limit of 4 days from lay to pack, and 21 days from date of pack giving a maximum life of 24–25 days. Eggs usually reach stores within 2–3 days of being laid, so stocks at packing stations must be less than 3 days of normal demand and are probably less than 1 day. The majority of the shelf life is at the consumers’ home.

Some dairies supply eggs as a complementary product to the milk delivery. There is no data on the volume, though it is probably relatively small. However this may be an important supply route for individuals with limited mobility. A small fraction of the volume is supplied directly from the farm gate to the consumer, with eggs for sale at their farm shop or local markets.

3.5.3 Possible pinch points

- **Low stock levels.** Based on the available information, there appear to be small stocks of eggs within the supply chain. It appears that, due to the daily supply of eggs into the chain and their short shelf life, eggs are moved along each step within a day. Data is provided by the packing sites on their packing rates, but there is no information available on the stock levels, for either the input or output stores at the packing centre. However, as noted above, the time to store implies that stocks must be less than 3 days of normal demand, and they are probably less than 1 day. The impact of a 7 day fuel supply disruption on a packing centre will, therefore, depend on the fuel contingency plan for the fleet at each packing centre.

- **Frequency of delivery.** Eggs are transported to packaging sites by a van. It is reported that collections from individual farms occur at varying frequency (daily to twice a week) to keep packaging machines functioning continuously.

- **Quality reduction.** Short delays to collection from farms could result in downgrading; longer ones would result in shortages for consumers and generate waste at the farms. The whole chain, from farm to consumer is potentially vulnerable with 7 days.

- **Packaging.** Packaging is essential to protect the eggs, but no data on stocks was found. Given the very high volumes being processed, it is likely that packers rely on frequent deliveries, which would also be vulnerable to disruption.

- **Reliance on third party logistics.** The majority of eggs and egg products are sold through multiple retailers, so deliveries typically depend on logistics service providers (see Sections 6.1 and 6.4). No evidence was found on the preparations of smaller producers, wholesalers or stores for fuel supply disruption.

Schools supplied by wholesalers and hospitals purchasing under the framework agreement will rely on the contingency plans of the large suppliers and logistics service providers. Those buying directly from local farms benefit from shorter transport distances, but they may be less well prepared, although no data could be found to assess this.

3.6 Bread

3.6.1 Sources

Enough information is documented to map the flow of the major ingredients along the bread supply chain, sources range from peer-reviewed papers, articles in magazines to company websites. No information was available for the minor ingredients (minerals, yeast and salt). Very little literature exists regarding the stability of the chain in terms of stock levels at each stage; any values found were from less reliable sources including outputs of workshops or testimonials on company websites. The literature discussing fuel contingency plans is very scarce; one article was found for a wholesaler. Only four papers from peer-reviewed journals contained relevant bread supply chain information and only the report by Peck (2006) considered their resilience to a fuel supply disruption.

3.6.2 Supply chain overview
Figure 7. Bread supply chain map (Sources: Federation of Bakers[55])

About 80% of the bread eaten in the UK takes the route Grain store – Mill – Plant Baker – Plant Baker Depot – Supermarket, represented by the bold arrows in Figure 7 (Barling et al., 2009).

In 2012 the total UK wheat harvest was 13.3 Mt[56]. The harvested grain is kept in stores, either on the farm or transported in trucks to a central store, owned by grain merchants or co-operatives. To maintain flour quality specifications (Magnan, 2011) or compensate for low yields, 18% of milled wheat is imported[57].

Major consolidation of milling sites has led to 31 flour milling companies running 53 operating mills[58]. The four largest companies account for over 65% of UK flour production with many of the smaller millers developing niches for specific uses[59]. Grain from the stores is transported to the flour mill to the correct specification of the miller (nabim, 2011); once accepted the grain is transferred to the mill silo. PAS 2050:2008 (BSI, 2008) assumes that grain is typically transported 100 km by road at this step, which is supported by the distances reported by mills sourcing local wheat[60]. Of the 2.97 Mt wheat milled for bread making flour, 86% is white, 11% is wholemeal and 3% is brown[61]. At this stage four minerals (calcium, iron, thiamine and niacin) are required by law to be added to flour other than wholemeal[62]. No information is documented regarding the delivery method, volume and frequency of these ingredients to the mill.

Millers now mill to order using blended flours (Peck, 2006), adding seeds and grains to the flour for special products[63]. Once milled the flour is stored in silos before being packed into sacks or loaded into bulk tankers for bakeries, and small bags for home bakers. Mills supply flour to bakeries direct, or via wholesalers. Kingsmill (Allied Bakeries) is the only brand using the rail network to transport their flour from their supplier to bakeries in Glasgow and Cardiff, reducing their road travel by 500,000 miles per year[64]. PAS 2050 assumes flour and packaging is transported 100 km by road.

The large plant bakers account for 80% of the UK bread production (largest are Hovis, Kingsmill and Warburtons)[55]. These mainly produce wrapped, sliced bread using the Chorleywood Process and all add preservatives to create a loaf with a longer shelf life. In-store bakeries accounts for 17% of the bread production[55] and either bake bread from scratch (in the larger multiple stores) or from part baked frozen dough produced by the large plant bakers. Master bakers now only produce 3% of the bread sold[55]; some of them supply supermarkets and the food service companies with craft-baked bread[65]. Other ingredients required for bread are yeast, salt and water. No information is documented regarding the delivery method, volume and frequency of these yeast and salt to a bakery, nor flour to the smaller baking sectors. PAS 2050 assumes that yeast is transported (chilled) by road for 95 km and salt 90 km (ambient).

Once baked, the bread is packaged and delivered to the retailer stores; store-baked bread may be transported to other stores. The majority of bread (87%) is sold through multiple retailers, specialist bakeries sell 6% with the remaining through retail and food service (Barling et al., 2009). Since bread has a short shelf life most products are baked to order daily and are delivered direct from the bakery to the store with no need for an intermediate step at the retailer’s distribution centre (Federation of Bakers,
However, the large plant bakers also distribute from their own depots, which are picked to zero every day so they carry no inventory of finished goods. Some bakeries own and operate their own fleets of delivery vehicles, so continuity of supply will depend on the contingency plans of the companies.

Some dairies supply bread as a complementary product to milk delivery. There is no data on the volume, which is probably relatively small. However this may be an important supply route for individuals with limited mobility.

A small fraction of the sector is supplied directly from the farm gate (or flour miller) to the consumer. These niche companies grow, store, mill, bake and package their bread products for sale at their farm shop or local markets. Yeast, salt, minerals would need to be supplied to these farms.

### 3.6.3 Possible pinch points

- **Post-harvest storage.** From the farm gate up to the start of the process at the bakers, any stock can be kept in stores for months due to the long shelf life of grain and flour if stored correctly. Short-term disruption of this step is unlikely to have an impact on the consumer. There would be a risk of spoilage if harvested grain could not be moved from farms without their own stores. It would be possible to delay harvesting slightly, but an extended delay would result in a loss of quality initially. Large grain stores usually collaborate with logistics service providers.

- **Uncertainty of stock levels.** Stock level data at UK flour millers is scarce. Data from five case studies imply that there is a correlation between levels of stock reported by mills and their confidence in their grain suppliers, with an increased confidence allowing for a more just-in-time approach (Table 4).

- **Short shelf life.** Once the ingredients have been combined and baked into bread, this commodity has a short shelf life, hence no stock is kept and it is moved quickly (within the day) along the supply chain to be made available to the consumer.

### Table 4. Stock levels of grain at mills, reported from workshop and players in the supply chain

<table>
<thead>
<tr>
<th>Miller</th>
<th>Date</th>
<th>Product</th>
<th>Stock level</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whitworth</td>
<td>2006</td>
<td>Bagged flour</td>
<td>9 days grain</td>
<td>Low. 27% on-time/in-full delivery from farmers and merchants</td>
</tr>
<tr>
<td>Heygates</td>
<td>2006</td>
<td>Biscuits</td>
<td>3 days? (Raw material = 6000 t, Capacity = 2000 t)</td>
<td>Low. 46% delivery errors. Order 25% more than required to compensate for delivery errors</td>
</tr>
<tr>
<td>Wright and Sons</td>
<td>?</td>
<td>Bread flour (for wholesale)</td>
<td>None. Constant flow of product</td>
<td>High. 100% supply record</td>
</tr>
<tr>
<td>Boortmalt</td>
<td>?</td>
<td>Malting</td>
<td>Operate Just In Time</td>
<td>High. Every confidence in their logistics</td>
</tr>
</tbody>
</table>

Sources: (Whitelam, 2005; http://www.camgrain.co.uk/testimonials, Cereals Industry Forum, 2006)

A 7 day fuel supply disruption would have a varied impact on the millers mentioned in Table 4. Those with lower confidence in their suppliers held larger stocks and could probably operate through a short disruption to deliveries. Those with high confidence were dependent on constant deliveries. Their vulnerability would depend on the logistics service providers used to transport the grain. Other sources confirm that there are substantial variations in grain stocks held by millers.

- **Transport of flour.** Most transport of flour from mills to the bakeries is by road (only Kingsmill utilises the rail network) and in some instances can involve bulk silo telemetry systems whereby millers monitor their customers’ bulk silos remotely to ensure they have enough stock. One bakery reported 2-3 days cover (Peck, 2006). No bread stock is normally held at bakeries.

During a 7 day fuel supply disruption a pinch point could occur at bakeries once they have used their flour stocks (which were not reported). Since most large millers have their own fleets of trucks, continuity of supply will depend on their contingency plans. In some cases, bakeries own the mills that supply them.

- **Yeast supplies.** The only information regarding yeast supply was from a cream yeast supplier in
America (Lallemand Inc, 1996). They delivered from the yeast plant direct to the bakery once a week using cold insulated lorries. The yeast had a shelf life of about 14 days and was stored in two tanks in alternate weeks. If a similar pattern was followed in the UK, the bakeries would have about 1 week of cover.

- **Retail stocks.** Large stores typically have 1 day of stock (Espinoza-Orias et al., 2011) and rely on the usual logistics services for daily supplies.

The chain supplying the majority of bread seems to be well protected during a 7 day fuel supply disruption due to contingency plans of logistics providers and large plant bread manufacturers, and the availability of grain stocks. Consumers could reduce demand by cutting waste and extend the keeping time of bread by various methods, including home freezing. However, there might be a peak in purchasing in response to a threat of disruption.

### 3.7 Fish

#### 3.7.1 Supply chain overview

![Fish supply chain map](image)

The Waste & Resources Action Plan (WRAP) developed resource maps for wholesale and retail supply chains for 17 individual species of finfish and shellfish (James et al., 2011). It suggested that most species of whitefish undergo some processing at sea, while farmed fish are usually gutted within aquaculture, before entering the UK processing sector. In 2010, UK vessels landed 411,000 tonnes of seafood spread, by volume, fairly evenly between demersal, pelagic and shellfish species. The largest ports, by volume, were Peterhead, Shetland and Fraserburgh, with Plymouth the largest English port. An additional 718,000 t were imported (in 2011).

Within the UK supply chain there are some 500 individual seafood processors, almost 100 wholesalers and more than 600 fishmongers. The report suggests that many companies have highly diverse and variable operations, with even small companies processing several species of fish and producing a complex range of products. Supermarkets dominate the seafood retail market, with over 87% of total spend.

Humberside and the Grampian region of Scotland dominate the fish processing industry. Both are relatively remote with respect to distribution to retail and more populated areas. A report for the North Devon Fisheries Action Group (Marine Environmental Research, 2013) suggested that 99% of fin fish and most shellfish landed are sold to a local processor and then sold on outside the region.

Packaging decisions are driven by the short shelf life of fresh fish products, and the need to prevent product deterioration. Therefore, expanded polystyrene is traditionally used for transit packaging and similarly primary packaging with a modified environment is used to ensure product freshness.

