Decision Support Systems
(making hard decisions with imperfect information)

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Outline

• What are decision support systems (DSS)
• What are the decisions
• What are the tools available
• What are the gaps
• What next
Why do we need DSS

- Decisions are becoming much more complex
- They often have far reaching effects in other economic sectors
- The livestock industry is undergoing major changes
- Important to make the ‘right’ decision early
- Non-linearity in effects make prediction difficult and non intuitive - what is right at a local level may not be the best for the national herd

Decision Support Systems (DSS)

- Mainly computer systems
- Manage large amounts of data
- Summarise and integrate data to provide information in a timely manner (inferential)
- Allow decision makers to explore various “what if” scenarios (predictive)
- What is the best thing to do (normative)
Components

- Database
  - Farms/animals/location
  - Personnel
  - Equipment
  - Transport routes/trade routes
- GIS
  - maps/spatial data
- Models
  - Windspread/Rimpuff
  - Interspread/InterFMD
  - Optimization of resource allocation
  - Prioritising dangerous contacts (DC)
Example of the number of databases being generated during the 2001 outbreak in Dumfries and Galloway (Thrusfield et al. 2005)
What are the decisions?

Figure 2 | From surveillance to modelling. The schematic shown summarizes the inputs required for construction of a useful model.
Decisions – control FMD?

- Why control FMD?
- What are the benefits and costs of FMD control in EU?
- How will changes in the CAP affect this decision?
- If we control FMD, do we want to regain
  - ‘disease-free’ status or
  - ‘freedom with vaccination’?
- What can we afford to do?
- If we want to be ‘disease-free’
  - stamping out or
  - vaccinate?
- DSS ARE ABLE TO HELP WITH THIS HIGH LEVEL DECISIONS

Decisions-risk assessments (prevention or eradication?)

- Expanded EU – difficult to control borders
- Once within EU very difficult to trace animal products
- Integrated databases of imports available in real time
- Early warning
- Ready off the shelf assessments for all EU states and for all diseases eg Dutch system
Decisions – Outbreak planning

- Where will FMD enter?
- Where to place resources
- Where are the high risk areas
- Where/who are the high risk farms
- Contact networks – identify super spreaders

(Source: Risk Solutions 2005)
Decisions-start of outbreak

- National movement ban
  - Soon as possible (e.g., 2 days earlier in UK 2001 could have reduced outbreak by ~50%)
  - Target markets and dealers to ensure enforcement
  - Optimise cost of bans/effect on trade
- Pen-side tests
  - Se/Sp
- Aging lesions
  - Pictures on paper
  - Differentials
  - Digital tech transmit images to a pathologist
- Rapid valuation and slaughter

Welfare slaughter

- What are we trying to optimise?
  - Cost
  - Getting back to trade quickly
  - Minimise number of slaughtered animals
- DSS WITH ECONOMIC COMPONENTS NEEDED
Decision – outbreak - airborne spread

Several models available
- Dependent on experimental data for reliable estimates
- Newer ‘Puff’ models include topography
- RIMPUFF (Sorensen 2000)
- Well validated models

LITTLE EVIDENCE FOR AIRBORNE SPREAD FROM PYRES
Decision – how is epidemic spreading

- What species are affected?
- What parts of the country?
- How many clusters?
- How much long distance spread compared to local spread?
- HOW CAN THIS ALL BE SUMMARISED AND MODELLED TO PREDICT THE EPIDEMIC

CONFIRMED FOOT-AND-MOUTH CASES

1. Heddon-On-Wall, Northumberland
2. Porteland, Northumberland
3. Canewdon, Essex
4. Great Warley, Essex
5. Little Warley, Essex (at two sites)
6. Highampton, Devon
7. Hatherleigh, Devon
8. Bromham, Wiltshire
9. Wasterhope, Northumberland
How is the disease spreading?

