AJJ Research

Frontier Systems Technical Paper

Public Company-Led Technical Disclosure Version

Version 1.0 | 2026

RR-Care™ FTE 2.3: A First-Definition-Type Care-Capacity Release Framework for Multi-Functional Embodied AI Humanoid Eldercare Robotics

A Public Company-Led Technical Disclosure Version for Human-Supervised Workflow Redesign, FTE-Based Care-Capacity Interpretation and Future Peer-Reviewed Research

Wentao Zhao[1], Qiang Huang[1], Weijie Tan[1], Xin Zhao[1], Hon Hsiang Ong[1], Tingting Shen[2], Tian Shen[1], Chunqiu Yan[2], Jian Zhang[1*]

[1]AJJ Healthcare Management Pte. Ltd., Singapore.
[2] Hangzhou Huaxi Intelligent Technology Co. Ltd., Hangzhou, China.
Correspondence: zhangjian@ajjmedtech.com.sg

Document Type: Company-led DOI-registered frontier systems technical paper
Status: Public research version; not yet independently peer-reviewed
DOI: 10.5281/zenodo.20774293 | Website: https://www.ajjmedtech.com.sg/publication-1
Research Programme: Embodied AI Humanoid Eldercare Robotics

Important Notice

This document is a company-led public research version prepared for transparent disclosure, public reference and subsequent scholarly discussion. It has not yet undergone independent peer review and should not be interpreted as a peer-reviewed journal article, regulatory approval, clinical validation, government endorsement, institutional endorsement, investment recommendation, sales forecast, staffing-reduction authorisation or evidence of universal deployment readiness.

Publication and Evidence Boundary

This AJJ Research public version is intentionally shorter than the full peer-reviewed journal manuscript under preparation. It summarises the RR-Care™ framework logic, FTE-based care-capacity interpretation and evidence-control approach, while withholding detailed source-record traceability files, S1–S7 supplementary materials, full calculation worksheets, site-level raw evidence and reviewer-facing methodological details.

1. Executive Research Summary

Institutional eldercare systems face increasing pressure from population ageing[1], caregiver shortages and rising routine workload[2]. In nursing homes and long-term care facilities, caregivers spend substantial time on repetitive tasks such as item delivery, reminders, environmental monitoring, basic assistance and repeated rounds. These tasks are necessary for safe care delivery, but they may reduce the time available for resident communication, emotional support, documentation, personalised care planning and staff recovery.

Humanoid eldercare robots have been introduced as potential workflow-support tools in institutional care[3]. However, their value should not be interpreted as direct caregiver replacement as current deployments often face technological constraints and user acceptance barrier[4][6]. From a nursing-management perspective, the key question is whether robot-supported workflows can release measurable routine workload while preserving human oversight, resident dignity and staff accountability. Existing eldercare robotics evidence has not yet sufficiently translated robot-supported routine task activity into auditable nursing workload-release and care-capacity indicators for institutional decision-making often leaving robots in supplementary roles[5][7].

To address this gap, this study proposes RR-Care™ as a Full-Time Equivalent (FTE)-based nursing management decision-support framework for institutional eldercare workflow assessment. The framework quantifies robot-supported routine workload release and interprets whether released care capacity can be reallocated within human-supervised institutional care workflows. It links task modules, caregiver-only versus robot-supported workflow mapping, time-motion indicators, FTE calculation, care-capacity reallocation, staff training requirements and anonymised data-governance boundaries.

This public research version applies RR-Care™ to a field-supported institutional eldercare pilot dataset at a summary level. It describes the framework architecture, principal care-task domains and management interpretation pathway, while retaining detailed source-record files, supplementary worksheets and site-level evidence for internal evidence control and future peer-reviewed journal submission.