The fish supply chain varies dependent on fish type and whether the product is for fresh, frozen or cooked retail. Some (e.g. mackerel) are processed straight from landing, whereas others (e.g. cod) will be taken from ports to auction markets and from there on to processing plants and wholesale. Aquaculture such as mussels must undergo an additional depuration phase, which takes 42 hours, as specified by the Food Standards Agency (FitzGerald et al., 2011).

For cod, of the 121 kt either imported or landed annually, 45 kt/year are used within the food service sector.
sector, while 40 kt/year enter the retail sector, with the remainder exported or classed as waste (James et al., 2011).

This is likely to be the case for other examples such as mackerel, which is landed mainly in NE Scotland or Shetland, into one of the few pelagic factories in the UK. The seasonal nature of mackerel fisheries means that a large proportion of the annual catch must be frozen to enable a year-round supply. After freezing the fish remain in cold storage until they are required for further processing. At this point they go through the smoking process – brining, hot smoking, removal from the kiln and packing. Fish are then distributed by lorry to UK multiple retailer distribution hubs (James et al., 2011).

Fish farms in the UK are concentrated in Scotland, particularly the west coast and the Hebrides (e.g. The Scottish Salmon Company). Once harvested, fillets must be cut within hours to preserve shelf life.

Peck (2006) suggested that one of the first products to run out in the event of fuel shortage would be canned fish. There is no readily available data on stock holding days for tinned fish, but Peck suggested a mean for ambient food of 7 days, with popular lines as low as 2 days. In the event of a crisis, consumers might be inclined to stock up, reducing the stockholding days further.

3.7.2 Possible pinch points

- **Stock levels.** In common with other highly perishable foods, stock levels for fresh fish are very low and rapid refrigerated transport is crucial.

- **Transport from landings and fish farms.** No evidence was found about transport between landings, processors (if not located at ports) and distribution centres or markets. Due to the locations of ports, long road journeys are required, making this the most likely step to be disrupted. Similar considerations apply to farmed salmon. It is not clear whether fishing fleets or aquaculture producers are given any priority with respect to marine fuel, so catches or farmed fish harvests might be disrupted. However, farmed fish are relatively slow growing (compared to poultry, for example), so short delays to harvest would probably be absorbed.

- **Packaging supplies.** Ice and insulated packaging are essential, but there was little evidence on either. Some processors have ice plants; otherwise stores are likely to last less than 7 days. Expanded polystyrene packaging has a very low density, so stocks are likely to be small.

- **Waste removal.** If transport was disrupted but landings continued, fish waste would accumulate, posing an environmental and health hazard. Similar risks exist with respect to disruption throughout the supply chain. Excessive delays or failure to maintain the cold chain would pose risks to public health. Clearly, frozen fish has much longer shelf life, provided storage is available.

3.8 Prepared/convenience foods

3.8.1 Frozen food

In a study of energy consumption across the frozen pea supply chain, Unilever suggested that there is poor data availability for chilled/frozen distribution, but that it is significantly more energy intensive than conventional non-chilled distribution, by an additional 1–3 litres diesel/hour. They estimated an average distribution distance of 250 km.

(McKinnon and Campbell, 1998) estimated that supermarket chains, co-operative societies and grocery discount chains handled around 78% of all frozen food sales in the UK. In volume terms the authors suggested this figure was around 84% with the remainder catering outlets served by wholesalers. Supermarket and freezer centre chains purchase directly from producers and thus McKinnon and Campbell suggest that only around a fifth of all frozen food sales were distributed via wholesalers.

There was very little peer-reviewed literature relevant to issues of fuel supply disruption. Two main issues would be likely to arise: harvest lag time and storage capacity. Some horticultural and agricultural commodities, such as vining peas, must be frozen within a short timeframe in order to retain sufficient freshness. Certain brands impose strict time cut-offs to ensure optimum freshness for premium products (e.g. 90 minutes for Birds Eye frozen peas, personal communication). Any that do not reach the freezing plant in this time will be sold as a more economy brand or subsequently used as animal feed. Additional to this is the relatively short harvesting season for vining peas. Therefore in the event of fuel disruption during harvest time, whole crops of peas for the frozen market might be lost if lack of fuel supply prevented peas from being harvested, or harvested peas from getting to the processing plants.

Once a product reaches a processing/freezing plant it will be packaged and loaded onto pallets for despatch. Freezing plants have limited storage facilities if they are unable to transport products to distribution centres. There appears to be sufficient capacity for 7 days within the distribution centres and supermarkets (Section 6.1), so supplies to consumers are less likely to be disrupted, unless product
substitution or stockpiling raises demand.

The main pinch points are, therefore, transport to freezing plants for freshly harvested produce and transport from freezing plants to distributions centres. In some previous fuel shortages, restrictions on the use of red diesel have been eased to assist with off-farm transport, but this might not be sufficient for tightly-constrained transport for some products.

3.8.2 Ready meals

Little formal literature on the supply chain for pre-prepared ‘ready’ meals could be found, other than a study that compared carbon dioxide emissions from chilled and frozen cold chains for a pre-prepared Sunday roast chicken meal (Evans, 2012). The study only considered food produced in the UK, with the meal consisting of chicken, peas, carrots, and potatoes

Ready meals, by their very nature, are a highly vulnerable section of the food supply chain. They are dependent upon a wide variety of ingredients arriving at a processing plant at the same time and thus are subject to many of the pinch points detailed for other commodities. Much of the literature relates to advances in packaging to extend the shelf life of ready meals and optimisation of the supply chain. However little information is available on stock holding days within retailers. Ready meal ranges are changed frequently and are highly driven by consumer demand, thus stocks of packaging materials are minimal due to this and rapid changes in labelling requirements.

For example, Kettleby Foods produces the majority of Tesco ready meals, supplying over 70 lines including cottage pies, stews, casseroles, pies, and dumplings for various ranges. The time between orders being received and delivery is very short. In an average day 40 different products can be run across the production lines. Products are packaged and loaded onto pallets, then to lorries for distribution. Production planning is said to be crucial because orders must be placed for raw materials and machinery configured for the production of multiple products. “The lead time on a product such as shepherd’s pie [from order to lorry?] may only be five hours.” The company is a subsidiary of Samworth Brothers, a privately-owned family business. Samworth Brothers Distribution has three distribution centres in Callington, Bristol and Leicester and a fleet of over 120 articulated vehicles. The three warehouses can handle more than 24,000 pallets and 1.2 million cases each week. Samworth Brothers also provide ready meals through a second subsidiary Saladworks, supplying 135 products across four customers, mainly focused on Italian and premium ranges. Although a decentralised organisation, such that each business has its own purchasing team, purchasing is coordinated, particularly for raw materials and packaging material.

This type of business, operating on short lead times, would clearly be vulnerable to transport disruption from its upstream suppliers, but no data was found on such businesses. There was also no data on the fuel stocks held within this type of company for distribution of products.

Aside from the supply of ingredients to ready meal manufacturing plants, another pinch point is again likely to be storage capacity once meals have been produced. These would normally be transported onward to distribution centres, but in the event of fuel disruption, this may lead to a backlog of packaged meals exceeding the available chilled storage.

3.9 Institutional customers

Some large institutions, notably schools, hospitals and prisons, are responsible for providing food to some groups that are either intrinsically vulnerable (young people, the sick and elderly) or cut off from access to other sources (in-patients and prisoners). The evidence that was found related to these institutions is collated here, rather than being presented under the relevant products, to reduce repetition.

3.9.1 Hospitals

The review did not have access to the contingency plans for fuel supply disruption in the Department of Health or the NHS, but some information could be gathered from publicly-accessible sources. Most procurement for hospitals takes place through a set of NHS framework agreements with suppliers. Suppliers from The Framework have their own fleet of vehicles, and so it will depend on the contingency plan of each company. The following are a few examples of the types of arrangements in place.

Hospitals are supplied milk, bread and eggs direct from the suppliers, generally regional or national producers or wholesalers. A hospital with a large budget (over £100,000/year) will place its order with a pre-vetted supplier on the framework agreement for “Milk, Cream, Dairy Products, Bread and Morning Goods”. A hospital with a lower budget (below £100,000/year) has the option to find alternative suppliers, such as a local dairy.

Seventeen suppliers provide the NHS with ready meals and frozen products. Ready meals such as shepherd’s pie, fish and chips, etc. typically have a lead time of a few days.
3.9.2 Schools

The review did not have access to the contingency plans for fuel supply disruption in the Department for Education or local authorities. Some information was available from publicly-accessible sources. Unlike hospitals, agreements are made at a county or local level.

Schools are supplied with eggs and many other products through wholesalers (such as the national 3663 First for Foodservice and Chaffins food service in the southwest\(^7,78,79\)). For example, in Hampshire, a local farm delivers 1200 dozen free range eggs per week to the wholesaler's depot, which supply the 451 primary schools, 34 secondary schools and 4 residential care homes\(^79\).

Schools receive bread either from national companies, from local bakeries\(^80,81\), or by baking on site\(^82,83\). Schools supplied by big plant bakeries depend on the contingency plan of the logistics service provider. Smaller bakeries may have less developed contingency plans, but no evidence was found.

Similarly, milk may be supplied by one of the large dairy processors or by a local dairy.

3.9.3 Prisons and other custody centres

The review did not have access to the contingency plans for fuel supply disruption in the Ministry of Justice. Some information was available from publicly-accessible sources.

The total number of people in custody in England and Wales is about 80,000 (MoJ, 2010). This population is highly vulnerable as a consequence of being in custody, so a failure of supplies would pose a health risk and a high risk of disorder.

Most food supplies to publicly-run prisons in England and Wales are managed through national contracts. For example, Premier Foods supply all publically run prisons in England and Wales with bread (Hovis and Mothers Pride)\(^84\) and in 2003 the egg supply contract for H.M. Prisons in England and Wales was fulfilled by a SME based in East Yorkshire, who supplied the eggs to H.M. Prisons’ five distribution centres\(^85\). The supplier of fresh milk for prisons in England and Wales is not documented. Similarly, the Scottish prison service makes contracts with national companies (Table 5).

### Table 5. Food supply contracts for Scottish prisons in 2009\(^86\)

<table>
<thead>
<tr>
<th>Food type</th>
<th>Supplier</th>
<th>Annual Spend (Contract year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-packed food</td>
<td>C J Lang &amp; Son Ltd</td>
<td>£1,468,000</td>
</tr>
<tr>
<td>Fresh and frozen meat and poultry</td>
<td>Campbells Prime Meat Ltd</td>
<td>£843,000</td>
</tr>
<tr>
<td>Frozen food</td>
<td>Brakes</td>
<td>£770,000</td>
</tr>
<tr>
<td>Milk and dairy</td>
<td>Robert Wiseman &amp; Sons Ltd</td>
<td>£548,000</td>
</tr>
<tr>
<td>Bread and bakery</td>
<td>Allied Bakeries</td>
<td>£405,000</td>
</tr>
<tr>
<td>Other</td>
<td>Other smaller suppliers</td>
<td>£10,000</td>
</tr>
</tbody>
</table>

There is a lack of evidence on stocks of non-perishable goods, but supplies of perishable foods would certainly be vulnerable to disruption within a few days. Given the types of suppliers used, it is reasonable to assume that most of the transport to the distribution centres is provided by third-party logistics service providers, as discussed below.

At least one company reports that it has had a long-term contract to supply all prisons in England and Wales with prepared and frozen foods, and has a logistical infrastructure to support HM Prison Service’s tightly defined timeframes\(^87\).

Although there is now an initiative to encourage the use of more local produce\(^88\), prisons are currently dependent on large suppliers with national supply chains. In general, these are likely to use logistics operators with contingency plans in place.

