

# Optional Economic Model in MACCS 4.0 - RDEIM



PRESENTED BY

**N. E. Bixler**

**Coauthors: A. V. Outkin, F. Walton**

**Sandia National Laboratories**

**Presented at 2020 Virtual International MACCS  
Users' Group Meeting, August 31 to September 2,  
2020**



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-XXXX C

# Contents

- Uses for economic modeling in MACCS
- Purpose for GDP-based model (RDEIM)
- Economic modeling in MACCS
  - Original, cost-based model
  - RDEIM model
  - Model comparison
- Current implementation of RDEIM (MACCS 4.0)
- Verification and benchmarking
- Summary

# Uses for MACCS Economic Model

## Cost/benefit analyses used in regulation

- National Environmental Policy Act (NEPA) analyses
  - Cost-benefit analyses to support license renewal (SAMA)
  - Cost-benefit analyses to support new licenses (SAMDA)
- Regulatory analyses by NRC
- MACCS used to estimate offsite costs
  - Offsite property damage costs (total loss reported by MACCS)
  - Public exposure costs ((population dose) x (cost per unit dose))
  - Occupational exposure costs (included with public exposure costs)
- Total averted cost risk also includes onsite costs
  - Cleanup and decontamination costs
  - Replacement power cost

## Other uses

- NRC research (e.g., Level 3 PRA study)

# Purpose for RDEIM Model

- Estimate effect of an accident on national GDP losses using state-of-practice macroeconomic model
- Create a consistent model across geographic regions and time periods
- Provide an economic model that enables MACCS analysts flexibility but also simplicity (does not require an economist)
- RDEIM (Regional Disruption Economic Impact Model) was created to serve these purposes

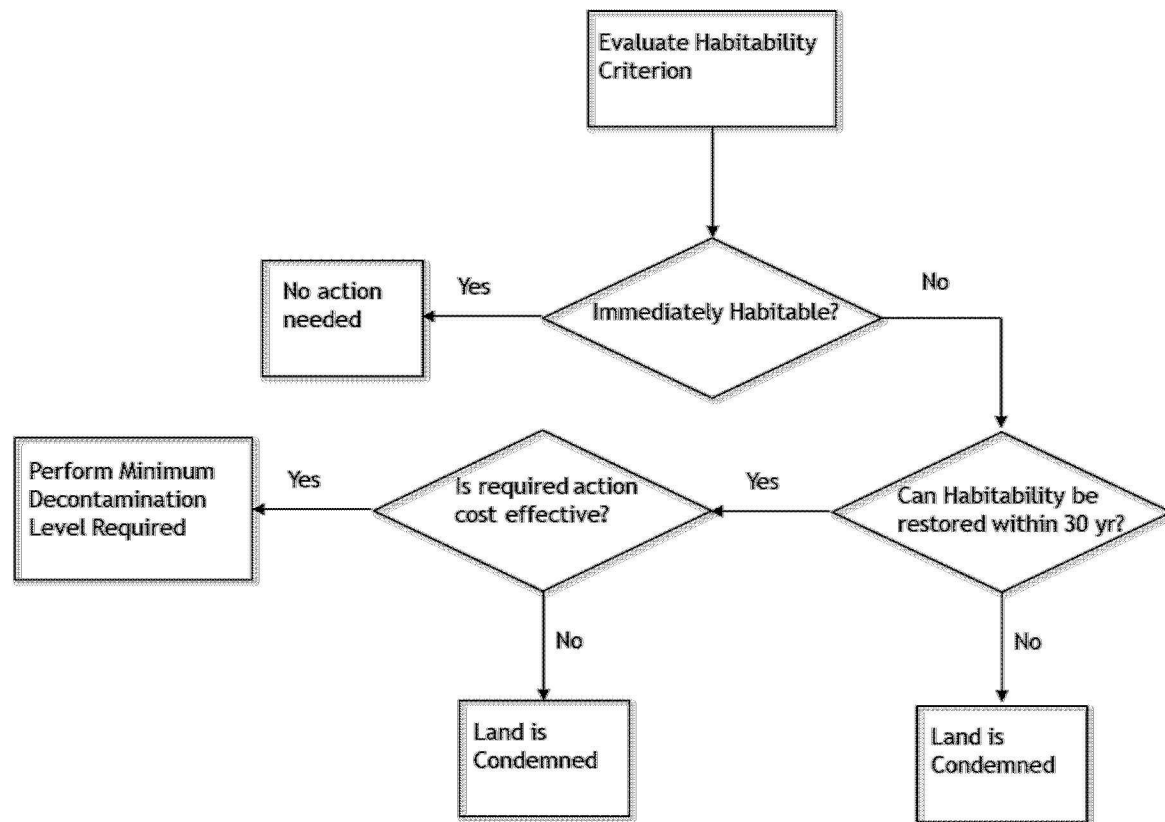
# Description of Original Economic Model

