The Thesis of Doctoral (PhD) dissertation

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Project Management Competencies and Performance: The Impact of Project Complexity in Hungarian Organizations

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1 INTRODUCTION

Project management remains a cornerstone of organizational strategy, directly influencing the success, growth, and adaptability of businesses across sectors. In a rapidly evolving global landscape, the ability to deliver projects effectively hinges not only on technical execution but also on the competencies of project managers and the complexity of the environments in which they operate (Mainga, 2017; Nicholas & Steyn, 2020). The intricate relationship among project management competencies, project complexity, and project performance has gained scholarly attention, especially as projects increasingly operate within volatile, uncertain, and interconnected contexts.

Project complexity is widely acknowledged as a critical determinant of project outcomes. According to Butler et al. (2020), higher complexity tends to reduce unit efficiency and increase project costs. Kerzner (2022) further emphasized that project complexity can significantly impair adherence to timelines and budgets, while Morcov et al. (2020) noted its negative effect on overall project success rates. Research by Khan et al. (2020) reaffirmed that complexity is not merely a contextual challenge but a structural impediment to project performance.

Large-scale analyses have reinforced these concerns. A survey by PricewaterhouseCoopers (PwC) involving more than 10,000 projects revealed that only 2.5% of organizations achieved full success in delivering all their projects as originally planned, with most experiencing delays or overruns. This finding underlines the pressing need to understand the causes of underperformance, particularly in light of project complexity (Kerzner, 2022).

Despite these insights, much of the existing research is centered around developed economies. There is a notable gap in scholarship focused on emerging markets, where the contextual dynamics of project management are often influenced by additional socioeconomic and institutional constraints (Kermanshachi et al., 2020). Addressing this gap, the present study explores the interplay among project management competencies, project complexity, and project performance within the Hungarian context, an emerging economy with evolving project governance structures.

This research aims to contribute both empirically and theoretically to this dialogue by investigating how project management competencies and the dimensions of complexity jointly influence performance. The objective is not only to test relationships but also to generate insights that support capacity-building and performance enhancement in project management, particularly in resource-constrained and dynamic environments.

Emerging debates in the discipline highlight a growing need to rethink traditional project management practices in light of increasing complexity (Alaloul et al., 2020). In this regard, the current study is situated at the intersection of competency theory and complexity theory, aiming to illuminate how these frameworks interact in shaping project success.

1.1 Problem Background

This study investigates the interplay between project management (PM) competencies, project complexity, and project performance, guided by complexity theory. Rooted in system dynamics, complexity theory highlights the interdependence of project components (Van Assche et al., 2019). While PM competencies enhance performance, rising project complexity introduces challenges that require further examination (Morcov et al., 2020). Empirical evidence suggests that complexity negatively impacts performance, whereas PM competencies improve outcomes. However, their combined influence remains underexplored.

As projects grow more complex, traditional management approaches become inadequate, necessitating adaptive strategies (Ahmad & Karim, 2019). This research contributes to the discourse by analyzing how PM competencies and complexity jointly affect performance, offering insights for managing modern projects.

1.2 Problem Statement

A gap exists in understanding how PM competencies and project complexity influence performance. Current literature provides limited insights into their combined effects (Khan et al., 2020). PM competencies encompassing technical, interpersonal, and leadership skills enhance success by fostering collaboration and crisis management (Fernandes & Araújo, 2019; Mainga, 2017; Theron & Roodt, 2001).

Project complexity, characterized by instability and dynamic demands, is a key research area (Locatelli et al., 2023). It contributes to up to 70% of project failures, yet lacks a universal definition. Complexity includes tangible (e.g., project size) and intangible factors (e.g., stakeholder pressures), requiring adept management (Sonta-Draczkowska & Mrozewski, 2019).

Project performance now extends beyond cost, time, and scope to include sustainability and stakeholder satisfaction (Alves et al., 2019). Complexity disrupts performance, but empirical research integrating these variables is lacking.

1.3 Study Objective

This study bridges the gap by examining how PM competencies and complexity predict performance in Hungary. Prior research has focused on complexity drivers but neglected their integration with competencies (Kocsir & Varga, 2020). Using a quantitative, correlational design, it assesses:

- **PM competencies** (measured via PMCQ),
- **Complexity** (via CAT), and
- **Performance** (via PSQ) among certified PM professionals (Maylor & Turner, 2017; Sugden et al., 2021).

Complexity involves structural, sociopolitical, and emergent challenges (Alaloul et al., 2020), while performance is defined by goal achievement within constraints (Fabbro & Tonchia, 2021).

