Cancer Prevention and Control with System Dynamics: Discussion of a Systematic Review

Erin Kenzie, PhD

Assistant Professor, OHSU-PSU School of Public Health, Oregon Health & Science University

Wayne Wakeland, PhD

Professor Emeritus, Systems Science Program, Portland State University

Funders

This project was supported by the Oregon Health & Science University Knight Cancer Institute National Cancer Institute Cancer Center Support Grant P30CA069533 and the National Cancer Institute of the National Institutes of Health under Award Number UH3CA244298.

ORPRN
Oregon Rural Practice-Based Research Network

OHSU

Team

Erin Kenzie, PhD
Oregon Health & Science University

Mellodie Seater, BS
Oregon Health & Science University

Wayne Wakeland, PhD
Portland State University

Gloria Coronado, PhD
University of Arizona

Melinda Davis, PhD
Oregon Health & Science University

ORPRN
Oregon Rural Practice-Based Research Network

OHSU

Kenzie et al. 2023

PLOS ONE

RESEARCH ARTICLE

System dynamics modeling for cancer prevention and control: A systematic review

Erin S. Kenzie[1,2,3]*, **Mellodie Seater**[3], **Wayne Wakeland**[2], **Gloria D. Coronado**[4], **Melinda M. Davis**[1,5]

1 OHSU-PSU School of Public Health, Oregon Health & Science University, Portland, Oregon, United States of America, **2** Systems Science Program, Portland State University, Portland, Oregon, United States of America, **3** Oregon Rural Practice-Based Research Network, Oregon Health & Science University, Portland, Oregon, United States of America, **4** Kaiser Permanente Center for Health Research, Portland, Oregon, United States of America, **5** Department of Family Medicine, Oregon Health & Science University, Portland, Oregon, United States of America

* kenzie@ohsu.edu

Check for updates

Citation: Kenzie ES, Seater M, Wakeland W, Coronado GD, Davis MM (2023) System dynamics modeling for cancer prevention and control: A systematic review. PLoS ONE 18(12): e0294912. https://doi.org/10.1371/journal.pone.0294912

Editor: Lucy W. Kivuti-Bitok, University of Nairobi, KENYA

Abstract

Cancer prevention and control requires consideration of complex interactions between multilevel factors. System dynamics modeling, which consists of diagramming and simulation approaches for understanding and managing such complexity, is being increasingly applied to cancer prevention and control, but the breadth, characteristics, and quality of these studies is not known. We searched PubMed, Scopus, APA PsycInfo, and eight peer-reviewed journals to identify cancer-related studies that used system dynamics modeling. A dual review process was used to determine eligibility. Included studies were assessed using quality criteria adapted from prior literature and mapped onto the cancer control continuum. Characteristics of studies and models were abstracted and qualitatively synthesized. 32 studies met our inclusion criteria. A mix of simulation and diagramming approaches were

ORPRN Oregon Rural Practice-Based Research Network

OHSU

Cancer is a complex phenomenon that is studied across a continuum.

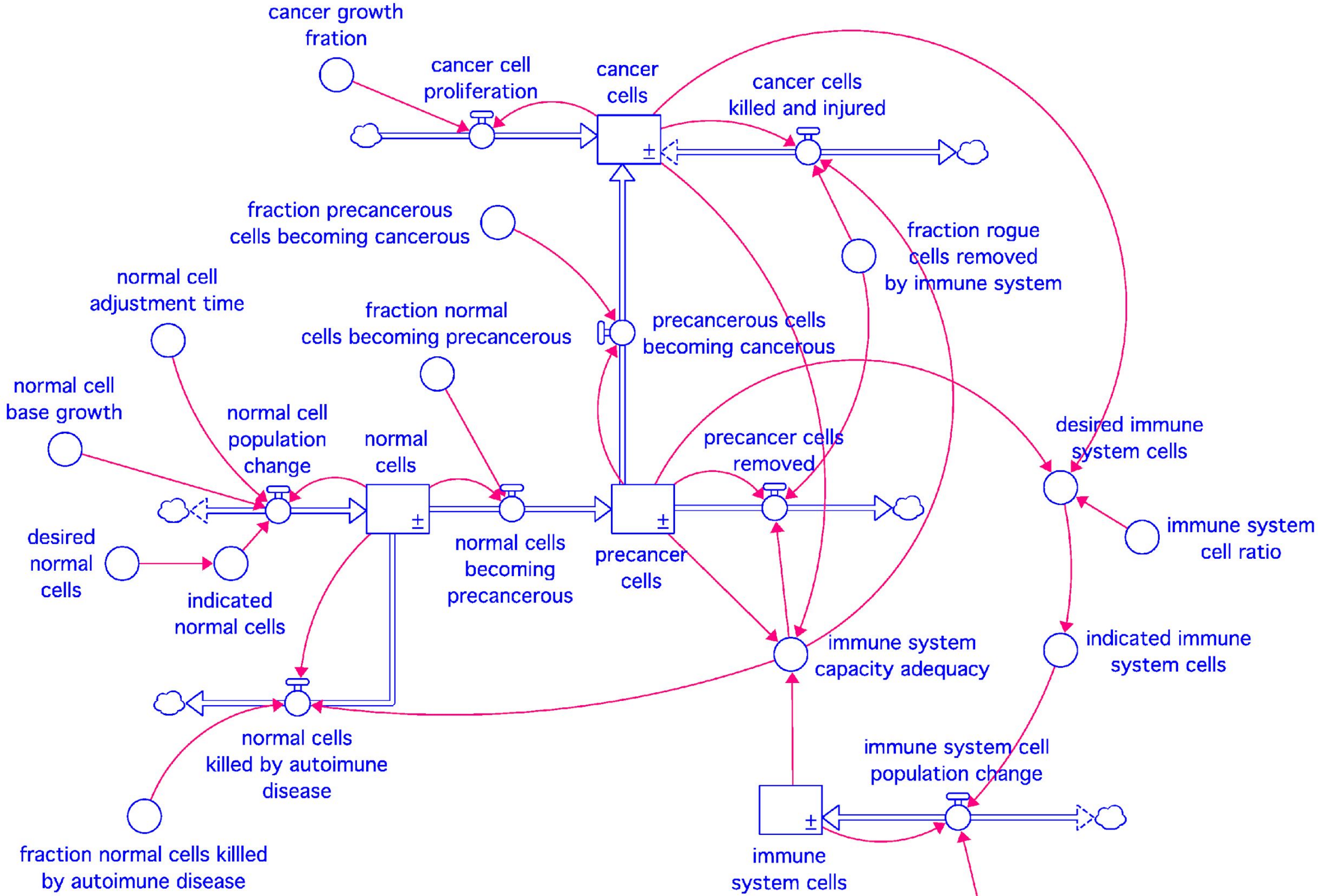
Etiology	Prevention	Detection	Diagnosis	Treatment	Survivorship
• Environmental factors • Genetic factors • Gene-environment interactions • Medication (or pharmaceutical exposure) • Infectious agents • Health behaviors	• Tobacco control • Diet • Physical activity • Sun protection • HPV vaccine • Limited alcohol use • Chemoprevention	• Pap/HPV testing • Mammography • Fecal occult blood test • Colonoscopy • Lung cancer screening	• Shared and informed decision making	• Curative treatment • Non-curative treatment • Adherence • Symptom management	• Coping • Health promotion for survivors

(National Cancer Institute, 2020) Adapted from David B. Abrams, Brown University School of Medicine