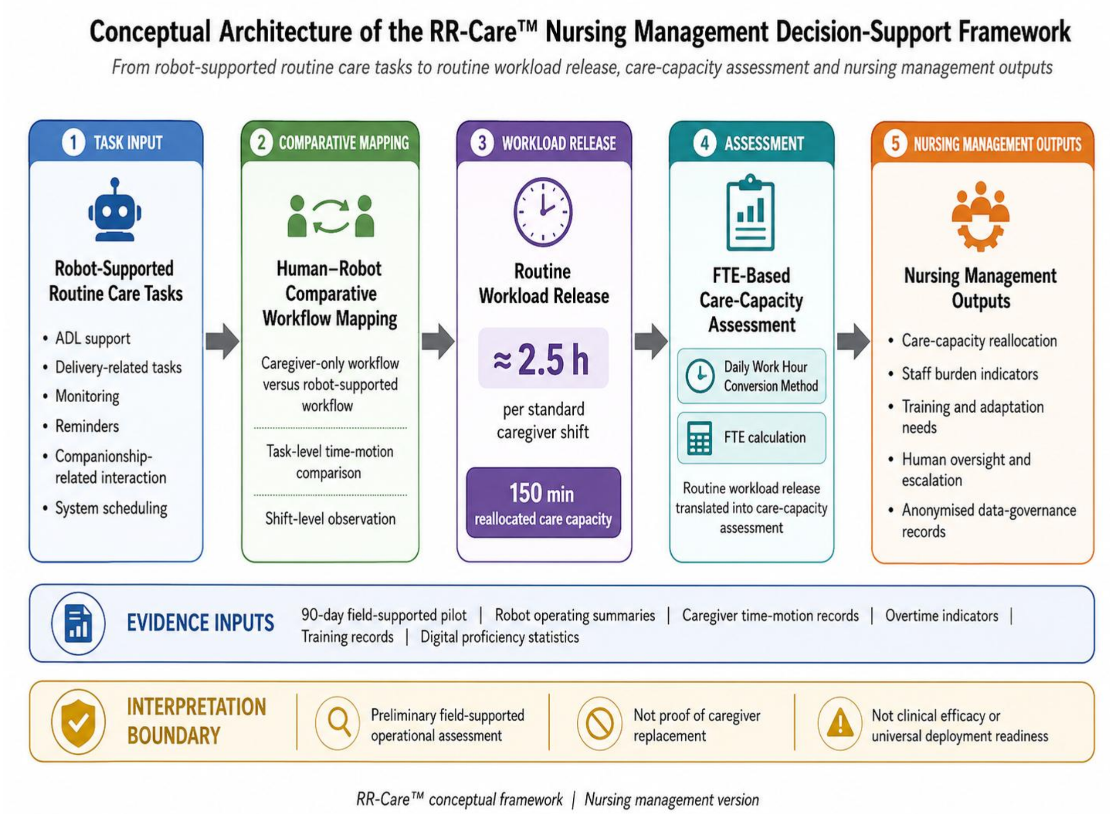

Figure 1. Conceptual architecture of the RR-Care™ nursing management decision-support framework.

The RR-Care™ framework makes three public-version contributions:

- It provides an FTE-based nursing management framework for translating robot-supported routine task activity into auditable workload-release indicators.
- It introduces human–robot comparative time-motion mapping to distinguish routine task support, human oversight and care-capacity reallocation.
- It integrates implementation boundaries, including training friction, digital-proficiency differences, operational constraints, source-record traceability and anonymised data governance.

First-Definition-Type Positioning

Within the reviewed literature and the bounded deployment context described in this public research version, RR-Care™ is positioned as a first-definition-type and early framework-setting approach for translating robot-supported routine task activity into FTE-equivalent care-capacity release indicators. This positioning is intended to describe the Company's framework contribution and research direction; it does not imply absolute global uniqueness, independent academic validation, regulatory approval, clinical efficacy or universal deployment readiness.

2. Technology and Deployment Context

Robotic systems have been increasingly studied in eldercare, including socially assistive, companion, and service robots[3][7]. While existing studies suggest that robots may support routine care-home functions like reminders and simple deliveries, their use heavily depends on staff acceptance, workflow redesign, and human oversight[8]. Therefore, robotic deployment in eldercare should not be interpreted as direct caregiver replacement, but as a potential source of routine workload release within human-supervised care workflows.

Much of the existing eldercare robotics literature focuses on technology acceptance, usability, human–robot interaction, perceived usefulness and resident or staff attitudes[9]. These perspectives are important, but they do not fully answer the operational question faced by nursing managers: how much caregiver time is released, from which task categories, under what conditions and with what additional coordination burden? Technical indicators such as operating time, navigation ability or task completion also do not directly translate into nursing workload outcomes.

Time-motion analysis provides one approach for measuring how time is distributed across care tasks[10]. In the context of eldercare robotics, this must be connected to nursing-management interpretation via human–robot comparative workflow mapping. Furthermore, Full-Time Equivalent (FTE) calculation can support staffing and workforce planning by converting work hours into a standardised measure of care capacity. In eldercare robotics, however, FTE should be applied cautiously. An FTE-based estimate should serve as a decision-support indicator for reallocating released time toward resident communication and staff recovery, rather than as proof of caregiver replacement.

The reviewed literature therefore indicates a methodological gap. Existing studies often describe acceptance, usability, technical feasibility or economic value, but less frequently integrate robot-supported task activity, human–robot comparative time-motion mapping, FTE-based care-capacity assessment, staff training friction and anonymised source-record governance into one nursing-management framework. Within this literature gap, RR-Care™ represents an early structured attempt to define an FTE-based nursing management decision-support framework for quantifying robot-supported routine workload release and care-capacity reallocation in institutional eldercare settings. This study addresses that gap by applying the framework to a field-supported pilot dataset and by examining how robot-supported workflows may be translated into auditable workload-release and care-capacity indicators.

