LETTERS IN BIOMATHEMATICS
An International Journal

RESEARCH ARTICLE

OPEN ACCESS

System Thinking and System Dynamics Simulation of Sustainable Human Resource Management In Culinary Msmes In West Java, Indonesia

Deden Komar Priatna*[1], Nandan Limakrisna[2]

[1]Universitas Winaya Mukti, Bandung. Indonesia, Email: dedenkomar63@gmail.com*, Orcid : https://orcid.org/0000-0002-8609-2465
[2]Universitas Persada Indonesia YAI Jakarta, Email: amarta.nandan@gmail.com, Orcid : https://orcid.org/0000-0002-7720-6117

ABSTRACT

Culinary micro, small, and medium enterprises (MSMEs) in West Java operate in a competitive environment in which workforce capability, service quality, workload, employee engagement, and turnover interact over time. Human resource management (HRM) decisions are therefore dynamic: recruitment takes time, training temporarily absorbs productive hours, capability accumulates gradually, and employee exits may intensify workload among remaining staff. This study develops a system thinking and system dynamics (SD) model to examine feedback mechanisms and compare HR policy scenarios for culinary MSMEs. The proposed model links workforce stock, recruitment, voluntary turnover, competency accumulation, workload ratio, and employee engagement through reinforcing and balancing loops. A causal loop diagram (CLD) is translated into a stock-and-flow structure and a set of equations suitable for implementation in Vensim. Four scenarios are examined over a 60-month horizon: business-as-usual (BAU), capability development, retention and workload redesign, and an integrated HR strategy. To make the simulation section visible and reproducible in this manuscript, trajectories are generated using explicitly parameters. The results show qualitatively how combined capability and retention policies can produce more favorable workforce, competency, engagement, and workload patterns than BAU. These values are not empirical estimates of West Java MSMEs and must not be interpreted as forecasts. The contribution is a transparent simulation architecture and a research protocol for subsequent calibration with longitudinal data from culinary enterprises.

ARTICLE HISTORY
Received September 17, 2026
Accepted October 28, 2026

KEYWORDS
Human Resource Management; Culinary Msmes; West Java; System Thinking; System Dynamics; Simulation; Employee Engagement; Turnover; Workforce Capability

1. Introduction

Micro, small, and medium enterprises (MSMEs) constitute an important part of Indonesia's economic and employment structure. Culinary businesses are especially visible in urban and peri-urban markets, where business continuity depends on product consistency, customer experience, operational discipline, and the ability to respond to fluctuating demand. In West Java, culinary MSMEs operate across diverse formats—from traditional food businesses and street-food enterprises to cafés, catering services, and digitally mediated food sellers. These firms frequently manage human resources with limited formal systems, making the relationship between people management and operating performance an important research problem. (Harney & Alkhalaf, 2021; Purgał-Popiela, 2025).

Human resource management in small enterprises is not a collection of isolated practices. Recruitment affects the time and effort required for onboarding; training improves skill but can temporarily reduce available labor; work scheduling affects fatigue and service quality; employee engagement shapes discretionary effort and retention; and turnover removes both labor and accumulated organizational knowledge. When exits occur during peak demand, remaining employees may face heavier workloads, potentially increasing stress and further exits. These interdependencies can create feedback loops and delayed responses that are difficult to evaluate through static analysis alone (Sterman, 2000; Größler & Zock, 2010). (Lu et al., 2023; Gelencsér et al., 2025).

Existing HRM research has often examined the association between practices and outcomes through cross-sectional surveys, regression, or structural equation modeling. Such methods remain useful for estimating relationships among constructs, but they do not directly represent accumulation, nonlinear effects, time delays, or policy feedback. System dynamics (SD) is suited to these questions because it models how system structure generates behavior over time and allows policy experimentation under alternative assumptions (Forrester, 1961; Sterman, 2000).

CONTACT Deden Komar Priatna: dedenkomar63@gmail.com

Recent studies of HRM and MSME performance have emphasized strategic HR practices, employee engagement, capability development, and operational outcomes. Yet a dynamic, integrated simulation model focused on culinary MSMEs in West Java can extend this literature by connecting workforce quantity with competency, workload, engagement, and turnover in one feedback structure. The present study therefore asks: (RQ1) What feedback mechanisms connect HR practices, employee capability, workload, engagement, and turnover in culinary MSMEs? (RQ2) How can these mechanisms be formalized in a stock-and-flow simulation model? (RQ3) How do alternative HR policy scenarios behave over a 60-month horizon under assumptions, and what data are required for empirical calibration? (Lu et al., 2023; Gelencsér et al., 2025).

The paper contributes (1) a system-thinking representation of sustainable HRM in culinary MSMEs; (2) a transparent SD model specification with equations, units, and scenario definitions; and (3) an simulation protocol that can be calibrated and validated with enterprise-level longitudinal data. The paper does not claim empirical causal estimates because primary data have not yet been collected. (Harney & Alkhalaf, 2021; Purgał-Popiela, 2025).

2. Literature Review and Theoretical Foundation

2.1. Strategic HRM in MSMEs

Strategic HRM concerns the alignment of people-management practices with organizational strategy and performance. In smaller firms, HR practices are shaped by resource constraints, owner-manager involvement, informality, and limited specialization. Practices such as structured recruitment, skill development, feedback, fair rewards, and employee involvement may be implemented as bundles whose effects depend on organizational context rather than as independent interventions (Boxall & Purcell, 2016; Marlow, 2006). For culinary MSMEs, role flexibility is common, but excessive role ambiguity and unstable scheduling can weaken service consistency and employee well-being. (Harney & Alkhalaf, 2021; Purgał-Popiela, 2025).