ORPRN Oregon Rural Practice-Based Research Network

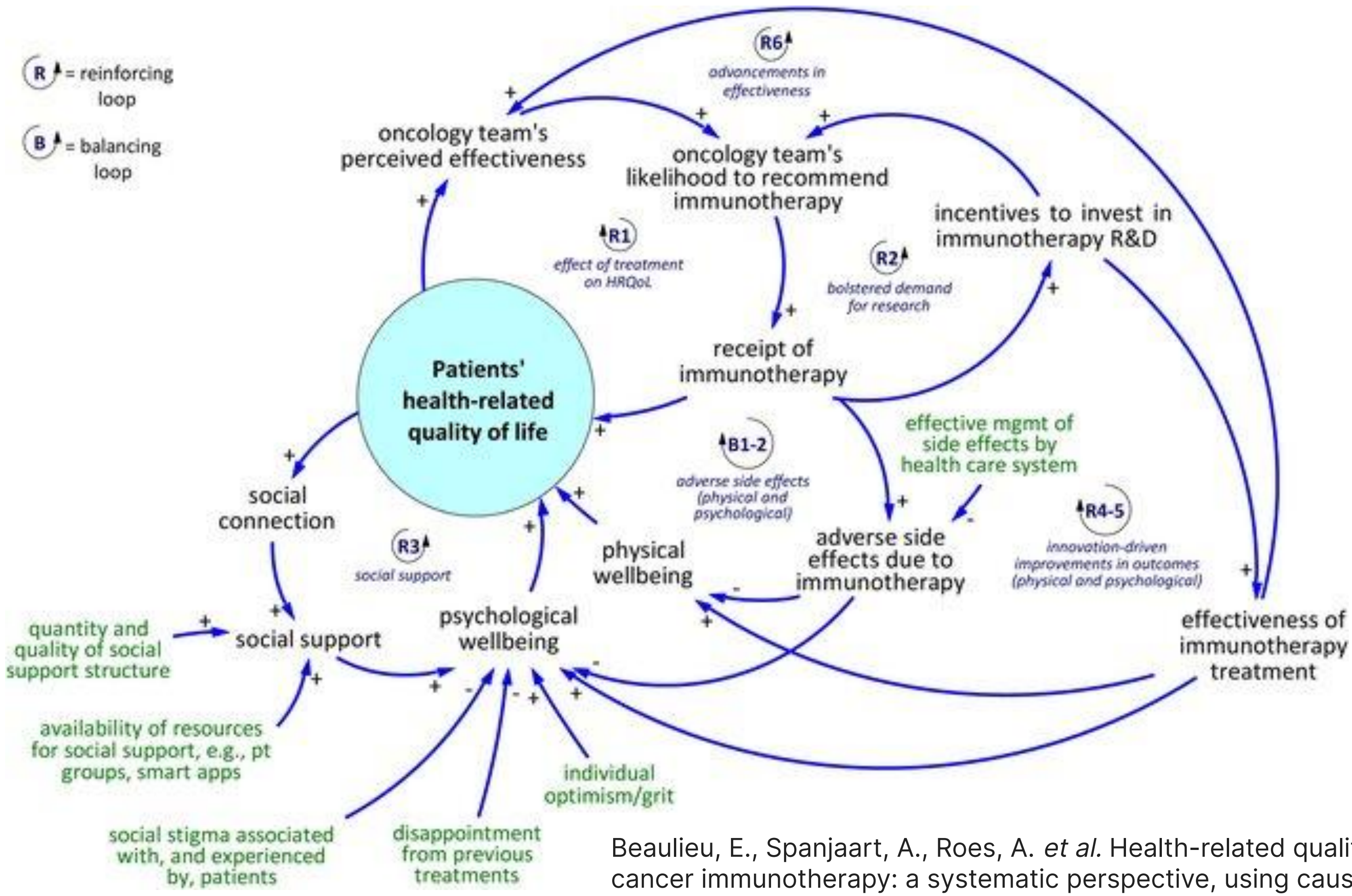
OHSU

System dynamics is well suited to cancer prevention and control.



Saeed K, Ryder EF, Manning AL. Cancer as a System Dysfunction. *Systems*. 2021; 9(1):14. https://doi.org/10.3390/systems9010014

System dynamics is well suited to cancer prevention and control.



Beaulieu, E., Spanjaart, A., Roes, A. *et al.* Health-related quality of life in cancer immunotherapy: a systematic perspective, using causal loop diagrams. *Qual Life Res* **31**, 2357–2366 (2022). https://doi.org/10.1007/s11136-022-03110-5

Methods

- Search
- Review
- Abstraction & Categorization
- Quality assessment

Search strategy

- Sources:
  - PubMed, Scopus, and APA PsycInfo
  - Peer-reviewed journals publishing high number of system dynamics papers
  - “Snowball” citation & author searching
- Search Terms:
  - “cancer” AND ("causal loop" OR "system dynamics*" OR "systems thinking" OR "group model*")
  - Searches were tailored to align with database or journal specifications.
- Scope:
  - Published between 2012-2022

Review strategy

- Eligibility:
  - Peer-reviewed
  - Published within the last 10 years
  - Primary focus on cancer prevention or control
  - Developed or applied a system dynamics model (simulation model or diagram)
- Titles and abstracts were independently reviewed for fit to criteria.
- Screened articles were reviewed by two analysts to ensure each article met inclusion criteria.
- Eligible articles were saved to a reference management software program.

Abstraction & categorization

- Information abstracted: Modeling type, topic, country, unit modeled, purpose, information sources, participants, appraisal of modeling & processes for model development, verification, validation, use
- Categorized according to cancer control continuum

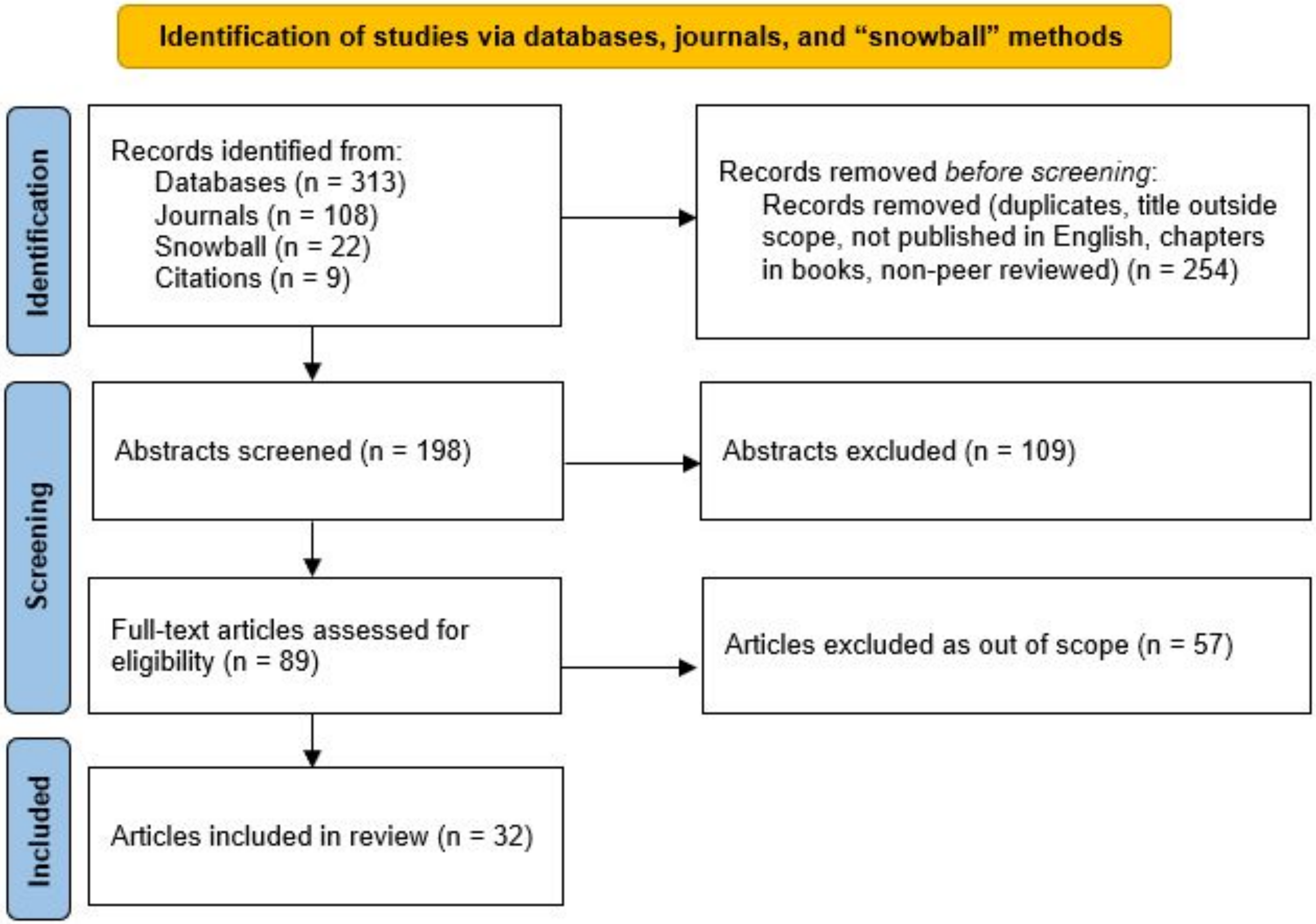
Quality assessment

Criteria	Diagram-only	Simulation
1. Present clear objectives or purpose appropriate for system dynamics		
2. Identify information sources supporting model development		
3. Clearly describe modeling process, including role of modeler(s) & participants		
4. Involve stakeholders in model development, validation, and use, as appropriate		
5. Verify and validate model		
6. Describe model structure using diagram(s) adhering to standard notation		
7. Calibrate the model using real-world data, as appropriate		
8. Present clear model output and results using graphs, charts, or tables		
9. Report model equations and parameter values		

Davahli, M.R., Karwowski, W. and Taiar, R. (2020) 'A System Dynamics Simulation Applied to Healthcare: A Systematic Review', *International Journal of Environmental Research and Public Health*, 17(16), p. 5741. Available at: https://doi.org/10.3390/ijerph17165741.

Rahmandad, H. and Sterman, J.D. (2012) 'Reporting guidelines for simulation-based research in social sciences', *System Dynamics Review*, 28(4), pp. 396–411. Available at: https://doi.org/10.1002/sdr.1481.

