ABM for **Circular Economy** incorporating **Bounded-rationality**

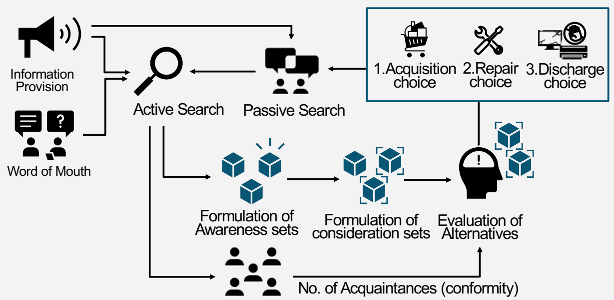
Objectives

- Simulating the **diffusion of circular economy** considering bounded rationality, social influences, and heterogeneity
- Prospective assessments of **sustainability impacts and circularity**
- Supporting policymakers and service providers to identify effective policies
- Applicable to **7 types of circular economy strategies** (sharing, reuse, etc.) for **consumer durables** (appliances, clothes, etc.)

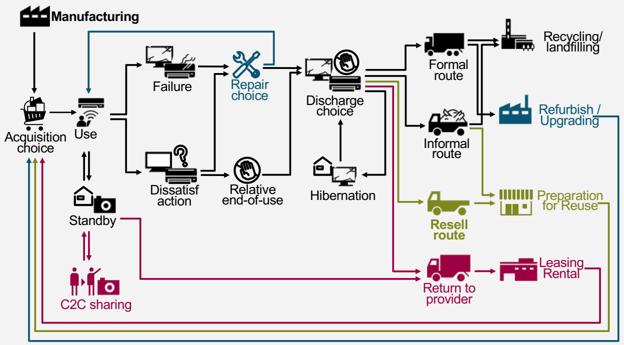
Theories

- Consideration set formulation (Roberts & Lattin 1991)
- Active and passive search (Wilson 1997)
- Social influence: conformity (Cialdini & Goldstein 2004)
- Absolute and relative product obsolescence (Cooper 2004)
- ABM with Life cycle Assessment and Material Flow Analysis (Micolier et al. 2019; Walzberg et al. 2021)

Consumer decision-making submodel for 3 choices in circular economy

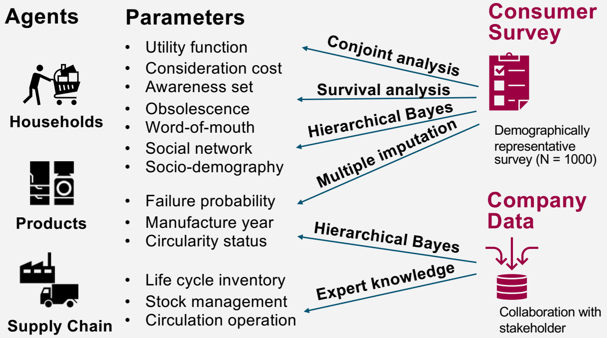


Product circulation submodel to simulate 7 circular economy strategies



Survey-based parameter setting with **Choice Experiment**

Empirically-grounded ABM with a demographically representative survey



Choice-based conjoint analysis with consideration set model (Roberts & Lattin 1991) to estimate utilities and consideration threshold

Probability of choosing alternative i

$$P_h(i) = \sum_{C \in A} P_h(i|C) P_h(C|A)$$

$$P_h(i|C) = \frac{exp(W_{i,h})}{\sum_{j \in C} exp(W_{j,h})}$$

$$W_{j,h} = \sum_{k=1}^{K} \beta_{k,h} x_{j,k}$$

Threshold to include i into choice set C

$$EU(C \cup i) - EU(C) > c_i$$

Case study: Reuse, Refurbishment, Subscription

Choice task example

	Brand-new	Refurbish	Reuse	Subscription
Price	164,800JPY	49,800JPY	49,800JPY	1,580 JPY/mon
Manufacture year	Latest	8 years	4 years	8 years (refurbished)
Free-repair warranty	1 year	Initial failure only	5 years	Free during use period
Appearance	—	As brand-new	With scratches	As brand-new

