Risk Assessment in Social Infrastructure: Consilient Digital Transformation, Knowledge Transfer, and Project Success Frameworks in Elderly Care PPP Projects

Nicholas Dacre[1], Hao Dong[1], M.K.S. Al-Mhdawi[2], and Jie Dong[1]

[1]University of Southampton, UK
[2]Teesside University, UK

Abstract

Ongoing demographic transitions and evolving pressures on healthcare systems have heightened the importance of effective risk management in social infrastructure development, particularly in regions experiencing significant growth in elderly populations. In response to these challenges, in this paper we examine the evolution of risk assessment approaches in social infrastructure projects, with a specific focus on elderly care Public-Private Partnerships (PPPs). The research develops a theoretical framework that synthesises five distinct but interconnected theoretical streams, including the evolution of risk assessment, conceptualisation of project success, impacts of digital transformation, mechanisms of knowledge transfer, and methodological innovations in evaluating PPP projects. Through a literature review the study identifies how these dimensions intersect with methodological advances in PPP risk evaluation. The framework emphasises the integration of Analytic Hierarchy Process (AHP) with fuzzy comprehensive evaluation methods to advance theoretical understanding of risk assessment. Our literature analysis reveals the critical importance of balancing technological innovation with traditional risk assessment approaches whilst maintaining sensitivity to local contexts and stakeholder needs. This research contributes to both theory and practice by advancing understanding of how different risk factors interact within elderly care PPP projects, moving beyond traditional siloed approaches to risk assessment. The paper concludes by highlighting theoretical implications and suggesting directions for future research in social infrastructure development, with particular attention to contexts where demographic shifts are creating demands on elderly care infrastructure.

Keywords: Risk Assessment, Public-Private Partnerships, Social Infrastructure, Digital Transformation, Knowledge Transfer, Project Success, Elderly Care, AHP Analysis, Fuzzy Evaluation, Healthcare Infrastructure, Infrastructure Development.

1. Introduction

The integration of emerging technologies with infrastructure project delivery has influenced the evolution of risk assessment and management approaches, particularly as projects become increasingly complex and interconnected (Al-Mhdawi, O'connor, et al., 2024; Bai et al., 2024; Mohamed et al., 2024; Wu et al., 2018). In this vein, recent advances in artificial intelligence and digital transformation suggest new methodologies for evaluating and responding to project risks, whilst evolving frameworks for project success highlight the inherent influence of institutional contexts and stakeholder dynamics on project outcomes (Biygautane et al., 2019; Corbin et al., 2024; Eggleton et al., 2023; Jayasena et al., 2021). These developments have particular relevance for social infrastructure projects, where technological innovation coalesces with changing societal needs.

Such intersections are notably evident in healthcare infrastructure development, where demographic transitions are creating new demands on service delivery systems (Chen et al., 2022; Dacre, AlJaloudi, Al-Mhdawi, et al., 2024; Feng et al., 2020). For instance, China provides an illustrative example of these pressures, with individuals aged 60 and above comprising 18.7% of the population and projections indicating 71% growth in the elderly population between 2015 and 2030 (Akimov et al., 2021; National Bureau of Statistics of China, 2021; Tu et al., 2022). This rapid demographic shift has heightened the need for effective risk management approaches in healthcare infrastructure projects, especially regarding the integration of new technologies with established delivery methods (Al-Mhdawi, Qazi, et al., 2024; Liu et al., 2024; Ma et al., 2024).

The response to these demographic pressures in China has highlighted endemic limitations in current elderly care provision models. Whilst public facilities benefit from government subsidies, they often show limitations in infrastructure quality. Conversely, private institutions offer enhanced amenities but experience high vacancy rates due to cost barriers (Feng et al., 2012; Fu et al., 2023; Liu et al., 2024). As such, these circumstances have led to exploration of Public-Private Partnerships (PPPs) as an alternative delivery model, though implementation challenges persist in adapting traditional risk management approaches to elderly care projects (Dai et al., 2021; Dong & Dacre, 2024; Zhang & Chan, 2023).