Included studies

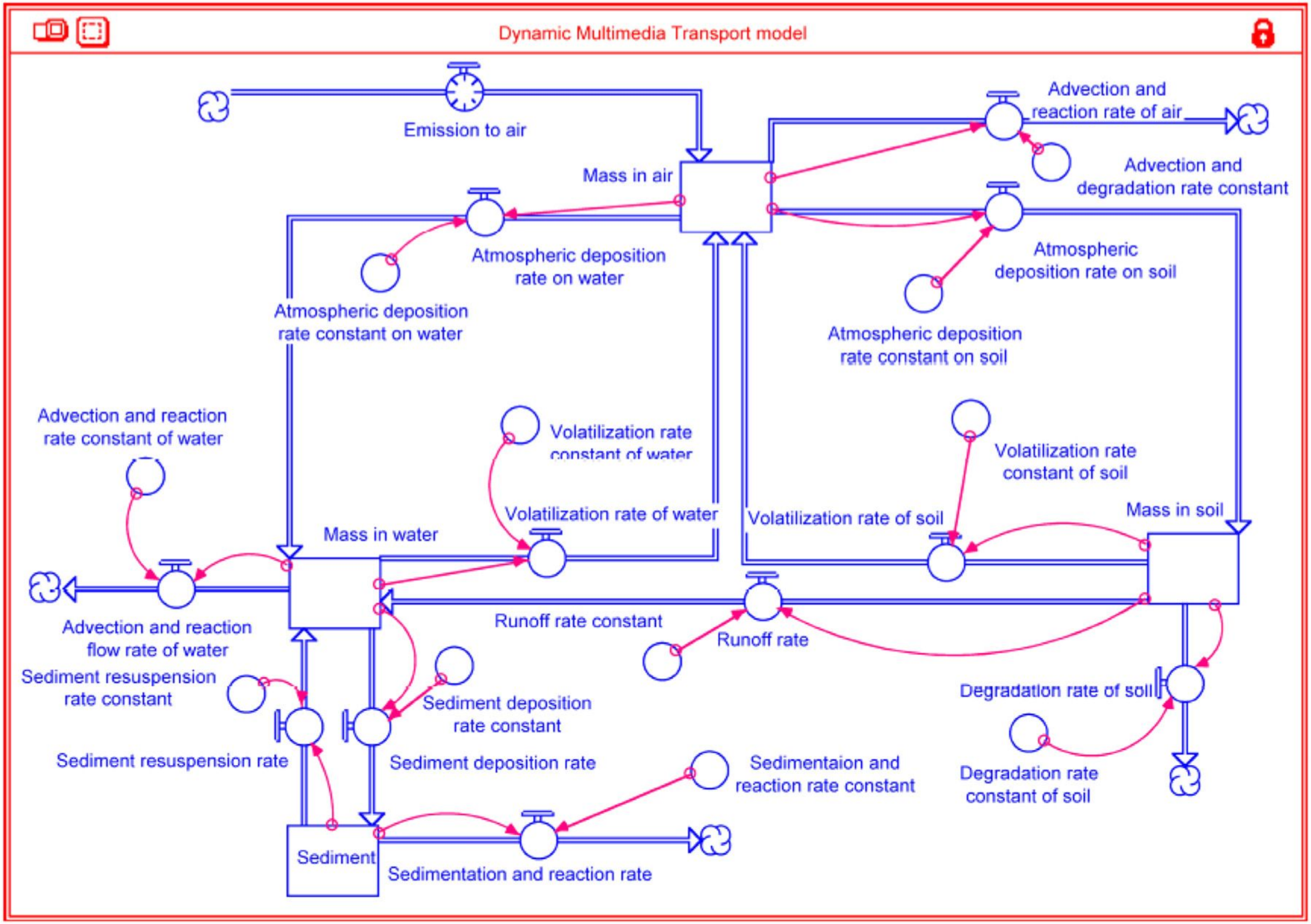


ORPRN
Oregon Rural Practice-Based Research Network

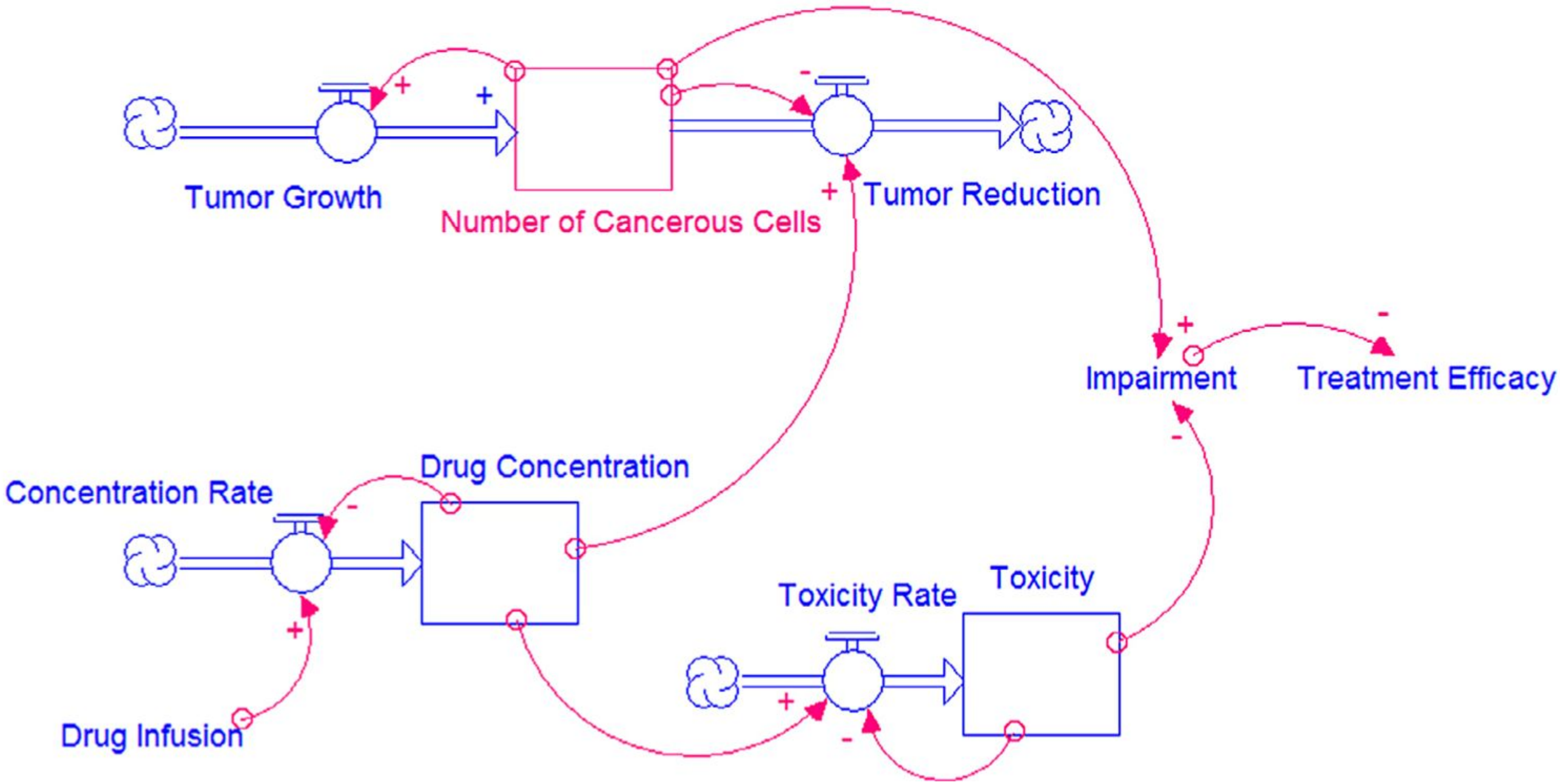
OHSU

Study characteristics

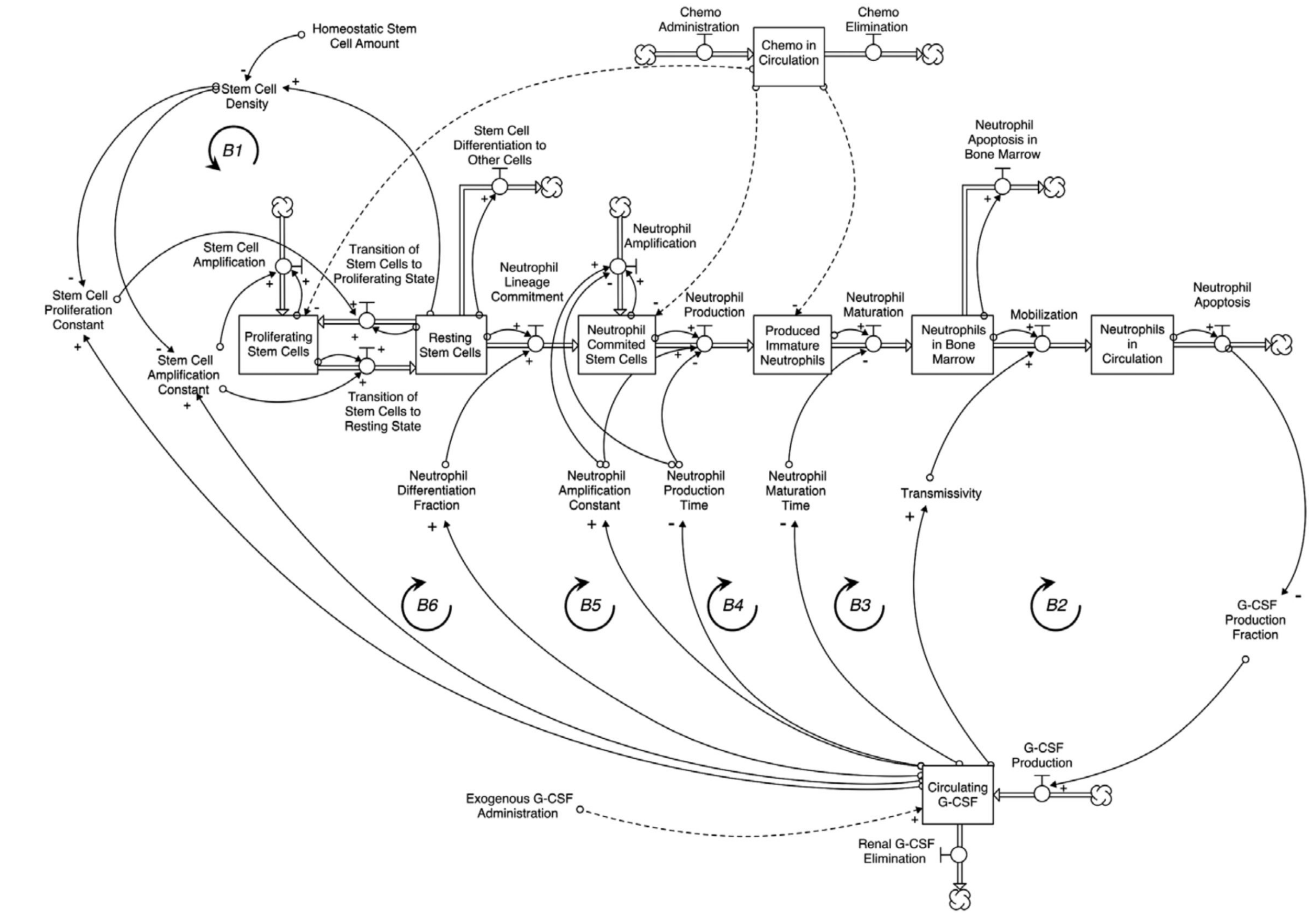
- Studies pertained to 14 countries; published in 29 journals; 78% funded
- Only 6 authors contributed to more than 1 paper
- Simulation models: 66%
- Diagram-only approaches: 34%
  - Causal-loop diagrams: 19%
  - Stock-and-flow diagrams: 6%
  - Hybrid: 9%
- Units modeled:
  - People (50%), patient experience or behavior (16%), cells (13%), environmental contaminants (13%), currency (6%), web search queries (3%)



Chen, L.-L., Tseng, C.-H. and Tseng, W.-J. (2018) ‘Development of a system dynamics model for polycyclic aromatic hydrocarbons and its application to assess the benefits of pollution reduction’, *Ecotoxicology and Environmental Safety*, 166, pp. 231–236. Available at: https://doi.org/10.1016/j.ecoenv.2018.09.072.