Partitioned survival model and proportional hazard model to estimate product lifetime due to failure and other social reasons

Failure probability of component i

$$h_{i,k}^{fail}(y_i) = \frac{\gamma_{fail}}{\lambda_{i,k}^{fail}} \left(\frac{y_i}{\lambda_{i,k}^{fail}}\right)^{\gamma_{fail}-1}$$

$$P_{j,k}^{troub} = \sum_{i=1}^{n} \left(\beta_{i,j} \times h_{i,k}^{fail}(y_i)\right)$$

Obsolescence probability by household h

$$h_h^{rel}(y_p) = \frac{\gamma_{rel}}{\lambda_h^{rel}} \left(\frac{y_p}{\lambda_h^{rel}}\right)^{\gamma_{rel}-1}$$

$$\lambda_h^{rel} = exp(\boldsymbol{Z_h \beta})$$

Social distance attachment (SDA) model (Talaga & Nowak 2020) for degree-calibrated social network generation reflecting homophily

Distance between household i and j

$$d_{ij} = \sqrt{\sum_m (x_{i,m} - x_{j,m})^2}$$

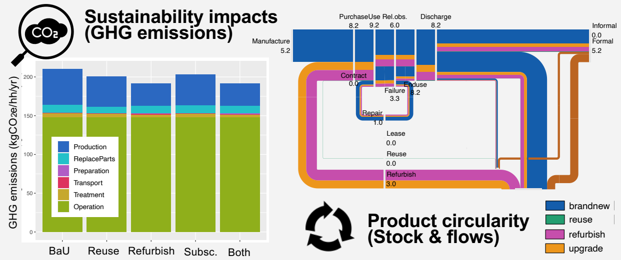
Probability of linking household i and j

$$p_{ij} = \frac{1}{1 + \left(\frac{d_{ij}}{b}\right)^{\alpha}}$$

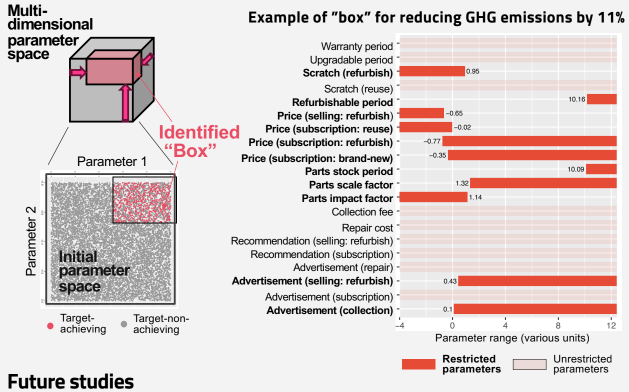
References Roberts, J. H. et al. 1991. *J. Mark. Res.*, 28 (4), 429–440; Wilson, T.D. 1997. *Inf. Process. Manag.* 33, 551–572; Cialdini, R.B. et al. 2004. *Annu. Rev. Psychol.* 55, 591–621; Cooper, T., 2004. *J Consum. Policy* 27, 421–449; Micolier, A. et al. 2019. *J. Clean. Prod.* 239, 118123; Walzberg, J. et al, 2021. *Front. Sustain.* 1, 620047; Talaga, S. et al. 2020. *JASSS*, 23, 6; Bryant, B. P. et al. 2010. *Technol. Forecast. Soc. Change*, 77(1), 34–49.

Scenario Discovery to explore policies for sustainability target

ABM outputs: product-service **diffusion and sustainability indicators**



Scenario discovery (Bryant & Lempert 2010) for exploring **target-achieving policies**



Future studies

- Applying **synesthetic population** to increase the number of agents
- Exporting **consumer-segment-wise** outcome indicators (e.g., identifying environmentally (dis)friendly segments)
- Distinguishing **uncertainty parameters** and policy levers (e.g., scenario discovery to identify risks of rebound effects)
- **Dynamic changes in parameters** (e.g., utilities, energy efficiency)
- Participatory simulation and toolkit development for stakeholders

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Empirically-grounded agent-based simulation of circular economy: Exploring scenarios towards sustainability

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