3. RR-Care™ Framework and FTE-Based Care-Capacity Assessment

The RR-Care™ framework evaluates robot-supported routine workload release through a dual-methodology approach, tailored to the granularity of available institutional data. The primary objective is to translate raw robotic operational hours into a standardized Full-Time Equivalent (FTE) metric, thereby providing nursing management with an auditable indicator of care-capacity release.

3.1. Framework-Level Formula Logic: Demand-Constrained FTE Conversion

In this public research version, RR-Care™ presents the core formula logic at framework level rather than as a full peer-review calculation appendix. The purpose is to explain the demand-constrained FTE conversion pathway while retaining full parameter tables, source-record worksheets and supplementary evidence files for subsequent peer-reviewed journal submission and qualified review.

Basic Public Formula Statement

Primary demand-constrained formula logic:

$$\textbf{Daily Hours Saved} = \sum_{i=1}^{n} \textbf{min}\,(H_{care,i}, H_{robot,i})$$

This formula defines routine workload release as the task-level overlap between institutional care demand and robot-supported routine task output.

$$FTE_{saved} = \frac{\text{Daily Hours Saved}}{H_{FTE,\ daily}}$$

This formula converts the estimated daily workload-release hours into an FTE-equivalent care-capacity planning indicator.

Under this logic, robot-supported routine task output is mapped against baseline human routine workload. Only the lesser of task demand and robot-supported output is counted as released routine workload, helping to avoid overstating care-capacity release where robot operating time exceeds actual institutional task demand.

Secondary comparison logic only:

$$FTE_{saved}\,(\textbf{substitution}) = \frac{\sum_{i=1}^{n} H_{robot,i}}{H_{FTE}}$$

This secondary formula provides a simplified substitution-based comparison, but it does not apply the same demand-side constraint as the primary formula.

The substitution logic is retained only as a secondary comparison pathway. It is computationally efficient, but it assumes a closer demand-supply alignment and may overestimate workload release if robot-supported hours exceed actual care requirements. The demand-constrained conversion pathway remains the preferred public interpretation.

For this public version, $H_{FTE,daily}$ refers to the locally applicable full-time equivalent daily working-hour benchmark used for care-capacity planning. The benchmark may vary by jurisdiction, institution and shift structure.

The above formulas are disclosed as framework-level method logic only. Detailed scenario tables, annualised FTE calculation tables, source-record worksheets, S1-S7 supplementary evidence files and complete peer-review calculation appendices are not published with this public version.

Table 1. Illustrative Framework-Level Task Mapping for FTE-Based Care-Capacity Release

Task domain	Framework-level interpretation	Public-version disclosure boundary
ADL and delivery-related support	Robot-supported routine task output is mapped against baseline human routine workload and interpreted as potential routine workload release under human oversight.	Indicative framework logic only; detailed parameter tables and source-record worksheets are retained for qualified review.
Mobility-related assistance	Mobility support is treated as a task-support domain where local logs and workflow observation permit reliable measurement.	No standalone public numerical claim; local recalibration is required.
Monitoring and reminders	Routine monitoring and reminder functions may reduce repeated rounds and reminder-related caregiver burden under escalation protocols.	Operational effect depends on alert burden, navigation friction and supervision requirements.
Companionship-related interaction	Basic interaction support may create time for deeper human communication, psychosocial support and resident-centred care.	Not evidence of emotional-care replacement or clinical outcome improvement.
Total FTE-based release interpretation	Released routine workload may be converted into an FTE-equivalent planning indicator using locally applicable working-hour assumptions.	This public version does not publish the full calculation table, annualised FTE scenario table or supplementary evidence package.

Note: This table is provided as a public-version interpretation matrix. It is not the complete peer-review calculation table and should not be read as a universal staffing benchmark, caregiver-replacement claim, clinical validation or financial return estimate.

3.2. Methodological Approaches to Workload Estimation

The framework prioritizes the Daily Work Hour Conversion Method, which introduces a critical demand-side constraint. Unlike traditional models that may overestimate robotic utility, this approach ensures that workload release is capped by the pre-existing human care requirement for any specific task. By calculating the intersection of institutional task demand and robotic output, the model yields a conservative and realistic estimation of saved hours. This ensures that even if a robot’s operational capacity exceeds the historical human workload for a task, the credited "saved time" remains aligned with actual clinical needs.

Alternatively, for environments where baseline human labor data are less granular, the framework offers the Substitution Model Method. This approach treats robotic operational time as a direct substitute based on total functional hours. While computationally efficient, it is primarily used as a secondary validation tool, as it assumes a perfect alignment between robot supply and care demand without the rigorous "ceiling effect" applied in the conversion method.

3.3. Indicators of Workload-Release Coverage

To evaluate the efficacy of the transition from human-led to robot-supported tasks, the RR-Care™ framework utilizes the Workload-Release Coverage Ratio. This metric represents the proportion of actual saved hours relative to the baseline human care demand. By applying this ratio across diverse care domains—including Activities of Daily Living (ADL) support, mobility assistance, and monitoring-related functions—management can identify which nursing modules are most receptive to robotic integration.