1.4 Significance of Study

This research advances PM literature by analyzing how complexity mediates the PM competencies-performance relationship. Integrating complexity theory with competency models, it explains how disruptions lead to new stable patterns (Byrne & Callaghan, 2022; Turner & Baker, 2019).

The study contrasts standard (competencies improve performance) and extended (complexity hinders performance) models (Miguel et al., 2019). It extends complexity theory's application in Hungary and offers practical insights for managing complex projects, emphasizing skill development (Andreev et al., 2022).

1.5 Research Questions and Conceptual Framework

The research questions guiding this study are anchored in contemporary project management literature and seek to examine the relationship between project management competencies, project complexity, and project performance. Drawing from the conceptual propositions of Geraldi & Söderlund (2018), the study hypothesizes that project complexity plays a mediating role in shaping the influence of project management competencies on project performance. This assumption formed the basis for formulating a central research question and a set of sub-questions, which are designed to empirically test this mediating mechanism.

The development of these questions adheres to the structured mediation testing framework suggested by Kroh and Schultz (2023), which recommends a three-step analytical approach: (1) testing the direct influence of the independent variable on the outcome variable, (2) analyzing the relationship between the independent and mediating variable, and (3) assessing how the mediating variable affects the outcome variable. This stepwise structure ensures rigorous examination of whether and how project complexity mediates the pathway from competencies to performance.

The questions are also informed by the methodological clarity advocated by Tehseen et al. (2017), reinforcing the alignment between theoretical assumptions and empirical testing procedures. This alignment strengthens the internal consistency of the research design.

Primary Research Questions

The following research questions were developed to investigate the main constructs of interest:

Table 1: Primary Research Questions

Q. Number	Research Question
Q1	To what degree does project complexity mediate the relationship between project management competencies (independent variable) and project performance (dependent variable)?
Q1.1	How much variation in project performance can be explained by project management competencies?
Q1.2	To what extent do project management competencies account for variations in project complexity?
Q1.3	How significantly does project complexity contribute to explaining project performance?

The research treats project management competencies, complexity, and performance as high-level constructs, following the approach of Ahmad et al. (2018). A two-level Hierarchical Component Model (HCM), as described by Martinez Avila et al. (2021), was implemented to analyze these constructs. This technique preserves the model's theoretical structure while allowing for deeper conceptual definitions at lower levels of abstraction.

Secondary Research Questions

The study further differentiates project management competencies into two distinct domains: Soft Skills and Personal Competencies, and Technical and Professional Competencies. This differentiation allows for a more nuanced investigation of how each domain interacts with complexity and performance.

Table 2: Secondary Research Questions

Q. Number	Research Question
Q2	To what degree does project complexity mediate the relationship between soft skills and personal competencies, and project performance?
Q2.1	To what extent do soft skills and personal competencies explain the variation in project performance?
Q2.2	How much variation in project complexity is accounted for by soft skills and personal competencies?
Q2.3	To what extent does project complexity explain variations in project performance?
Q3	Does project complexity mediate the relationship between technical and professional competencies and project performance?
Q3.1	To what extent do technical and professional competencies explain the variation in project performance?
Q3.2	How much variation in project complexity is explained by technical and professional competencies?
Q3.3	To what extent does project complexity contribute to project performance?

This layered structure of inquiry allows for an in-depth exploration of the mediating effects of project complexity in different competency domains. As noted by Aarseth et al. (2017), traditional project management frameworks often assume that competencies automatically translate to performance. However, this study tests that assumption by embedding complexity as a critical intervening factor.

1.6 Research Hypotheses

The study proposes a comprehensive set of hypotheses corresponding to the above research questions. These hypotheses operationalize the relationships within the conceptual model and facilitate statistical testing using PLS-SEM. The model includes two exogenous constructs, project management competencies (split into soft/personal and technical/professional), a mediating variable, project complexity, and the endogenous construct project performance.

The hypotheses are organized into three categories based on the primary and secondary research questions.

Hypotheses for Q1: General Mediation Model

- **H0.1**: Project management competencies, project complexity, and project performance are not significantly related.
- **H1.1**: Project management competencies, project complexity, and project performance are significantly related.
- **H0.1.1**: Project management competencies do not significantly affect project performance.
- **H1.1.1**: Project management competencies significantly affect project performance.
- **H0.1.2**: Project management competencies do not significantly affect project complexity.
- **H1.1.2**: Project management competencies significantly affect project complexity.
- **H0.1.3**: Project complexity does not significantly influence project performance.
- **H1.1.3**: Project complexity significantly influences project performance.

Hypotheses for Q2: Soft Skills and Personal Competencies

- **H0.2**: Soft skills and personal competencies have no significant relationship with project performance.

