Economically Optimal Timing of Insect Control in Processing Facilities: A Real Option Approach

SULING DUAN, DOCTORAL RESEARCH ASSISTANT
BRIAN D. ADAM, PROFESSOR
OKLAHOMA STATE UNIVERSITY
Insect Control is an Economic Compromise

- **Cost of Insect Damage**
- **Cost of Control**

Cents per bushel

Treatments

Cost of Insect Damage

Cost of Control
Research Question

- When, and how often, should insects be treated in a processing facility?

- Objective is to balance costs of insect infestation/damage and costs of treatment
Problem: uncertainty in estimating costs

- Sources of insect damage uncertainty:
  - Weather uncertainty (affects insect population and activity)
  - Insect immigration uncertainty
  - Uncertainty of insects entering food
  - How much economic damage do insects cause, if they do enter food? (recalls, etc.)
Insect population without treatment

Red Flour Beetles in a Flour Mill: no treatment

Insect Number vs. Days for different floors:
- First Floor
- Second Floor
- Third Floor
- Fourth Floor
- Fifth Floor
Tradeoff

- There is a risk of treating too early or too late
  - Too early → need more treatments (costly)
  - Too late → greater insect damage (costly)
Examples of varying treatment dates

Red Flour Beetles: Fumigation after 90 days

Insect Number

Days

First Floor
Second Floor
Third Floor
Fourth Floor
Fifth Floor
Red Flour Beetles: Fumigation after 180 days

- Insect Number
- Days
- First Floor
- Second Floor
- Third Floor
- Fourth Floor
- Fifth Floor
Red Flour Beetles: Fumigation after 300 days

Days

Insect Number

First Floor
Second Floor
Third Floor
Fourth Floor
Fifth Floor
Since fumigating too early increases the frequency of fumigation and fumigation cost, and fumigating too late increases the potential insect damage cost:

- What is the optimal time to fumigate to balance these two offsetting costs?
- There is risk in waiting, and risk in not waiting – what is the cost of that risk?
- Traditional approaches do not consider $ value of risk
Real Option Approach

- Measures risk in dollar terms
- Borrows from finance theory (worth paying a little now to protect against large loss)
- Examples:
  - Insurance
  - Options on futures contracts
- How much would I be willing to pay now to make a better decision later?
Real Option – a simple “real-life” example

“Should I choose to carry an umbrella today? That would be inconvenient, but I will be prepared if it rains.”
Umbrella Example

- Not carry:
  - No rain: It’s OK
  - Rain: Get wet

- Carry:
  - No rain: Inconvenient
  - Rain: Inconvenient, but STAY DRY
An economic example

- Option to wait to invest in a project
  - Investment cost = $600
  - Possible outcomes: $1,000 or $0 one year later, each with 50% probability
    - Expected revenue = $500
    - Don’t invest (expected loss = $100)
An economic example

- What if we can delay the investment until the uncertainty is resolved (say 1 year)?
- How much would that option be worth?
- (Suppose I want to build a factory to build electric cars, but the profitability of the factory depends on battery technology. I could buy the land for the factory, which leaves open the possibility of building the factory if the technology advances sufficiently)
Wait Until Uncertainty Becomes Resolved

Investment cost = $600

Decide Year 1

Invest $600, Expect to receive $500

Good 50%

$1,000

Bad 50%

$0

Expected return = -$100
Investment cost = $600

Wait
Year 1

Decide
Year 2

Good Outcome → Invest $600, Receive $1,000, Net $400

Bad Outcome → Invest $0, Receive $0

Waiting is worth up to $400 (expected return from waiting = $200)
Objective for this research:

- Determine optimal time to treat for insects
- Traditional approach:
  - Treat when economic benefit = economic cost
  - (loss from insect damage avoided = treatment cost)
- Traditional approach ignores uncertainty
Uncertainty in this problem

- **Waiting to treat** might cost more insect damage
- **Treating now** might incur more treatment costs later
The value of the option to wait to treat is:

\[ F(V) = E[\max\left((V_T - TC) \times e^{-rT}, 0\right)] \]

- \( V_T \): cost avoided by treating (return from treating)
- \( TC \): treatment cost
- \( r \): discount rate
Timing Option

\[ F(V) = E[\max((V_T - TC) \cdot e^{-rT}, 0)] \]

- \( V_T \)
- \( TC \)
- \( r \)
Option Value

Option value
\[ = \text{Intrinsic Value} + \text{Time Value} \]
\[ = \text{Net Value of Treating} + \text{Value of Waiting} \]
### Timing Option

- **Simulation:**
  - Insect Growth – simulated with Flour Mill Model by Flinn et al.
  - Weather Data: 2010-2011
  - 3rd floor

---

**Red Flour Beetles, 3rd Floor, 2010-2011**

![Graph showing the number of insects over time](image-url)
### Optimal Results

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>157</td>
</tr>
<tr>
<td>Treatment Cost</td>
<td>$937</td>
</tr>
<tr>
<td>Option Value (F(V))</td>
<td>$6,466</td>
</tr>
<tr>
<td>Insect Number</td>
<td>526</td>
</tr>
</tbody>
</table>
Value of waiting = value of treating (time value = 0)

Option Value (F(V))

Net Value of treating immediately

Optimal treatment time without considering risk

Value of treating immediately

Optimal treatment time taking into account risk
Red Flour Beetles: Fumigation after 180 days

Insect Number

Days

Option approach

Traditional approach

First Floor
Second Floor
Third Floor
Fourth Floor
Fifth Floor

0 100 200 300 400 500 600 700 800 900
What’s the bottom line?

1) A real option approach takes into account uncertainty the decision-maker faces
2) It puts a dollar value on the option to wait
3) In this specific example, a real option approach recommends delaying treatment longer than static economic analysis that doesn’t consider risk
4) Extended work with collaborators will include more detailed insect growth and damage cost estimates

Questions? Comments?
Thank You!

Questions?
Figure. Diagram for option to wait to treat insect for rice mill in one location

Weather uncertainty:
- Indoor Temperature
- Humidity
- Outdoor temperature

Immigration uncertainty:
- Insects moving from other location
- Insects immigrating from outside

Insect population uncertainty

Insect growth and adult insect death

Facility layout
Sanitation conditions

Option to wait to treat

Uncertainty of insects’ entry into food

Effect of waiting to treat

Product recall from insect infestation (-)
Product rejection from insect infestation (-)
Postpone treatment cost (+)

Decision Model

Effect of treating

Reduced insect damage (+)
Treatment cost (-)

What’s the trigger value?