- Costs are summed over three phases – emergency, intermediate, and long-term.
- Cost equations and additional details are provided in SAND2020-5567.
- Losses are reported in 8 categories:
  - Emergency-phase evacuation and relocation (per diem)
  - Intermediate-phase relocation (per diem)
  - Long-term relocation (one time)
  - Decontamination
    - Restore habitability when cost-effective
    - Performed separately for farmland and non-farmland
    - Allows up to 3 levels of dose reduction, cost, and time to implement
    - Accounts for characterization, on-site cleanup, and waste management
  - Loss of use (expected return on property investment)
  - Depreciation (on improvements to property)
  - Condemnation (entire value of property)
  - Milk and crop disposal (annual farm income)
- Losses do not account for indirect affects due to supply-chain disruption or lost income.

# Original Economic Model Logic

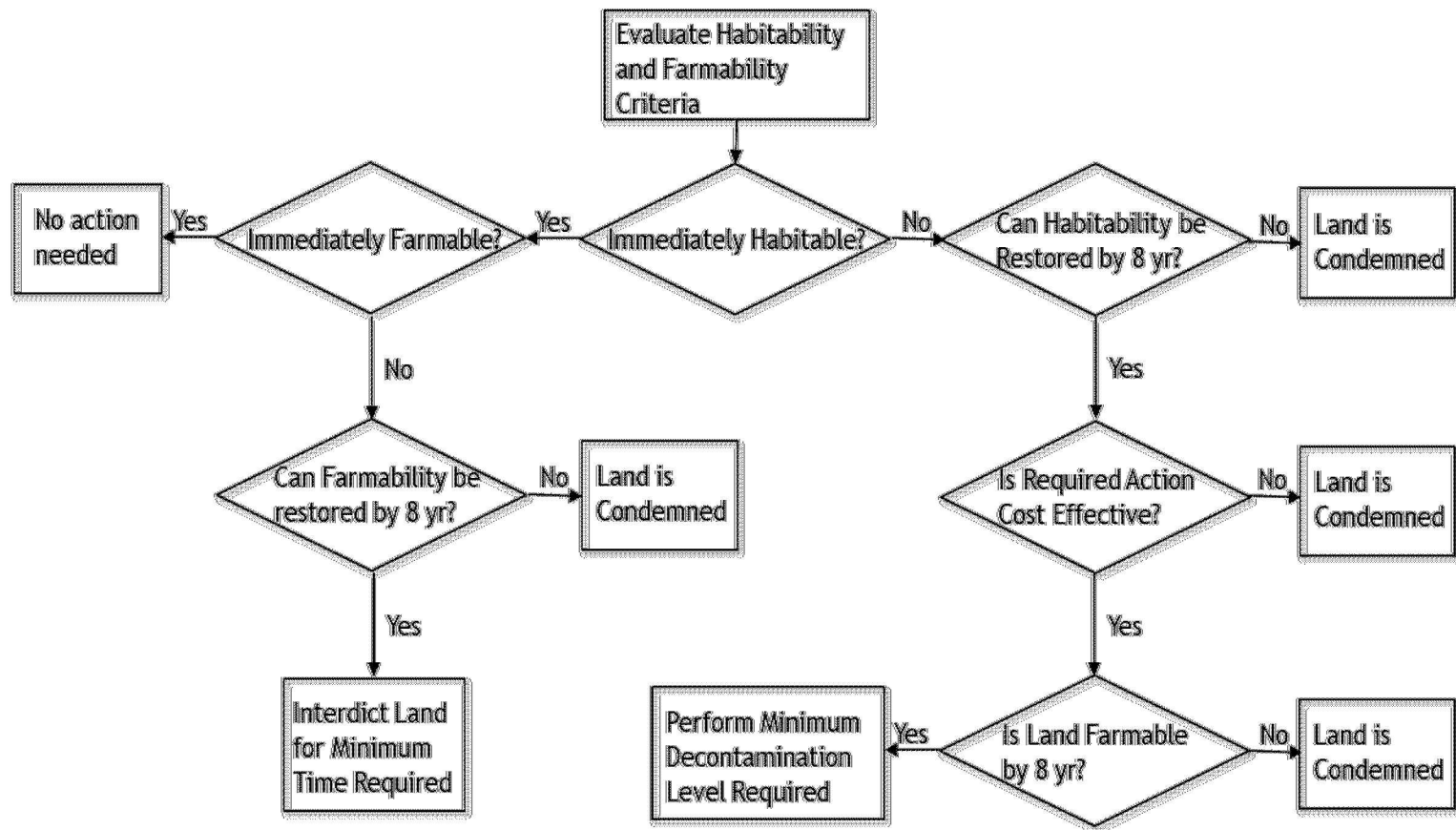
- Decision to decontaminate is based on cost effectiveness:  