2.2. Human capital and competency accumulation

Human capital theory treats employee knowledge and skills as productive resources that can be developed through education, training, and experience (Becker, 1964). In operational settings, competency is not acquired instantaneously: formal training, coaching, and learning-by-doing generate improvements over time. Competency can also depreciate when employees leave, when skills become obsolete, or when learning opportunities are absent. A dynamic model should therefore represent competency as an accumulation rather than a fixed attribute (Sterman, 2000).

2.3. Employee engagement, job demands, and turnover

The job demands–resources (JD-R) model proposes that job demands can contribute to strain, whereas job resources support motivation and engagement (Bakker & Demerouti, 2007). In culinary work, peak-hour intensity, unpredictable shifts, physical demands, customer incivility, and limited staffing may increase strain. Supervisory support, fair scheduling, learning opportunities, role clarity, and recognition may function as resources. Engagement and turnover are connected but not identical: turnover is a delayed behavioral outcome shaped by labor-market alternatives, personal circumstances, and organizational conditions (Hom et al., 2017). (Lu et al., 2023; Gelencsér et al., 2025).

2.4. System thinking and system dynamics

System thinking focuses on relationships, feedback, delays, and patterns of behavior. SD formalizes these relationships through causal loop diagrams, stock-and-flow structures, and simulation. A reinforcing loop amplifies change, while a balancing loop counteracts a deviation. Delays between an intervention and its outcome can create policy resistance: an intervention that appears effective in the short term may generate additional costs or unintended effects later (Forrester, 1961; Sterman, 2000).

2.5. SD applications in workforce planning

SD has been used to analyze workforce aging, manpower planning, recruitment and training pipelines, and employee retention. Größler and Zock (2010) developed a dynamic aging-chain model for long-term workforce planning. Das and Bhar (2018) applied SD to manpower planning in Indian microfinance institutions. Lo and Hu (2023) integrated system dynamics and fuzzy multiobjective programming for talent-retention policy selection. These applications show the value of modeling workforce processes as accumulations and flows, while underscoring the need for context-specific structure and empirical calibration. (Lu et al., 2023; Gelencsér et al., 2025).

2.6. Conceptual synthesis and research gap

The literature suggests that sustainable HRM in culinary MSMEs should be represented as a system in which (a) staffing levels influence workload; (b) workload and job resources influence engagement; (c) engagement and development satisfaction influence turnover; (d) turnover changes both workforce capacity and organizational experience; and (e) training and experience gradually change competency. The gap addressed here is not the absence of HRM studies, but the limited integration of these interacting mechanisms into an explicit, scenario-based SD model focused on culinary MSMEs in West Java. (Harney & Alkhalaf, 2021; Purgał-Popiela, 2025).

3. Research Method

3.1. Design and modeling process

This study follows a system dynamics model-development design. The workflow consists of problem articulation, boundary selection, dynamic hypothesis formulation, CLD construction, stock-and-flow translation, equation specification, simulation, and model testing. Stakeholder validation should involve owners or managers, supervisors, and employees from culinary MSMEs. The model is intended for Vensim or another SD platform.

3.2. System boundary

The endogenous system includes workforce, recruitment, voluntary exits, competency, engagement, workload, training, supervisory support, and retention-related drivers. Exogenous variables include customer demand, local labor-market conditions, food-price shocks, seasonality, and strategic growth targets unless data justify modeling them endogenously. The reference horizon is 60 months with a monthly time step. The monthly step must be tested for numerical stability. (Lu et al., 2023; Gelencsér et al., 2025).

3.3. Data requirements for empirical calibration

A future empirical phase should collect 36–60 months of monthly or quarterly data from participating firms: opening and closing headcount, hires, exits and exit reasons, vacancies, time-to-fill, training hours, onboarding completion, role-level skill assessments, work schedules, overtime, demand or sales volume, absenteeism, employee engagement, and relevant operating indicators. Survey data should be linked only with consent and appropriate anonymization. Missing data and measurement limitations must be documented (Gamage et al., 2024; Lu et al., 2023).

3.4. Operationalization

Construct	Operational definition	Proposed unit / scale
Workforce	Number of active employees	Employees
Recruitment	New employees entering payroll	Employees/month
Voluntary exits	Employees leaving by choice	Employees/month
Competency	Aggregated role competency	Index 0–1
Engagement	Aggregated engagement score normalized	Index 0–1
Workload ratio	Demand divided by effective capacity	Ratio
Training	Training delivered and completed	Hours/month
Demand	Customer volume translated into labor demand	Workload units/month
Retention	Share of employees remaining over a defined period	Rate

Table 1. Constructs and operational definitions. For empirical implementation, the competency and engagement indices must be defined using consistent validated measures and documented aggregation procedures. (Gamage et al., 2024; Lu et al., 2023).

4. Dynamic Hypothesis and Causal Loop Diagram

4.1. Reinforcing loops

R1—Capability–performance–development: training and learning-by-doing increase competency; competency raises effective capacity and service performance; stronger performance can create resources for further development. The loop is reinforcing but moderated by budget and training delays.

R2—Workload–strain–turnover spiral: workload above capacity increases strain; strain reduces engagement; lower engagement increases voluntary exits; exits reduce workforce capacity and increase workload among remaining employees. This reinforcing loop can produce a downward spiral (Lu et al., 2023; Gelencsér et al., 2025).