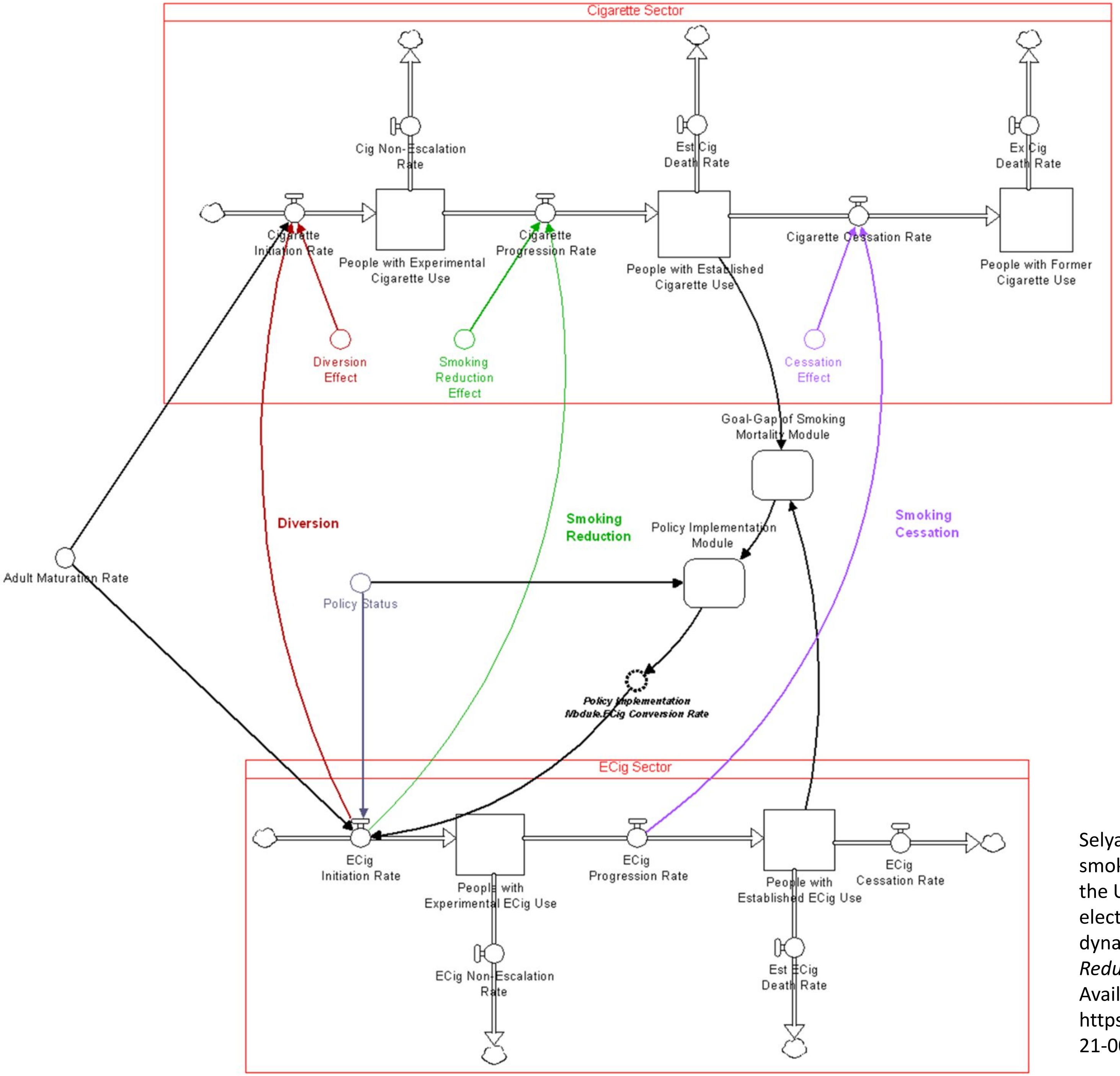
Heshmat, M. and Eltawil, A. (2018) 'A system dynamics-based decision support model for chemotherapy planning', *Journal of Simulation*, 12(4), pp. 283–294. Available at: https://doi.org/10.1057/s41273-017-0059-8.



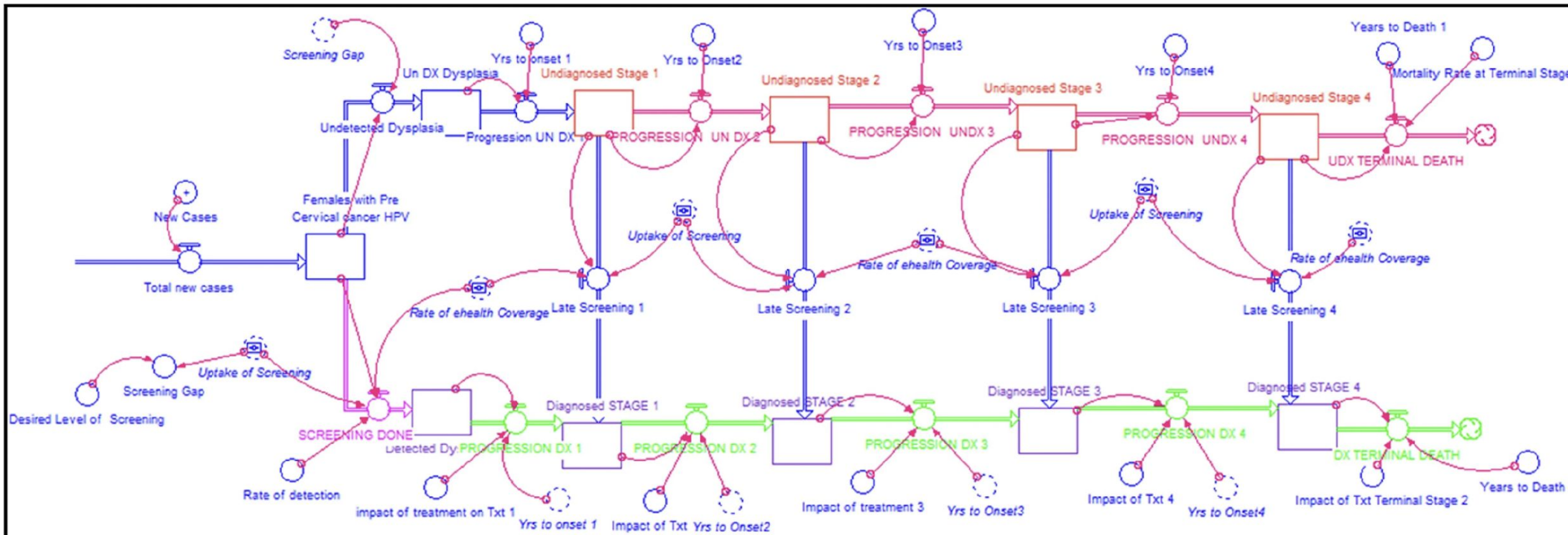
İrsoy, O. *et al.* (2020) 'Dynamic trade-offs in granulocyte colony-stimulating factor (G-CSF) administration during chemotherapy', *System Dynamics Review*, 36(4), pp. 397–446. Available at: https://doi.org/10.1002/sdr.1671.