4. Interview results

Interviews were conducted roughly 3 weeks following the start of the literature review. Any major questions or uncertainties arising from the literature review were thus incorporated into appropriate interviews to inform the literature search. However, the preliminary purpose of this research was to gather new evidence (as opposed to reviewing past evidence) on where industry representatives perceive the key pinch points to be in the supply chain, understand the impacts that they might expect, and explore business contingency planning procedures for fuel disruption events. Given very little evidence was found in the literature to describe contingency planning, this was a key focus during the interviews.
A total of six interviews were conducted with individuals whose expertise spanned food and food safety, chilled goods, packaging, and logistics. It is important to note that given the small sample size, we consider these results to be indicative evidence on industry reception. However, further research is likely to be needed in order to fully understand the intricacies of the supply chains, their pinch points, and contingencies.

The following sections present results under two key areas: pinch points and contingencies, and impacts. Key issues in each of these areas were identified by considering the number of times the theme was coded (R), the number of interviews it was coded within (S), in addition to the interviewer’s interpretation of the importance of the theme. Those issues with the highest number of Codes and themes were validated by colleagues who had not attended the interviews.

### 4.1 Pinch points and contingencies

#### 4.1.1 Bunkered fuel stocks (S=5, R=18)

The availability of bunkered fuel stocks was both the most frequently cited pinch point and key focus for contingency planning across the interviews. Generally, it was assumed that storage facilities across the industry are limited and infrequent. Whilst distribution centres were generally noted to have fuel stocks, there was a degree of uncertainty relating to the fuel available for warehouses. One participant noted:

“There’s the storage tanks we have in some of the DCs, but warehouses today aren’t built with storage tanks, because they’re expensive to put in, supply is normally good, and it’s a big investment for something that might never happen.” [Participant 1]

This may highlight that there is little investment in fuel stock contingencies in UK warehouses due to the cost of installation. Whilst it was noted that some, older warehouse sites did have fuel bunkers, it appears that this trend has ceased, and that future premises are unlikely to retain this facility. There was also a great deal of uncertainty regarding the presence of fuel bunkers amongst third party logistics companies:

“Because we don’t know with the 3rd party hauliers, what their contingency looks like.” [Participant 3]

“They should [have bunkered stocks]. Well, they may not have their own fuel stocks but what they might have is an arrangement with their local fuel suppliers because they are big spenders and big companies.” [Participant 2]

This may suggest that the absence of fuel stocks amongst warehouses and third party logistics companies could be a vulnerability in the supply chain. In a discussion on the impact of this lack of bunkered stocks to vulnerable communities, one participant was asked whether it might be possible for organisations responsible for their care (e.g. the NHS or prison service) to enforce the use of bunkered stocks amongst their third party suppliers. However, the participant responded “That would be a very difficult one to actually contractually agree to.” [Participant 2] suggesting that such contingencies may not be enforced in the supply to vulnerable communities. As part of the study included an interview with one large third party logistics company, we are able to confirm that at least one large company “hold[s] around 80,000 litres” [Participant 6]. Whilst the participant was “not sure about [their] other sites” there was some basic knowledge of fuel stocks. Overall, a possible lack of knowledge surrounding third party logistics fuel contingencies may be a pinch point in the event of a fuel disruption. This has the potential to cause major effects to organisations caring for vulnerable communities who rely on these providers.

Generally, there appears to be a level of confidence around the assertion that the fuel stocks across the industry are held in quantities capable of supporting logistics activity for 7-10 days [Participant 2, 3, 6]. No information was gained from Participant 5, or Participant 1 who was unsure of reserves. Participant 4 (somewhat removed from the logistical side of the supply chain) noted that fuel stocks are likely to last for only 2-3 days.

Whilst the message was clear from Participants 2, 3, and 6 that a fuel disruption of 7 days should not cause major impacts (“So from our understanding, we wouldn’t have any problem within a week.” [Participant 6]), further questioning suggested that there are uncertainties surrounding this assertion. In particular, one participant noted:

“your 10 days could very easily turn into 9 – because you were doing things that you hadn’t planned. So they might plan for 10 on the basis that everything else is working as you would expect it to.” [Participant 3]

This could introduce a critical pinch point into the supply chain. If fuel stocks are calculated based on ‘typical’ weekly usage, there is a potential to quickly run out of fuel if other areas of the supply chain were to break down and request support from those with fuel stocks. This is particularly pertinent as distribution centres, who hold much of the stores, “don’t know what else [they] might be called upon to do for [their]...
customers” [Participant 3].

In the past, priority, influential, or fuel-rich organisations have needed to ‘step in’ to maintain flows in the supply chain where less influential or well-stocked components were restricting supply [Participant 3]. For example, where individual employees could not get to work, employers arranged transport services to collect them. In addition, it was noted that “you were removing waste for retailers, backhauling other stuff because you were the only people with fuel. Your 10 days could very easily turn into 9 – because you were doing things that you hadn’t planned.” [Participant 3].

This highlights the potential need for systems thinking within fuel stock planning. If organisations become complacent and rely on ‘business as usual’ predictions for fuel usage, there could be critical weaknesses in the supply chain as well-stocked providers are called upon to meet client demands ‘above and beyond’ their usual operations.

Finally, it is important to note that whilst many participants noted they are likely to be capable of maintaining supply throughout a fuel disruption of 7 days, there is a great deal of uncertainty about what would happen if a fuel disruption were to continue past this point. This represents a potential ‘tipping point’ and much larger impacts may be expected past the seven day term.

4.1.2 Food storage (S=5, R=18)

The rise of “just in time delivery” is widely recognised as having reduced the amount of food stocks residing in warehouses or site-stores. One participant suggested that at any point, inventory levels “would be measured in days rather than weeks.” [Participant 2] This was noted to be true of chilled foods (where one participant stated “There aren’t warehouses in the industry for anything.” [Participant 1]) and meat (“with foot and mouth, we ran out of meat within this side of a week. I remember saying ‘we’ve got to start killing animals or the shelves will be empty’. There isn’t this stuff in store or in chill.” [Participant 1])

In support of this theory, participants were in some cases able to provide more concrete information of stock levels at RDCs and retailers:

“Normally we hold around 2-3 weeks [ambient] stock in those [RDC] sites. [The supermarket] took quite a high priority on their availability.” [Participant 6]

“That’s pretty much it [a day or two’s worth of cover]. A day or a day and a half possibly. They [retailers] don’t have very big chillers in a lot of stores; it’s pretty much real-time.” [Participant 6]

Based on this indicative evidence, it is possible that in a ‘zero fuel’ and ‘zero movement’ scenario, food supply could be negatively impacted within two days, due to the shortage of stock at points other than regional distribution centres. However, given the diffuse availability of bunkered fuel stocks through the chain, ‘zero movement’ is unlikely, and consumers may not be impacted severely. This assumption would need further testing.

In some cases, organisations acted to ensure stock levels were maintained in the event of a fuel disruption. One participant noted “when we have something like a fuel disruption, we would bring in additional food stock where we thought we might run low.” [Participant 2]. However, others disagreed, noting “there’s little point in stockpiling anything… it’s not feasible” [Participant 4].

Finally, it is important to note that this is an extremely tight system, which can become very ‘stretched’ very quickly:

“it only needs a small blip, in a very shallow area, to create a problem. It’s not just that it’s impacted immediately, it can take a long time to get out of it, because there’s no capacity in the network to deal with that level of disruption.” [Participant 2]

This quote suggests that even short term issues might impact the network severely for an extended period of time, given the capacity of the network to cope with sever disruption.

4.1.3 Employee fuel supply (S=6, R=14)

Large parts of the food supply chain are driven by manual labour as opposed to by machinery. Participants discussed their reliance on a full complement of staff to maintain business as usual operations.

“We’re quite labour intensive in chilled. There’s no such things as a lasagne or chicken curry machine. There are robots for filling sandwiches with spreadable fillings and there are only 3 of those in the country. Everything else is hand made. So if you can’t get people in, you can’t make the food.” [Participant 1]

The concern was echoed by others, but in relation to the ability of logistics professionals and drivers to attend work:

EVID4 Evidence Project Final Report (Rev. 06/11) Page 35 of 58
“The real worry was that we could have all of this bunkered fuel stock and lorries raring to go, but the widely available forecourt suppliers could dry up so workers couldn’t get in to work to actually drive the lorries.” [Participant 3].

Thus, a restriction of fuel supply to employees could have a major impact on the food supply chain. The labour-intensive nature of production and processing, plus the need for lorry drivers to support the movement of stock could present a key pinch point in a fuel disruption scenario. Indeed, one participant discussed how the inability of staff to get to work was the key rate-limiting-issue in a previous disruption:

“We had the stock, we had the trucks, we had the fuel for the trucks, we just didn’t have the people to do the work.” [Participant 2].

The problem was seen to be exacerbated by the fact that much of the supply chain is close to growers with “not a lot of public transport. So if there’s no fuel for people to put in their cars, they’re really stuck.” [Participant 1].

Whilst some organisations discussed the possibility of “hiring a transit van to go and pick people up” [Participant 2] as part of their contingency planning, others noted doing so would further reduce the number of days of fuel cover “your 10 days could very easily turn into 9” [Participant 3].

Thus, there was considerable concern amongst participants over the impact that fuel restrictions could have on the ability of staff to work, and the impact that this might have on the supply chain. It is likely that this is a key pinch point which may need to be explicitly covered in industry contingency plans. Whilst some organisations suggest mitigating actions (e.g. staff buses), this fuel requirement must be planned into fuel bunkering reserves.

4.1.4 Fuel prioritisation (S=5, R=11)

There was a general assumption amongst some participants that the food industry would benefit from prioritised access to fuel supplies in the event of a disruption. However, this assumption was notably unqualified in some instances (Q1) and openly challenged in others (Q2 and 3).

Q1 – “My understanding is that because we’re in food and because it’s a priority chain, we are given priority. Now I don’t have anything in writing, that’s my understanding from discussions.” [Participant 6]

Q2 – “I think the whole priority user scheme is actually defunct. The honest answer is that I’d be very surprised? if they have any priority usage.” [Participant 5]

Q3 – “there is a tendency to think back to priority use schemes and logo’s schemes from the early noughties and people have tended to rely on the historical aspect. And that’s probably down to the fact that there’s nothing else there – that fills the vacuum. If government is a lot clearer about what people can expect and can’ expect, then it would make life a lot clearer and a lot easier.” [Participant 3]

The lack of clarity surrounding the prioritisation of fuel stocks holds the potential to be a major pinch point in the supply chain. If there is a genuine industry-wide lack of understanding in relation to this, and a false expectation that food companies will be given priority, current contingency plans may not be sufficient in the future. Additional research is necessary to generate a fuller picture of industry understanding in this area.

4.1.5 Packaging availability (S=3, R=20)

Low packaging stocks were deemed to be a potential pinch point due to the level of turnover in the industry:

“They are held in stock but the problem for chilled foods, is that at any one time there are about 12,000 SKUs being made every day. There is a high churn rate of reform and new product development so 50% of products are changing every year. So you don’t really keep lots of labels and packs in store because if you spend 9 months developing a new product, and then people don’t buy it within the first few weeks, it’s just dropped, so you don’t want to end up with a whole warehouse of boxes being made.” [Participant 1]

“there is a huge change going on in next few months involving redesign, as there is new legislation on type size. That does mean that there aren’t huge stocks of anything, period. No one can afford to have huge sways tied up in packaging anymore. I would be very surprised if stocks are in anything more than days not weeks. [Participant 5]

The lack of packaging availability is a clear pinch point as, without this, many products cannot be ‘finished’ and distributed: “When you start to talk to [the dairy industry] about availability of resin for bottles and that end of the supply chain, packaging availability is pretty crucial, […] I wouldn’t underestimate some of the
issues of packaging” [Participant 3].

This evidence suggests that a lack of packaging has the potential to halt production and therefore reduce supply to retailers. However, a lack of packaging was also noted to be “an integrity and food safety issue” [Participant 3], in part due to the potential for use of substitute sub-optimal packaging materials which may compromise shelf-life.