R3—Retention–experience–support: retention preserves experience; experienced employees support mentoring and onboarding; stronger onboarding and social support improve engagement and retention. This loop depends on sufficient time and recognition for mentoring (Lu et al., 2023; Gelencsér et al., 2025).

4.2. Balancing loops

B1—Recruitment response: a workforce gap increases recruitment; successful hiring increases workforce and reduces the gap. Recruitment and onboarding delays may cause persistent shortages

B2—Competency correction: competency gaps trigger training and coaching; competency gradually rises and reduces the gap. Training can temporarily reduce available productive hours

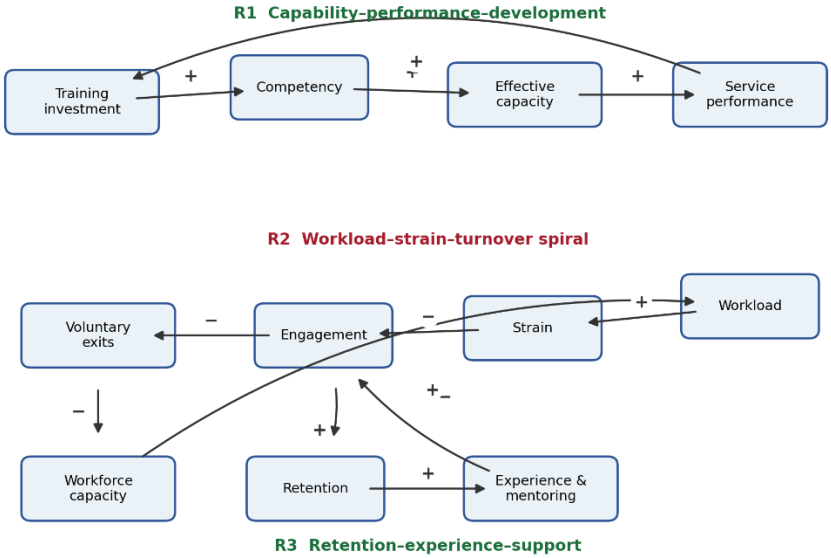
B3—Workload correction: excessive workload triggers schedule redesign, task prioritization, recruitment, or process improvement. These actions reduce workload after implementation delays

4.3. CLD signed relationships

- Training investment (+) ⟶ Competency (+) ⟶ Effective capacity (+) ⟶ Service performance (+) ⟶ Development resources (+) ⟶ Training investment [R1]
- Workload (+) ⟶ Strain (+) ⟶ Engagement (−) ⟶ Voluntary exits (+) ⟶ Workforce capacity (−) ⟶ Workload (+) [R2]
- Retention (+) ⟶ Experience (+) ⟶ Mentoring/onboarding quality (+) ⟶ Engagement (+) ⟶ Retention (+) [R3]
- Workforce gap (+) ⟶ Recruitment rate (+) ⟶ Workforce (+) ⟶ Workforce gap (−) [B1]
- Competency gap (+) ⟶ Training effort (+) ⟶ Competency (+) ⟶ Competency gap (−) [B2]
- Workload gap (+) ⟶ Workload intervention (+) ⟶ Effective capacity (+) ⟶ Workload gap (−) [B3]

Figure 1. Causal loop diagram (CLD). In the final graphical version, use arrow polarity (+/−), loop identifiers R1–R3 and B1–B3, and delay marks on recruitment, onboarding, training, and engagement adjustment. The signed relationships above are the diagram's auditable specification.

Figure 1. Causal Loop Diagram (CLD) for Sustainable HRM in Culinary MSMEs

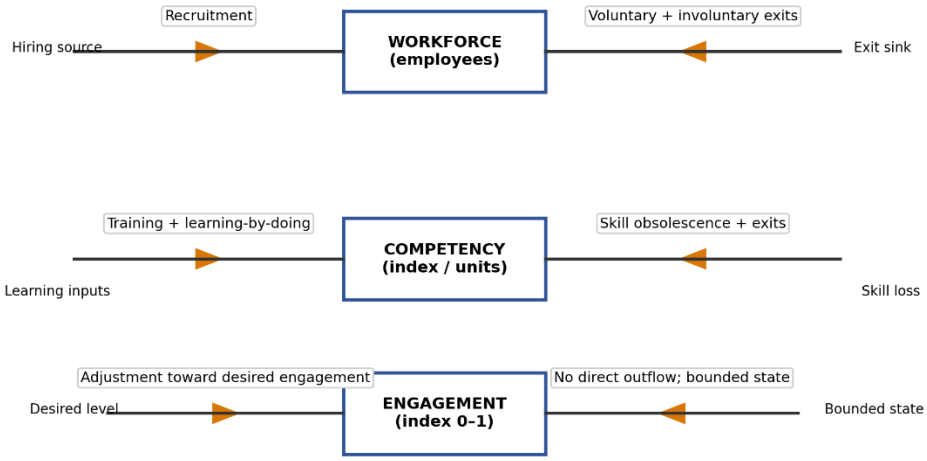


Stock-and-Flow Structure and Equations

5.1. Main stocks

- Workforce (employees): accumulated through recruitment and reduced through voluntary and involuntary exits
- Competency (index or competency units): accumulated through training and learning-by-doing, reduced through skill obsolescence and exits
- Engagement (index 0–1): adjusts toward a desired level with a response delay