ORPRN
Oregon Rural Practice-Based Research Network

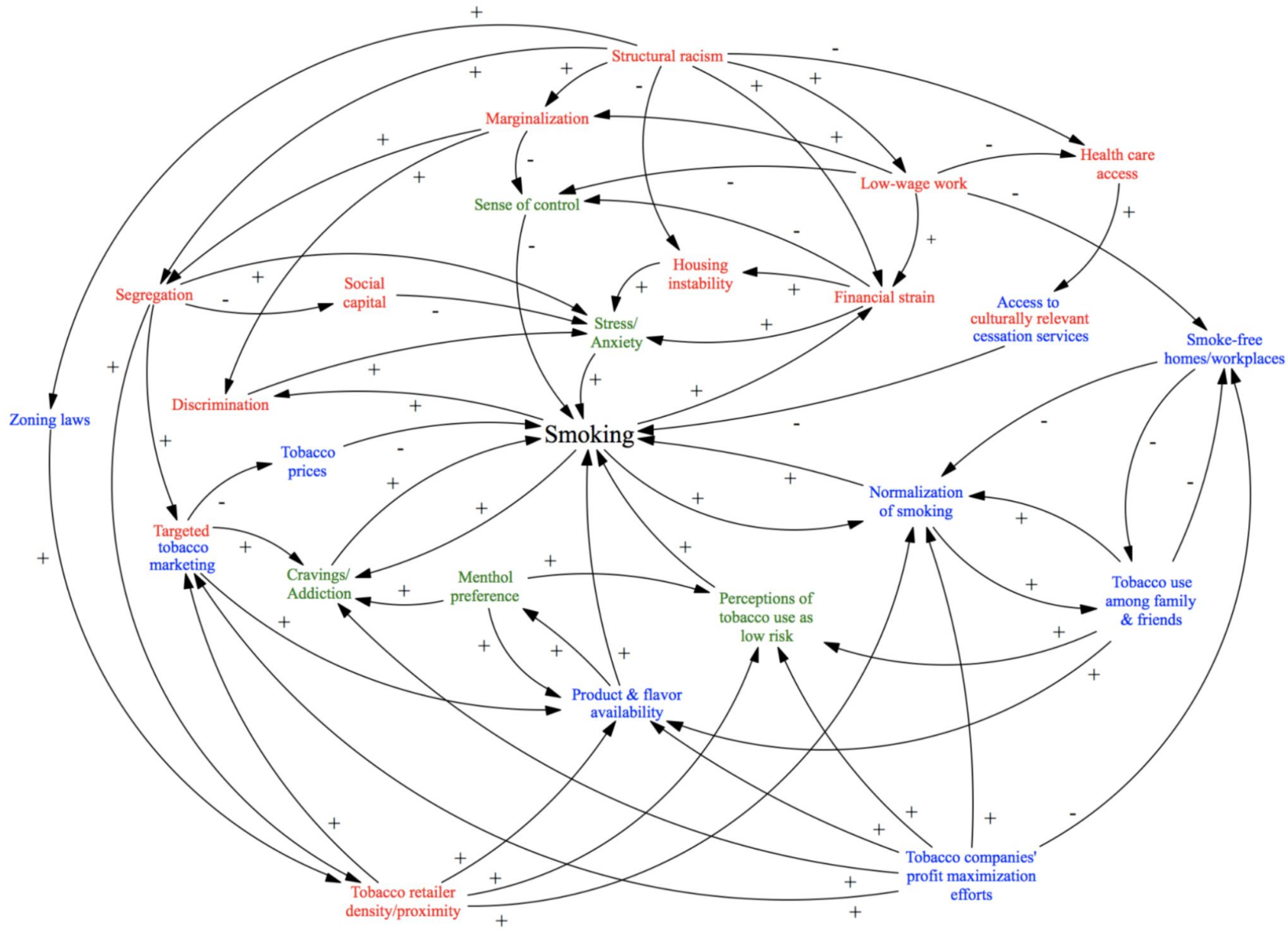
OHSU



Selya, A.S. (2021) 'Reducing the smoking-related health burden in the USA through diversion to electronic cigarettes: a system dynamics simulation study', *Harm Reduction Journal*, 18(1), p. 36. Available at: https://doi.org/10.1186/s12954-021-00484-6.

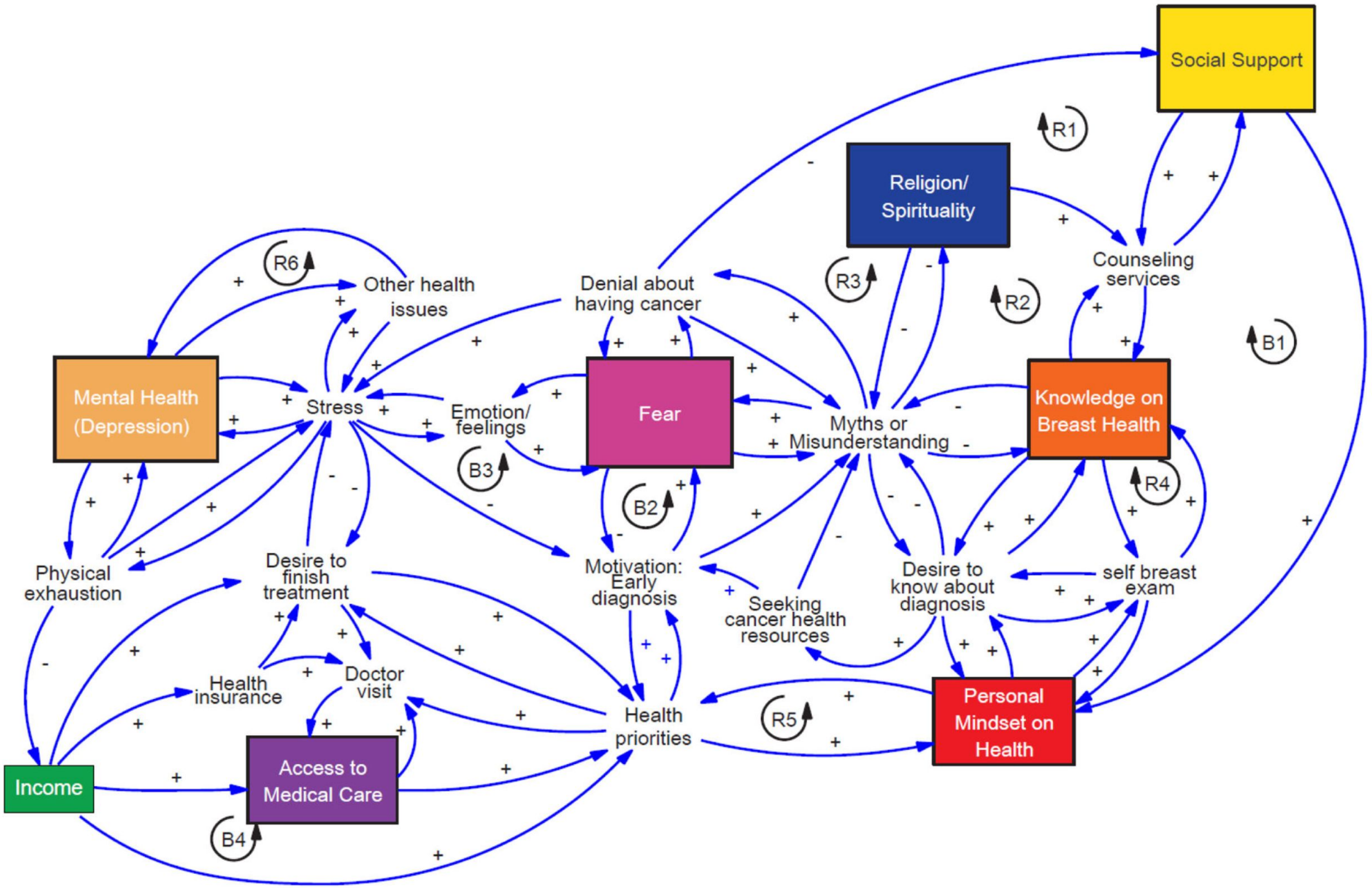


Kivuti-Bitok, L.W. *et al.* (2014) 'System dynamics model of cervical cancer vaccination and screening interventions in Kenya', *Cost Effectiveness and Resource Allocation*, 12(1), pp. 1–19. Available at: https://doi.org/10.1186/1478-7547-12-26.



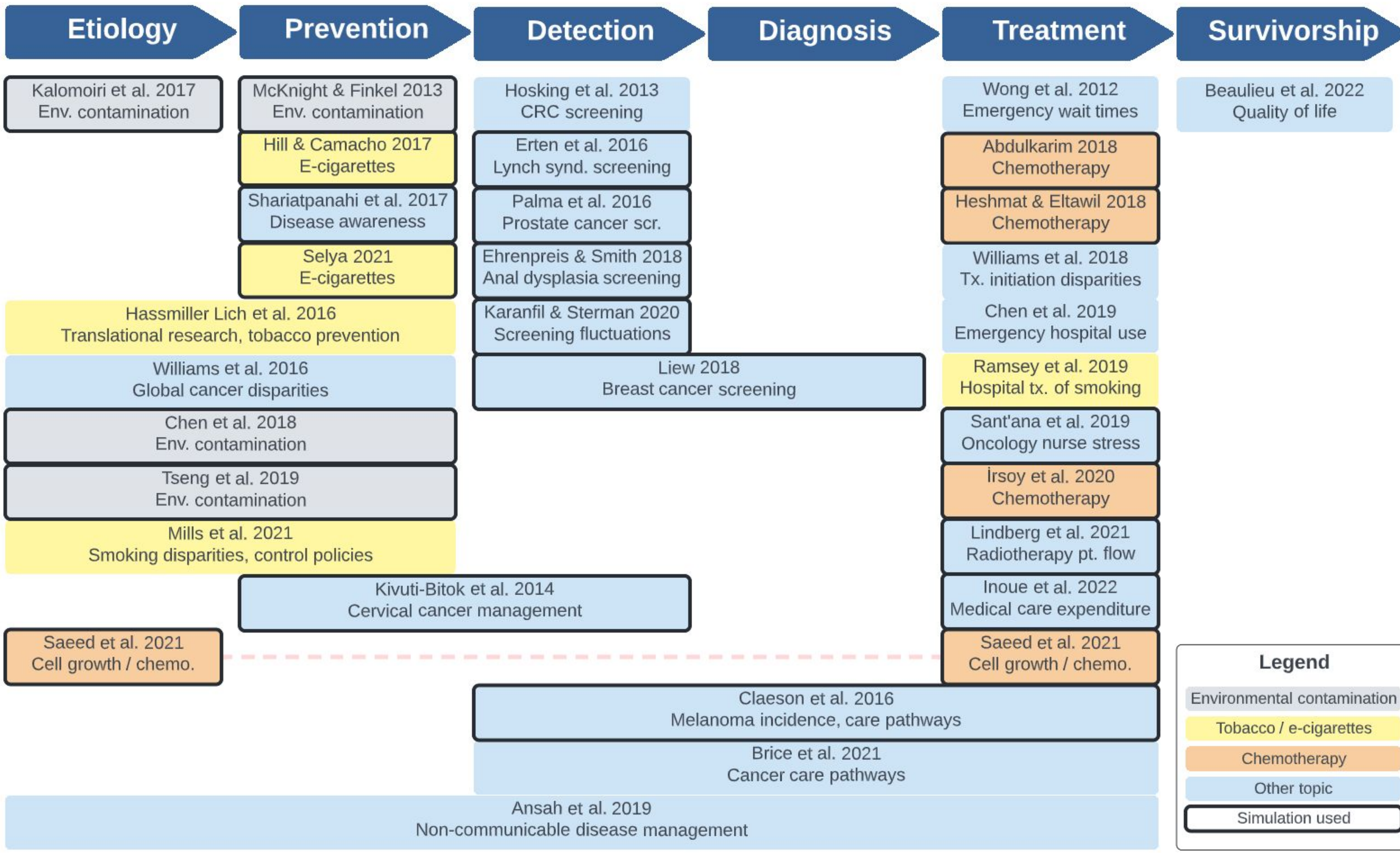
Green:	Individual factors
Blue:	Environmental factors
Red:	Root causes or fundamental factors
+ sign	Variables move in the same direction
- sign	Variables move in the opposite direction

Mills, S.D. *et al.* (2021) 'Using systems science to advance health equity in tobacco control: a causal loop diagram of smoking', *Tobacco Control*, p. tobaccocontrol-2021-056695. Available at: https://doi.org/10.1136/tobaccocontrol-2021-056695.