Recent developments in project management methodology and digital transformation suggest potential pathways forward. Research has examined the adoption of artificial intelligence and machine learning in risk assessment (Chen et al., 2020; Hsu et al., 2021a; Li & Wang, 2018), alongside the emergence of agile methodologies and adaptive frameworks in addressing infrastructure challenges (Baxter et al., 2023; Loosemore & Cheung, 2015; Zhang et al., 2023). Contemporary advances in knowledge transfer and experiential learning approaches may offer additional insights for elderly care PPP implementation (Gkogkidis & Dacre, 2021; Xia et al., 2018), whilst developments in risk assessment techniques suggest new

possibilities for integrating technological and institutional considerations (Valipour et al., 2016). The application of these approaches to elderly care infrastructure might benefit from consideration of institutional dynamics and organisational contexts, particularly in dint of the unique characteristics of healthcare service delivery (Dong et al., 2024; Joudyian et al., 2021; Schuurmans et al., 2021).

This research thus aims to examine risk factors in elderly care PPP projects within the Chinese context (Fu et al., 2023; Li & Wang, 2018), with particular attention to the following key dimensions: the evolution of risk assessment approaches in infrastructure projects, the transformation of project success frameworks and delivery models, and the integration of technological innovation in risk assessment methodologies (Chen et al., 2020; Valipour et al., 2016). This research particularly examines how these dimensions intersect with knowledge transfer mechanisms and methodological advances in PPP risk evaluation (Liu et al., 2020). In order to develop an evidence-based assessment framework, we propose combining Analytic Hierarchy Process (AHP) with fuzzy comprehensive evaluation methods, building upon methodological advances in project risk assessment (Al-Mhdawi, O'Connor, et al., 2023; Al Fozaie & Wahid, 2022; Peng et al., 2021). As such, we seek to contribute to the literature on social infrastructure PPPs whilst providing practical insights for the development of elderly care facilities (Dai et al., 2021).

The remainder of this paper is organised as follows. Section 2 provides a review of the literature, examining the evolution of risk assessment in infrastructure projects, project success and delivery models, digital transformation in PPP risk assessment, learning and knowledge transfer in PPP risk management, and methodological innovation in PPP risk assessment. Section 3 develops an integrated theoretical framework that synthesises these core themes and underpins our methodological approach. Section 4 outlines the research methodology employed for data collection and analysis. Finally, Section 5 discusses the contributions and implications of the findings, while proposing directions for future research.

2. Literature Review

2.1 Risk Assessment Evolution in Infrastructure Projects

Research into risk assessment in PPP projects reflects a gradual shift from traditional infrastructure delivery approaches towards more complex analytical frameworks (Grimsey & Lewis, 2002; Rybnicek et al., 2020). Whilst early studies focused primarily on discrete risk categories such as financial, operational, and technical risks, recent literature has begun to examine the interconnected nature of risk factors in PPP projects (Liu et al., 2015; Xia et al., 2018). This evolution in the literature reflects growing attention to the challenges posed by extended stakeholder networks and complex financing arrangements in contemporary PPP structures (Demirag et al., 2011). Certain researchers have also investigated the potential of Generative AI in risk identification and response strategies (AlJaloudi, Thiam, et al., 2024), whilst others have examined fuzzy-based optimisation models

for evaluating risk response strategies (Al-Mhdawi, Qazi, et al., 2023; Li & Wang, 2018; Valipour et al., 2016). These studies present varying perspectives on the role of technological tools in project risk assessment, with differing analytical approaches and methodological considerations.

The emergence of AI-enabled risk management has particular significance for social infrastructure PPPs. In this context, recent research has highlighted the potential for machine learning algorithms to enhance predictive accuracy in project risk assessment, especially regarding long-term performance monitoring and stakeholder management (Chen et al., 2020; Hsu et al., 2021b; Liu et al., 2024). Whilst these technological innovations offer promising capabilities for PPP risk evaluation, their implementation presents endemic challenges regarding data quality and algorithmic transparency (Kockum & Dacre, 2021; Valipour et al., 2016). As such, the integration of AI-driven risk assessment tools might benefit from consideration of broader institutional and organisational contexts specific to PPP arrangements (Casady et al., 2020; Dacre & Kockum, 2022a; Xia et al., 2018).

The application of these evolving risk assessment approaches to social infrastructure PPPs highlights distinctive challenges in the Chinese context (Chang & Chen, 2016; Cheng et al., 2016). For instance, healthcare infrastructure projects face unique risk factors related to service delivery requirements and stakeholder complexity (Liu et al., 2024; Yip et al., 2019). Conversely, financial sector applications have demonstrated the potential for integrated risk management frameworks to enhance PPP project outcomes (AlJaloudi, Dacre, et al., 2024; Chen et al., 2020; Li & Wang, 2018). This body of research illustrates the varied approaches to understanding risk factors across different types of PPP projects (Cui et al., 2018; Zuo et al., 2024).