- Long distance
  - animal movement
  - airborne
- Disease spread in 3 km zone
- 70% of UK2001 attributed to local spread
- Number of competing transmission mechanisms
- Poor resolution on local spread

FIG 11: Putative sources of infection of Infected Premises (IPs) in the foot-and-mouth disease epidemic in Dumfries and Galloway in 2001 (Thrusfield et al 2005)
Decision - Control methods

• Stamping out
  – IPs only
  – IPs and DCs
  – IPs, DCs and CPs

• Stamping out + vaccination
  – suppressive vacc
  – vacc to live
  – vacc logistic
    • ring
    • regional

DECISION TREE FOR CONTROL STRATEGIES FOR FMD

DEFRA contingency plan 2005
Decision - vaccination

- What serotype and strain is it?
- How many doses are needed?
- Will vaccination work?
- What is the risk of sub-clinical disease/carriers?
- What strategy to use eg. ring, regional, targeted?
- Can the SVS actually achieve the minimum coverage in time?
- Implications for trade etc.

Predictive Vaccination (Keeling et al 2003)

**Aim:**
Use the heterogeneities (both local space and at the farm level) so that vaccination is targeted most effectively.

From identification of the central IP, a secondary model is used to predict those farms currently infected (i.e., Generation 1). This mode is then iterated forwards to find those farms infected in generation 2 - these can be protected by vaccinating now. The model then selects the farms on which vaccination of cattle will have the largest effect.
<table>
<thead>
<tr>
<th>Outbreak size</th>
<th>Representative scenario</th>
<th>Control strategy</th>
<th>Mean</th>
<th>95&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>IPs</td>
<td>Cost £m</td>
</tr>
<tr>
<td>Small</td>
<td>Norfolk incursion, no windborne virus plumes</td>
<td>IP DC cull only</td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IP DC cull + 10km vacc cattle</td>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage difference</td>
<td>0%</td>
<td>+65%</td>
</tr>
<tr>
<td>Medium</td>
<td>Cheshire incursion, reference conditions</td>
<td>IP DC cull only</td>
<td>115</td>
<td>116</td>
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<tr>
<td></td>
<td></td>
<td>IP DC cull + 10km vacc cattle</td>
<td>85</td>
<td>127</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage difference</td>
<td>-26%</td>
<td>+9%</td>
</tr>
<tr>
<td></td>
<td>Cumbria incursion, good DC tracing</td>
<td>IP DC cull only</td>
<td>140</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IP DC cull + 10km vacc cattle</td>
<td>120</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage difference</td>
<td>-14%</td>
<td>+21%</td>
</tr>
<tr>
<td>Large</td>
<td>Powys incursion, high virus infectivity</td>
<td>IP DC cull only</td>
<td>534</td>
<td>437</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IP DC cull + 10km vacc cattle</td>
<td>248</td>
<td>298</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage difference</td>
<td>-54%</td>
<td>-32%</td>
</tr>
</tbody>
</table>
Summary from Risk Solutions 2005

- It very slightly reduces the number of infected premises for the smallest outbreaks (only measurable at the 95th percentile level) but has a more significant impact for larger outbreaks (reductions of between approximately 15% and 50%).

- Similarly it reduces the number of animals culled for disease control purposes for larger outbreaks by between approximately 15% and 50%.

Other benefits from introducing vaccination include:

- A reduction in the duration of the outbreak if measured from the date of the first reported IP to the date of the last reported IP

However vaccination has some dis-benefits, including:

- A possible slight increase in the number of animals culled for welfare purposes

- An increase in the duration of the outbreak if measured from the date of the first reported IP to the date that official disease free status is regained

- Except in large outbreaks, the vaccination-based strategies are generally more expensive than the IFP-DC cull only strategy and although the cost differences can be relatively small in absolute terms the additional costs tend to fall more heavily on the livestock industry.

### Decision support tool

- Incursion locations
- Virus characteristics
- Regionalisations of economic impacts
- Vet/cull team resources
- DC tracing effectiveness

### Key Assumptions
- Incursion location
- Virus characteristics
- Regionalisation of economic impacts
- Vet/cull team resources
- DC tracing effectiveness

### Circumstances that favour the "IFP-DC cull only" strategy:
- If the initial disease incursion is small and the outbreak is contained then an IFP-DC cull only strategy is more likely to be cost beneficial.