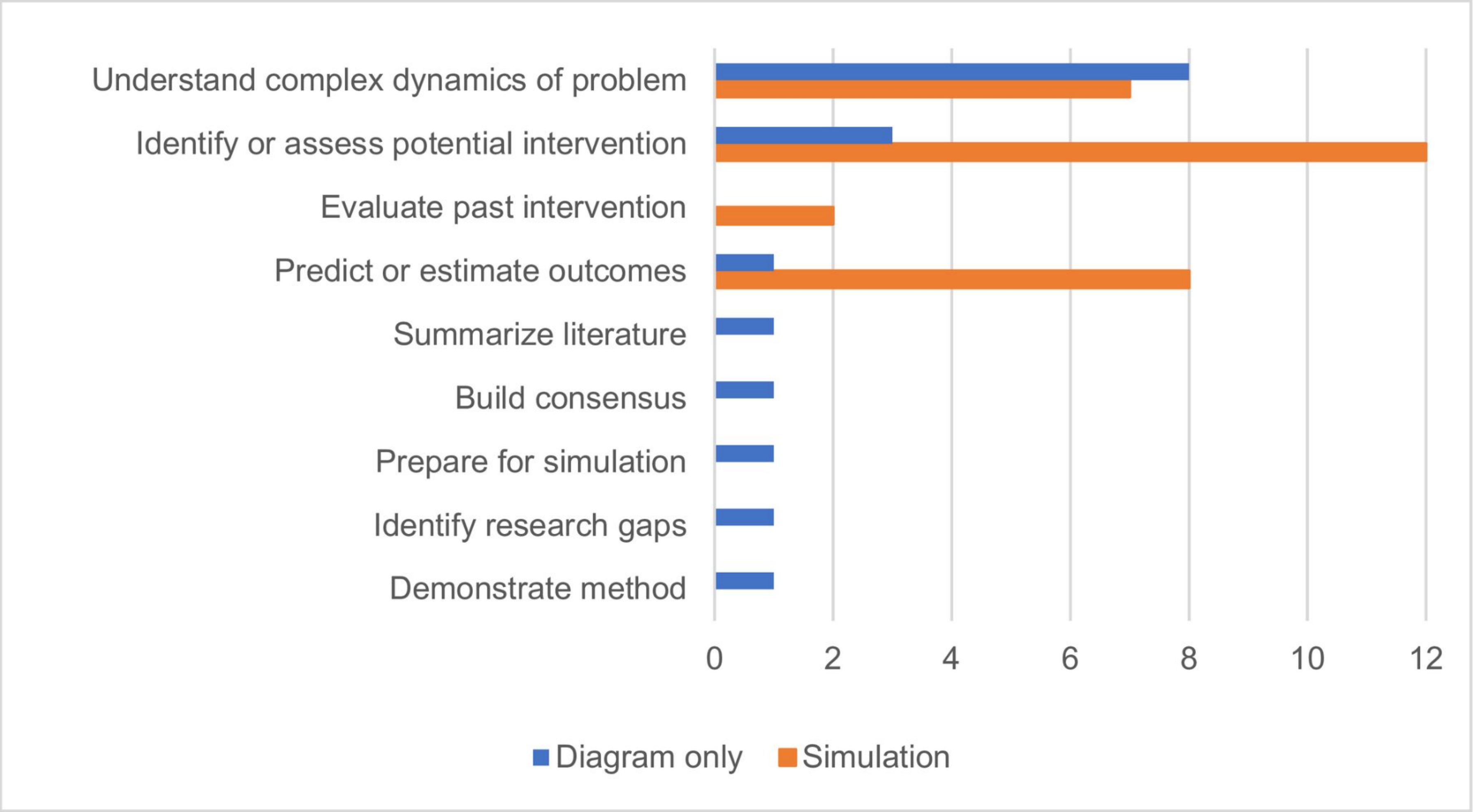


Williams, F. *et al.* (2018) 'Combining Community-Engaged Research with Group Model Building to Address Racial Disparities in Breast Cancer Mortality and Treatment', *Journal of Health Disparities Research and Practice*, 11(1), pp. 160–178.