2.2 Project Success & Delivery Models

The conceptualisation of project success has evolved beyond traditional metrics of time, cost, and quality towards more nuanced frameworks that consider broader institutional and societal impacts (Dacre, Eggleton, Cantone, et al., 2021; Eggleton et al., 2021; Li et al., 2005; Osei-Kyei & Chan, 2015). In this vein, recent empirical research examining multidimensional success models suggests that PPP evaluation frameworks might benefit from incorporating measures of long-term service quality and social value creation (Casady et al., 2020; Eggleton et al., 2023; Fabre & Straub, 2023). For instance, the implementation of PPP models in the Chinese context highlights distinctive institutional considerations. Research into public sector projects underscores organisational dynamics and the influence on PPP outcomes, particularly regarding the alignment of public and private sector objectives (Baxter et al., 2023; Chang & Chen, 2016; Dong et al., 2021a; Li & Wang, 2024). In dint of these findings, an increasing number of studies explore the role of digital transformation and how it might enhance project integration and success in complex PPP environments (Gong et al., 2022). Such research suggests that effective

PPP delivery may benefit from consideration of both technological capabilities and local institutional arrangements (Loosemore & Cheung, 2015; Zhang & Chen, 2013). Furthermore, recent industry analysis indicates shifting preferences towards flexible, fit-for-purpose PPP structures in response to post-pandemic effects and increased digitalisation (Manh et al., 2024; Sonjit et al., 2021a). Hitherto, research has explored how these changes manifest in different institutional contexts, with growing attention to the role of agile methodologies in addressing PPP project complexity in healthcare settings (Joudyian et al., 2021; Sonjit et al., 2021c; Zhang & Chan, 2023).

Adjacent research examining crisis resilience in institutional settings, also suggests that PPP frameworks might benefit from greater consideration of stakeholder dynamics and social outcomes specific to elderly care provision (Krings et al., 2022; Zhang & Chan, 2023). Conversely, studies of project management processes indicate that traditional PPP structures may need adaptation when applied to healthcare delivery contexts such as China (Barber et al., 2021; Chang & Chen, 2016; Joudyian et al., 2021). As such, the evolution of PPP models continues to influence approaches to healthcare infrastructure delivery, particularly in contexts characterised by complex social and institutional requirements (Casady et al., 2020; Yip et al., 2019).

2.3 Digital Transformation in PPP Risk Assessment

The practical implications of digital transformation for PPP risk assessment in elderly care projects can be illustrated through several potential applications. For instance, if a PPP project involves multiple elderly care facilities across different regions, machine learning algorithms could analyse historical performance data from existing facilities to identify patterns in service quality variations (Chen et al., 2020; Hsu et al., 2021b; Liu et al., 2024). Such analysis might reveal how factors like local demographics, staff attrition, and facility size interact to influence project success, thus enabling more nuanced risk assessment approaches (Dai et al., 2021; Li et al., 2023).

The application of Generative AI technologies also affords the potential to transform how stakeholder engagement risks are evaluated in elderly care PPPs. For example, if a proposed PPP project faces resistance from local communities due to cultural preferences for family-based care, GenAI models could analyse social media sentiment and local news coverage to gauge public opinion trends (AlJaloudi, Thiam, et al., 2024; Xia et al., 2018; Zhang et al., 2019). In dint of such capabilities, project managers could develop more targeted stakeholder engagement strategies and better assess reputational risks throughout the project lifecycle (Figueiredo Filho et al., 2022; Osei-Kyei & Chan, 2017).

Real-time data analytics might fundamentally alter how operational risks are monitored in elderly care facilities. For instance, through the use of IoT sensors

throughout a facility in order to continuously track patterns in service delivery, resource application, and resident well-being (Brookes et al., 2020; Liu et al., 2024; Mu & Kang, 2022). If occupancy rates in one wing of the facility begin to decline whilst staff response times increase, predictive analytics could highlight these patterns prior to significant impact on project viability. Such early warning systems hold the potential to transform traditional approaches to risk monitoring in healthcare PPPs (Chen et al., 2020; Valipour et al., 2016). The integration of systems thinking with artificial intelligence also suggests new possibilities for understanding complex risk interactions. For instance, if a PPP project experiences unexpected changes in local healthcare policies, AI-enabled simulation models could rapidly assess the cascading effects on financing structures, operational procedures, and service delivery obligations (Dacre, 2024a; Ma et al., 2024; Mao et al., 2024). Therefore, by modelling these complex interactions project stakeholders might be better positioned to interpret and understand how seemingly isolated risks may coalesce to create systemic challenges for elderly care PPPs (Lima et al., 2021; Loosemore & Cheung, 2015).