It is worth specifically noting that a number of products rely on modified atmosphere packaging, and an inability to supply materials to support this process may represent an important pinch point in the chain. One individual noted:

“I remember one manufacturer was running out and they kept being told “It'll be tomorrow, it'll be tomorrow” so they were looking at not being able to make any food. So that's quite a niche things but it does affect a few million pounds worth of stuff.” [Participant 1]

This highlights that like food, packaging is often made of multiple components and that the unavailability of any one component may cease production, compromise shelf life, compromise quality, or lead to additional waste if the product can no longer be used.

4.1.6 Suppliers (S=3, R= 9)

Some participants expressed a concern over the ability of suppliers to move their goods to RDCs or elsewhere:

“It was more about the suppliers and the smaller suppliers that come in on the fresh end” [Participant 6]

“That's the biggest issue in my mind, is getting the stuff out of the field or out of the abattoir.” [Participant 2]

Clearly, suppliers represent the beginning of the supply chain and any disruptions here are likely to have negative impacts throughout the chain. Whilst they are not as ‘close’ to consumers (and therefore impact to consumers is likely to be delayed), the inability of small suppliers to deliver their goods has the capacity to cease production. Importantly, these smaller suppliers were deemed to suffer lack of priority at the petrol pumps, and a general lack of bunkered stocks:

“Growers don't have the capacity to do anything about it – they are queuing up at petrol stations like everyone else. They just have to rely on good will. That's where people are most at risk.” [Participant 2]

This quote suggests that small suppliers may not have bunkered fuel stocks, and are thus reliant on fuel supply from petrol stations. The quote also seems to suggest that smaller suppliers may not have any priority status in the event of a fuel disruption (as was anticipated in some cases for large suppliers/logistics companies).

4.1.7 Waste removal (S=2, R=6)

A poignant remark made by one participant, was that whilst studies often discuss the capacity to deliver into a business during a fuel disruption, the ability to remove materials is seldom investigated. Throughout interviews, waste removal issues were discussed at both retail outlets and food production facilities. In particular, a failure to remove packaging from retail sites may disrupt supply and reduce the space available for new deliveries:

“If retailer vehicles are without fuel and can’t get in, then surplus packaging sits at the back of the store, builds up and up and up and the stores then say – ‘sorry, we can’t take in any more stock as we have no way of clearing the back log of packaging at the back of the store’” [Participant 3].

Similarly, the build-up of waste in food production was noted to be a key health and safety, and food safety concern for industry:

“If you’re producing perishable goods and the waste is perishable, there is a greater need to remove things frequently from the site.” [Participant 4]

A failure to remove these goods may result in microbiological hazards, physical containment hazards, and environmental impacts. The criticality of this pinch point was said to vary between commodity types:

“I suppose in the meat plant world, removal of bones and meat by-products is going to be absolutely fundamental. I imagine that would be happening on a daily basis at least, depending on the size of the plant” [Participant 4]

“I guess if you are looking at something like the fruit or veg industry, the waste there is going to be largely dumped at compost, and so that's probably less critical to get it off your site
This represents a unique pinch point in the supply chain and is worth noting as a potential drain on bunkered fuel stocks. As mentioned, if retailers request the help of suppliers in removing waste, pressures on the supply chain and fuel supply are likely to be transferred through the network. As such, there may be a need to establish contingencies for waste removal (at the point of waste production) to help maintain flows of waste during disruptions and reduce the transfer of negative impact.

4.1.8 Labelling (S=2, R =6)

It was also discussed that where stock was stationary and running out of shelf life, some opportunistic areas of the supply chain may look to repackaged stock with new shelf life dates:

“[Participant 4]”

“Clearly there are less reputable supply chain areas out there, which wouldn’t even go into the consideration of whether there was microbiological issue and would just re-label the product.” [Participant 4]

Should a fuel disruption event lead to fraudulent relabeling, there are likely to be quality and/ or health issues arising from food which has passed the safe microbial levels and is unfit for human consumption. However, the likelihood of this assumption was contested by other participants:

“My initial reaction is that it [fraudulent relabeling] would be a remote possibility for packaging. Packaging is very product specific, so unless something starts with plain packaging it would be difficult to re-label.” [Participant 5]

“The only things that are likely to come plain are plain bottles, some food cans (most are pre-paper labelled) and lidding films for produce packaging or fruit and vegetable packing.” [Participant 5]

It was also noted that there are multiple other routes for product use that may be exploited by organisations who were concerned about profit. For example, waste product unfit for human consumption may be used by animals or ploughed into fields. Other stock at its sell-by date may also be distributed to charities. Finally, it was noted that big brand would be “unlikely to compromise their product integrity”, given that their reputation and brand is worth more to their business than profit that might be retained through labelling.

This issue requires further investigation to understand how much of a vulnerability this issue might be in the supply chain.

4.1.9 Quality checks (S=1, R=2)

A key concern for many food production companies and manufacturers is the maintenance of food safety standards. Establishments are in many cases required to check food safety standards on a “pretty much continuous, a half-hourly basis” with something “less critical in the infrastructure [checked] daily or half daily” [Participant 4]. Thus, the ability of trained veterinary professionals, safety experts, and Environmental Health Officers to travel to site could limit production, or, if allowed to continue without these experts, compromise food safety.

4.2 Impacts

4.2.1 Economic impacts (S=6, R=8)

Impacts discussed were largely in relation to reductions in stock movement (and thus payment – Q1), food waste (Q3) or possible penalties for failure to meet service level agreements (Q3).

Q1 - “So if the volume didn’t arrive because the goods in didn’t arrive, we wouldn’t earn the case rate picking those products.” [Participant 6]

Q2 - “it’s an economic impact as if the fuel supply to a machine was cut off, or to refrigerator, then you then look at disposal” [Participant 3]

Q3 - “So if I order 1,000 products and I get 999 I don’t get my figure, that’s a failure and we could be penalised. It’s quite brutal.” [Participant 2]

Whilst the possibility of service level penalties were mentioned by two participants, further questioning revealed that there is an appeal procedure in the event of weather or other major disruptions outside the control of the service provider [Participants 2 and 6]. Thus, the economic impact of penalties is likely to be
minimal, although waste and reduction in case rates might be more severe.

4.2.2 Food safety (S=3, R=17)

As noted in the previous section, food safety implications were noted to include an increased potential for food fraud (Q1), microbiological contamination (Q2), and traceability issues (Q3).

**Q1** - “There is tremendous amount of products which might be sitting around with date codes that might be running out, and there is a possibility that could be relabelled as part of fraudulent practice, and have its integrity compromised a result of that” [Participant 4]

**Q2** - “I would have to go microbiological contamination [as the most important issue] from temperature breakdowns. Not just within the manufacturing chains, it’s also in the consumers chain as well” [Participant 4]

**Q3** - “There might be a breakdown in the supply chains and control of traceability.” [Participant 4].

Food with microbiological contamination issues has the potential to cause mild to serious illness amongst consumers. Whilst this has health implications, it also incurs secondary costs via the NHS. It is important to note that some of these claims were contested by other participants.

4.2.3 Impacts on small businesses (S=2, R=5)

There was general consensus on the fact that small businesses are likely to be impacted very differently (and most likely more severely) from a fuel disruption than major organisations.

“At [a major supermarket] and [a major logistics company] we do hold some sway with the fuel companies. If you’re a fresh food grower in Lincolnshire, you’re on your own.” [Participant 2]

Small businesses were deemed less able to gain priority status at local petrol stations for fuel, relying on the goodwill of operators. This has the potential to cause major localised impacts amongst small growers and processors. Critically, there is also likely to be a lack of communication with these organisations, meaning support during the disruption is likely to be poor for these communities.

“but there are 60,000 food businesses in the UK, and we’ve got 250 members, there’s a huge huge number of SME’s that no one is talking to – at least in this scenario” [Participant 3]

A lack of communication with small businesses may also mean that generating an accurate understanding of the impacts is unlikely.

4.2.4 Shorter shelf lives and waste (S=3, R=4)

There is potential for products to remain in storage for longer [Participant 5] and/or have “sub-optimal packaging”, resulting in shorter shelf lives [Participant 6]. Clearly, this raises the potential for additional wastage.

5. Discussion: pinch points

Eight key types of food supply chain were analysed using the results of a literature review and a series of 6 short interviews with industry. This analysis sought to understand the issues with the potential to create or exacerbate pinch points along the food supply chain, in addition to the location of those pinch points. The cause and location of pinch points are discussed separately below.

5.1 Causes or contributing factors to pinch points

Four key issues (spanning multiple food types and supply stages) were identified (Table 6), with supporting evidence from both the literature review and interviews:

1. **Low food stocks** are a key feature of today’s lean supply chains, but a lack of storage capacity at most key stages increases vulnerability in the event of disruption. This is likely to create pinch points throughout the chain (i.e. the whole chain is a pinch point – see Table 8 for more data).
2. **Heavy reliance on third party logistics companies** may create large pinch points in the chain, as organisations are reliant on the contingency plans of these providers. There is little evidence to suggest whether these plans are sufficient, thus creating a large uncertainty regarding the resilience of this supply component.
3. **Staff fuel shortages** are likely to cause pinch points at multiple points in the chain, given the manual nature of much of the work in the food industry. Processing plants are often situated in rural locations which may not be well-serviced by public transport, and distribution centres still
require staff to reach work to ensure logistics are maintained. Some organisations had considered contingency plans (e.g. staff buses) following previous fuel disruptions, but it is unclear whether they would be equipped to deliver these during a period of disruption.

4. **Requirement for food temperature control** is a cause of pinch points at multiple points in the chain for highly perishable products, because it is impossible to hold significant stocks at any point and it reduces the flexibility of transport options and timing. Milk, fresh fruit and fresh fish are all examples of this: even a short interruption to chilled transport would render them unfit for consumption, causing the supply to fail and generating waste, with attendant disposal problems.

In addition to these issues, four additional key concerns were raised during the interviews only. Whilst these factors do not currently have underpinning evidence in the literature, they were considered to have the potential to impact on multiple points throughout the chain:

1. **Issues such as food fraud, re-labelling, and reduction in safety checks** have the potential to impact on multiple points in the chain. However, impacts are likely to be confined to high value, perishable goods such as meat and fish.

2. **The possibility of insufficient bunkered fuel stocks** could mean that deliveries or collections at each stage of the chain could be halted. Whilst the interviews suggested that many companies had some bunkered stocks, there was concern that these may not be sufficient for a 7 day disruption.

3. **Some lack of clarity surrounding fuel prioritisation schemes** could create key points across all chains. In particular, this could lead to complacency and a lack of contingency planning (given assumptions about priority use). There are also concerns about how such schemes could operate in practice, and whether small traders and essential non-food goods (e.g. waste, packaging, inert gases and cleaning supplies) would also receive priority access.

Finally, those issues affecting three or fewer stages in the supply chain, for fewer product types include:

- Low packaging and non-food stocks
- High frequency of delivery
- Susceptibility to shocks due to harvest schedules or seasonality
- Low holding capacity for live animals
- Centralisation of production
- Reliance on imports
- Lack of contingency plans in small businesses

The literature reviews highlighted several issues relating to the technical requirements of supply chains and ‘business as usual operations’. However, we feel that the interviews offered an important insight into the ‘human’ component of these systems and highlighted several undocumented issues that may compound those found in the literature. For example, the lean nature of the supply chains and the reliance on third-party logistics companies are well-known. However, when considered alongside indicative evidence from the interviews on possible shortages of bunkered fuel stocks and insufficient contingency planning from small businesses, the level of impact that might be anticipated is much higher.

Similarly, the literature review highlighted the need for constant temperature control for many product types, pointing to the potential for microbiological contamination and food safety concerns. However, interviews expanded this topic, noting that the fear of economic loss may drive some organisations to adulterate or fraudulently re-label goods to avoid loss through quality procedures.