Studies spanned the continuum



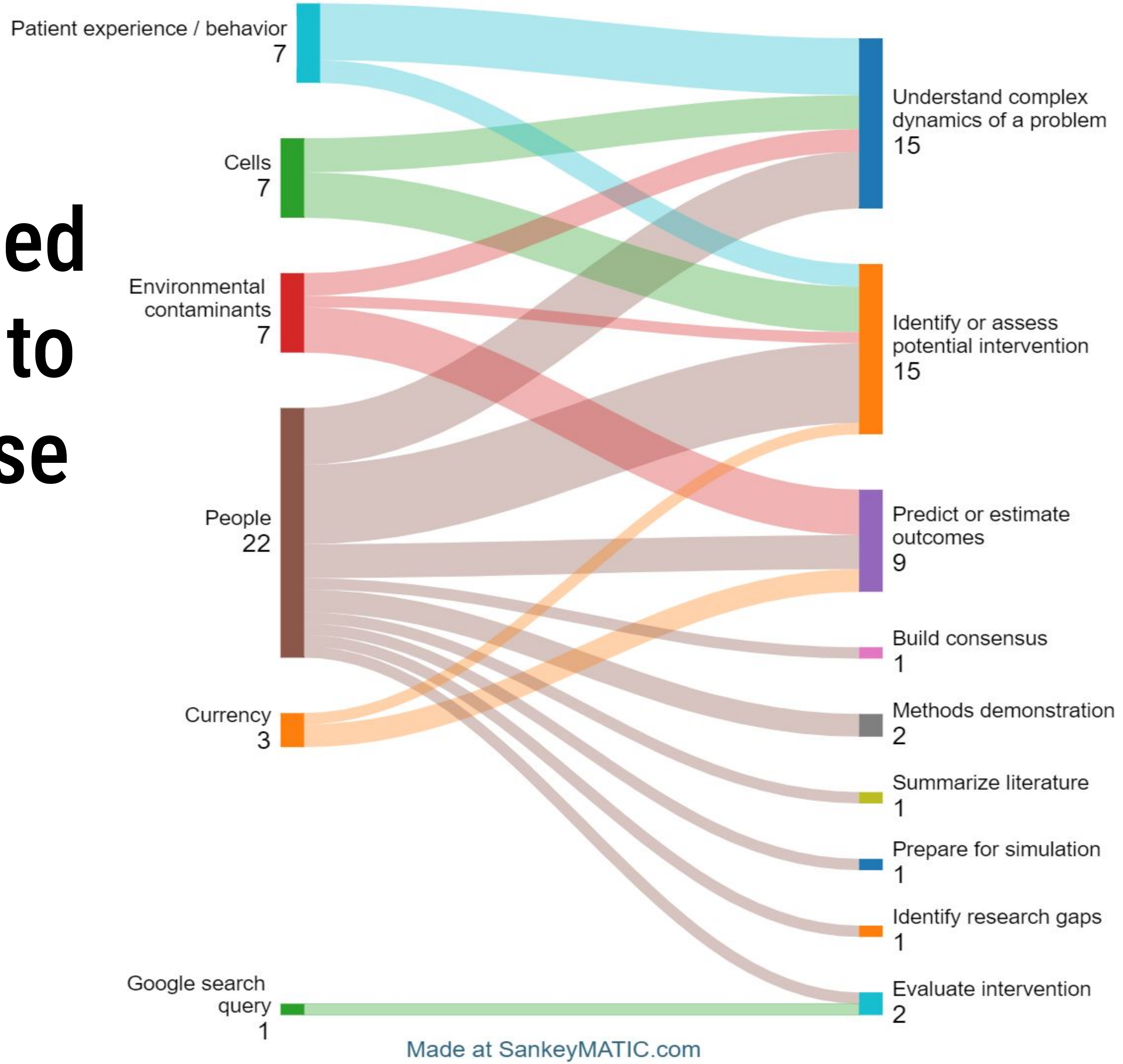
Modeling purposes differed



ORPRN
Oregon Rural Practice-Based Research Network

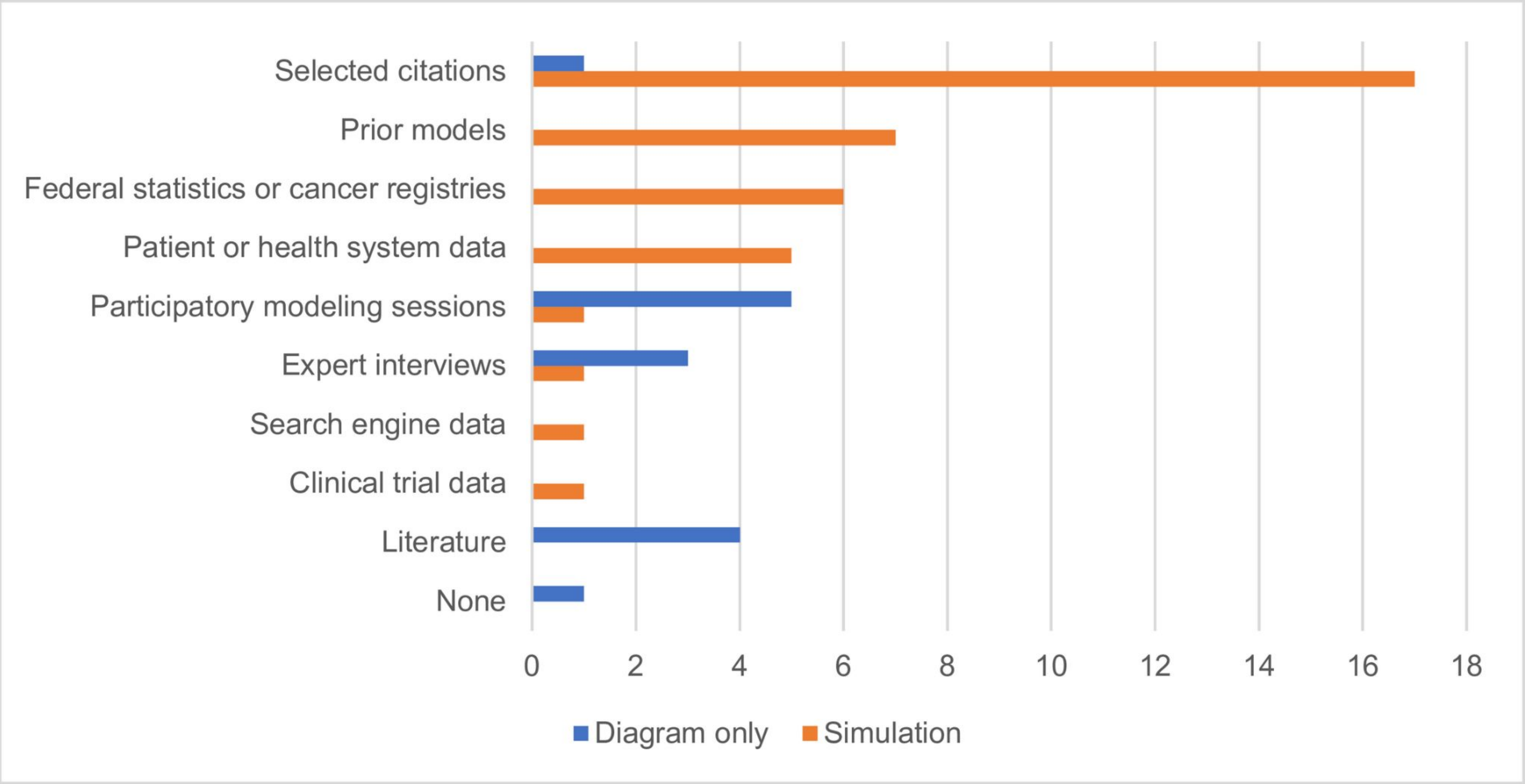
OHSU

Units modeled relate to purpose



ORPRN
Oregon Rural Practice-Based Research Network

Information sources varied by approach



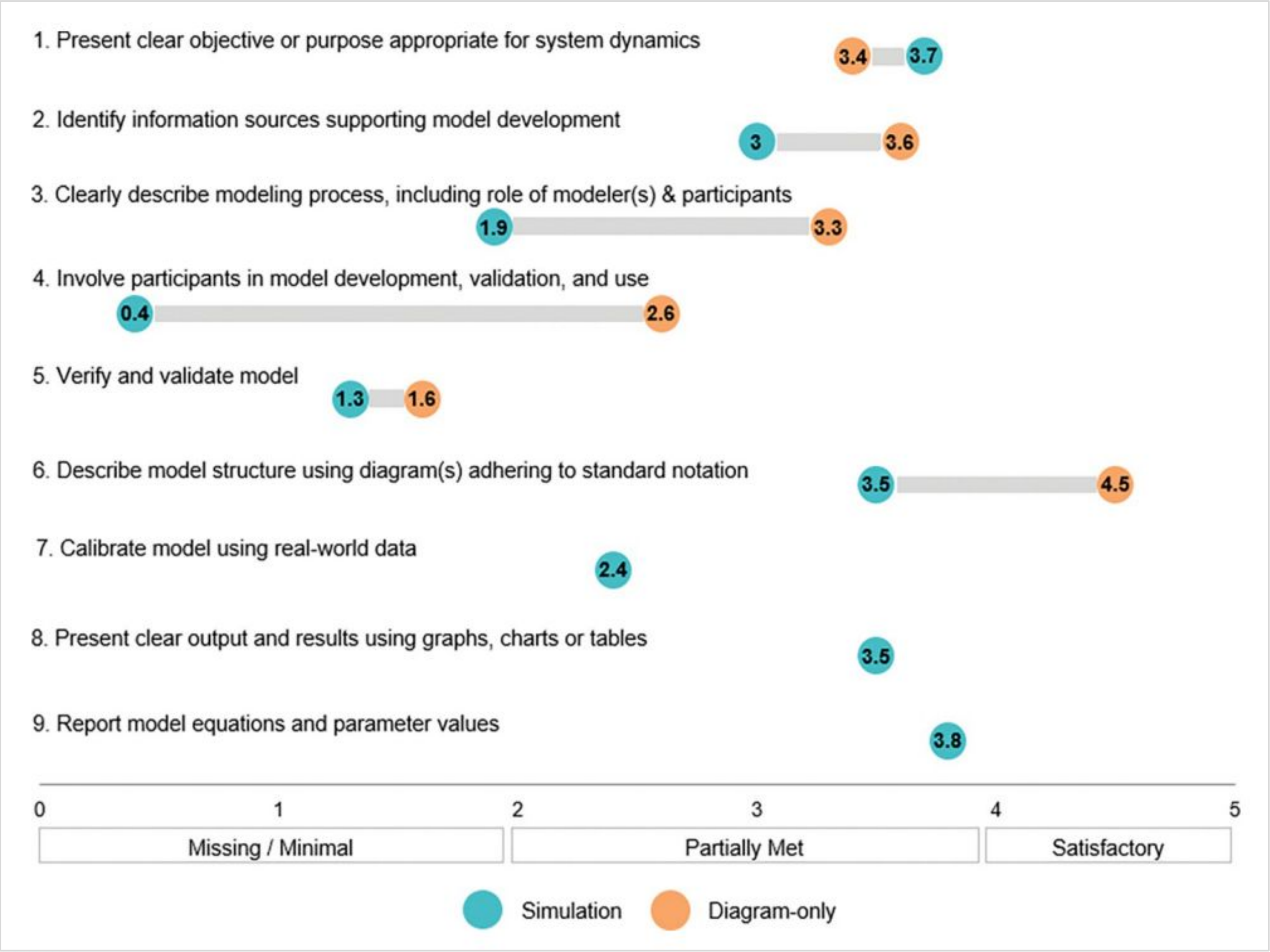
ORPRN Oregon Rural Practice-Based Research Network

OHSU

Appraisal of modeling

- Studies valued ability of system dynamics to describe interactions, feedback loops, and patterns of behavior; use as decision support
- Simulation: Test specific scenarios, modifiable
- Diagrams: Engaging participants, understand feedback
- Drawbacks: Source data limitations, difficulty representing heterogeneity