2.4 Learning and Knowledge Transfer in PPP Risk Management

Knowledge creation in PPP projects often emerges through unexpected pathways. Research into co-creation and synchronous partnership suggests that innovative ideas frequently arise from unplanned interactions between diverse stakeholders (Dacre, 2024b; Dacre et al., 2018; Osei-Kyei & Chan, 2017; Xia et al., 2018). This understanding might shape how practitioners approach risk management workshops and training sessions in elderly care PPPs, for instance by incorporating elements of structured randomness to spur creative problem-solving. In this vein, traditional approaches to project learning often fail to capture the rich interactions between technical, social, and institutional factors that characterise healthcare infrastructure projects (Loosemore & Cheung, 2015; Torchia et al., 2015). However, within these challenges there are opportunities for innovative knowledge transfer approaches that might transform how project teams understand and respond to risks. For example, experiential learning environments could enhance how PPP stakeholders develop risk assessment capabilities. Research into serious play methodologies afford promising applications for complex project environments (Antonopoulou & Dacre, 2021; Dacre, 2024c; Figueiredo Filho et al., 2022; Gkogkidis & Dacre, 2020a, 2023), where project teams can rely on structured play sessions to explore risk scenarios. This might include scenarios where stakeholders physically model different risk interactions using Lego serious play (Gkogkidis & Dacre, 2020b), creating tangible representations of abstract project relationships. Such approaches may reveal hidden risk patterns and challenge established assumptions about project dynamics (Rybnicek et al., 2020).

The role of technology in facilitating knowledge transfer also warrants particular attention, especially given the increasing evolution of digital learning platforms (Liu et al., 2020; Tite et al., 2021b; Xia et al., 2018). Contemporary research exploring

gamification in project management education hints at this potential for risk management training (Chen et al., 2020; Dacre et al., 2015; Dacre, Dong, Gkogkidis, et al., 2022). A virtual simulation environment, for instance, may afford PPP practitioners the opportunity to experiment with different risk response strategies, and learn from simulated failures whilst mitigating real-world consequences (Ng, Xie, Cheung, et al., 2007; Pontin & Dacre, 2024; Xu et al., 2012). The development of sustainable learning ecosystems (Tite et al., 2021a) in PPP projects represents both a dichotomy of challenge and an opportunity. However, by reviewing knowledge transfer through a systems thinking lens, project teams can better understand how different learning mechanisms interact and reinforce each other over time (Dacre & Kockum, 2022b; Loosemore & Cheung, 2015). The essential focus is on establishing self-sustaining knowledge networks that continuously adapt to the evolving demands of projects, rather than maintaining a static structure.

2.5 Methodological Innovation in PPP Risk Assessment

Methodological innovation extends beyond technological innovations to encompass fundamental questions about how we understand project complexity. For instance, project data analytics research underscores the potential for more effective approaches to risk assessment in social infrastructure projects (Chen et al., 2020; Dacre et al., 2020; Liu et al., 2020). Rather than relying on static risk matrices, project teams might employ dynamic assessment frameworks that evolve with changing project conditions. In this vein. the convergence of traditional risk assessment methods with emerging analytical approaches suggests intriguing possibilities for PPP evaluation, as innovative methodological frameworks have the potential not only to advance technical practices but also to reshape how project success is conceptualised and measured in elderly care infrastructure (Dacre, AlJaloudi, Thiam, et al., 2024; Dacre, Yan, Frei, et al., 2024; Peng et al., 2021; Valipour et al., 2016). For example, the integration of recurrent neural networks with risk assessment frameworks opens particularly relevant avenues for further examination, in that traditional PPP evaluation often struggles to capture the temporal dynamics of risk factors, treating each assessment point as independent. Neural networks, however, could address this limitation by learning from historical patterns while adapting to emerging trends (Hsu et al., 2021a; Ng, Xie, Cheung, et al., 2007; Ng, Xie, Skitmore, et al., 2007; Xu et al., 2023). A healthcare PPP might benefit from such capabilities when monitoring service quality indicators over time, with the system learning to distinguish between normal variations and early warning signs of systemic issues (Liu et al., 2024; Wang et al., 2016).

