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# Evaluating Engagement and Decision-Making in a Gamified VR Management Simulator

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ABSTRACT:*We evaluate Fisherman Manager VR, a Virtual Reality Serious Game game designed to train strategic-decision making and resource management in a coastal operations context. The system is presented only as an educational game but as a case study in simulation-based system engineering. We detail in its real-time architecture (Unreal Engine, HMD Integration), stochastic resource models and logging pipeline for decision analytics. A formative evaluation analyzes engagwment (playtime), user satisfaction, decision-making latency, and action success rate under a gamified design aligned with Flow Theory and Self-Determination Theory. Results indicate high engagement (3.4h cumulative per participant), high satisfaction (4.6/5 Likert), fast average decision speed (0.7s) and a high successful-action rate (91%). We highlight implications for engineering education, simulation design, and also Virtual Reality-based decision support environments.*

KEYWORDS:Index Terms – Virtual Reality, Serious Games, Gamification, Engagement, Decision-Making, Education, Resource Management, Systems Engineering.

**1) Introduction:**Gamified VR experiences can create immersive, feedback rich learning environments that support deliberate practice [1], [2]. Fisherman Manager VR combines progression, dynamic difficulty, and real- time feedback to train strategic decisions (e.g., route planning, fuel use, maintenance, timing of fishing, and selling strategies) while balancing profitability and sustainability. Our goals are to (i) quantify engagement and performance signals under this design, (ii) demonstrate a reproducible pipeline for system-level VR simulation, and (iii) surface design implications for VR-based engineering training. Prior studies have emphasized that VR-based training can improve presence, engagement, and transfer of knowledge [3], . Gamification, when aligned with psychological theories, has been shown to enhance intrinsic motivation and persistence in learning environments[4],[5]. Complementing this, systems engineering literature highlights the role of simulation idelity, latency, and stochastic modeling in operator training. Contributions. This paper offers: [6] an instrumented evaluation of a management-oriented VR simulator using theory aligned gamification; (2) expanded description of the technical architecture, stochastic models, and logging pipeline; (3) a transparent measurement protocol with task-agnostic metrics (engagement, satisfaction, decision speed, success rate) that can be reused across domains; and ( practical guidance for aligning mechanics with Flow and Self- determination Theory in engineering simulations.

## II. RELATED WORK

VR serious games have shown improvements in presence and training transfer across technical domains [7], [8]. Gamification elements mapped to motivational theories are associated with persistence and enjoyment [9],[10] . Prior research has suggested that VR-based simulators can promote reflection and experiential learning in complex operational tasks [11]. Parallel work in systems engineering has employed simulation-based training for power grid control, disaster response, and logistics. Our work extends this line by integrating an operations-style simulator with a compact, reproducible analytics layer that captures decision timing, system responsiveness, and action quality alongside subjective satisfaction. A. Comparative Analysis of Related VR Training Systems Recent work in engineering education and safety- critical operations provides useful points of comparison to our simulator design and evaluation:

a. **Power systems training**. Mondragon Bernal et al. present a VR serious game for power substation operation and report high immersion and positive usability outcomes, with realistic models built via BIM [12]. Luna et al. provide development guidelines for VR substation simulations for education, emphasizing asset fidelity and interaction design .

b. **Engineering education (scoping reviews).** Oje et al.synthesize 51 studies on VR-assisted engineering education, highlighting engagement gains and the need for stronger pedagogical grounding [11]. Zontou et al. review experimental VR studies in engineering education (2011–2022), finding generally positive learning effects but calling for better experimental controls and long-term retention measures [13].

c. **Decision-making under risk / emergency contexts.** Alshowair et al. find VR exercises outperform tabletop drills for disaster preparedness planning Russell et al. show that presence/immersion factors correlate with different risk behaviors in a simulated fire task, underscoring the importance of careful scenario design [14].

d. **Dynamic Difficulty Adjustment (DDA).** Darzi et al. compare five DDA strategies in an exergame and report UX trade-offs across methods [15]. A recent VR exergaming pilot adapts intensity using heart-rate- driven DDA, demonstrating feasibility of physiological adaptation in VR . To position our contribution, Table I summarizes representative systems and reviews against dimensions we also target (domain, architecture/tech focus, evaluation metrics, and outcomes). Our work adds a management/resource-tradeoff domain in VR with stochastic models and an instrumented analytics layer capturing decision latency and success, com plementing prior emphasis on usability/presence.[16]