- **H1.2**: Soft skills and personal competencies significantly influence project performance.
- **H0.2.1**: Soft skills and personal competencies do not explain significant variation in project performance.
- **H1.2.1**: Soft skills and personal competencies significantly explain variation in project performance.
- **H0.2.2**: Soft skills and personal competencies do not significantly affect project complexity.
- **H1.2.2**: Soft skills and personal competencies significantly affect project complexity.
- **H0.2.3**: Project complexity does not significantly mediate the relationship between soft skills and performance.
- **H1.2.3**: Project complexity significantly mediates the relationship between soft skills and project performance.

Hypotheses for Q3: Technical and Professional Competencies

- **H0.3**: Technical and professional competencies do not significantly affect project performance.
- **H1.3**: Technical and professional competencies significantly affect project performance.
- **H0.3.1**: Technical and professional competencies do not explain variation in project performance.
- **H1.3.1**: Technical and professional competencies explain significant variation in project performance.
- **H0.3.2**: Technical and professional competencies do not significantly affect project complexity.
- **H1.3.2**: Technical and professional competencies significantly affect project complexity.
- **H0.3.3**: Project complexity does not significantly mediate the relationship between technical competencies and project performance.

H1.3.3: Project complexity significantly mediates the relationship between technical competencies and project performance.

1.7 Theoretical model

The modified conceptual framework adopted in this research is based on the expanded standard project management model (Martinez Avila et al., 2021), visualized in Figure 1.

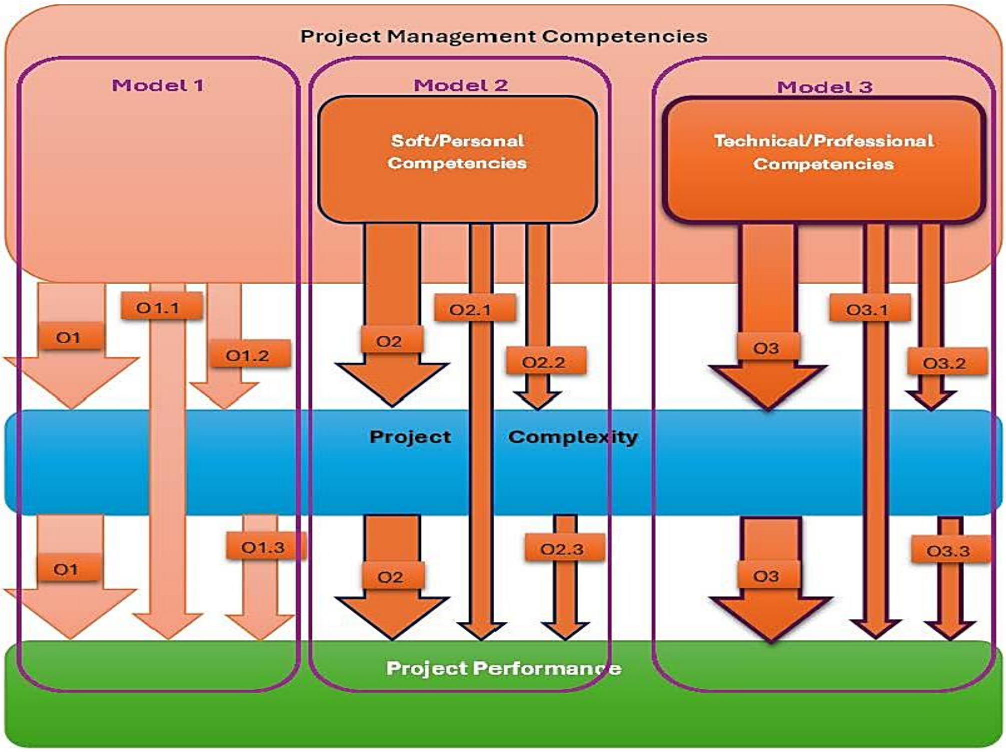

Figure 1: Conceptual Model

This model integrates project complexity as a mediator, aligning with complexity theory, which suggests that project outcomes are shaped not only by managerial competencies but also by the dynamic and multidimensional nature of project environments. The extended Standard Project Management Model was developed based on the conceptual framework, shown in Figure 2.