Increasing developments in agile methodologies also suggest potential avenues for more responsive risk assessment frameworks (Al-Mhdawi, Dacre, et al., 2023; Chen et al., 2020; Dacre, 2024d; Dacre, Dong, & Nagar, 2022; Dong et al., 2022; Loosemore & Cheung, 2015; Sonjit et al., 2021b). Traditional PPP evaluation often relies on sequential project management methodologies, characterised by rigid, predefined assessment cycles that may overlook emerging risks or opportunities as the project

progresses (Dacre et al., 2014; Lima et al., 2021; Rybnicek et al., 2020). This linear approach, while effective in structured environments, can prove inadequate in complex, dynamic settings such as healthcare infrastructure, where shifting needs and external factors frequently disrupt initial assumptions (Joudyian et al., 2021). Conversely, agile methodologies emphasise iterative cycles of planning, implementation, and evaluation, enabling continuous feedback and real-time adaptation to changing conditions (Dacre et al., 2019; Dong et al., 2021b; Xia et al., 2018). When adapted to the PPP context, these iterative approaches could facilitate more dynamic and proactive risk monitoring, ensuring that emerging risks are identified and addressed promptly while still aligning with the overarching goals of the project (Valipour et al., 2016). The critical challenge is to achieve an equilibrium between the flexibility necessary for adaptation and the stability essential for ensuring sustainable long-term healthcare service delivery (Torchia et al., 2015).

Drawing from the literature review, we present a systematic categorisation that synthesises the dimensions of risk assessment in elderly care PPP projects (Table 1). This synthesis illustrates the overlapping nature of contemporary theoretical approaches that shape our understanding of risk management in social infrastructure development.

Table 1: Synthesis of Risk Assessment in Elderly Care PPP Projects

Theme	**Primary Areas of Focus**	**Methodologies Explored**	**Contributions and Insights**	**Literature**
Evolution of Risk Assessment	- Transition from traditional, compartmentalised frameworks to integrated approaches - Exploration of interrelated risk factors in PPPs - Role of AI and machine learning in predictive risk management	- Application of generative AI - Fuzzy optimisation models - Predictive analytics	- Emphasis on addressing systemic risk interactions rather than isolated factors - Challenges surrounding data quality and algorithmic transparency	(Chen et al., 2020; Liu et al., 2015; Valipour et al., 2016)
Conceptualisation of Project Success	- Expansion of success criteria to encompass social value creation and long-term service quality - Impacts of institutional and stakeholder dynamics on outcomes	- Success evaluation frameworks - Case-based analysis of public-private alignment	- Flexible and context-sensitive PPP models are critical to achieving broader societal impacts - Enhanced focus on service quality metrics	(Casady et al., 2020; Fabre & Straub, 2023; Osei-Kyei & Chan, 2015)

Digital Transformation in Risk Management	- Integration of IoT and AI for advanced monitoring and risk prediction - Analysis of stakeholder sentiment through digital platforms	- IoT-enabled monitoring systems - AI-driven simulation and predictive modelling	- Digital tools enable nuanced risk assessment but create new vulnerabilities, such as cybersecurity and privacy concerns	(Chen et al., 2020; Liu et al., 2024; Valipour et al., 2016)
Knowledge Transfer and Organisational Learning	- Co-creation of knowledge through diverse stakeholder collaboration - Use of experiential learning to address complex project dynamics	- Serious play methodologies - Gamification in project training - Digital knowledge-sharing platforms	- Effective knowledge transfer mechanisms enhance adaptive risk management - Experiential learning fosters creative solutions and innovative practices	(Loosemore & Cheung, 2015; Xia et al., 2018)
Methodological Innovation in PPP Evaluation	- Development of dynamic risk frameworks that evolve with project conditions - Temporal analysis of risks in long-term infrastructure projects	- AHP and fuzzy comprehensive evaluation - Recurrent neural networks - Agile iterative approaches	- Emerging methods address gaps in static evaluation techniques - Agile and machine-learning frameworks improve responsiveness to changing risks	(Liu et al., 2020; Rybnicek et al., 2020)

3. Theoretical Framework

The theoretical framework for our research draws on Table 1 and thus arises from the synthesis of five distinct but interconnected theoretical streams identified in the literature review, including the evolution of risk assessment, the conceptualisation of project success (Dacre, Eggleton, Gkogkidis, et al., 2021), the impacts of digital transformation, mechanisms of knowledge transfer, and methodological innovations in evaluating PPP projects. The evolution of risk assessment approaches in infrastructure projects suggests a transition from traditional, siloed evaluations towards more integrated frameworks that recognise the complex interplay of technical, financial, and operational factors (Rybnicek et al., 2020; Xia et al., 2018). Contemporary understanding of project success has similarly transitioned beyond conventional triple-constraint metrics to include broader institutional and societal impacts, which are particularly relevant in the context of social infrastructure projects (Casady et al., 2020; Lima et al., 2021). This broader conceptualisation of success requires more advanced approaches to risk assessment, capable of capturing both quantitative performance metrics and qualitative social outcomes. As such, the growing role of digital transformation in