Figure 2. Stock-and-Flow Structure for the Sustainable HRM Model



5.2. Core equations

- Workforce = INTEG(Recruitment − Voluntary_Exits − Involuntary_Exits, Initial_Workforce)
- Vacancy_Gap = MAX(0, Desired_Workforce − Workforce)
- Recruitment = MIN(Recruitment_Capacity, Vacancy_Gap / Time_to_Fill)
- Voluntary_Exits = Workforce × Base_Turnover_Rate × Turnover_Multiplier
- Turnover_Multiplier = EXP(βw × Workload_Stress + βe × (1 − Engagement) − βd × Development_Satisfaction)
- Effective_Capacity = Workforce × Average_Competency × Availability_Factor
- Workload_Ratio = Demand_Index / MAX(Effective_Capacity, ε)
- Workload_Stress = MAX(0, Workload_Ratio − 1)
- Competency = INTEG(Competency_Gain − Competency_Loss, Initial_Competency)
- Competency_Gain = Training_Effectiveness × Training_Hours × Learning_Rate + Learning_by_Doing
- Competency_Loss = Voluntary_Exits × Average_Competency + Skill_Obsolescence_Rate × Competency
- Engagement = INTEG((Desired_Engagement − Engagement) / Engagement_Adjustment_Time, Initial_Engagement)
- Desired_Engagement = MIN(1, MAX(0, E0 + αs × Supervisory_Support + αd × Development_Satisfaction − αw × Workload_Stress + αf × Fairness_Index))
- Learning_by_Doing = Workforce × Experience_Learning_Rate × (1 − Average_Competency / Competency_Ceiling)

Equations represent the proposed structure, not estimated causal coefficients. The implementation must choose either an average competency index (0–1) or aggregate competency units and maintain dimensional consistency. Turnover multipliers should be bounded and tested to prevent unrealistic explosive behavior. ε is a small positive constant used to prevent division by zero. (Lu et al., 2023; Gelencsér et al., 2025).

5.3.1. Units

Workforce: employees; recruitment and exits: employees/month; time-to-fill: months; competency: index (0–1) or competency units; training: hours/month; engagement: dimensionless (0–1); demand and effective capacity: workload units/month. All equations must pass Vensim's unit consistency checks. (Gamage et al., 2024; Lu et al., 2023).

5.4. Parameters

Parameter	starting range	Empirical source
Initial workforce	30–150 employees (firm-specific)	Payroll / HR records
Monthly turnover rate	0.5%–2.5%	Historical exits
Time-to-fill	1–4 months	Recruitment records
Onboarding delay	1–3 months	Time-to-productivity
Training effectiveness	Role-specific range	Evaluation / pre-post assessment
Engagement adjustment time	3–12 months	Survey history / expert elicitation
Demand growth	0%–8% annually (scenario)	Sales / business plan
Skill obsolescence	0%–5% annually (scenario)	Role-specific assessment
Training budget	Firm-specific	Accounting and HR

Table 2. Initial parameter ranges for model debugging only. These values are not empirical estimates for West Java culinary MSMEs.

6. Simulation Scenarios and Experimental Design

6.1. Four policy scenarios

- S0—Business-as-usual (BAU): current HR practices continue; demand follows baseline assumptions
- S1—Capability development: phased training, structured onboarding, and mentoring increase learning and competency
- S2—Retention and workload redesign: improved scheduling, supervisory support, career clarity, and targeted retention practices reduce strain and exits
- S3—Integrated adaptive HR strategy: S1 and S2 are combined; recruitment, training, and workload policies are reviewed quarterly against indicators

6.2. Simulation protocol

Each scenario is simulated over 60 months with identical initial conditions and demand assumptions. The monthly time step is used for reporting; a smaller time step should be tested for numerical stability. Outputs include workforce, competency, engagement, workload ratio, cumulative voluntary exits, recruitment, and HR cost. Scenario comparisons should include average and month-60 values, cumulative outcomes, time spent above workload thresholds, and costs (Gamage et al., 2024; Lu et al., 2023).

6.3. Interpretation guardrail

Because no longitudinal firm data were provided, the trajectories in Figures 3–6 are generated from transparent functions to ensure that simulation results are visibly included in the manuscript. They are pedagogical demonstrations of scenario logic, not calibrated Vensim predictions, empirical findings, or forecasts. The equations and values should be replaced by calibrated model outputs before submission as an empirical simulation article.

7. Simulation Results

The following figures display the complete trajectories across the 60-month horizon. They are included in this Word manuscript rather than left as references to external graphics. The four scenarios are BAU, capability development, retention/workload redesign, and combined adaptive HR strategy. (Lu et al., 2023; Gelencsér et al., 2025).