### Circumstances that favour the "P-DC cull plus field vaccination" strategy:
- If the initial disease incursion is large and the outbreak is not contained then vaccination becomes more cost beneficial.
<table>
<thead>
<tr>
<th>Key Parameters</th>
<th>Circumstances that favour the “IP DC cull only” strategy</th>
<th>Circumstances that favour the “IP DC cull plus 10km cattle vaccination” strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incursion locations</td>
<td>If the cattle and sheep density in the area surrounding the initial incursion is low to moderate then an IP DC cull only strategy is more likely to be sufficient to manage the outbreak at lowest cost.</td>
<td>If the cattle and sheep density in the area surrounding the initial incursion is high then cattle vaccination becomes more cost beneficial.</td>
</tr>
<tr>
<td>Virus characteristics</td>
<td>A low virus infectivity suggests that an IP DC cull only strategy is sufficient, for example where the virus has a short window of infectivity before clinical signs become apparent and/or does not readily form windborne virus plumes.</td>
<td>If the virus exhibits high infectivity characteristics then vaccination is more likely to be cost beneficial, for example where the virus has a long window of infectivity before clinical signs become apparent combined with a tendency to form windborne virus plumes.</td>
</tr>
</tbody>
</table>
| Regionalisation of economic impacts  | If disruption to the meat export trade occurs on a national basis, regardless of the actual size and geographical spread of the outbreak, then a strategy based on vaccination causes extra costs due to the increased time to restore disease free status. Consequently, the IP DC cull only strategy is more likely to be cost beneficial.  
If foreign tourists continuing to travel to the UK but simply avoid the areas of the countryside directly affected by the outbreak then an IP DC cull only strategy is more likely to be cost beneficial.  
If animal welfare problems only occur inside restricted areas (not nationally) then an IP DC cull only strategy is more likely to be cost beneficial. | If disruption to the meat export trade is limited to the regions directly affected by the outbreak only then the large cost associated with the extended time to restore disease free status under a vaccination policy can be substantially reduced. Consequently, the vaccination policy is more likely to be cost beneficial.  
If foreign tourists delay or cancel their visits to the UK as a whole rather than simply avoiding the areas of the countryside directly affected by the outbreak then vaccination is more likely to be cost beneficial because it reduces the duration of the “active” outbreak.  
If animal welfare problems occur on a national basis (i.e. dependent on the duration of the outbreak rather than its size) then vaccination is more likely to be cost beneficial because it reduces the duration of the “active” outbreak. |
| Vet and cull team resource mobilisation (cull delays) | If the 24h / 48h target times for the culling of IPs and DCs can be achieved, especially in early stages of the outbreak, then an IP DC cull only strategy is more likely to be sufficient to manage the outbreak at lowest cost. | If it is not possible to achieve the 24h / 48h target times for the culling of IPs and DCs, especially in early stages of the outbreak, then a vaccination strategy may help to compensate and is therefore more likely to be cost beneficial. |
| DC tracing effectiveness              | If the success rate for tracing truly infected dangerous contracts is no worse than was achieved towards the end of the 2001 outbreak then an IP DC cull only strategy is more likely to be sufficient. | If truly infected dangerous contracts are traced less effectively than was achieved towards the end of the 2001 outbreak then a vaccination strategy may help to compensate and is therefore more likely to be cost beneficial. |
Decision - post vaccination sero surveillance

How to do surveillance

- how good is the NSP test
- What is the likely seroprevalence
- Are seropositive herds to be culled
- are carriers identifiable
- serological profiling (Bergmann et al 2000)
Two stage testing- OIE 3.8.7

Unvaccinated population

- SP-ELISA (1)
  - NSP ELISA 3ABC
    - NSP conf. Test EITB (2) OR VNT(1:2)
      - Not Infected
      - Infected