These results highlight the need to look across multiple forms of evidence to identify cumulative impacts and confounding factors, which may serve to elevate risk at each stage of the supply chain. We would recommend a more in-depth, interview-based study, to gather additional information on additional pinch points, interdependencies and cumulative impacts.
Table 6. Summary of possible causes and locations of pinch points across multiple food chains in the event of a 7 day fuel supply disruption.

Letters are used to denote the foods affected: meat (M), sea fish (S), vegetables (V), dairy (D), eggs (E), fruit (F), bread (B) and pre-prepared food (P), or all types. Brackets indicate that only some companies or some foods within a given type would be affected. Issues highlighted in dark orange are those where evidence was found in both the literature and interviews to suggest that a large number of food supply chains could be affected for 3 or more stages in the supply chains. Issues highlighted in light orange are those where one type of evidence was found to suggest that a large number of food supply chains could be affected for 3 or more stages in the supply chains. Other issues affected fewer food types or had more localised effects.

<table>
<thead>
<tr>
<th>Evidence (I= interview, L= literature review, or B= both)</th>
<th>Issue (possible cause of pinch point)</th>
<th>Location of pinch point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distribution from farm/ import</td>
<td>Process/ packaging</td>
</tr>
<tr>
<td>B</td>
<td>Low food stock</td>
<td>M, S, V, D, E, F, P</td>
</tr>
<tr>
<td>B</td>
<td>Reliance on third party logistics</td>
<td>V, E, (B)</td>
</tr>
<tr>
<td>B</td>
<td>Staff fuel shortages</td>
<td>All</td>
</tr>
<tr>
<td>I</td>
<td>Other food safety issues (fraud/ reduction in quality checking)</td>
<td>All (mostly M/S)</td>
</tr>
<tr>
<td>I</td>
<td>Possibly insufficient bunkered fuel stocks</td>
<td>All</td>
</tr>
<tr>
<td>I</td>
<td>Fuel prioritisation concerns (unclear operational plans, lack of cover for non-food supply areas/ small bus.)</td>
<td>All</td>
</tr>
<tr>
<td>I</td>
<td>Need for waste removal</td>
<td>(?)</td>
</tr>
<tr>
<td>B</td>
<td>Low packaging and non-food stocks</td>
<td>All</td>
</tr>
<tr>
<td>B</td>
<td>High frequency of delivery</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Susceptibility to shocks due to harvest schedule/ seasonality</td>
<td>(V)</td>
</tr>
<tr>
<td>L</td>
<td>Low holding capacity for live animals</td>
<td>M</td>
</tr>
<tr>
<td>L</td>
<td>Centralisation of production</td>
<td>B, M, (D), (P)</td>
</tr>
<tr>
<td>L</td>
<td>Reliance on imports</td>
<td>F, S, V, (M)</td>
</tr>
<tr>
<td>I</td>
<td>Lack of contingency in small businesses</td>
<td>All (D, B to a lesser extent)</td>
</tr>
</tbody>
</table>

Indicative count (each food = 1 and letters in brackets = 0.5)

31.5  67  61.5  74.5
5.2 Location of pinch points

Table 6 includes an indicative total of the number of issues and food types affected at each stage of the supply chain. While these counts do not measure the severity of impact that disruptions at these points may have, they do help to assess which parts of the supply chain may be affected by the most pinch issues, across the most food types.

The retail and food service sector received the highest score, suggesting they have the greatest number of pinch points impacting the greatest number of food types. Any disruption at this stage will have a direct impact on consumers, as shown in Table 8. The processing/packaging and RDC/wholesale stages also had high scores due to the diversity of the issues affecting them. The data in Table 8 shows that impact on consumers for less perishable products from this stage would be delayed and might not occur within seven days in some cases. The head of the supply chain had the lowest score, but this may be artificially low, because the scope of the study included transport from this point only, and not the agricultural impacts. Effects here were least likely to propagate to consumers within seven days.

6. Stakeholders

This section draws together and discusses the evidence from the review and the interviews relating to some of the large stakeholder groups including businesses in the supply. Most of the discussion of the effects on consumers appears in the next section, under the heading of social impacts, which looks specifically at some of the geographical variations and impacts on vulnerable groups.

6.1 Multiple retailers

Multiple retailers have highly integrated operations, typically using direct supply from producers or processors to their own distribution centres. For the more perishable products, very little stock is held in the stores or the distribution centres, and they rely on frequent rapid deliveries with total lead times less than 3 days to maintain the flow of goods to customers (Table 7).

Table 7. Average inventory at regional distribution centres. From McKinnon (2006) based on IGD (2004a)

<table>
<thead>
<tr>
<th></th>
<th>Inventory level (days) at RDC</th>
<th>Lead time: supplier to RDC (days)</th>
<th>Lead time: RDC to shop (days)</th>
<th>Delivery frequency (drops/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast moving ambient</td>
<td>9</td>
<td>2.2</td>
<td>1.4</td>
<td>11.6</td>
</tr>
<tr>
<td>Slow moving ambient</td>
<td>11.2</td>
<td>2.8</td>
<td>2</td>
<td>5.6</td>
</tr>
<tr>
<td>Produce</td>
<td>0</td>
<td>2.2</td>
<td>0.9</td>
<td>11.2</td>
</tr>
<tr>
<td>Chilled</td>
<td>0</td>
<td>1.9</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>Fresh meat</td>
<td>0</td>
<td>1.9</td>
<td>0.9</td>
<td>11.1</td>
</tr>
<tr>
<td>Frozen</td>
<td>8.9</td>
<td>1.6</td>
<td>1.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Beers, wines and spirits</td>
<td>19.2</td>
<td>18.1</td>
<td>1.6</td>
<td>5.4</td>
</tr>
<tr>
<td>Non-food</td>
<td>19.6</td>
<td>23.3</td>
<td>2.3</td>
<td>4.4</td>
</tr>
</tbody>
</table>

The implication of these near-stockless supply chains is the need to maintain transport operations to and from the distribution centres. Given that this is critical to the maintenance of their businesses, the companies have generally made plans for the case of fuel supply disruption. Transport services are often provided by third-party logistics companies, so contingency planning is a joint exercise involving both parties. Most of the large supermarkets also operate home delivery services. While some of their customers use these as a matter of preference and are able to switch to other channels, they may serve others who have reduced mobility and are thus vulnerable in the event of disruption. There is therefore both a business case and a social responsibility to ensure that these services remain operational.

A further potential problem is the ability of staff to travel to work during fuel supply disruptions. The impact of this on consumers will depend on the number of staff using different modes of travel (foot/bicycle, private cars and public transport) and the provision of cover for those requiring fuel. Maintaining public transport is important for many sectors of the economy and forms part of civil contingency planning by
central and local government. Assuming that these plans are sufficient to provide adequate services, the critical group are those staff who rely on private cars and are unable to switch to public transport.

As many multiple stores are also fuel retailers, they could provide priority supplies to their own staff, but this would risk unrest among other fuel customers. An alternative, which is part of the planning of third-party logistics companies, would be to plan to provide private bus services to transport staff. They might also be able to mitigate the impact somewhat by emulating banks and other organisations and instructing staff unable to reach their normal workplace to travel to their closest store, if possible.

A further transport requirement is the removal of waste from supermarket premises, which relies on commercial waste handling and recycling companies. This normally includes both food that has exceeded its shelf life and packaging waste. While changes in buying patterns during fuel disruption might affect the volume of food waste being produced, it is unlikely that it would be eliminated. Failure to remove it would present an environmental hazard. While less hazardous, accumulation of packaging waste could eventually interrupt the operations of a store. The risk of interruption to waste collections depends on the contingency plans of the companies involved, which is beyond the scope of this review.

Supermarkets have very high standards for the stock they accept: undamaged items arriving in damaged outer packaging are rejected and sent back to the RDC to be re-packaged and re-delivered. During a fuel supply disruption this high level of inspection and rejection should be adjusted accordingly to ensure safe and edible products make it to the shelf (Peck, 2009).

6.2 Other food retailers

Food retailers other than the major supermarkets are often referred to as ‘independents’, but this conceals a wide range of different business types, including street markets, independent traders and smaller supermarkets and convenience stores, which are often members of ‘symbol groups’ (e.g. SPAR, Budgens, Costcutter).

Very little information was found on most of these, though there was some indication that the distribution systems for symbol groups might take similar approaches to the larger supermarkets. However, many individual stores within these groups use local suppliers for some of their goods (e.g. bread from a local craft bakery), which might be less well-prepared.

Other small retailers are usually supplied by wholesalers, for which little information was found. Some of these also use logistics service providers, which are considered below.

Peck (2006) found that sales at some smaller stores increased during the fuel crisis in 2000: SPAR reported a 300% increase. Thus there is no evidence to suggest that their businesses would be significantly harmed, provided that they continued to receive stock. However, if their supply routes failed, stocks would be sold rapidly after which income would fall. McKinnon (2006) noted that “At any given time there are many companies whose trading and cash flow positions are fragile. They would be unable to withstand even a temporary loss of business.”

6.3 Food service businesses

About one-third of expenditure on food is on meals purchased outside the home at fast food outlets, restaurants and hotels (McKinnon, 2006). These businesses would be sensitive to interruptions of deliveries and the ability of customers to travel to them. For example, a country town hotel reported cancellations and a drop in demand during the fuel shortage in 2000, although they had sufficient food from local suppliers (Peck, 2009). Similarly, some businesses reported a fall in demand for sandwiches, as customers stocked up and ate food prepared at home. However, Peck noted that parts of the sector, especially ‘grab and go’, had changed significantly since 2000, making it difficult to extrapolate.

Most of the businesses interviewed by Peck had confidence in their suppliers and logistics service providers, although one noted that their suppliers took advantage of the crisis to raise prices. From this limited evidence, it seems likely that food service businesses would suffer a loss in trade during a fuel crisis, but there are no estimates of its magnitude. In view of this, and the vulnerability of some businesses noted in the previous section, some of the responses found by Peck might appear slightly complacent.

6.4 Third-party logistics companies

Third-party logistics companies are specialists in road transport and are used by many companies in preference to maintaining their own fleets of vehicles. There is an expectation that they have good contingency plans, including fuel stocks for at least 7 days. Some of the interview participants reported stocks for 7–10 days. However, some also expressed concerns that events could quickly reduce those stocks. In a discussion unrelated to this project, it was noted that contingency plans could be out of date if they were not updated when the fleet expanded or distances travelled increased.
Some companies reported that their contingency plans included methods to ensure that drivers were available. However, others expressed doubts about the ability of staff to get to work if forecourts dried up, so it is not clear that all have the necessary plans in place.

The interviews also showed that there was a lack of clarity about the procedures for supplying priority users, including companies transporting food.

6.5 Processors and distributors

Processors and distributors are intermediaries in food supply chains between the producers or importers and the final suppliers to customers. For many of the products reviewed, the limited evidence available showed that they normally held only small stocks of products and, in the case of processors, of materials. The inventory level was usually less than 3 days at normal demand and less than 1 day for some perishable products (see Table 8). An interesting exception was noted for one flour miller that had low confidence in its grain suppliers and held a stock of 9 days of cover.

As intermediaries, these businesses are vulnerable to both upstream and downstream disruption. If their supplies were disrupted, but demand continued at normal levels, their stocks would rapidly become exhausted. From this point onward they would suffer loss of income. Even short periods without cash flow could harm some small businesses. Conversely, if they were unable to move their stock, without storage they would have to stop accepting deliveries, which would push the problem back to their suppliers.

Perishable products that could not be moved would generate waste with potential environmental impacts, which are discussed below.

6.6 Farmers and growers

Although the agricultural impact of fuel disruption was outside the scope of this study, it is clear that farmers and growers are important stakeholders in the food supply chain who could suffer lost income and would influence some of the environmental consequences.