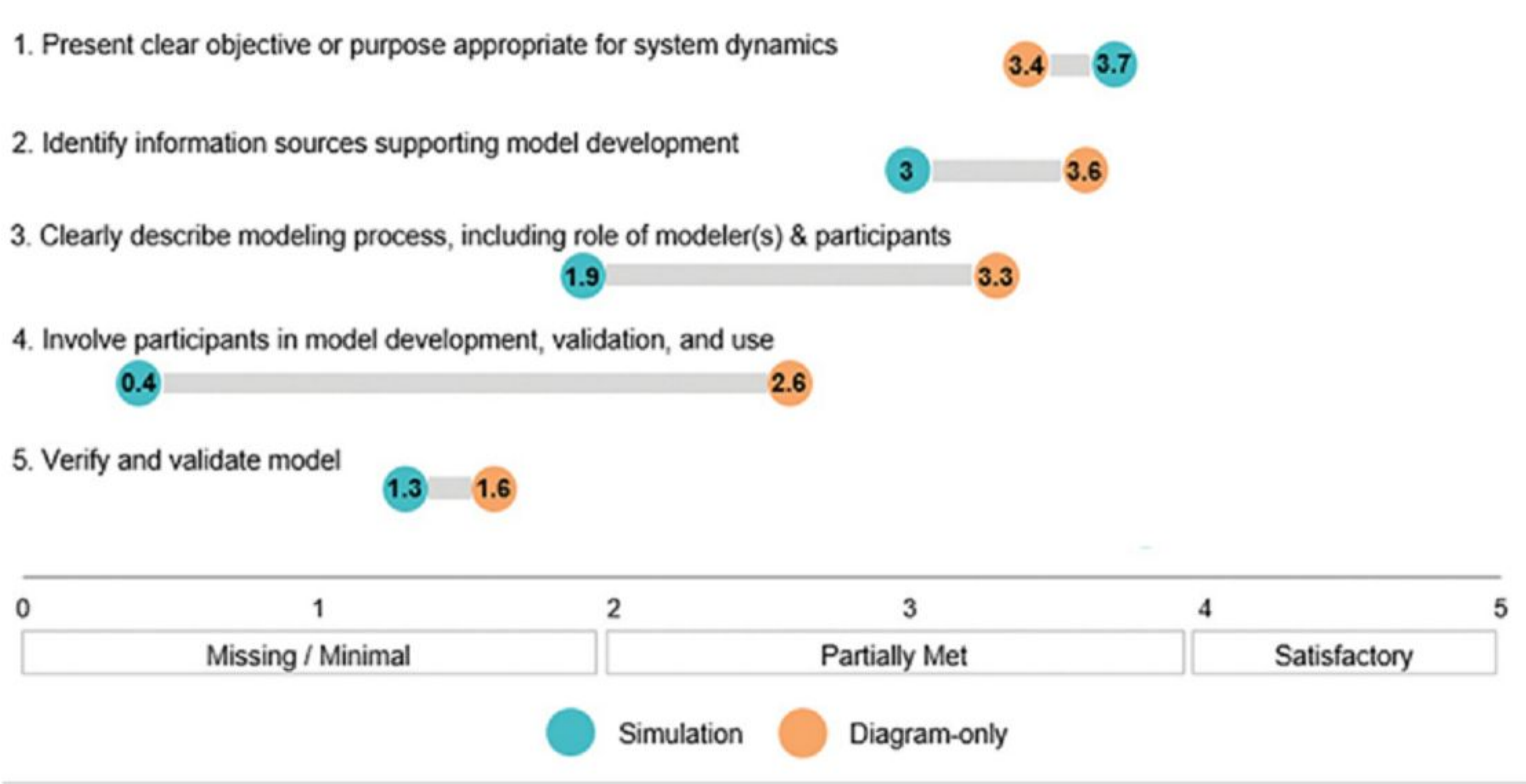
Overall assessed quality was low



ORPRN Oregon Rural Research Network

OHSU

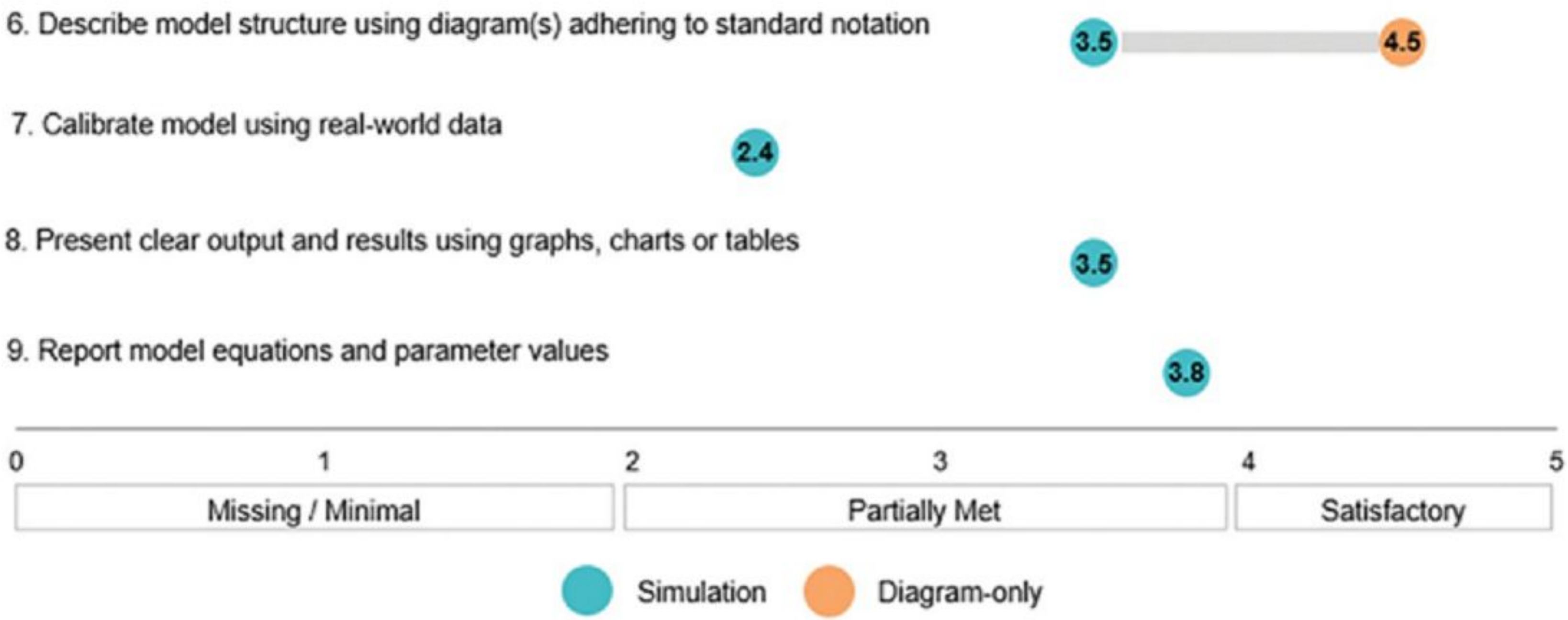
Overall assessed quality was low (1)



ORPRN
Oregon Rural Practice-Based Research Network

OHSU

Overall assessed quality was low (2)



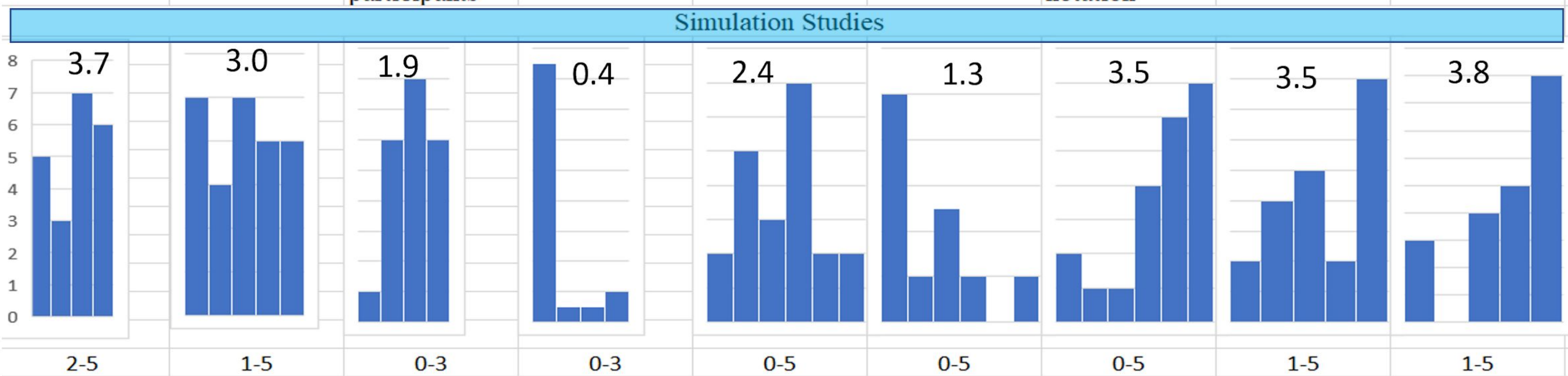
ORPRN
Oregon Rural Practice-Based Research Network

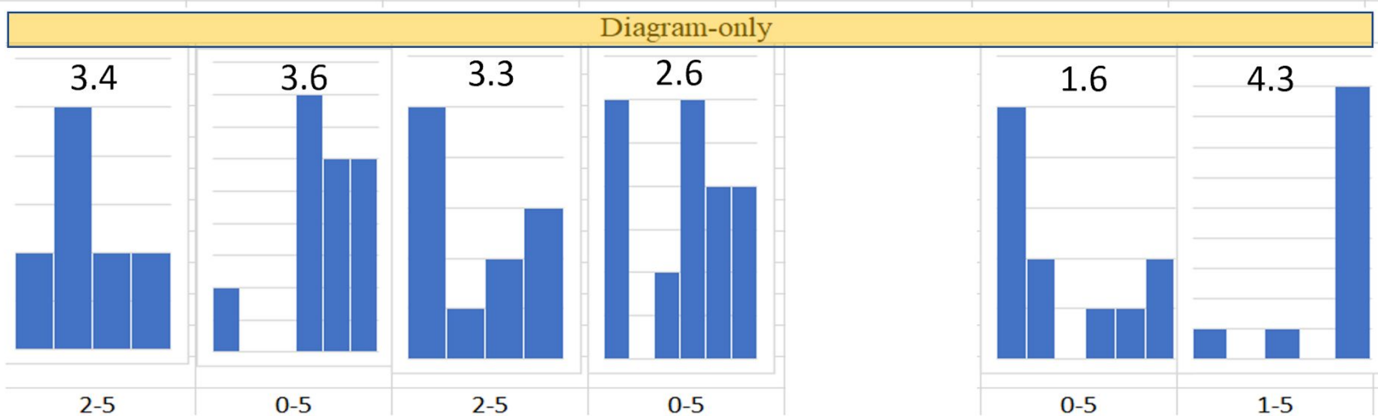
OHSU

Quality score distribution

Criteria

Present clear objectives or purpose?	Identify information sources supporting model development	Clearly describe modeling process, incl, role of modeler(s) & participants	Involve stakeholders in model development, validation, and use	Calibrate model using real-world data*	Verify and validate model	Describe model structure using diagram(s) adhering to standard notation	Present clear outcomes and results using graphs, charts or tables*	Report model equations and parameter values*





KEY

Horiz. Axes

Score on criteria, from low (0-2) to high (3-5)

Height of Blue Bars

Nbr. of studies with each possible score for that criteria

Recommendations

- Provide opportunities for system dynamics training and skill development.
- Facilitate connections between cancer researchers and skilled modelers.
- Develop best practice for modeling across the cancer control continuum.
- Encourage participatory approaches to model development, validation and use.
- Provide a supportive funding environment.
- Refine and make accessible model quality criteria.

Limitations

- Search limited to 10 years; excludes older studies
- Excluded studies without explicit reference to cancer (e.g., physical activity, nutrition)
- Quality assessment was limited to information provided in papers, which was shaped by journal
- Development of quality assessment criteria was limited by the diversity of model purposes, types, and applications

Main takeaways

- System dynamics models are well suited to address cancer prevention and control, but are hampered by lack of rigor and transparency.
- Supportive infrastructure for increasing awareness and accessibility of system dynamics for cancer researchers and further development of best practices are needed.

Thank you!

Contact: Erin Kenzie, kenzie@ohsu.edu

Scan the QR code below to view the full paper:

ORPRN
Oregon Rural Practice-Based Research Network

OHSU