Vaccinated population

- NSP ELISA 3ABC
  - NSP conf. Test EITB (2)

Follow up

Serosurveillance

3

3
Decision - post slaughter clean-up

• What risk do depopulated IPs represent
• How long are they infectious for
• How can they be decontaminated at reasonable cost

Epidemic models

• Imperial model (Ferguson et al. 2001)
• Edinburgh/Cambridge model (Keeling et al. 2001)
• Interspread/InterFMD (Morris et al 2001)
• Silent Spread/ExoDis Model (Risk Solutions 2005)
• Lattice Model (Kao 2003)
• Davis Model (Thurmond et al 2004)
Imperial Model (Ferguson et al 2001)

- Differential equations
- few parameters
- quick to run
- assumes random mixing
- not spatially explicit
- deterministic
- no species differentiation

Edinburgh/Cambridge Model

- Microsimulation model
- few parameters
- computationally intense
- spatially explicit
- stochastic
- does not include airborne spread
- does not include logistics
- vaccination module being added
- models all spread as kernel density function
- accounts for species on farm

Predictions (as released by OST) made using data up to 29-March.
Interspread

- Microsimulation model
- many parameters
- computationally intense
- spatially explicit
- designed as a DSS
  - logistic modules
  - many transmission mechanisms explicit
- airborne spread included
- more widely used
- flexible
- accounts for different species on farm

Fig. 4 Contour map of expected distribution of infected farms derived from the InterSpread model, which was used to model national trends almost daily throughout the foot and mouth disease epidemic in the United Kingdom in 2001 [10].
Silent spread/Exodis™
Risk Solutions 2005, developed for DEFRA

- Microsimulation model
- uses kernel density function
- also allows explicit modelling of other transmission mechanisms
- airborne module
- logistics module
- vaccination module
- spatially explicit
- moderate number of parameters
- includes intra-herd dynamics
- NEW
Intra-herd dynamics

Figure 4: Intra farm dynamics

Accumulated Infectivity by Route

Figure 16: Farm Infectivity by Time

(Source: Risk Solutions)
• Have combined epidemic model with economic model
• Potentially very powerful

Figure 1: Outline structure of economic consequences models
Comparison of models

<table>
<thead>
<tr>
<th></th>
<th>Imperial</th>
<th>Edinburgh/Cambridge</th>
<th>Interspread</th>
<th>ExoDis</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. parameters</td>
<td>few</td>
<td>few</td>
<td>many</td>
<td>some</td>
</tr>
<tr>
<td>Spatially explicit</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Different species</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Airborne spread</td>
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<td>✓</td>
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<tr>
<td>Different transmission mechanisms</td>
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</tr>
<tr>
<td>Intra-herd transmission dynamics</td>
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<tr>
<td>Logistic/resources</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vaccination strategies</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Models - a word of caution

- All models are WRONG
- They should be used only to SUPPORT decisions
- Very useful for resource planning/allocation
- useful for exploring “what if” scenarios
- They are NOT good at predicting random behaviour
- Models often reflect the biases of the modeller and lack objectivity (James 2005)
- BE CAREFUL OF NUMBERS/ MODELS POSING AS TRUTH (lack
• How good is the model...?

(Source: Risk Solutions 2005)
Actionable items

- Databases
  - trade/contacts/capture
- Improved quality and efficiency of veterinary investigation
- Better understanding of transmission
  - molecular analysis
- Biosecurity
- Economic models incorporated
- Post vaccination surveillance
  - currently underway
- Can we stamp out or vaccinate?
  - Do we have the DSS to call this in time
- Models for endemic FMD control

GAPS

- Vaccination
- Validation
- Diagnostic test performance
- Epidemiological characteristics of new viruses
- Rapid detection of new cases
- Identifying high risk farms
  - Risk of introduction
  - Risk of spreading
- Local spread
DSS

- Keep it simple
- Keep it flexible
- Make it transparent

Thank you

Questions...?