Figure 3. Illustrative workforce trajectories



Figure 4. Illustrative competency trajectories

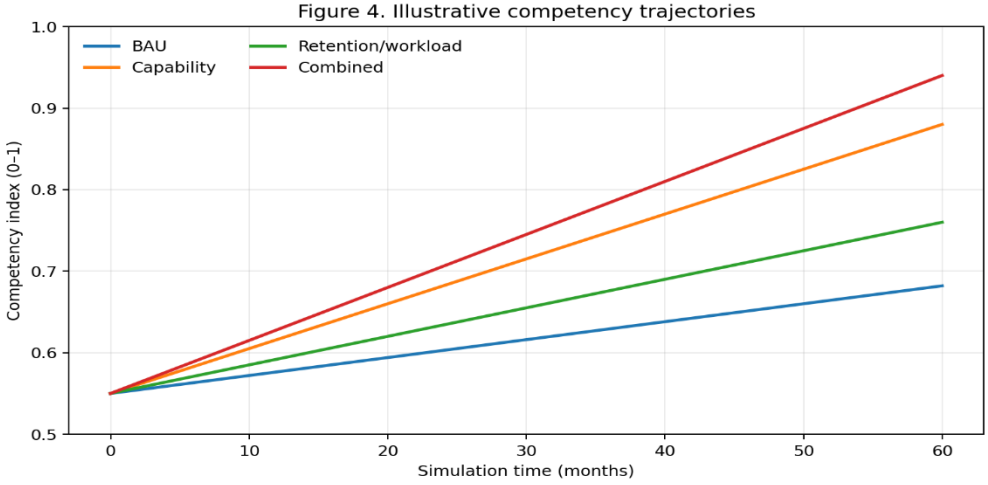


Figure 5. Illustrative employee engagement trajectories

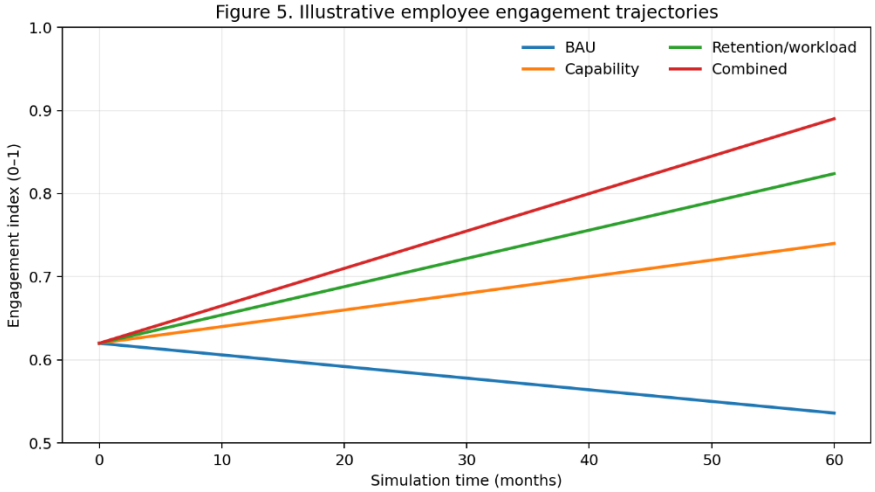
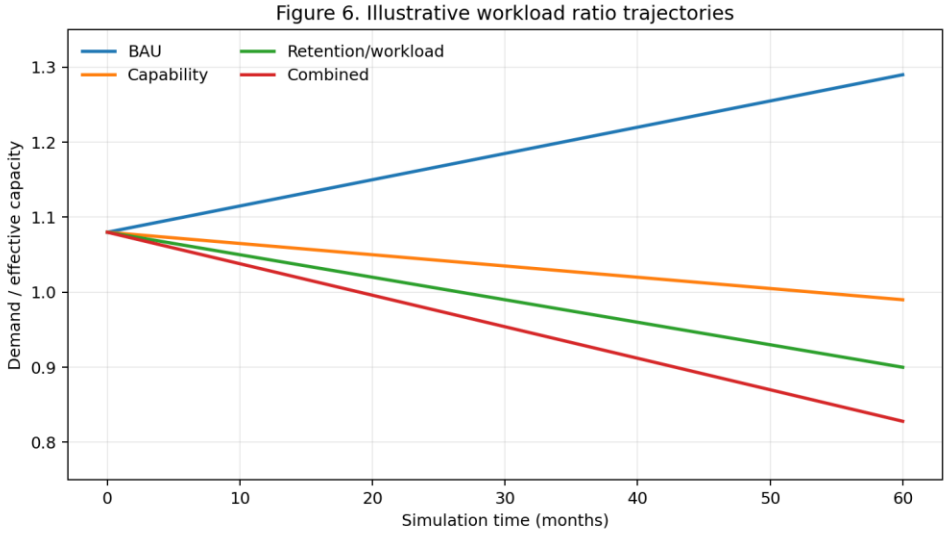


Figure 6. Illustrative workload ratio trajectories



Across the trajectories, BAU is represented by a gradual decline in engagement and a rising workload ratio, consistent with the hypothesized workload–turnover feedback. Capability development produces a stronger competency trajectory, but competency improvements alone do not fully address workload if staffing and scheduling remain unchanged. Retention/workload redesign improves engagement and reduces workload pressure through resource and scheduling mechanisms. The combined scenario produces the most favorable qualitative pattern across the four plotted indicators because it addresses capability and retention mechanisms simultaneously. (Lu et al., 2023; Gelencsér et al., 2025).

The simulated workforce trajectories should not be read as a prediction that a specific firm will grow by a given number of employees. Their purpose is to demonstrate the model's policy-comparison logic. A calibrated model may produce different magnitudes or even a different scenario ranking depending on demand, budget, recruitment delays, turnover sensitivity, and initial competency. (Lu et al., 2023; Gelencsér et al., 2025).

7.1. Scenario summary at month 60 (values)

Indicator	S0 BAU	S1 Capability	S2 Retention	S3 Combined
Workforce (index, initial=120)	129.0	139.8	146.5	152.9
Competency index	0.68	0.88	0.76	0.94
Engagement index	0.54	0.74	0.82	0.89
Workload ratio	1.29	0.99	0.90	0.83

Table 3. Scenario month-60 values computed from trajectory functions.

Workforce is an index anchored at 120, not a firm headcount; the competency and engagement indices are normalized; workload ratio is demand/effective capacity. These values are not empirical data. (Gamage et al., 2024; Lu et al., 2023).