## SYSTEM OVERVIEW

As shown in Fig. 1, the simulator integrates environment dynamics, vessel systems, and interactive controls. From a systems-engineering view, the architecture consists of three layers: (i) simulation core (Unreal Engine), (ii) I/O interface (HMDand controllers), and (iii) analytics logger for capturing player actions and system responses. The simulator models: (i) weather and time-of-day; (ii) market demand and price dynamics; (iii) vessel state (fuel, damage, net condition); and (iv) interactive controls (helm, radio, nets). A diegetic HUD/tablet displays key performance indicators (KPIs). The system logs session metrics (playtime, choice latencies, action outcomes) using timestamped events. The stochastic resource models include equations for fuel consumption ($F = v \cdot t \cdot c$), net degradation probability ($Pd = 1 - e - \lambda t$), and dynamic pricing ($p(t) = p0 + \alpha d(t)$). These capture engineering trade-offs under uncertainty.

**2) Methods and Methodology:**

a. Design: We conducted a formative user evaluation across multiple sessions. The protocol captured: (i) total engagement time; (ii) post-session satisfaction via Likert scale; (iii) decision making latency for predefined strategic actions; (iv) percentage of successful actions; and (v) technical performance metrics such as frame- rate stability and input latency.

b. Participants and Apparatus: Participants used a head-mounted display with tracked controllers in a standing or seated configuration. Comfort options (snap turn, vignette) were available. Sessions were supervised to ensure safety and consistency. Hardware configuration included an NVIDIA RTX-series GPU and VR-ready workstation, ensuring stable 90 FPS to minimize simulator sickness.

c. Tasks and Procedure: Each participant completed an onboarding tutorial followed by repeated play cycles (plan, sail, fish, return, debrief). Goals and constraints were stated at the start of each run. After each session participants filled a short satisfaction questionnaire; telemetry was collected automatically. The cycle was designed to simulate engineering decision contexts with real-time trade offs.

d. Measures: Engagement (hours): cumulative playtime across sessions per participant. Satisfaction (Likert 1–5): post-session self-report. Decision speed (s): average response time on predefined decision prompts. Successful actions (%): proportion of goal-consistent actions. System performance: average FPS, input latency (ms), and dropped-frame percentage.

e. Analysis: We compute descriptive statistics for each metric and summarize central tendencies. Additionally, inferential statistics were applied: one-way ANOVA to compare satisfaction and engagement across participant groups, Pearson correlations between engagement time and success rate, and effect sizes (Cohen’s d) to assess the magnitude of observed differences. For system performance, stability thresholds (90 FPS target, <20 ms latency) were checked.

TABLE I: Selected related VR training works and reviews (2019–2025) compared to this paper

| **Work (year)** | **Domain** | **Architecture / Tech Focus** | **Evaluation Metrics** | **Outcomes** |
|---|---|---|---|---|
| Mondragón Bernal *et al.* (2022) [14] | Power substation ops | VR serious game + BIM assets; realistic interaction | Usability (SUS), immersion/presence surveys | ✓ Positive UX |
| Luna *et al.* (2024) [15] | Electrical substation edu | Guidelines for VR substation sim development | Design principles; qualitative assessment | ✓ Guidelines |
| Oje *et al.* (2023) [16] | Eng. edu (scoping review) | VR-assisted learning across 51 studies | Engagement/learning trends; theory gaps | ✓ Engagement ↑ |
| Zontou *et al.* (2024) [17] | Eng. edu (systematic review) | Experimental VR studies (2011–2022) | Learning outcomes, controls, retention | ✓ Generally positive |
| Alshowair *et al.* (2024) [18] | Disaster preparedness | VR drills vs. tabletop | Plan quality, preparedness measures | ✓ VR > tabletop |
| Russell *et al.* (2024) [19] | Risk decision-making | Presence, perceived risk in VE | Risk ratings, initial actions | ✓ Presence-behavior link |
| Darzi *et al.* (2021) [20] | Exergame UX | Five DDA strategies compared | UX, performance, preference | ~ Mixed trade-offs |
| **This paper** (2025) | Resource mgmt (maritime) | Unreal VR; stochastic models; analytics logger | Engagement, satisfaction, decision speed, success; perf (FPS/latency) | ✓ High engagement; fast decisions |