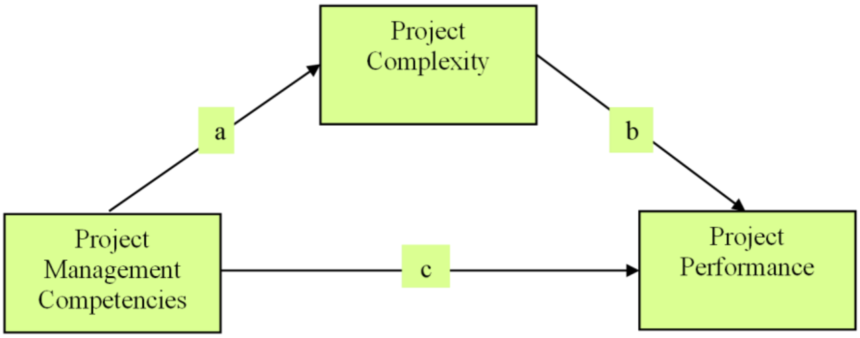

Figure 2: Extended Standard Project Management Model (Adapted from Martinez, 2021)

The structural framework includes:

- Two third-level latent constructs under project management competencies (soft skills/personal and technical/professional)
- Two second-level constructs under project complexity (structural and sociopolitical)
- A single latent variable for project performance

This layered modeling supports the use of HCM-PLS SEM, providing an accurate representation of how different layers of competencies and complexity dimensions interact to impact performance.

2 MATERIALS AND METHODS

2.1 Research Design

This study employed a **quantitative, non-experimental** approach using **Partial Least Squares Structural Equation Modeling (PLS-SEM)** to examine relationships between variables. The design was **exploratory**, assessing how **project complexity mediates** the link between **project management (PM) competencies** and **project performance**. Data were collected via a **structured multi-section questionnaire**, measuring latent variables in the research model (Martínez-Ávila et al., 2021). Given the impracticality of experimental controls, this method was optimal for analyzing post-project relationships among randomly assigned participants (Tehseen et al., 2017). The research procedure is shown in Figure 3.

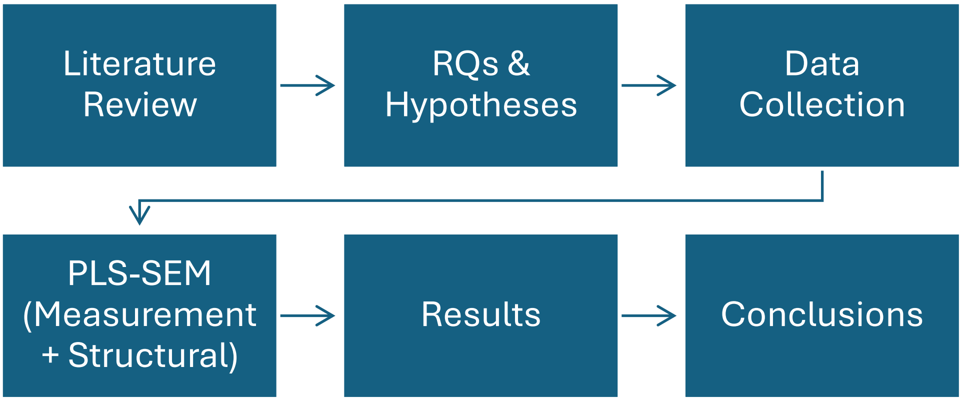

Figure 1: Research process from formulation of research questions to analysis and results

2.1.1 Population

The target population included **employed professionals in Hungary (aged 18+)** managing projects as defined by PMI, **"a temporary endeavor to create a**

unique product, service, or result" (Deterding & Waters, 2021; PMI, 2021). Respondents were required to have **active project management experience**.

2.1.2 Sample

The sample consisted of **project managers** across various organizational levels, responsible for distinct deliverables. Participants were **proficient in English or Hungarian** and were excluded if they failed to meet the inclusion criteria. **Demographic data** were collected to assess external validity.

2.1.3 Power Analysis

An a priori power analysis was conducted following PLS-SEM guidelines (Faber & Fonseca, 2014). Since the "Structural Complexity" construct had the most indicators (22), the minimum sample was set at 220.

G*Power 3 analysis (Cardona-Meza & Olivar-Tost, 2017) confirmed this, using an effect size of 0.05 (Montgomery, 2021), yielding a required minimum of 221 responses. The study secured 243 participants (229 valid), ensuring robust statistical power.

2.2 Procedures

2.2.1 Participant Selection

Participants were recruited through **Google Forms, email, LinkedIn, Facebook groups, and paper surveys**. Randomly selected individuals meeting inclusion criteria received standardized invitations detailing the study's purpose, privacy measures, and timeline. Only consenting participants proceeded to the survey.

2.2.2 Data Protection of Participants

To ensure confidentiality, the survey collected only **basic demographic data**, preventing respondent identification. This approach adhered to ethical principles of **respect, beneficence, and justice** (Hanushek & Jackson, 2013).