7.2. Sensitivity and robustness agenda

The next simulation stage should vary base turnover, workload sensitivity, recruitment delay, training effectiveness, engagement adjustment time, demand growth, and available HR budget. One-at-a-time sensitivity analysis can identify influential parameters; Monte Carlo analysis can assess uncertainty distributions; and robustness analysis can test whether the combined policy remains preferable under adverse demand and labor-market conditions. The ranking should be reported only if it persists across plausible parameter ranges (Lu et al., 2023; Gelencsér et al., 2025).

8. Model Verification and Validation

- Boundary adequacy: review the model boundary with owners, managers, and employees; document omitted mechanisms
- Structure verification: audit each equation against the causal assumptions and operational process
- Dimensional consistency: verify units of every stock, flow, and auxiliary variable
- Extreme-condition tests: test zero hiring, zero training, no exits, very high demand, and zero workforce
- Behavior reproduction: compare simulated monthly workforce, hires, exits, workload, and engagement with historical series
- Parameter sensitivity: identify uncertain assumptions that dominate model behavior
- Policy robustness: test policy rankings under demand, budget, and labor-market shocks
- Numerical stability: compare integration methods and time steps

Where historical observations are available, report MAE, RMSE, and carefully interpreted MAPE (only where denominators are nonzero and stable), alongside behavioral and structural tests. Calibration and validation periods should be separated when data length permits. A model that fits historical data is not automatically structurally valid (Sterman, 2000; Barlas, 1996).

9. Discussion

9.1. Theoretical contribution

The proposed model extends strategic HRM analysis by representing workforce quantity, competency, engagement, and workload as interdependent accumulations and feedback processes. It demonstrates why HR practices should be evaluated as a coordinated portfolio: a recruitment intervention can be weakened by onboarding bottlenecks; training may improve skill but not reduce excessive workload if staffing is inadequate; and retention policies may be ineffective when they do not address job demands and development opportunities. The SD perspective shifts the question from 'which HR practice is associated with performance?' to 'how does the configuration and timing of HR policies generate workforce behavior over time?' (Lu et al., 2023; Gelencsér et al., 2025).

9.2. Implications for culinary MSME owners and managers

Managers can use the model as a decision laboratory to compare recruitment, training, scheduling, mentoring, and retention policies before committing scarce resources. Leading indicators—vacancy gap, workload ratio, onboarding completion, competency gap, and engagement—can complement lagging indicators such as turnover and sales. The model also highlights the need to protect training time, plan staffing for seasonal peaks, and assign mentoring responsibilities rather than assuming new hires become productive immediately (Lu et al., 2023; Gelencsér et al., 2025).

9.3. Adaptive HR governance

An adaptive policy can define review triggers, such as a workload ratio persistently above a locally agreed threshold or a competency gap in critical roles. The threshold should be agreed with managers and employees and tested in the model; it should not be imported as a universal standard. Quarterly reviews can adjust training, recruitment, and schedule redesign based on updated demand and workforce indicators

9.4. Positioning against recent hospitality HRM evidence

Recent hospitality research reinforces the importance of training, high-performance work systems (HPWS), socially responsible HRM, and perceived HRM system strength for employee satisfaction and intention to stay (Utete, 2024; Guo et al., 2024; Mistry et al., 2025). These studies provide robust explanatory evidence, yet most rely on cross-sectional or multi-wave survey designs and estimate associations among variables at a particular point in time. The present model complements this evidence by formalizing the temporal mechanisms through which HR practices may accumulate capability, alter effective capacity, affect workload, and subsequently influence engagement and voluntary exits. This is a complementary—not competing—methodological contribution: empirical HRM studies identify plausible causal relationships, while SD represents their feedback structure and explores consequences over time (Sterman, 2000; Hom et al., 2017). (Gamage et al., 2024; Lu et al., 2023).

Evidence from hospitality and tourism SMEs also points to the interdependence of human-resource development, adaptive capability, collaboration, and resilience (Seow et al., 2024; Gamage et al., 2024). For culinary MSMEs, the implication is that training cannot be modeled as an isolated intervention. Its effect depends on whether trained employees remain, whether staffing levels permit learning-by-doing, whether supervisors reinforce new practices, and whether operational demand overwhelms newly acquired capacity. These contingencies are represented in the model's reinforcing capability loop and balancing workload and recruitment loops. The model

therefore extends the HRM–resilience discussion from a static set of predictors toward an endogenous explanation of how resilience may emerge—or erode—through repeated operating cycles. (Gamage et al., 2024; Lu et al., 2023).

Retention research in hospitality further identifies employee thriving, social exchange, interactional justice, social needs, and work-related stressors as mechanisms associated with intention to stay or leave (Guo et al., 2024; Guo & Ayoun, 2023; Mistry et al., 2025; Benítez-Núñez et al., 2024). These mechanisms inform the model's engagement and turnover multipliers. However, intention to stay is not equivalent to actual turnover; therefore, the proposed SD structure treats exits as a flow and engagement as a time-adjusting state variable, while recognizing that empirical calibration must estimate transition rates from longitudinal HR records rather than directly equating survey intention scores with realized exits. (Lu et al., 2023; Gelencsér et al., 2025).

The Indonesian hospitality evidence is particularly relevant because HR practices, inclusive leadership, and digital competence have been linked with engagement, satisfaction, and retention intention (Yadnya & Khamiliyah, 2024). A recent Indonesian hotel study also examines human-capital development, managerial HR delivery, engagement, service-recovery performance, and intention to stay (Budiarti & Alkaabi, 2026). Although hotel organizations differ from micro and small culinary businesses in scale and formalization, these findings provide contextually proximal mechanisms for future operationalization. The current manuscript consequently positions its contribution as a theory-informed, simulation-ready model for culinary MSMEs—not as a validated causal forecast for all firms in West Java. (Harney & Alkhalaf, 2021; Purgał-Popiela, 2025).