In many cases, farmers are paid only on delivery within strict specifications. They would therefore face an immediate loss of income. In addition, they might also be left with unsalable goods for disposal. The financial consequences would depend on the types of contracts with their customers: for example, in other markets, ‘take or pay’ contracts would place some of the delivery risk on the customer. Further investigation would be needed to ascertain the types of contracts used in the different types of agricultural commodities.

In some cases the disposal cost for growers would be relatively small (crops could be ploughed in, or be rented out as temporary grazing for sheep). Other products would attract higher disposal costs because of their potential environmental impacts (e.g. milk and eggs) or the need for humane slaughter of animals followed by rendering of carcasses.

Clearly, the magnitude of the effects on farmers would depend on the time of year. For less-perishable crops and large animals, a delay of up to a week could often be accommodated. Conversely, some crops, notably peas for freezing, are very sensitive to timing of harvest and duration of transport. Even a short delay could result in downgrading or complete loss of the crop with a consequent loss of income. For crops that can be stored on farm of left in the ground, including cereals, potatoes and root vegetables, the economic effect on farms with sufficient storage would probably be limited. They would often not expect to sell the whole crop at the time of harvest, and might already have made forward contracts. Conversely, farms without sufficient storage or with contracts whose delivery dates coincided with transport disruption might face losses, though the latter would be able to recover some of the losses by selling their produce subsequently.

Production is also related to seasonal demand, such as turkeys at Christmas and lamb at Easter. Lost sales for seasonal purchases would probably not be recovered at other times. Importers are also subject to seasonal effects, either to meet seasonal demand or to complement seasonal production within the UK.

6.7 Importers and sea fish suppliers

Almost half (47% by raw food value) of the food consumed in the United Kingdom is imported, mainly from the EU (28%) with smaller proportions from north America, central and south America, Asia and Africa (Defra, 2012). All imported goods enter through a limited number of ports, which are remote from much of the population. Supplies of these products therefore depend on road transport away from the ports, typically to the importer’s processing, packaging or distribution centres. Disruption of transport from ports could, therefore, have a significant impact of food supplies. The largest group of imported commodities is fresh fruit (85% of consumption) and vegetables (45% of consumption), for which the stocks in the supply chain are necessarily low, as they are for other perishable foods.
The situation with sea fish is similar, except that processing and packing often happens within the port. Importers unable to move their goods would still receive shipments that were in transit, unless they were able to divert them to other markets. Similarly, fish already caught would be landed, unless they were dumped at sea. Therefore, these companies might accumulate stocks of perishable goods equivalent to several days of normal demand, but they would not have the management and disposal options that are available to farmers. Waste disposal would be costly and would also rely on road transport. Companies could suffer both loss of income and disposal costs.

7. Impacts

This project did not conduct primary research on the impacts of fuel supply disruption, but did include the impacts of food supply chain disruption within the literature searches. The available evidence was scarce, especially on the economic impacts, consisting mainly of one modelling study (McKinnon, 2006) and retrospective interviews about the effects of disruptive events. This section briefly discusses the direct and indirect evidence found, and draws some limited inferences.

7.1 Social impacts

7.1.1 Consumer behaviour

There is no research in the literature that investigated in detail the impact of fuel supply disruption on consumer purchasing behaviour. However, anecdotal evidence on system interdependencies at the Peak Oil Day conference in 2005 suggests the uncertainty of the length of the UK fuel protests in 2000 and the impact on food supplies caused consumers to alter their normal purchasing habits, acquiring more food than normal. SPAR, a grocery symbol group, reported an increase in sales by 300%, while Safeway, a multiple retailer, rationed bread and milk at its stores as staple items were in short supply. Retailers reported trucks had run out of fuel which limited their ability to guarantee food deliveries and media coverage of these issues increased panic buying in shops and supermarkets across the country (Church, 2005).

It seems likely that buying patterns would change when disruption was imminent. Most UK consumers (92%) do their main grocery shopping in supermarkets, over half shop weekly, one-third more frequently and about half top up with purchases from convenience stores between supermarket visits (McKinnon, 2006 citing IGD, 2004b). This implies that most households will have less than one week’s stock of some commodities most of the time. Thus it is plausible to assume that the threat of disruption would lead to a short-term increase in purchasing to raise domestic stock levels, including less perishable foodstuffs, and that there might be a differential effect on local and more distant stores if consumers attempted to conserve fuel.

7.1.2 Geographical differences

Anecdotal evidence gathered as part of a study of the resilience of Scottish Food Supply Chain (Weir, 2009) revealed that parts of the supply chain that were heavily reliant on transportation (i.e. long distance haulage or high frequency distributions) have a disproportionally higher impact than parts of the supply chain that have more localised distribution networks (or larger and less frequent deliveries). It also suggested that more vulnerable geographic locations in the UK may hold higher stocks of meat supplies, particularly where they have previously experienced food supply chain disruptions (e.g. from ferry strikes or severe weather), enabling them to cope with short periods of disruption. In general, people in rural areas hold larger stocks of groceries than those in towns (McKinnon, 2006 citing IGD, 2004b), so they may less vulnerable to temporary transport disruption.

A study conducted in 2001 elicited provider views on issues of food provision in the Western Isles of Scotland (Byrom et al., 2001a; Byrom et al., 2001b). In general, providers seemed to have greater confidence than consumers in an earlier study (Clark et al., 1996), noting that temporary stocks are generally sufficient to manage a disruption of a few days. Where stock levels did fall it was generally considered to be a result of bad retail practice. It was noted that the 17 food outlets provided the population of the islands with a shop density significantly greater than the average for the UK.

Large towns and cities are generally supplied by several multiple, who are the most likely to have contingency plans, supplemented by more local independent retailers. However, smaller towns may only contain independent retailers and smaller chains, with residents often travelling to other towns for bulk shopping. This might mean that these areas would be most likely to experience difficulties.

7.1.3 Vulnerable groups

Households in higher socio-economic brackets tend to buy in greater bulk and hold larger stocks
Thus the most vulnerable groups are likely to be poorer families and the elderly especially, as noted above, in urban areas. The problem could be exacerbated if retailers took advantage of shortages by raising prices, for which there is some anecdotal evidence from 2000.

It is estimated that approximately 4,000,000 people in the UK are affected by food poverty, defined as the inability to obtain healthy affordable food, either through a lack of local shops, high prices or other (Gordon et al., 2000). Food poverty is typically intimately tied with issues such as social exclusion, deprivation, health issues, and income inequality, suggesting that those affected are likely to be vulnerable in a number of respects. Hence, this vulnerability could be exacerbated in the event of a fuel disruption. Individuals may have less financial resource available to stockpile foods, or respond to an increase in prices at the local level.

For example, Wrigley (2002) found that in addition, evidence was available from a number of UK surveys (such as the 1993 Health Education Authority’s ‘Health and Lifestyle Survey’—see Caraher et al., 1998) that those in the lowest income/socioeconomic grouping were less likely to have access to or use a car for food shopping, were significantly more likely to use smaller local shops and much more likely to suggest that ‘problems of carrying/transporting foods’ limited the food they purchased.

This implies that the maintenance of supplies through smaller shops, despite the relatively low volumes normally moving through this channel, would be important for some social groups.

The situation of housebound people would depend on the continuity of the services on which they relied, whether local authority meal deliveries or home shopping. In the last two days of the 2000 fuel disruption, Cornwall health authority said it had three days of food left (Church, 2005). There might be a similar risk to “meals on wheels services”.

Hospital patients are highly vulnerable to disruption of their food supplies due to their health status and dependence on the institution. Large NHS hospitals are supplied by large companies, so the risk of disruption in the short term is probably relatively low, assuming that the suppliers have appropriate contingency plans. Smaller hospitals may contract out to local suppliers, which are potentially less well-prepared for fuel disruption, so local shortages of individual commodity groups are possible.

Prison inmates are similarly dependent on the institution for food. All publicly-operated prisons are supplied through central contracts so, as with large hospitals, it is likely that the risk of disruption is low because the suppliers will rely on large company fleets or logistics service providers.

Although most children do not rely on schools for all their meals, the provision of the midday meal is an important function. The suppliers are more diverse, because contracts are made at county or local level. Where these contracts are with smaller local suppliers there is a greater risk that they will not have reliable contingency plans for fuel shortages.

### 7.1.4 Food quality, choice and health

Both the literature review and the interviews discussed possible implications of a fuel disruption on food quality, and hence health. Disruption in cold chains could compromise the microbiological safety of perishable foodstuffs. The inability of food inspectors, veterinary professionals, or environmental health officers to attend work might also reduce the normal controls. Furthermore, disruption could provide an opportunity for food fraud. There is no evidence available, and the likelihood of this was questioned by some interviewees, but increased vigilance might be required. 

Whilst there might be significant reductions in choice, for example if imported fruit was unavailable, the long-term health or social impacts from a week-long disruption are unlikely to be large. The majority of individuals might have to change their eating habits, especially towards the end of the disruption, but few would be likely to have no access to food. However, those individuals with allergies, diabetes or other dietary needs, including religious dietary restrictions, might be more affected by a reduction in choice.

### 7.2 Economic impacts

In the extreme case considered by McKinnon (2006), the economic consequences of complete cessation of road haulage were predicted to be rapid and severe:

> The level of economic activity would drop sharply in the days following the withdrawal of road transport. After a week, the country would be plunged into a deep economic and social crisis. Once the trucks starting running again, it would take several weeks for most production and distribution systems to recover. Many businesses would not survive a week-long suspension of their operations. At any given time there are many companies whose trading and cash flow positions are fragile. They would be unable to withstand even a temporary loss of business.

These comments did not relate specifically to the food supply, although it was highlighted as one of the
critical areas that would be disrupted very quickly.

In practice, fuel supply disruption would have a less immediate effect on road haulage. The protest in 2000 reduced lorry traffic in the UK by 10–12% (Hathaway, 2000) and a press estimate placed the loss of economic output at £1 billion (Griffin and Wilson, 2000), but the proportion attributable to the food industry is unknown.

It is reported that customers stock up on food items in response to potential supply disruption (Church, 2005), but we found no studies of the economic consequences of this behaviour. It would be expected increase turnover initially, but it would also exhaust in-store stock rapidly and drain the supply chains of both fast-moving perishable goods and normally slow-moving, less perishable items. Reducing supplies of fuel would limit the flexibility of the supply chain to respond, so turnover would probably diminish from an initial peak. The effects would continue for some time after normal deliveries resumed, as stocks would need to be replenished. There would probably be a net near-term increase in sales of perishable items, as some stockpiled items would perish before consumption.

McKinnon speculated that sales close to the point of production, such as farmers’ markets and pick-your-own schemes would benefit in the absence of lorries. However, the effect of a fuel shortage might be different, as consumers would ration their own use of fuel and favour outlets in their own neighbourhoods.

As noted above, McKinnon (2006) suggested that some businesses could be vulnerable to a temporary loss of business. In many of the sectors reviewed, processing, distribution and retail are dominated by large companies, which probably have the reserves to survive. However, there are also small companies involved at all stages of some of the supply chains, such as farmers, local dairies and other processors, and small retailers. The social cost if small producers and retailers were forced to close is probably higher than their economic significance would imply.

All businesses could suffer if staff were unable to travel to work, or if staff had to stay at home because schools were closed, but no research on the magnitude of the effects on the food industry was found. It might be possible to make estimates by studying the effect of severe weather during recent winters. Significant absences might reduce production, but also reduce costs, as absent staff would not be entitled to be paid. The effects on a business could be severe if key staff, such as hygiene inspectors, were absent, so it would be in their interests to have contingency plans.

In the long term, severe or frequent disruption would increase costs throughout the supply chain. Some suppliers faced with the prospect of disruption might seek to insure against it. Alternatively, reverting to higher stock levels within the chain could improve resilience, but would increase operating costs.