PPP risk assessment has introduced new opportunities for data-driven decision-making, while simultaneously creating novel categories of risk that must be evaluated and managed (Chen et al., 2020; Loosemore & Cheung, 2015).

Mechanisms of knowledge transfer underpin a crucial role in mediating the effectiveness of risk management, particularly in complex project environments where learning and adaptation are key to success (Loosemore & Cheung, 2015; Xia et al., 2018). Recent methodological innovations in risk assessment, including the integration of artificial intelligence and machine learning approaches, have created new possibilities for more dynamic and responsive risk evaluation frameworks (Chen et al., 2020; Liu et al., 2020). As such, this theoretical framework conceptualises risk assessment in elderly care PPP projects as a dynamic system in which these five dimensions interact and influence one another through multiple dimensions. Traditional risk assessment approaches form the foundational structure for evaluation, while project success frameworks guide the selection and prioritisation of risk factors (Osei-Kyei & Chan, 2015; Sehgal & Dubey, 2019). Digital transformation simultaneously introduces new risk categories and enables assessment capabilities, facilitated by knowledge transfer mechanisms that support learning and adaptation throughout the project lifecycle (Valipour et al., 2016). Finally, methodological innovations provide the tools and techniques needed to operationalise this integrated approach to risk assessment (Figure 1).

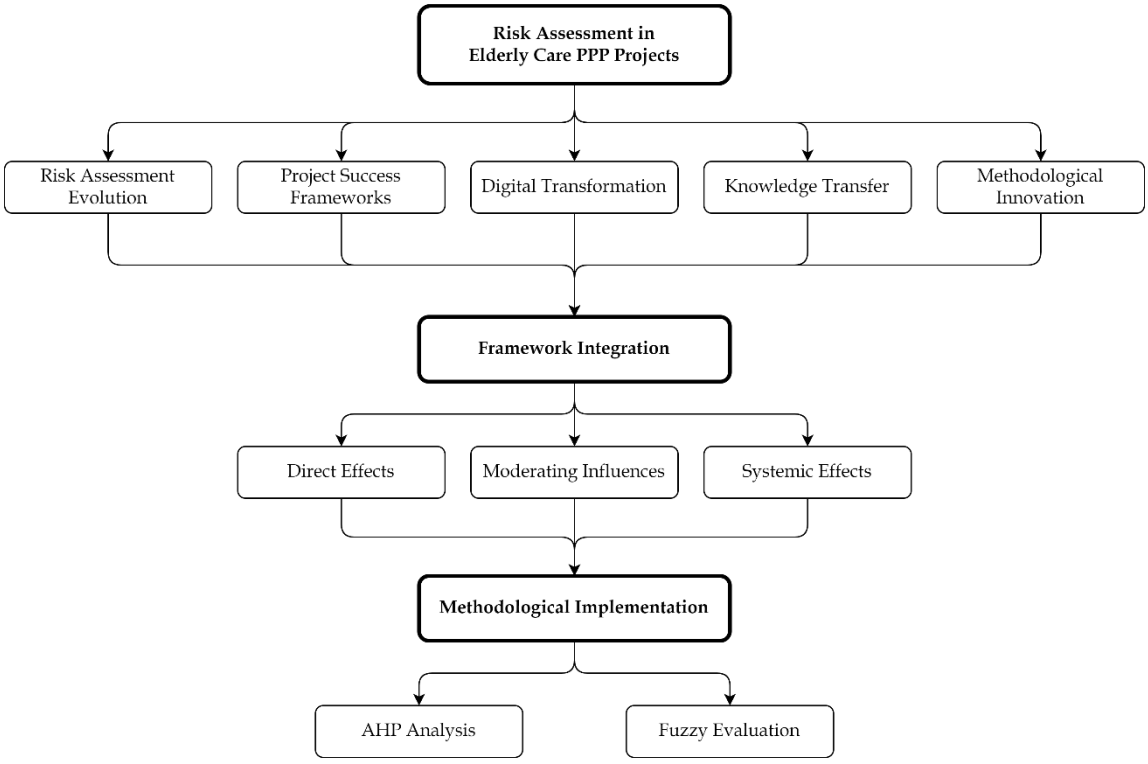

Figure 1: Risk Assessment and Methodological Implementation in Elderly Care PPP Projects