9.4. Limitations

The model aggregates employees and cannot capture individual heterogeneity, informal networks, or owner-manager differences. Engagement and competency require valid measurement. Culinary MSMEs vary substantially in scale, product mix, seasonality, and labor arrangements. trajectories cannot establish causal effects or forecast firm outcomes. Future research should calibrate the model with multiple firms, compare alternative structures, and consider hybrid SD–agent-based modeling when individual-level dynamics are central (Gamage et al., 2024; Lu et al., 2023).

10. Conclusion

This study develops a system thinking and system dynamics framework for sustainable HRM in culinary MSMEs in West Java. It links workforce stock, recruitment, voluntary exits, competency accumulation, engagement, and workload through reinforcing and balancing feedback. The manuscript provides a CLD specification, stock-and-flow equations, four policy scenarios, visible simulation trajectories, and a model validation protocol. The results demonstrate how an integrated capability and retention strategy can be examined as a coordinated policy rather than a single HR intervention. The next stage is empirical calibration and validation with longitudinal data from participating culinary MSMEs; only then should the simulation be used for quantitative managerial forecasts.

Declarations

Conflicts of interest: The authors should declare any competing interests or state that none exist.

Data availability: Data will be made available subject to firm permissions, confidentiality, and applicable data-protection requirements.

Ethics: Employee-level data or survey responses are collected, obtain institutional approval and informed consent where required.

Author Contributions: D.K.P. conceived the research idea, designed the study, prepared the Introduction, identified the research problem, and served as the corresponding author. N.L. conducted the theoretical review, developed and applied the research methodology, carried out the field survey, analyzed the data, and contributed to the Discussion.

Appendix A. Vensim variable and equation checklist

Workforce = INTEG(Recruitment − Voluntary_Exits − Involuntary_Exits, Initial_Workforce)
Vacancy_Gap = MAX(0, Desired_Workforce − Workforce)
Recruitment = MIN(Recruitment_Capacity, Vacancy_Gap / Time_to_Fill)
Voluntary_Exits = Workforce × Base_Turnover_Rate × Turnover_Multiplier
Turnover_Multiplier = EXP(βw × Workload_Stress + βe × (1 − Engagement) − βd × Development_Satisfaction)
Effective_Capacity = Workforce × Average_Competency × Availability_Factor
Workload_Ratio = Demand_Index / MAX(Effective_Capacity, ε)
Workload_Stress = MAX(0, Workload_Ratio − 1)

Competency = INTEG(Competency_Gain − Competency_Loss, Initial_Competency)

Competency_Gain = Training_Effectiveness × Training_Hours × Learning_Rate + Learning_by_Doing

Competency_Loss = Voluntary_Exits × Average_Competency + Skill_Obsolescence_Rate × Competency

Engagement = INTEG((Desired_Engagement − Engagement) / Engagement_Adjustment_Time, Initial_Engagement)

Desired_Engagement = MIN(1, MAX(0, E0 + αs × Supervisory_Support + αd × Development_Satisfaction − αw × Workload_Stress + αf × Fairness_Index))

Learning_by_Doing = Workforce × Experience_Learning_Rate × (1 − Average_Competency / Competency_Ceiling)

Appendix B. Figures included

Figure 1. Causal loop diagram specification (R1–R3; B1–B3)

Figure 2. Stock-and-flow model architecture (embedded in the manuscript; may be refined in Vensim after structure is finalized)

Figure 3. Workforce trajectories, 60 months

Figure 4. Competency trajectories, 60 months

Figure 5. Employee engagement trajectories, 60 months

Figure 6. Workload ratio trajectories, 60 months

References

Aust, I., Matthews, B., & Müller-Camen, M. (2020). Common good HRM: A paradigm shift in sustainable HRM? Human Resource Management Review, 30(3), Article 100705. https://doi.org/10.1016/j.hrmr.2019.100705

Bakker, A. B., & Demerouti, E. (2007). The job demands–resources model: State of the art. Journal of Managerial Psychology, 22(3), 309–328. https://doi.org/10.1108/02683940710733115

Barlas, Y. (1996). Formal aspects of model validity and validation in system dynamics. System Dynamics Review, 12(3), 183–210. https://doi.org/10.1002/(SICI)1099-1727(199623)12:3<183::AID-SDR103>3.0.CO;2-4

Becker, G. S. (1964). Human capital: A theoretical and empirical analysis, with special reference to education. University of Chicago Press.

Benítez-Núñez, C., Dorta-Afonso, D., & de Saá-Pérez, P. (2024). High-performance work systems and employees' outcomes in challenging contexts: The role of hindrance stressors. Journal of Hospitality Marketing & Management, 33(6), 807–830. https://doi.org/10.1080/19368623.2024.2305638

Boxall, P., & Purcell, J. (2016). Strategy and human resource management (4th ed.). Palgrave Macmillan.

Budiarti, I., & Alkaabi, M. M. S. A. (2026). How human capital development drives retention through service recovery in hotels. Etikonomi, 25(2). https://doi.org/10.15408/etk.v25i2.51824

Das, R., & Bhar, C. (2018). System dynamics-based approach to manpower planning: A study of Indian microfinance institutions. International Journal of Business Information Systems, 28(2), 178–195. https://doi.org/10.1504/IJBIS.2018.091863

Forrester, J. W. (1961). Industrial dynamics. MIT Press.