If the effects of disruptions were as severe as suggested by McKinnon, causing some businesses to fail, more market share would be concentrated in the remaining companies. The consequences would depend on the types of businesses lost. The loss of small retailers would increase dependence on the large supermarkets and strengthen their dominance of domestic food supply. The closure of suppliers would increase the market share of the remaining companies, potentially imposing greater bargaining tension on retailers, which might result in higher prices for consumers.

7.3 Environmental impacts

No quantitative information was found on the likely environmental impacts of fuel disruption within food supply chain, though several points can be inferred from the nature of those supply chains. For the country as a whole, there would be a reduction in road travel, which would reduce vehicle emissions, including greenhouse gases. However, this cannot be attributed to food supply chains.

The most likely environmental impacts directly related to the food supply would be changes in waste arisings throughout the chain. At some points there are potential positive and negative effects, and it is not certain which would dominate.

Consumers could attempt to conserve food supplies by reducing the levels of wastage, for example by using products that had passed-best before (but not use-by) dates, which might reduce quality without a risk to health. Conversely, stockpiling could result in food perishing before it could be used. Depending on the balance between these factors, waste going to landfill, compost or anaerobic digestion could increase or decrease. The fate of the waste would also depend on the extent to which collections were disrupted.

It is likely that food waste at retailers would decrease in response to an expected increase in purchasing at the start of a crisis. However, other waste, such as packaging, could accumulate if collection and disposal services were disrupted.

Disruption of the distribution system would rapidly generate large volumes of output at processors, unless they were able to prevent deliveries pre-emptively. Similar problems could arise if supplies of trace ingredients (e.g. preservatives) or packaging, including gases for modified atmosphere packaging were interrupted. At best these would reduce the shelf life, tending to increase waste; at worst they would
prevent production completely.

As most processors have very limited storage, outputs that could not be distributed would quickly become waste, as they passed safe storage limits. Perishable products would rapidly pose a public health risk if they could not be disposed of properly. Many could also become environmental pollutants. For example, milk has a very high biochemical oxygen demand if it finds its way into water courses.

All biodegradable wastes emit greenhouse gases as they decay. If food wastes emit carbon dioxide, these are considered to be biogenic emissions of carbon that was originally captured from the atmosphere, so their effect is neutral. However, decay in anaerobic conditions produces methane, which has a global warming potential 25 times that of carbon dioxide (IPCC, 2007), if it is emitted to the atmosphere. However, if the methane is captured and burned, it is eventually emitted as (biogenic) carbon dioxide. Nitrogen in proteins in food may also lead ultimately to emissions nitrous oxide, which is a very potent greenhouse. It is thus the change in methane and nitrous oxide that determines the net effect.

The main disposal routes for food waste is landfill (Terry et al., 2011), with some going to compost and anaerobic digestion, whereas consumed food goes into the sewage system. Composting and anaerobic digestion followed by combustion of the methane should emit mainly carbon dioxide. Landfill also produces methane, which may be captured for combustion, but there will be some long-term fugitive emissions. Given the complexity of the different routes, it is not possible to make a simple estimate of the impact on greenhouse gas emissions. The total waste-related greenhouse gas emissions from potato consumption (the largest of the fruit and vegetables studies) were estimated to be 2.7 Mt CO₂e/year (Terry et al., 2011). Assuming that emissions were doubled for one week, giving an additional 51 kt CO₂e, this is tiny in the context of the UK's total annual emissions of 552 Mt CO₂e (DECC, 2013).

Other than disposal, the only recourse for processors would be to stop accepting deliveries and push the problem back to their suppliers, whether importers or farmers. The result for the suppliers would be similar if the transport services they used were interrupted.

Importers would face the same disposal choices as processors. Farmers have a wider range of options, which were briefly considered above. If they were able to store products temporarily or leave crops in the ground for sale later, the environmental impact would be minimal. Diversion of crops into animal feed would substitute them for other feedstuffs. Provided that it did not cause waste from other routes, the environmental impact would probably be small and some would occur overseas by displacing imported feed.

Delays to the slaughter of animals would tend to increase the environmental burdens, because they would have to be fed to maintain them. If it was necessary to slaughter animals that could not be moved normally through the supply chain, disposal of the carcasses by rendering would inevitably have some negative environmental impacts, which are difficult to quantify without a full analysis of the numbers likely to be affected.

The main animal products, milk and eggs, would become environmental hazards if they could not be transported normally. This would be particularly acute for milk, as most farms have storage for only one or two days. Most methods of disposal would risk pollution of watercourses.

### 7.4 Mitigation and resilience

Given the present system, in which most stock is held close to the producer and several steps removed from the consumer, it is vital to ensure that the transport links throughout the chain remain operational. This requires up-to-date contingency planning by the logistics service providers and smaller operators, including fuel bunkering and plans to ensure that staff are available if private transport is disrupted.

Some of the interviewees were uncertain of the extent of priority user status for fuel supplies and how this would operate in a crisis. Anecdotes suggest that a vehicle with an NHS livery or clearly related to food that appeared to jump a fuel queue might be tolerated, but others would result in protests. Since non-food ingredients and packaging are required by food processors, it is important that these deliveries are protected in addition to the farm-to-fork chain.

One method of helping to maintain off-farm transport would be temporary relaxation of the rules on the use of farm 'red' diesel for road transport, which has been done in some previous crises.

Some food wastage could also be reduced by relaxing best-before, sell-by and display-until dates, provided that use-by dates were retained to ensure consumer safety. (Note that the FSA wishes to phase out the use of some of these to provide clearer information to consumers.) Retailers could also relax their acceptance criteria for imperfectly packed loads to prevent fuel wastage in returns and redeliveries.

The booklet “Preparing for Emergencies: What You Need to Know”, circulated by the government to all homes in Britain in the summer of 2004, advised households to stock up on tinned food and drinking water to guard against the possibility of a disruption to supply. Maintaining such stocks, which are generally higher in rural areas where interruptions are more common (McKinnon, 2006 citing IGD, 2004b), would
make consumers more resilient and reduce the need for stockpiling at the start of a crisis. However, this might be difficult for poorer households and those with restricted storage space.

It was noted at the outset, and reinforced by the example of flour millers (Table 4), that the move to leaner supply chains based on high levels of trust and good communications have produced a supply system that is highly efficient when conditions are certain, but not resilient when faced with uncertainty.

8. Implications for decision makers and research needs

Concern was expressed in some of the interviews about how the priority user scheme would operate in practice. It is important that this information is clearly communicated to the industry before a crisis, so that it can be integrated into their contingency planning. This will be important in avoiding complacency.

Companies need to review their contingency plans regularly, because they may become out of date as businesses develop.

A related issue is the status of small companies, such as individual farmers and retailers. Interviews and anecdotal information suggest that they ‘have to queue at the pumps with everyone else.’ This should be reviewed.

The security of supplies to institutions when they opt out of central contracts needs to be reviewed. If they use local contracts for staple foods, they need to ensure that adequate contingency plans are in place to guarantee continuity in the event of transport disruption.

Although the large supermarkets are responsible for the majority of food supplies to consumers, the important social role of smaller retailers, especially for vulnerable groups, should not be overlooked in contingency planning.

The quantitative data on stock levels and lead times is summarised in Table 8, which illustrates the ranges of values found and those about which there was uncertainty (‘?’) or lack of information. Some of these ranges represent variability in practices within the industry, but there is also limited available data. As a result, there are large residual uncertainties in the time taken for disruption of fuel supplies to have an impact on consumers. Without such evidence, the assumption is that stock levels are very low. Little evidence was gathered on stocks of non-food materials such as packaging, gases, yeast or additives. More investigation is needed in this area.

This gap could be addressed by direct research with a wide range of companies, including supermarkets, wholesalers and processors. It would be valuable to gather additional data on processing and transport times. This data would allow more detailed, quantitative estimate of the time for disruption at any point in the supply chain to propagate to consumers.

There is a general assumption that the contingency planning of the large logistics service providers is good, but a few doubts were expressed in the interviews. A relatively small consultation could reduce this uncertainty.

It might also be useful to consult the Departments for Education and Health, the NHS and the Ministry of Justice to understand the contingency plans in place for schools, hospitals and prisons. This is likely to be important in the protection of vulnerable consumers.

The other major uncertainty was the level of fuel stocks held by smaller operators, including company fleets, producers, wholesalers and retailers if they did not use large logistics service providers. Given the large number of small companies involved, this would require a survey of a representative sample of companies to estimate the position across the industry.

More interviews with industry experts (at both a strategic and operational level) are likely to be beneficial. The small sample size in this study cannot be considered to be representative or wholly inclusive. However, despite this the interviews yielded information on numerous issues that were not discussed in the literature. Additional interviews may highlight new issues, offer new data on typical stock levels, and reinforce or contradict information gathered in this study. In particular, it would be important to interview supermarkets and small retailers in future studies.

The study demonstrated that the food supply chain is highly interdependent. Future work may wish to model the dynamics of the system as a whole in a quantitative manner, to understand the real impact of shocks on the system. With sufficient time and access to data, it would be possible to gain a much clearer picture of exactly how fuel disruptions would impact access to food.

Little concrete evidence was found on the impacts of a fuel disruption on consumer behaviour or panic buying. Similarly, little evidence was available on the environmental, social or economic impacts. It may be necessary to commission this research during or immediately after future events, in order to inform future planning.
9. Conclusions

There has been little academic study of the robustness of UK food supply chains; most research has focused on improving the efficiency of value chains, reflecting a trend towards leaner operations by most of the big providers. Consequently, this review relied on diverse sources of information, including official statistics, reports for public and private sectors, and publicly-accessible company information. Although individual information sources may not have been subject to independent review, multiple sources and cross-verification were used to support the robustness of the conclusions, albeit with some imprecision and uncertainty about specific details. Expert opinion was also elicited from a range of individuals to identify issues leading to pinch points that were not discussed in the literature. Issues common to most supply chains are grouped thematically below.

Low food and non-food stocks and the consequent reliance on regular road transport

The picture that emerged from examination of the literature clearly confirmed the trend towards very low stock levels throughout supply chains.

The information found is summarised in Table 8, which shows the low stock levels for many commodities and the uncertainties or gaps in the information. The parts of the supply chains shaded red are those where disruption would be highly likely to propagate to consumers within 7 days. There is sufficient uncertainty and variability about the unshaded areas that these could affect consumers, but the effect might be localised. For example, a typical stock level of 5 days typically means that most retailers have less than 5 days of cover some of the time, so an interruption in supply would affect some outlets quicker than others.

For most of the products, with the possible exceptions of eggs, some vegetables and ready meals, there is little stock held at processors, RDCs/warehouses and retailers. The largest bulk stocks of most UK-produced foods are on farms or upstream of the processors (e.g. grain merchants). Consumers often buy sufficient stocks of most product types for a week or more of normal consumption. However, these will often be run down before restocking, so the average stock level is lower and the timing of disruption relative to purchase will be significant.

Table 8. Typical lead times and inventory levels at processors, RDCs/wholesalers and supermarkets. Disruption to the steps shaded in red would be highly likely to affect supplies to consumers within 7 days.