$$C_{Decon} + C_{Reloc} + C_{Loss\ of\ Use} + C_{Dep} < V_{Prop} + C_{Reloc}$$
- The following logic is used at the beginning of the long-term phase to determine which action to perform for non-farmland





# Decision Process for Farmland (COMIDA2)



- Farmland is immediately farmable when both first- and second-year food-ingestion limits are satisfied and farmland is habitable
- Food-disposal costs are invoked when farmland is not immediately farmable
- Farmland is never decontaminated because of farmability

# RDEIM Model Concepts

- Like with the original cost-based model, habitability and farmability criteria define the disrupted region.
  - When a grid element is not habitable, all industrial sectors are affected.
  - When a grid element is habitable but not farmable, farming is affected.
- National recovery is faster than local recovery.
- Losses are reported as real (as opposed to nominal) GDP losses discounted to the base year, currently 2011.
- GDP losses account for
  - Direct losses to industry within the disrupted region
  - Indirect losses caused by loss of demand for commodity flows outside the disrupted region
  - Induced losses from lost pay throughout the national economy



# RDEIM Is Based on Input-Output Theory

- I-O theory is based on empirical tables of final demand, industry income, and interindustry transactions.
- Among other uses, I-O models can capture the short-term effects of a regional disruption, e.g., a hurricane.
- Classical I-O models do not account for long-term effects in which there is adaptation of the economy.
- Parent of RDEIM, the Regional Economic Accounting Tool (REAcct), was designed to evaluate short-term economic losses.
- RDEIM evolved from REAcct to better capture long-term economic losses based on recommendations by an external peer review panel of experts.
- Direct losses are estimated according to the number of disrupted workers in each industry based on county-level employment data.
- Indirect and induced losses are estimated by multiplying direct losses by Type I and Type II net total requirements multipliers from Bureau of Economic Analysis (BEA).
  - Type I multipliers estimate direct plus indirect losses.
  - Type II multipliers estimate direct, indirect, plus induced losses.

# Peer Review

## Peer review panel consisted of three experts

- Dr. Jeff Werling, University of Maryland
- Mr. Neil Higgins, Public Health England
- Dr. Haydar Kurban, Howard University

## Significant recommendations included

- Results should account for induced losses.
- Capital losses for condemned property should be included.
- Depreciation during periods of interdiction should be included.
- National economy should recover faster than regional economy.
  - National economy recovers linearly over period (default is 3 yr).
  - Disruption of regional economy can last longer (default is 10 yr).
- Double counting should be minimized by modifying multipliers to account for commodity flows within disrupted region.