Our framework identifies three levels of interaction, direct effects between individual components, moderating influences that shape how components

interact, and systemic effects arising from the collective operation of multiple components. These interactions are particularly evident in elderly care PPP projects, where service quality requirements, technological integration challenges, and institutional dynamics create complex risk landscapes requiring careful evaluation and management (Chen et al., 2020; Liu et al., 2024). The practical application of this framework relies on the complementary use of AHP and fuzzy comprehensive evaluation methods. The AHP methodology allows for the systematic decomposition of complex risk relationships into manageable hierarchical structures, while fuzzy evaluation techniques address the inherent uncertainty in expert judgments regarding risk factors (Liu et al., 2020; Saaty, 2008; Wang, Liu, et al., 2008; Wang, Luo, et al., 2008). The framework thus serves as a theoretical basis for examining how different risk factors interact and influence project outcomes, towards providing practical guidance for developing more effective risk assessment approaches in social infrastructure PPPs (Loosemore & Cheung, 2015; Xia et al., 2018).

4. Research Approach

This research adopts a two-stage approach, with the initial phase focusing on theoretical framework development and analysis through a literature analysis (Reynolds & Dacre, 2019). This first stage examines how the five identified theoretical streams intersect and interact within the context of elderly care PPP projects, providing a foundation for subsequent empirical investigation. The planned second phase will employ purposive snowball sampling to identify and recruit industry experts with relevant expertise in PPP projects, elderly care operations, and risk management (Archibald & Munce, 2015; Braun & Clarke, 2021). Expert participants will comprise key stakeholder categories, including project risk management specialists, heads of elderly care institutions, relevant government personnel, and staff members with PPP project experience. This sampling approach aims to ensure representation across technical, operational, and policy domains whilst maintaining focus on practical project implementation experience (Brinkmann, 2014; Langley & Meziani, 2020; Parker et al., 2019).

The empirical data collection process will involve two primary phases. Initial qualitative data will be gathered through semi-structured interviews with industry experts, exploring their experiences and perspectives regarding risk factors in elderly care PPP projects (Brinkmann, 2014; Langley & Meziani, 2020; Maldonado-Castellanos & Barrios, 2023). Following the interview phase, participants will complete structured risk assessment matrices: a pairwise comparison matrix for AHP analysis and a risk assessment scale for fuzzy comprehensive evaluation (Liu et al., 2020; Saaty, 2008; Wang, Liu, et al., 2008). The AHP methodology will facilitate decomposition of complex decision problems into hierarchical structures, whilst fuzzy comprehensive evaluation will accommodate the inherent uncertainty in expert judgements regarding risk factors (Dacre, Yan, Dong, et al., 2024; Peng et al., 2021; Tian & Yan, 2013). This integration enables both qualitative insight into

risk factor relationships and quantitative assessment of their relative importance (Li & Wang, 2018). The planned fuzzy comprehensive evaluation phase will employ a five-level linguistic scale for risk assessment, ranging from "very low risk" to "very high risk" (Nguyen & Macchion, 2023). Membership functions will be established to translate expert judgements into fuzzy numbers suitable for mathematical analysis, with particular attention paid to maintaining consistency in the treatment of linguistic variables whilst acknowledging the inherent uncertainty in expert judgements regarding risk factors (Wang, Luo, et al., 2008).

5. Discussion

A potentially fundamental tension emerges in the Risk Assessment and Methodological Implementation in Elderly Care PPP Projects framework's attempt to reconcile traditional risk assessment approaches with the dynamics of technological innovation (Chen et al., 2020; Jayasena et al., 2021). Whilst the framework acknowledges both dimensions, their interaction potentially uncovers a more complex relationship than theorised. The integration of digital technologies in elderly care facilities introduces not only new capabilities for risk monitoring but also creates novel forms of institutional vulnerability that existing assessment approaches struggle to capture (Loosemore & Cheung, 2015). For instance, the implementation of IoT sensors for resident monitoring might enhance operational efficiency whilst simultaneously introducing cybersecurity risks and data privacy concerns that traditional risk frameworks are ill-equipped to evaluate (Liu et al., 2024). The emphasis on knowledge transfer mechanisms also suggests that successful risk assessment depends not only on formal evaluation frameworks but also on organisations' capacity to capture and transmit tacit knowledge across project phases and stakeholder groups (Xia et al., 2018). This observation challenges conventional approaches to knowledge management in PPP projects, which prioritise formal documentation over the cultivation of institutional learning capabilities (Casady et al., 2020).