Preliminary field-supported analysis using the RR-Care™ framework suggests that robot-supported outputs may cover a meaningful proportion of baseline routine care demand under defined institutional conditions. The public version intentionally reports the interpretation at a summary level and does not publish the full calculation worksheets, source-record tables or detailed supplementary evidence files.

3.4. Management Interpretation and Operational Constraints

While the framework provides a mathematically grounded assessment of care-capacity release, the RR-Care™ model acknowledges several stochastic variables inherent in clinical settings. The theoretical FTE savings must be interpreted alongside operational constraints, including battery charging cycles, navigation friction in unstructured environments, and the necessity for human oversight. The choice between the conversion and substitution models ultimately depends on the institution's data maturity; however, the framework's emphasis on demand-constrained evaluation ensures that the resulting FTE indicators remain a robust and defensible basis for strategic staffing and resource reallocation.

3.5. Annualized FTE-Based Care-Capacity Analysis

To evaluate the long-term impact of robotic integration on institutional staffing, the RR-Care™ framework may project daily workload-release metrics onto an annual scale under locally defined operating assumptions. In this public research version, annualised FTE interpretation is described conceptually only; detailed 365-day/260-day scenario tables, annual hours calculations and parameter-specific FTE estimates are retained for subsequent peer-reviewed journal submission and qualified review.

The projection logic is rooted in normalizing the cumulative daily saved hours against institutional standards for annual human work hours. By applying this normalization, the model translates raw operational data into a standardized care-capacity unit that aligns with international nursing management benchmarks. This dual-track approach allows for a nuanced interpretation of the data. The first scenario, a 24/7 institutional operating model typical of high-dependency nursing environments, assesses the robotic system’s utility across a full 365-day calendar. This metric reflects the theoretical maximum technical potential of the equipment to alleviate the constant, uninterrupted care burden. In contrast, the second scenario applies a more conservative labor-accounting benchmark to provide a realistic estimate for budgetary and human resource planning.

By comparing these scenarios, the RR-Care™ framework offers a sophisticated analytical tool that distinguishes between absolute technical utility and conservative labor-impact benchmarks. The results generated by this methodology provide nursing administrators with a defensible basis for evidence-based workload planning and human-supervised workflow redesign. Rather than providing a single, static figure, the framework acknowledges local variations in labor standards, such as those observed in the Singapore healthcare context, where standard annual work hours and shift structures define the boundaries of care capacity.

Ultimately, the annualized assessment within RR-Care™ establishes a bridge between technical robotic performance and institutional strategic management. By adopting the saved Full-Time Equivalent (FTE) as its foundational metric, the model ensures that robot-supported operating hours are translated into units that are directly auditable and applicable to staffing discussions. This systematic approach ensures that any identified care-capacity release is both measurable and reallocable, supporting the transition toward more resilient, technology-augmented institutional care models without compromising the oversight and accountability of the human nursing staff.

4. Care-Capacity Reallocation and Implementation Planning Models

The RR-Care™ framework includes specialized analytical modules designed to translate robot-supported workload release into tangible implementation value and workforce transition indicators. These models move beyond mere time-quantification to assess social return and distributive equity within institutional care. It is essential to note that the parameters utilized within these modules are intended to demonstrate the framework's computational logic and applicability across varied institutional deployment conditions, serving as a strategic guide for decision-makers rather than a universal empirical prescription.

4.1. Strategic Skill Reallocation and Labor Quality Enhancement

The framework extends its utility by modeling how the time recovered from routine, repetitive tasks can be strategically reallocated toward higher-value nursing, clinical, and psychosocial care roles. This process is governed by a defined reallocation coefficient, which represents the proportion of released labor hours directed toward specialized medical care, rehabilitation therapy, and psychological counseling. Conversely, the remaining balance accounts for residual routine tasks or necessary human-robot coordination activities.

By quantifying this reallocation potential, the RR-Care™ framework demonstrates that robotic integration should be interpreted primarily as a workflow-support mechanism that fosters staff professionalization. When a significant portion of recovered time is reinvested into high-value professional services, the resulting enhancement in care capacity allows institutions to strengthen resident-centered care models without increasing raw headcount. This shift in labor quality is particularly critical in environments facing chronic shortages of specialized nursing talent, as it enables the existing workforce to operate at the top of their clinical license.

Furthermore, the skill reallocation model provides a structured pathway for nursing managers to justify the adoption of humanoid systems based on labor-quality enhancement rather than simple cost-reduction. By converting recovered time into standardized capacity units, the model offers a defensible basis for human-supervised workflow redesign, ensuring that the integration of embodied AI leads to measurable improvements in both staff job satisfaction and the overall quality of clinical outcomes. This logical progression from routine task automation to professionalized capacity expansion forms the core of the RR-Care™ value proposition in institutional eldercare.