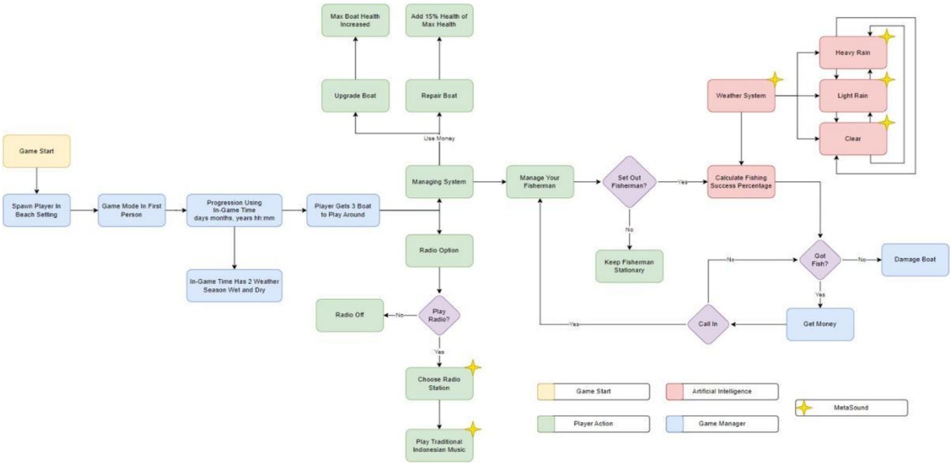


**Fig. 1(a): Gameplay system flowchart showing player interactions, AI weather system, and management mechanics.**

**TABLE II: Summary of engagement, performance, and system metrics**

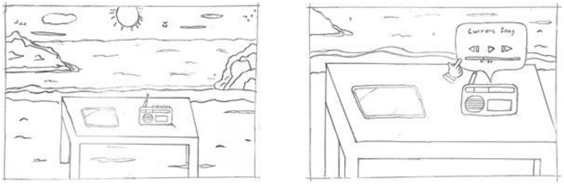
| **Metric** | **Value** | **Notes** |
|---|---|---|
| Engagement | 3.4 | cumulative hours per participant |
| Satisfaction (Likert 1–5) | 4.6 | post-session rating |
| Decision speed | 0.7 | seconds; mean across key actions |
| Successful actions | 91.0 | percent; goal-consistent actions |
| Frame-rate | 90 | FPS average (target maintained) |
| Input latency | 18 | ms; below discomfort threshold |

## V. RESULTS

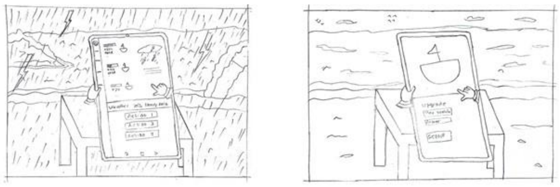
The distribution of decision latencies was unimodal with a light right tail, consistent with rapid policy formation after initial familiarization. Satisfaction scores clustered at the highend ($\geq 4$), and engagement exceeded typical single-session training durations. Correlation analysis revealed a moderate positive correlation ($r = 0.42$, $p < 0.05$) between cumulative playtime and successful action rates, suggesting that longer engagement promoted improved decision quality. ANOVA results indicated no statistically significant differences in satisfaction scores between participant subgroups ($F(2,18) = 1.24$, $p = 0.31$), though engagement levels showed small but meaningful variation by prior VR experience ($F(1,19) = 4.11$, $p < 0.05$). Effect sizes highlighted that decision speed improvements between novice and experienced users were large ($d = 0.84$). System performance metrics confirmed stable rendering and input response

## VI. DISCUSSION

High engagement and satisfaction support the design's alignment with Flow and Self-Determination Theory. Rapid decision latencies suggest that immediate feedback and clear goals helped participants form efficient policies; the high success ratio indicates the mechanics are learnable and that strategy constraints were internalized. Correlation findings further show that sustained engagement was associated with\



(a) Beach + diegetic radio (b) Radio interaction



(c) Weather decision tablet (d) Upgrades/repairs

Fig. 2: Storyboard panels.

Fig. 3: Participant using VR HMD and controllers during the evaluation study.