$$m_i^I = m_i^{I,N} - m_i^{I,R} + 1$$

# Economic Model Comparison

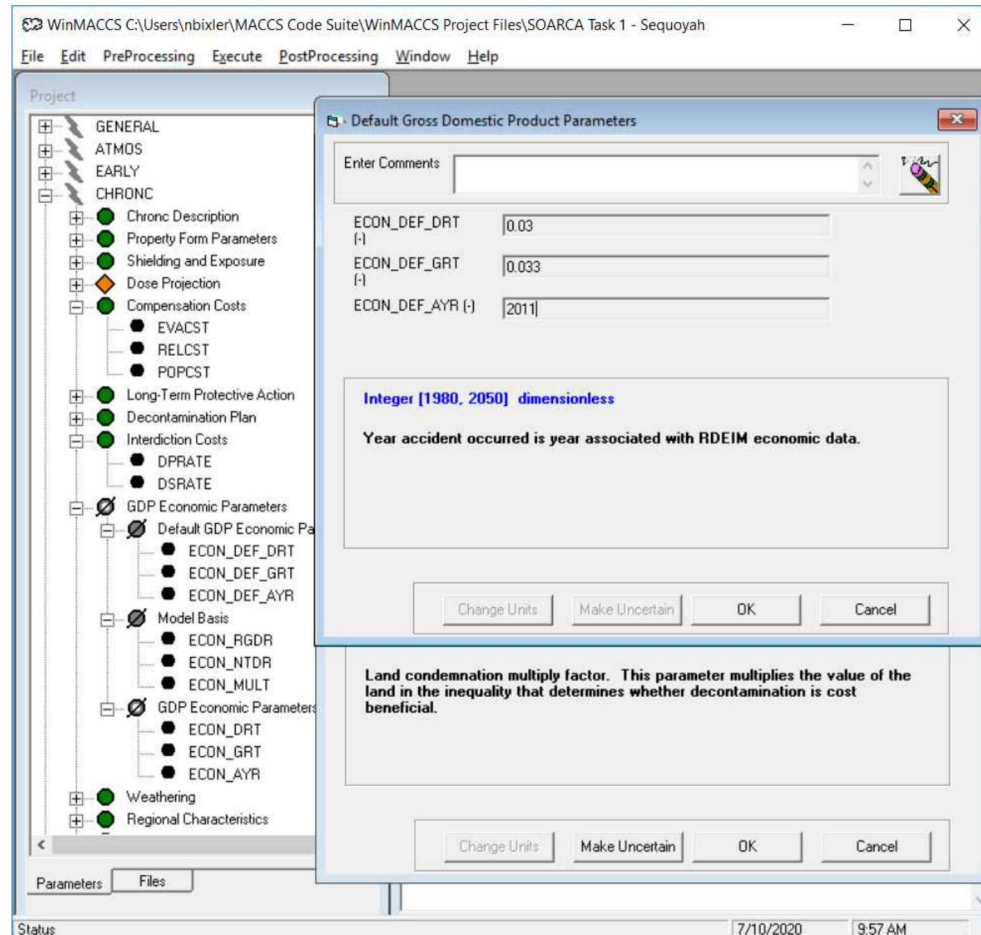
- Most loss elements are the same for both models.
- GDP losses replace expected return on investment in cost-based model
  - RDEIM model reports both regional (direct) and national (total) losses.
  - Cost-bases model only accounts for regional losses.
- Disposal of contaminated crop and dairy products is not currently included in RDEIM model.
- Inequality to determine cost effectiveness of decontamination is different.

$$C_{Decon} + C_{Reloc} + GDP_{Disrupt} + C_{Dep} < V_{Prop} + C_{Reloc} + GDP_T$$

Cost-Based Model	RDEIM Model
Evacuation/relocation costs	Evacuation/relocation costs
Long-term relocation costs	Long-term relocation costs
Decontamination cost	Decontamination cost
Depreciation on property improvements	Depreciation on property improvements
Value of condemned property	Value of condemned property
Expected return on investment	GDP losses (direct, indirect, and induced)
Disposal of crop and dairy products	