A particularly significant insight emerges regarding the framework's treatment of institutional dynamics by revealing that effective risk assessment in elderly care PPPs must address local institutional contexts, and nonetheless the framework's standardised approach may not fully capture the different fashion in which institutional factors influence project outcomes. This tension between standardisation and contextualisation may become especially apparent in the Chinese context, where rapid demographic changes and evolving healthcare priorities create dynamic risk landscapes that mitigate simple categorisation (Chang & Chen, 2016; Feng et al., 2020). Furthermore, the research also reveals an emergent challenge regarding the framework's treatment of social impact metrics. Whilst we acknowledge the importance of social outcomes in elderly care PPPs, the increasing emphasis on social value creation in infrastructure projects points to emergent priorities in evaluating and managing social risks. This consideration becomes particularly relevant in the context of elderly care facilities, where social

outcomes often prove as important as traditional performance metrics in determining project success (Dai et al., 2021; Li & Wang, 2018). The integration of digital transformation considerations also provides a theoretical basis for examining AI applications in risk assessment, however the rapid evolution of AI capabilities imposes a process for more dynamic approaches to evaluating algorithmic risks (Chen et al., 2020; Liu et al., 2024). A final consideration emerges regarding the framework's adaptability to emerging organisational forms in infrastructure development. The increasing prevalence of hybrid delivery models that combine elements of traditional PPPs with more flexible partnership arrangements raises questions about how risk assessment frameworks should evolve to address these new organisational contexts. This consideration becomes particularly relevant as governments and private partners experiment with innovative approaches to elderly care infrastructure development (Casady et al., 2020; Fu et al., 2023).

6. Conclusion

This research advances our understanding of risk assessment in elderly care PPP projects through the development of an integrated theoretical framework that synthesises traditional project management approaches with emerging technological and institutional considerations (Chen et al., 2020; Valipour et al., 2016). The framework's application reveals several important theoretical and practical contributions to infrastructure project management, whilst also highlighting critical areas for future investigation. The primary theoretical contribution lies in the framework's novel integration of distinct dimensions revealing a richer understanding of how different risk factors interact within elderly care PPP projects, thus moving beyond traditional siloed approaches to risk assessment (Loosemore & Cheung, 2015; Xia et al., 2018). The research particularly advances our understanding of how technological innovation can both enable and complicate risk assessment practices in social infrastructure projects.

From a practical perspective, the research suggest that effective risk assessment in elderly care PPPs requires a more dynamic and context-sensitive approach than traditionally employed (Lima et al., 2021; Rybnicek et al., 2020). This has particular relevance for the Chinese context, where demographic transitions and evolving healthcare needs create unique challenges for infrastructure development (Chen et al., 2022; Feng et al., 2020). The research also highlights the critical importance of institutional learning capabilities in effective risk management, suggesting a need for more sophisticated approaches to knowledge transfer in PPP projects (Casady et al., 2020). However, the emphasis on standardised assessment approaches may not fully capture the myriads of ways in which institutional factors influence project outcomes in different contexts (Chang & Chen, 2016). Additionally, the rapid evolution of technological capabilities, particularly in artificial intelligence and data analytics, suggests that risk assessment frameworks should continue to evolve to address emerging challenges in infrastructure development.

Future research directions emerging from this work might explore how the role of emerging technologies in PPP risk assessment could further enhance understanding of digital transformation in social infrastructure projects. For instance, the application of emerging technologies like blockchain and advanced AI systems in PPP risk management could offer new perspectives on how to enhance transparency and effectiveness in risk assessment practices. Moreover, longitudinal studies might examine how risk profiles evolve throughout project lifecycles, contributing to more dynamic approaches to risk management in elderly care PPPs.

In conclusion, whilst this research provides theoretical insights into risk assessment in elderly care PPP projects, it also highlights the continuing evolution of this area. Future success in elderly care infrastructure development will likely depend on the ability to balance sophisticated analytical approaches with practical implementation considerations whilst maintaining sensitivity to local contexts and stakeholder needs. As this continues to evolve, the integration of technological innovation with traditional risk assessment approaches will become increasingly important in ensuring the successful delivery of social infrastructure projects.

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