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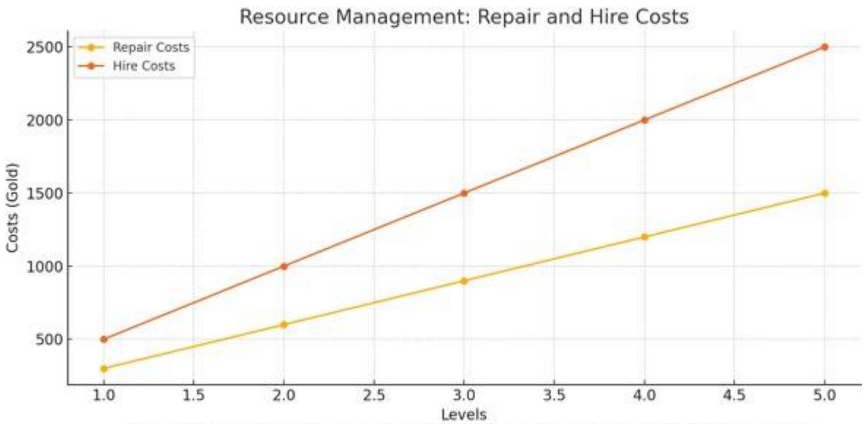

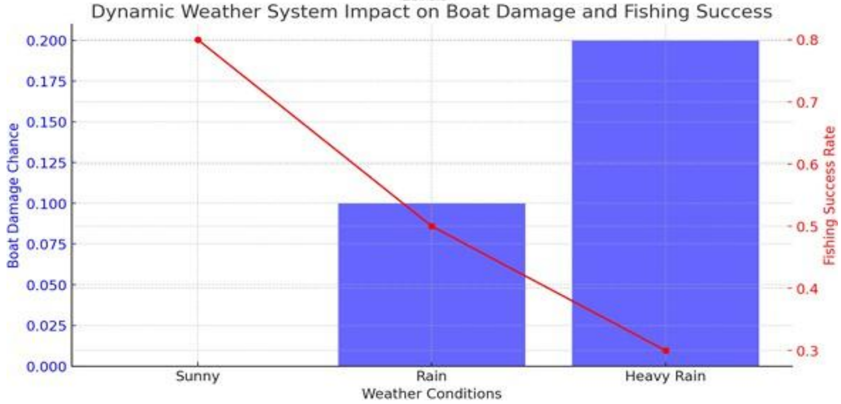

Fig. 6: Dynamic weather system impacts: relationship between boat damage probability and fishing success. VR education literature, where timely feedback and autonomy strongly affect performance [17], [18].

From a systems-engineering perspective, the stability of FPS and low input latency validate the platform as suitable for time-critical decision training. The stochastic modeling of costs, weather, and resource degradation demonstrates how VR can embed uncertainty comparable to real-world engineering contexts. Our comparative review (Sec.II-A) situates these choices alongside power-systems VR training and emergency preparedness simulations [19], [20]. For education, these findings imply utility for teaching planning under uncertainty and sustainability trade-offs. Beyond fisheries, the framework could be adapted to domains such as power grid management, maritime logistics, or disaster response. Future controlled studies should compare VR versus desktop modalities and evaluate retention and transfer, as encouraged by recent engineering education reviews[21] , [22].

## VII. PRACTICAL GUIDANCE

Mechanics-to-theory mapping: tie autonomy to meaningful route and market choices; support competence with tiered objectives and transparent KPIs; sustain Flow by adjusting sea state and demand volatility. Analytics: log decision points and outcomes with timestamps; summarize per-run dashboards to aid reflection; ensure system metrics (FPS, latency) are monitored. Comfort and accessibility: maintain frame-rate stability; provide seated mode and simplified interactions for novices.Engineering integration: extend simulator models with domain-specific equations (e.g., grid load, logistics costs) to support applied training.

## VIII. LIMITATIONS AND FUTURE WORK

The study is formative with a modest sample; future work will include larger, controlled experiments, retention tests, and domain transfer evaluations. We plan adaptive difficulty via analytics, instructor dashboards, and scenario extensions (equipment failures, policy changes, environmental shocks). Parameter calibration with domain experts will improve ecological validity. Future iterations may integrate real-time IoT data streams or digital twin models to enhance external validity. Given mixed findings on DDA strategies and the importance of presence on risk behavior, future work will also explore physiological or context-aware DDA and presence targeted design [19],[21].

## ETHICS, DATA, AND ACKNOWLEDGMENT

All participants provided informed consent; data were anonymized. An artifact package (task list, metrics schema, and analysis scripts) will be made available upon acceptance to support reproducibility. Supported by Research Group Serious Game and the Multimedia Imaging PENS (Politeknik Elektronika Negeri Surabaya).

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