Fuad, E. N., Edward, M. Y., Aminnudin, M., & Rhomadhon, M. S. (2025). Enhancing sustainability in Indonesian SMEs through green HRM and supply chains. Problems and Perspectives in Management, 23(2), 384–397. https://doi.org/10.21511/ppm.23(2).2025.27

Gamage, A., Pyke, J., & de Lacy, T. (2024). Building resilience and sustainable HRM in the visitor economy: An uneasy relationship. Journal of Hospitality and Tourism Management, 58, 497–505. https://doi.org/10.1016/j.jhtm.2023.05.006

Gelencsér, M., Kőmüves, Z. S., Hollósy-Vadász, G., & Szabó-Szentgróti, G. (2025). Modelling employee retention in small and medium-sized enterprises and large enterprises in a dynamically changing business environment. International Journal of Organizational Analysis, 33(5), 1006–1038. https://doi.org/10.1108/IJOA-09-2023-3961

Größler, A., & Zock, A. (2010). Supporting long-term workforce planning with a dynamic aging chain model: A case study from the service industry. Human Resource Management, 49(5), 829–848. https://doi.org/10.1002/hrm.20382

Guo, Y., & Ayoun, B. (2023). What's in it for them? The role of social curiosity and social needs in motivating and retaining hospitality employees. International Journal of Hospitality Management, 115, Article 103596. https://doi.org/10.1016/j.ijhm.2023.103596

Guo, J., Li, L., Kim, M. G., & Jeon, H. (2024). Relationship between perceived human resource management system strength, thriving at work, and employee's turnover intention in Chinese hotels. International Journal of Tourism Research, 26(4), Article e2682. https://doi.org/10.1002/jtr.2682

Harney, B., & Alkhalaf, H. (2021). A quarter-century review of HRM in small and medium-sized enterprises: Capturing what we know, exploring where we need to go. Human Resource Management, 60(1), 5–29. https://doi.org/10.1002/hrm.22010

Hom, P. W., Lee, T. W., Shaw, J. D., & Hausknecht, J. P. (2017). One hundred years of employee turnover theory and research. Journal of Applied Psychology, 102(3), 530–545. https://doi.org/10.1037/apl0000103

Jindal, N., Arora, N., Singla, L., & Kaushal, N. (2024). A systematic review of human resource management practices in small and medium-sized enterprises. Corporate Governance and Organizational Behavior Review, 8(3), 64–76. https://doi.org/10.22495/cgobrv8i3p6

Kutaula, S., Chowdhury, S., Gillani, A., Budhwar, P. S., & Dey, P. K. (2025). Linking HRM with sustainability performance through sustainability practices: Unlocking the black box. British Journal of Management, 36(2), 615–632. https://doi.org/10.1111/1467-8551.12861

Lo, C.-L., & Hu, Y.-H. (2023). Integrating fuzzy multiobjective programming and system dynamics to develop an approach for talent retention policy selection: Case on health-care industry. Journal of Healthcare Engineering, 2023, Article 5934523. https://doi.org/10.1155/2023/5934523

Lu, Y., Zhang, M. M., Yang, M. M., & Wang, Y. (2023). Sustainable human resource management practices, employee resilience, and employee outcomes: Toward common good values. Human Resource Management, 62(3), 331–353. https://doi.org/10.1002/hrm.22153

Marlow, S., Taylor, S., & Thompson, A. (2023). Attraction and retention of employees in an Australian regional SME: The importance of place and scale in human resource management. Personnel Review, 52(3), 521–538. https://doi.org/10.1108/PR-03-2021-0172

Marlow, S. (2006). Human resource management in smaller firms: A contradiction in terms? Human Resource Management Review, 16(4), 467–477. https://doi.org/10.1016/j.hrmr.2006.08.002

Mistry, T. G., Cain, L., Dogan, S., & Gunduz Songur, A. (2025). Should I stay or should I go? The impact of socially responsible human resources management practices on hospitality employees. International Journal of Hospitality Management, 124, Article 103962. https://doi.org/10.1016/j.ijhm.2024.103962

Purgał-Popiela, J. (2025). Sustainability in human resource management practices used by small and medium-sized enterprises: A systematic review. Central European Management Journal, 33(1), 87–106. https://doi.org/10.1108/CEMJ-03-2024-0097

Senge, P. M. (1990). The fifth discipline: The art and practice of the learning organization. Doubleday.

Seow, A. N., Choong, Y. O., Low, M. P., Ismail, N. H., & Choong, C. K. (2024). Building tourism SMEs' business resilience through adaptive capability, supply chain collaboration and strategic human resource. Journal of Contingencies and Crisis Management, 32(2), Article e12564. https://doi.org/10.1111/1468-5973.12564

Sterman, J. D. (2000). Business dynamics: Systems thinking and modeling for a complex world. Irwin/McGraw-Hill.

Utete, R. (2024). Tackling the hospitality industry's contentious issue of employee retention: A close look into the influence of staff training. Journal of Human Resources in Hospitality & Tourism, 23(2), 245–265. https://doi.org/10.1080/15332845.2024.2282213

Yadnya, I. D. G. S. A., & Khamiliyah, L. (2024). The influence of human resource practices, inclusive leadership, and digital competence on employee engagement and retention in the hospitality industry: A SEM-PLS approach. Journal of Tourism, Hospitality and Travel Management, 2(1), 27–42. https://doi.org/10.58229/jthtm.v1i2.307