4.2. Implementation Cost and Resource Planning

Economic interpretation within the RR-Care™ framework is treated as an implementation-planning function rather than as proof of financial return, labor-cost saving or staffing reduction. For institutional administrators, cost review is necessary because robot-supported workflow redesign may require capital expenditure, recurring maintenance, charging infrastructure, software or IT support, staff training, workflow redesign and additional supervision time.

Accordingly, any cost-related interpretation should be linked to locally observed workload-release evidence rather than to robot operating time alone. The relevant planning question is not whether a robot replaces a caregiver, but whether robot-supported routine task activity can be translated into FTE-equivalent workload-release capacity that supports care-capacity planning, overtime-burden review, training-resource allocation and sustainable workflow redesign.

4.3. Workforce Adaptation and Training Readiness

Robot-supported routine workload release may create new training and coordination requirements for nursing supervisors, registered nurses, caregivers and deployment teams. Staff may need to learn task dispatch, charging procedures, alert verification, error reporting, escalation pathways, documentation routines and fallback procedures. Training readiness should therefore be interpreted as part of implementation quality rather than as an external operational issue.

The RR-Care™ framework recommends that institutions record training completion, first-assessment outcomes, retake needs, staff confidence, digital-proficiency differences and role-specific support requirements. Where staff require more time to adapt, peer support, repeated demonstration, simplified user guidance and supervisor-led troubleshooting should be provided before wider deployment.

When longer-term staff role transition is assessed, institutions may record adaptation duration, retraining needs, sustained-use outcomes and continued supervision requirements as part of local workforce-readiness monitoring. Detailed transition-time, reemployment or survival-style calculations, if used, should be treated as optional local planning tools rather than interpreted as universal employment or staffing-policy models.

4.4. Equity, Access and Digital-Proficiency Considerations

Implementation should also consider whether robot-supported workflows create unequal adaptation burdens across staff groups. Differences in age, prior technology exposure, language confidence, digital proficiency, shift pattern and role responsibility may influence how easily staff adopt robot-supported workflows. These differences should be monitored as implementation-quality indicators rather than ignored as individual resistance.

RR-Care™ therefore treats training access, user support, digital-proficiency variation, staff feedback and peer-support mechanisms as part of responsible deployment. Institutions should use anonymized and aggregated staff categories only, avoid disclosure of identifiable staff-level information and provide additional coaching where specific groups experience disproportionate adaptation difficulty.

Detailed access-equity or sensitivity calculations, where used, should be interpreted only as local monitoring tools. They do not constitute universal fairness metrics, employment-policy prescriptions or evidence that deployment is equally acceptable across all institutions or staff groups.

4.5. Practical Implementation and Stakeholder Interpretation Framework

To facilitate the localized application of the RR-Care™ framework, the methodology is supported by a modular suite of operational tools designed to translate theoretical workload-release estimates into role-specific clinical practice. These resources emphasize that the framework does not replace local governance or professional judgment but serves to provide evidence-bounded and recalibrated operational insights. The implementation toolkit encompasses structured checklists for administrative planning, caregiver-facing reference modules for frontline training, and data-collection worksheets for pre-post deployment analysis. These components ensure that institutional budgeting and resource allocation are informed by actual robot operating logs and implementation-friction indicators rather than idealized performance claims.

The successful integration of RR-Care™ requires a multidimensional interpretation of the FTE-equivalent baseline across various institutional roles. For administrators and directors, the framework serves as a strategic reference for workflow redesign and staffing-pressure review, replacing abstract performance metrics with locally calibrated workload-release indicators. Within this context, any illustrative baseline values—such as those derived from pilot scenarios—must be interpreted as context-specific estimates rather than universal standards for staffing reduction. Nursing supervisors and registered nurses utilize the framework to distinguish between delegable routine tasks and non-delegable professional responsibilities. While repetitive burdens such as basic monitoring and delivery are optimized, clinical accountability, medication verification, and emotional care remain strictly within the human nursing domain.

For frontline caregivers and deployment teams, the RR-Care™ indicators provide a measure of potential physical and reminder-related workload release, allowing for a strategic reinvestment of time into resident-centered care and staff recovery. However, the framework maintains rigorous boundary conditions, emphasizing that robotic support does not substitute for human presence or dignity-based caregiving. Finally, for researchers and evaluators, the framework establishes a traceable evidence trail for comparing pre- and post-deployment workloads. By framing the FTE-equivalent baseline as a dynamic nursing management indicator rather than a static success metric, the RR-Care™ framework provides a transparent pathway for continuous workflow optimization and multi-site validation within the complex landscape of institutional eldercare.