# RDEIM Implementation

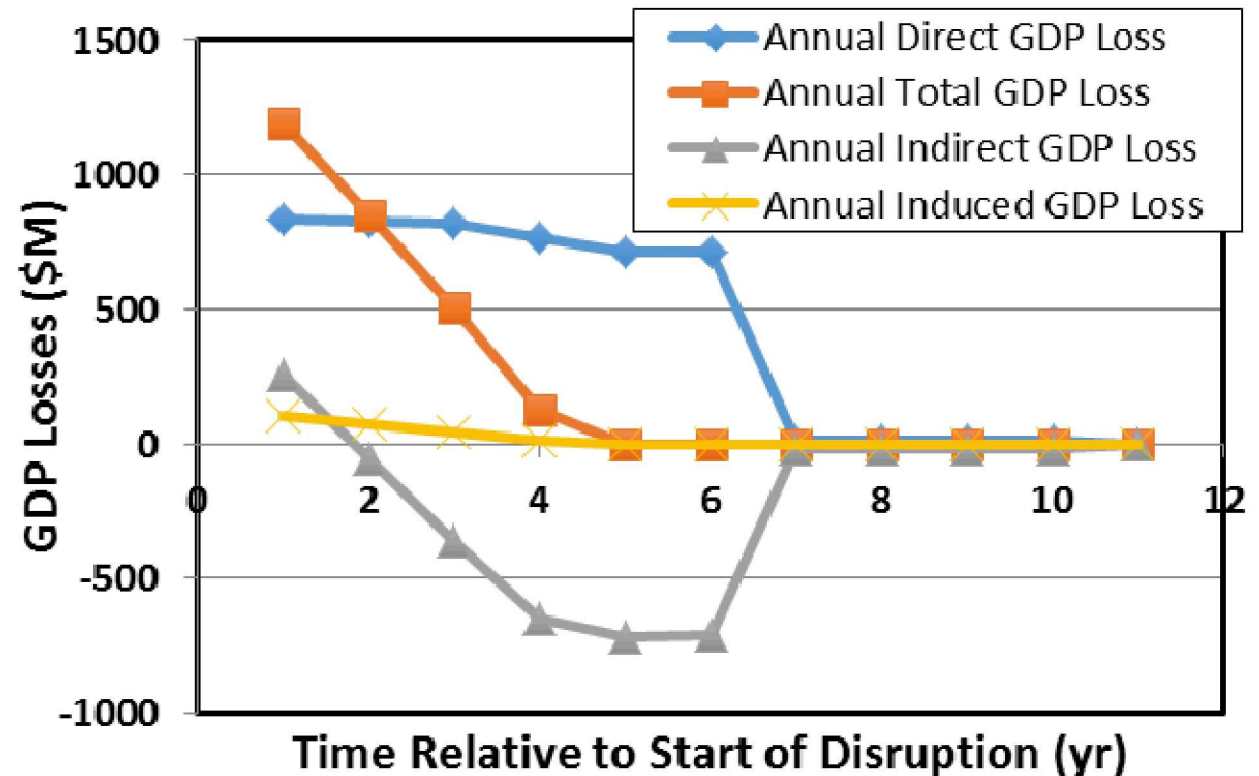
- SecPop 4.3 creates site data required by RDEIM model.
- RDEIM contains economic multipliers to estimate indirect and induced losses.
- Many of the input parameters have defaults that can be modified.
  - Social discount rate (default is 0.03/yr)
  - GDP annual growth rate (default is 0.033/yr)
  - Year accident is assumed to occur
- User specifies the following parameters:
  - Maximum duration of regional disruption (default is 10 yr)
  - Maximum duration of national disruption (default is 3 yr)
    - National economy recovers linearly over this period
  - Land value multiplier (affects decision to decontaminate or condemn)





# Illustration of Results

- Total loss curve (orange) shows all losses at the national level.
  - National economy recovers faster than regional economy
- Direct loss curve (blue) shows regional losses (excluding induced losses).
- Indirect losses have two components:
  - Losses due to disruption of the supply chain outside the affected region
  - Gains from economic adaptation outside the disrupted region
- Induced losses are always positive and are distributed across economy.