<table>
<thead>
<tr>
<th>Inventory level (days) at processor</th>
<th>Lead time: processor to RDC (days)</th>
<th>Inventory level (days) at RDC</th>
<th>Lead time: RDC to shop (days)</th>
<th>Inventory level (days) at shop</th>
<th>Delivery frequency (drops/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef and sheep</td>
<td>2-2.5</td>
<td>2.8</td>
<td>0.5?</td>
<td>?</td>
<td>2.5?</td>
</tr>
<tr>
<td>Pig meat</td>
<td>2-2.5</td>
<td>2.25</td>
<td>0.5</td>
<td>1?</td>
<td>2.5</td>
</tr>
<tr>
<td>Poultry</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>&lt;1</td>
<td>1-2</td>
</tr>
<tr>
<td>Strawberries</td>
<td>?</td>
<td>?</td>
<td>0.5-1?</td>
<td>3</td>
<td>5-7</td>
</tr>
<tr>
<td>Potatoes</td>
<td>2?</td>
<td>0.25-1?</td>
<td>0.5</td>
<td>0.25-1?</td>
<td>7</td>
</tr>
<tr>
<td>Potatoes (stored)</td>
<td>140</td>
<td>1-2?</td>
<td>0.5</td>
<td>0.25-1?</td>
<td>7</td>
</tr>
<tr>
<td>Milk</td>
<td>&lt;1</td>
<td>n/a</td>
<td>n/a</td>
<td>&lt;1</td>
<td>0.5-3</td>
</tr>
<tr>
<td>Eggs</td>
<td>&lt;3</td>
<td>n/a</td>
<td>n/a</td>
<td>&lt;1</td>
<td>7-14</td>
</tr>
<tr>
<td>Bread</td>
<td>0.5</td>
<td>n/a</td>
<td>n/a</td>
<td>1</td>
<td>1-2</td>
</tr>
<tr>
<td>Fish</td>
<td>1-4 days</td>
<td>n/a</td>
<td>n/a</td>
<td>1</td>
<td>1-2</td>
</tr>
<tr>
<td>Ready meals (chilled)</td>
<td>0.4-2?</td>
<td>0.4-2?</td>
<td>?</td>
<td>0.5-1</td>
<td>5?</td>
</tr>
</tbody>
</table>

As a result, the UK population is dependent on transport, principally road transport, especially third-party logistics services, to maintain continuity of the food supply. In many cases, interruptions to transport of
supplies to processors or at any point downstream would cause shortages within one week.

Transport from ports is a potential pinch point for many foods, although it would take several days for its effects to be felt by consumers. Almost half (47% by raw food value) of the food consumed in the United Kingdom is imported, mainly from the EU, which supplies 28% of the food consumed (Defra, 2012). All imported goods and landed fish enter through a limited number of ports, which are remote from much of the population. Disruption of transport from ports could, therefore, have a significant impact of food supplies, especially for fresh fruit, of which 85% is imported, vegetables, processed pork and fresh fish.

The final transport step to the large multiple stores, is essential for bulk food supplies to most of the population, as these stores supply about 90% of many commodities. Table 8 shows the information that was found on the frequency of deliveries to supermarkets. For perishable products there were usually one or two deliveries per day, highlighting the importance of this delivery step.

Highly perishable products that require temperature control are particularly vulnerable to transport disruption, because it is impossible to hold significant stocks at any point. Milk, fresh fruit and fresh fish are all examples of this: even a short interruption to chilled transport would render them unfit for consumption.

Most food products require non-food supplies, such as packaging, inert gases and cleaning supplies, as well as minor ingredients including required additives (e.g. in bread) and preservatives. There was little information on the stocks of most of these, but some evidence that stocks of packaging at processors are generally very low. Transport for these materials is thus essential to maintain food supplies.

Contingency planning, bunkerred fuel stocks, and priority access

The major retailers are aware of their dependence on transport, so they and their logistics service providers have contingency plans, including fuel bunkering. However, some doubts were expressed in the interviews about the adequacy of these fuel stocks. There may be a need to review these contingency plans.

There was a recognition that food transport might be given priority in a crisis, but uncertainty about how this would operate. It is important to have clear, comprehensive and communicated procedures in place in advance so that these can be integrated into the contingency plans of companies to prevent confusion in the event of a fuel crisis.

It was unclear whether transport of essential non-food materials, such as packaging and labelling supplies, would be given the same priority as food.

Staff fuel shortages are also likely to disrupt multiple points in the chain, given that processing, distribution, retail and food services all have high labour requirements. Some companies had plans for these contingencies, such as the provision of buses for staff, but it is unclear whether they would be equipped to deliver these during a period of disruption.

Systemic concerns and cumulative impacts

Whilst many of these issues may have a negative impact in isolation, it is possible that the cumulative effects of disruptions at multiple points could rapidly escalate the level of risk to the environment, society and economy. Understanding these interdependencies in the chain, and the possible cumulative impacts of disruptions may be an important next step in the research.

Social impacts

Although large supermarkets supply most of the retail food in the UK, smaller stores have an important role, both for top-ups between bulk shopping and for consumers unable to travel to large stores for several reasons, including lack of mobility, poverty and remoteness. It is uncertain whether these have the same level of contingency planning. Some businesses whose trading and cash flow positions are fragile might be unable to withstand a period of serious disruption.

Dwellers in rural areas generally maintain larger stocks of food than those in urban areas, and those in very remote areas subject to extreme weather are often well-provisioned. They are likely to be less quickly affected than urban dwellers. The groups with the lowest stocks are typically low income groups in urban areas.

Most hospitals and prisons are supplied with food through national contracts with large producers and processors using third-party logistics services. The contingency planning issues are therefore similar to those for the large multiple retailers and presumably fall within the contingency plans of the relevant government departments. If hospitals opt out of the national contracts they need to ensure that local suppliers have appropriate contingency plans.

Supplies to schools are generally organised at the level of local authorities or individual schools, with sources ranging from large companies to smaller local suppliers. These may be vulnerable to disruption if small suppliers do not have good plans in place. However, in the event of severe transport disruption,
schools might be forced to close due to the shortage of staff, displacing the problem.

Interruption of the cold chain for perishable foods could pose a health risk unless strict controls remained in place. Disruption of imports could reduce the variety of fresh fruit and vegetables available, but would be unlikely to have a serious health impact within a week. Individuals with restricted diets for any reason might be more affected by a reduction in choice.

**Economic impact**

There is insufficient evidence to make a reliable estimate of the potential economic impact. Clearly there is a potential loss of turnover around any of the pinch points identified. During the 2000 fuel protests, most retailers continued to receive supplies and some reported increased turnover. Conversely, many food-service enterprises reported a decrease in business. At any time, some companies will be fragile and vulnerable to a temporary loss of business.

**Environmental impacts**

Any disruption to distribution of perishable products would generate waste upstream, with attendant disposal problems. For milk in particular there is no way to stop the supply and few environmentally benign disposal methods.

When operating normally, waste arises at several points in the supply chain, notably at food processing plants, especially abattoirs, and packaging waste at retailers. Disposal of these wastes relies on road transport. A prolonged disruption of waste removal would halt operations and could present an environmental or health hazard.
References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

Papers and reports


Church, N., 2005. Systems and interdependencies and their effect on peal oil.


Federation of Bakers, 2011. Factsheet No. 4: Distribution.
Mapping fruit and vegetable waste through the retail and wholesale supply chain. (No. RSC008).
WRAP, Banbury.

Web pages and unpublished documents

1. www.mcdonalds.co.uk/ukhome/whatmakesmcdonalds/articles/in-our-burgers.html?gclid=CODYkq-mqbcCFZMbtAodW2cARA
2 www.freshproduce.org.uk/
3 www.dairyco.org.uk/market-information/farming-data/cow-numbers/uk-cow-numbers/
6 www.dairytransport.co.uk/resources/000/634/681/HACCP_Milk_Collection__26_Apr_12.doc
7 www.dairyco.org.uk/market-information/supply-production/uk-milk-flow-diagram/uk-milk-flow-diagram/
8 www.dairycrest.co.uk/
9 www.muller-wiseman.co.uk/
10 www.arlafoods.co.uk/
11 www.muller-wiseman.co.uk/all-about-milk/from-farm-to-fridge/#
14 infinibottle.com/nampak/
15 www.ethicalconsumer.org/buyersguides/drink/milk.aspx
16 www.bbc.co.uk/news/business-18733248
17 www.yeovalley.co.uk/british/farming-here-forever
18 www.bbc.co.uk/news/uk-england-20972578
19 www.guardian.co.uk-money/2012/jul/27/dairy-farmers-milk
21 scdairies.co.uk/item/wholesale-catering.html?category_id=16
22 www.dairycrestfoodservice.co.uk/products/retail-convenience/dairy/
23 www.milkforfree.co.uk/freemilk.html
24 www.dartmouthdairy.co.uk/products.asp
25 www.cotteswold-dairy.co.uk/Semi-Retail_Products
26 investor.dairycrest.co.uk/ir/dcg/html/corporate-responsibility-2012/Transport.html
29 archive.defra.gov.uk/foodfarm/food/industry/sectors/eggs-poultry/statistics/flow4.htm
30 www.farmlayeggs.co.uk/about/
33 www.glenrathfarms.co.uk/
34 www.youtube.com/watch?v=mMsTm-h5gn0
35 www.stonegate.co.uk/
36 www.angliafreerangeeggs.co.uk/our-eggs-collection-and-distribution.htm
37 www.badgersmeadfarm.co.uk/eggs.php
38 www.johnbowler.co.uk/introduction-to-john-bowler
39 www.lioneggfarms.co.uk/information/british-lion-quality-code-of-practice/
40 www.farmlay.co.uk/facts.html
41 www.scotland.gov.uk/Publications/2010/07/29090045/4
www.oaklandsfarmeggs.co.uk/
www.noblefoods.co.uk/farms/packing-centres
www.stonegate.co.uk/compTour.aspx
www.stonegate.co.uk/compFarms.aspx
www.noblefoods.co.uk/
www.noblefoods.co.uk/good-to-great-about-noble-foods
www.oaklandeggs.co.uk/tl_files/research/oaklands/oral_evidence_oakland_farm_eggs.pdf
www.wpsa-foodsafety.com/index.php?item=114
awards.fwi.co.uk/past-winners/2010-winners/poultry-farmer-year/
www.fridays.co.uk/vertical-integration.html
www.farmersguardian.com/home/livestock/livestock-features/egg-business-started-small-but-grew-into-a-free-range-empire/41303.article
www.gov.uk/eggs-trade-regulations
www.lakesfreerange.co.uk/egg-facts/
www.bakersfederation.org.uk/the-bread-industry/about-the-bread-industry.html
www.nabim.org.uk/content/1/100/statistics.html
www.carrs-flourmills.co.uk/wheat.html
www.newsandstar.co.uk/carrs-secures-new-contract-to-supply-top-uk-bread-producer-1.171373?referrerPath=personal_finance_news_2_2913
www.openfield.co.uk/grain/logistics.php
www.allied-mills.co.uk/english/service/supplychain.php
www.heygates.co.uk/general/the-mills/
www.fleetnews.co.uk/fleet-management/fleets-in-focus-allied-bakeries/44818/
www.seafish.org/about-seafish/seafood-industry-overview-
www.scottishsalmon.com/en/home
www.fcrn.org.uk/sites/default/files/Unilever.pdf
www.foodprocessing-technology.com/projects/kettlebyfoods/
www.samworthbrothers.co.uk/ourbusiness-saladworks.asp
www.chaffinsfoodservice.co.uk/
www.havensfieldeggs.co.uk/news/news.html
archive.defra.gov.uk/foodfarm/policy/publicsectorfood/casestudies/hampshire-county-council.htm
81 archive.defra.gov.uk/foodfarm/policy/publicsectorfood/casestudies/nottingham-dawsons.htm
82 www.sustainweb.org/realbread/case_studies/
83 archive.defra.gov.uk/foodfarm/policy/publicsectorfood/casestudies/humphrey-perkins.htm
84 www.foodmanufacture.co.uk/Business-News/Premier-Foods-goes-to-jail-and-collects-15M
85 archive.defra.gov.uk/foodfarm/policy/publicsectorfood/casestudies/ps-eggs.htm
86 www.scotland.gov.uk/Publications/2009/06/25102105/6
88 www.foodservicefootprint.com/features-2/interviews/opportunity-on-your-doorstep
89 www.igd.com/our-expertise/Retail/Convenience/3381/Symbol-Groups---Market-Overview/