Table 2. Role-Based Interpretation Matrix for FTE-Based Care-Capacity Release

Role	How to interpret the FTE-based release indicator	Boundary
Institutional directors / administrators	Use as a workload-redesign and care-capacity planning reference, subject to local calibration and source-record review.	Not a staffing-reduction target, universal benchmark, regulatory approval, financial guarantee or sales forecast.
Nursing supervisors / nurse managers	Assess which routine tasks may be released and where time may be redirected toward communication, observation, documentation, handover and resident-centred care.	Released time does not automatically become high-value care without local workflow validation and human supervision.
Registered nurses	Interpret reminders, patrol support, delivery and basic monitoring as potential reductions in repetitive workload.	Does not replace clinical judgement, escalation duty, care planning, medication verification or nursing accountability.
Caregivers / care aides	Use as an indication that repetitive physical and reminder-related tasks may be partly released, allowing more time for resident support and staff recovery where workflow permits.	Does not replace human presence, dignity support, emotional care or hands-on caregiving.
Deployment / implementation teams	Compare FTE indicators with workflow observation, alert burden, navigation limits, supervision needs, task-fit review and coordination time.	Must be interpreted with implementation friction and human oversight, not as a standalone success metric.
Researchers / evaluators	Use as a context-specific reference point for future multi-site validation and local recalibration.	Not a universally validated constant; requires local recalibration, external validation and transparent evidence boundaries.

Note: The FTE baseline is a context-specific workload-release and workflow-redesign indicator. It is not proof of caregiver replacement, clinical effectiveness, staffing authorization or universal deployment readiness. Rounded public references such as "FTE 2.3" should be locally recalibrated using institutional workload, operating assumptions and source-record review.

5. Field-Supported Application and Evidence Boundary

To illustrate the field-supported application of the RR-Care™ framework, a pilot deployment was examined at a summary level using anonymised, aggregated operational indicators from an elderly care facility. The public research version is designed to communicate the framework logic, management interpretation and evidence-control approach. It does not publish the complete source-record traceability file, S1–S7 supplementary materials, full calculation worksheets or site-level raw evidence.

5.1. Operational Attrition and Implementation Friction

The field-supported analysis highlights a divergence between theoretical robotic capacity and observed institutional utility. While the RR-Care™ framework identifies potential workload-release areas in structured tasks such as ADL support and delivery-related routines, actual deployment remains constrained by charging requirements, navigation friction, task scheduling, staff adaptation and human-oversight needs. These constraints support the use of a demand-constrained evaluation model and caution against any direct 1-to-1 caregiver substitution interpretation.

5.2. Workflow Transformation and Labor Reallocation

A field-supported comparison of caregiver time-motion patterns before and after robot-supported workflow introduction was used to examine task-composition change. The analysis suggests that certain repetitive "errand-type" and reminder-related burdens may be reduced and that part of the released capacity may be redirected toward human interaction, psychosocial communication, care planning and staff recovery, subject to local workflow conditions and supervision arrangements.

Field-supported observations also indicate potential institutional benefits, including review of aggregate overtime burden and routine workload pressure. These indicators should be interpreted together with local payroll records, staffing policies, source-record evidence and management review. They are presented as planning and decision-support indicators rather than as financial-performance claims, investment guarantees or staffing-reduction targets.

5.3. Human Factors: The Digital Divide and Training Friction

A notable implementation finding concerns digital-proficiency differences and training friction. The pathway from formal intensive training to sustained high-frequency use may be influenced by age profile, prior technology exposure, language confidence, shift pattern and role responsibility. These factors require structured training support, simplified user guidance and supervisor-led troubleshooting before wider deployment.

At a public-research level, the framework therefore treats training readiness and digital-proficiency variation as implementation-quality indicators. Institutions considering similar deployments should assess staff adaptation, retraining needs and human-machine coordination burden as part of local calibration, rather than assuming that robot-supported workflow benefits are immediately or uniformly realised across all staff groups.

5.4. Data Governance, Evidence Availability and Methodological Boundaries

The public research version is supported by an internal anonymised source-record traceability file, including system-log summaries, caregiver workflow observations, benefit-side variables, training-conversion records and anonymised statistical summaries. The detailed supporting file is retained by the Company for evidence-control and traceability purposes and is not published with this public version in order to preserve confidentiality, data protection, institutional anonymity and the integrity of subsequent academic peer review. Where appropriate, the supporting file may be made available to journal editors or qualified reviewers under suitable confidentiality and data-protection arrangements.

6. Discussion and Methodological Positioning

This study positions RR-Care™ as a first-definition-type, early framework-setting and systems-oriented nursing-management framework for translating robot-supported routine care activity into FTE-equivalent workload-release, care-capacity and implementation-readiness indicators.

Within the reviewed scope of publicly available English and Chinese academic and institutional sources, this public version did not identify a widely established framework that integrates task-level robotic support, demand-constrained FTE-equivalent workload-release calculation, care-capacity reallocation, workforce adaptation, training friction, implementation-cost interpretation and access-equity considerations into one nursing-management decision-support pathway for humanoid eldercare robot deployment.