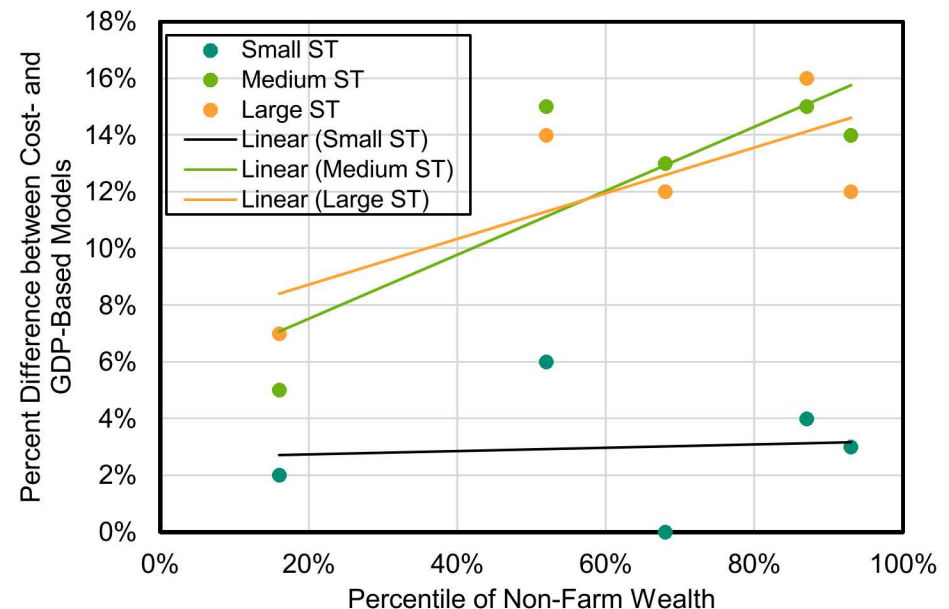
# RDEIM Verification

- Three cases were evaluated by comparing with REAcct (parent code of RDEIM) using default economic parameters.
- Case 1: entire economy of the contiguous US is disrupted.
  - RDEIM first-year direct loss is the same as REAcct result to three significant digits.
  - Result is within 1% of BEA value.
- Case 2: nearly all of a single county and a small fraction of a neighboring county are disrupted.
  - RDEIM and REAcct results agree to three significant digits.
- Case 3: a fraction of a single county is disrupted.
  - Disruption boundaries were estimated approximately.
  - Results agree within 5% of estimated value.



# Benchmark of RDEIM Model

- Default economic parameter values were used.
- Five US sites representing a range of non-farmland wealth were evaluated.
  - Points near left of plot are more rural with lower population densities.
  - Points near right of the plot are more urban with higher population densities.
- Three source-term magnitudes were evaluated.
- RDEIM model produces greater losses (less than 16%) than the original cost-based model.
  - Difference between models is greater for larger source terms.
  - Difference generally increases with wealth of region (population density).
  - Larger losses are attributable in part to including losses outside disrupted region.



# Summary

- MACCS 4.0 includes an alternative economic model (RDEIM).
  - Based on input-output theory
  - Accounts for direct, indirect, and induced GDP losses
  - Peer reviewed by panel of experts
    - Panel recommended several changes, including accounting for faster national than regional economic recovery.
    - Panel evaluated RDEIM model to be state of practice.
- Major difference between the economic models is that GDP losses replace expected return on property investments.
- RDEIM implementation was verified by comparing with REAcct.
- A benchmark study was performed for five sites and three source terms.
  - Results are remarkably similar for cost- and GDP-based models.
  - Losses predicted by RDEIM are consistently larger (but by less than 16%).
  - Differences generally increase with source-term magnitude and population density.

# List of Acronyms

BEA	Bureau of Economic Analysis
GDP	Gross Domestic Product
I-O	Input-Output
MACCS	MELCOR Accident Consequence Code System
NRC	Nuclear Regulatory Commission
RDEIM	Regional Disruption Economic Impact Model
REAcct	Regional Economic Accounting Tool
SAMA	Severe Accident Mitigation Alternative
SAMDA	Severe Accident Mitigation Design Alternative
SOARCA	State-of-the-Art Reactor Consequence Analysis
US	United States