The originality of this study lies not merely in proposing another robot evaluation method, but in defining a structured evaluation language for humanoid eldercare robotics in institutional care. By linking robot-supported task performance with FTE-equivalent workload-release estimation, annualised care-capacity assessment, implementation-readiness interpretation, workforce adaptation and access-equity considerations, RR-Care™ moves the field from descriptive deployment narratives toward auditable nursing-management calculation and responsible workflow redesign.

This positioning does not imply absolute global uniqueness, regulatory recognition or external validation. Rather, the contribution lies in the integrated structure, terminology, calculation pathway, nursing-management applicability and evidence-boundary discipline of the framework. RR-Care™ should therefore be interpreted as a framework-shaping public research version that requires future independent peer review, external validation and local recalibration.

Several methodological boundaries should be emphasised. First, FTE-equivalent workload-release capacity should not be interpreted as automatic staff replacement or staffing-reduction authorisation. Second, robot operating time should not be equated with caregiver time saved unless actual caregiver free time, supervision burden, coordination time and exception-handling workload are locally documented. Third, the pilot findings should be interpreted as preliminary field-supported calibration rather than definitive multi-site validation. Fourth, implementation value depends on local workflow conditions, staff training, human oversight, environmental constraints, data governance and institutional readiness.

Future research should therefore conduct independent multi-site validation, longer follow-up, resident-level outcome assessment, staff wellbeing evaluation and local recalibration across different institutional settings. Additional studies should also examine whether released routine workload is consistently reallocated toward resident communication, personalised care planning, documentation quality, staff recovery and safer human-supervised workflows. Such validation may further strengthen RR-Care™ as a responsible, scalable and evidence-informed framework for evaluating humanoid eldercare robots in institutional care.

7. Conclusion

Against the backdrop of caregiver shortages and rising routine workload, this public research version presents RR-Care™ as a structured, FTE-based decision-support framework for interpreting robot-supported routine workload release and care-capacity reallocation. The framework is designed to support nursing-management discussion, workflow redesign and responsible institutional evaluation.

However, the realisation of potential operational benefits depends on implementation constraints. Robotic integration should not be interpreted as a linear substitution of human caregivers. It is a human-supervised workflow transition influenced by charging requirements, environmental navigation friction, training readiness, digital-proficiency differences, source-record quality and institutional governance.

Ultimately, RR-Care™ provides an evidence-informed foundation for the systematic evaluation of embodied AI humanoid eldercare robots in institutional care. The public version is intended to establish a transparent research record and support subsequent scholarly discussion. Further peer-reviewed journal submission, multi-site validation, resident-level outcome assessment and external benchmarking remain necessary.

8. Evidence Availability and Future Journal Submission Boundary

The FTE-based care-capacity release logic described in this public research version is supported by an internal anonymised source-record traceability file, including system-log summaries, caregiver workflow observations, benefit-side variables, training-conversion records and anonymised statistical summaries. The detailed supporting file is retained by the Company for evidence-control and traceability purposes and is not published with this public research version in order to preserve confidentiality, data protection and institutional anonymity. Where appropriate, the supporting file may be made available to journal editors or qualified reviewers under suitable confidentiality and data-protection arrangements. Any future peer-reviewed journal submission should be interpreted as a substantially expanded academic manuscript, subject to the policies of the target journal.

Declarations

Author Contributions:

Conceptualization, Jian Zhang; methodology, Wentao Zhao and Jian Zhang; formal analysis, Wentao Zhao and Qiang Huang; investigation, Wentao Zhao, Qiang Huang, Chunqiu Yan and Tingting Shen; data curation, Wentao Zhao, Qiang Huang and Tingting Shen; writing-original draft preparation, Wentao Zhao; writing-review and editing, Qiang Huang, Xin Zhao, Hon Hsiang Ong, Weijie Tan, Chunqiu Yan, Tingting Shen, Tian Shen and Jian Zhang; supervision, Jian Zhang and Chunqiu Yan; project administration, Jian Zhang. All authors have read and agreed to the public research version of this document.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The pilot deployment described in this public research version was conducted as an operational workflow assessment and technology deployment evaluation within an institutional elderly care environment, rather than as a clinical intervention study involving diagnosis, treatment or medical decision-making. Formal institutional approval was obtained from the participating elderly care institution. The study used aggregated robotic telemetry, anonymised operational records and non-invasive time-motion observations of standard caregiver workflows. No identifiable resident medical records, biometric identification data or individual clinical decision data are disclosed in this public research version.

Informed Consent Statement:

Not applicable. This public research version does not disclose identifiable resident-level clinical data, individual medical decision-making, facial images, voice recordings, biometric identifiers or personally identifiable information. Staff-related operational observations are discussed only in aggregated or anonymised form.

Data Availability Statement:

The FTE-based care-capacity release logic described in this public research version is supported by an internal anonymised source-record traceability file, including system-log summaries, caregiver workflow observations, benefit-side variables, training-conversion records and anonymised statistical summaries. The detailed supporting file is retained by the Company for evidence-control and traceability purposes and is not published with this public research version in order to preserve confidentiality, data protection and institutional anonymity. Where appropriate, the supporting file may be made available to journal editors or qualified reviewers under suitable confidentiality and data-protection arrangements.

Supplementary Materials:

The full S1-S7 supplementary evidence package, complete calculation tables, source-record worksheets and detailed operational evidence files are not published with this public research version. These materials are retained for controlled academic review and future peer-reviewed journal submission. They do not constitute clinical validation, regulatory approval, caregiver-replacement proof, staffing-reduction authorisation or universal deployment evidence.

Acknowledgments:

The authors acknowledge the participating elderly care institution, frontline caregivers, technical deployment personnel and operational support teams involved in the pilot deployment, source-record coordination and data-validation process. No government, regulatory or institutional endorsement is implied by this acknowledgment.

Conflicts of Interest:

Some authors are affiliated with AJJ Healthcare Management Pte. Ltd. and Hangzhou Huaxi Intelligent Technology Co., Ltd., which are involved in the development, deployment or technical-support context of the humanoid eldercare robotics discussed in this public research version. This document is a company-led public research version and should not be construed as independent third-party validation, regulatory approval, clinical validation, medical device certification, commercial endorsement, market-performance assertion or product-performance guarantee.

Ethics and Evidence Boundary Statement:

This public research version presents a framework-level and field-supported operational assessment. It does not report a clinical trial, patient-level outcome study, medical diagnosis, treatment intervention or individual healthcare decision-making evaluation. The findings should be interpreted as preliminary, context-specific and evidence-bounded support for the RR-Care™ framework, subject to independent peer review, multi-site validation and local recalibration.

Declaration of AI-Assisted Language and Editorial Support:

AI-assisted language and editorial tools may have been used to support English language refinement, grammar checking, formatting consistency and document readability. The authors retained full responsibility for the study design, data interpretation, mathematical framework, evidence boundaries, intellectual content and final document. No AI tool was used to independently generate, alter or verify the underlying source data, institutional records or empirical findings described in this public research version.

REFERENCES

[1] World Health Organization (2020) Decade of Healthy Ageing: Baseline Report. World Health Organization, Geneva. License: CC BY-NC-SA 3.0 IGO.

[2] Acemoglu, D. and Restrepo, P. (2018) The Race between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment. The American Economic Review, 108, 1488-1542 https://doi.org/10.1257/aer.20160696

[3] Sawik, B., Tobis, S., Baum, E., Suwalska, A., Kropinska, S., Winczewska-Wiktor, A., Talarska, D., & Wieczorowska-Tobis, K. (2023). Robots for elderly care: Review, multi-criteria optimization model and qualitative case study. Healthcare, 11(9), Article 1286. https://doi.org/10.3390/healthcare11091286

[4] Sanders, G. D., Neumann, P. J., Basu, A., Brock, D. W., Feeny, D., Krahn, M., Kuntz, K. M., Meltzer, D. O., Owens, D. K., Prosser, L. A., Salomon, J. A., Sculpher, M. J., Trikalinos, T. A., Russell, L. B., Siegel, J. E., & Ganiats, T. G. (2016).

Recommendations for conduct, methodological practices, and reporting of cost-effectiveness analyses: Second Panel on Cost-Effectiveness in Health and Medicine. JAMA, 316(10), 1093–1103. https://doi.org/10.1001/jama.2016.12195

[5] Lopetegui, M., Yen, P.Y., Lai, A., Jeffries, J., Embi, P. and Payne, P. (2014) Time Motion Studies in Healthcare: What Are We Talking about? Journal of Biomedical Informatics, 49, 292-299. https://doi.org/10.1016/j.jbi.2014.02.017

[6] Broadbent, E., Stafford, R., & MacDonald, B. (2009). Acceptance of healthcare robots for the older population: Review and future directions. International Journal of Social Robotics, 1(4), 319–330. https://doi.org/10.1007/s12369-009-0030-6

[7] Bemelmans, R., Gelderblom, G. J., Jonker, P., & de Witte, L. (2012). Socially assistive robots in elderly care: A systematic review into effects and effectiveness. Journal of the American Medical Directors Association, 13(2), 114–120.e1. https://doi.org/10.1016/j.jamda.2010.10.002

[8] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340. https://doi.org/10.2307/249008

[9] de Graaf, M. M. A., & Ben Allouch, S. (2013). Exploring influencing variables for the acceptance of social robots. Robotics and Autonomous Systems, 61(12), 1476–1486. https://doi.org/10.1016/j.robot.2013.07.007

[10] Lim, M. L., & Ang, S. Y. (2019). A time–motion observation study to measure and analyse clinical nursing workload in an acute care hospital in Singapore. Proceedings of Singapore Healthcare, 28(2), 124–128. https://doi.org/10.1177/2010105819834569