2.2.3 Data Collection

A three-stage process ensured data integrity:

Preliminary study: Reviewed and adapted research instruments.

Instrument validation: Pilot-tested tools with a small sample.

Full study: Collected data from the target sample for analysis.

2.2.4 Preliminary Study

Existing measurement tools were adapted for **PM competencies, complexity, and performance**. Modifications, including tense adjustments (Geraldi, 2018), were made in consultation with **Dr. Anna Dunay**. The revised instrument underwent expert review by academics and practitioners to ensure clarity and scale appropriateness.

2.2.5 Instrument Validation Study

A pilot test (n=22) assessed the composite instrument's reliability (Kroh & Schultz, 2023). Results confirmed consistency with original studies, validating its use without further changes.

2.2.6 Full Study

Data collection involved the utilization of a composite survey instrument. The researcher disseminated participation invitations via email and personal messages to the target population, each containing a hyperlink to the survey. Upon receipt, participants exercised their discretion to engage in the study by clicking on the provided link. Concurrently, the reception of the instrument, consent for participation, and submission were monitored and documented. Subsequently, reminders were dispatched to participants to maximize their engagement in the study.

2.2.7 Data Analysis

PLS-SEM (Hierarchical Component Model) was employed to analyze complex relationships (Martínez-Ávila et al., 2021; Tehseen et al., 2017). The approach included:

- **Measurement model**: Linked observed indicators to latent constructs.
- **Structural model**: Mapped hypothesized relationships between variables.

PLS-SEM was chosen over CB-SEM due to its **predictive capabilities** and suitability for theoretically sparse models (Geraldi & Söderlund, 2018). Analysis was conducted using **SmartPLS and SPSS**, covering:

1. Data preparation
2. Instrument validation
3. Structural equation modeling
4. Hypothesis testing

Data Structuring and Statistical Description

The dataset exhibited **no missing values**. Descriptive statistics summarized demographics, while **Kolmogorov-Smirnov/Shapiro-Wilk tests** assessed normality (Martínez-Ávila et al., 2021). Though PLS-SEM does not require normality, these tests informed bootstrap procedures for hypothesis validation.

2.2.8 Hypothesis testing

This study's central research question was derived from a systematic review of project management literature, particularly building on Geraldi and Söderlund's (2018) work examining project complexity as a mediator between management competencies (independent variable) and project performance (dependent variable). The investigation followed Banihashemi et al.'s (2017) three-step mediation analysis framework:

1. Relationship between independent and dependent variables
2. Association between the independent variable and the mediator
3. Mediator's effect on the dependent variable.

Construct Operationalization

The key constructs—project management competencies, complexity, and performance—were modeled as higher-order variables with multiple dimensions, analyzed through a two-tier Hierarchical Component Model (HCM) (Hanushek & Jackson, 2013). The analytical process involved:

- **Model Development**: Created a hierarchical structure in SmartPLS 4 with: Outer layer: Latent variables and indicators and Inner layer: Construct relationships
- **Score Extraction**: Used PLS Algorithm to generate latent variable scores, which were reintroduced as first-order indicators

Hypothesis Testing Procedure

The analysis employed three distinct models (Figures 4-6):

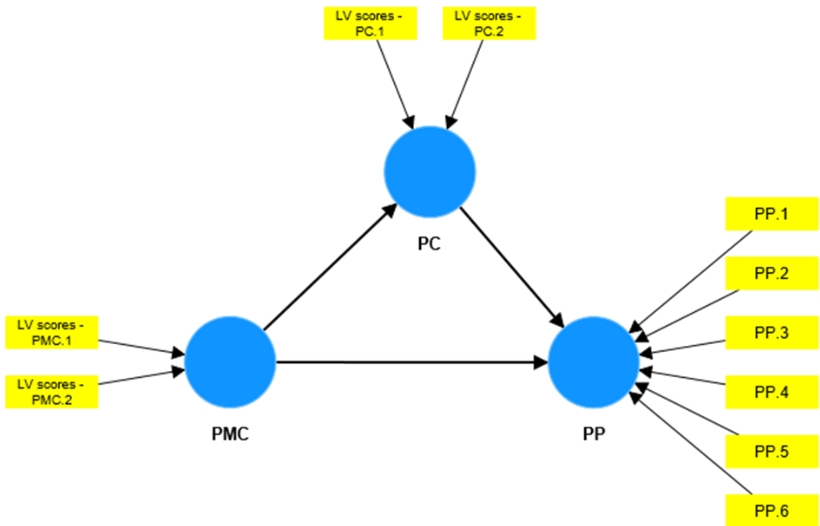

Figure 4: PLS-SEM for hypotheses testing for question Q.1

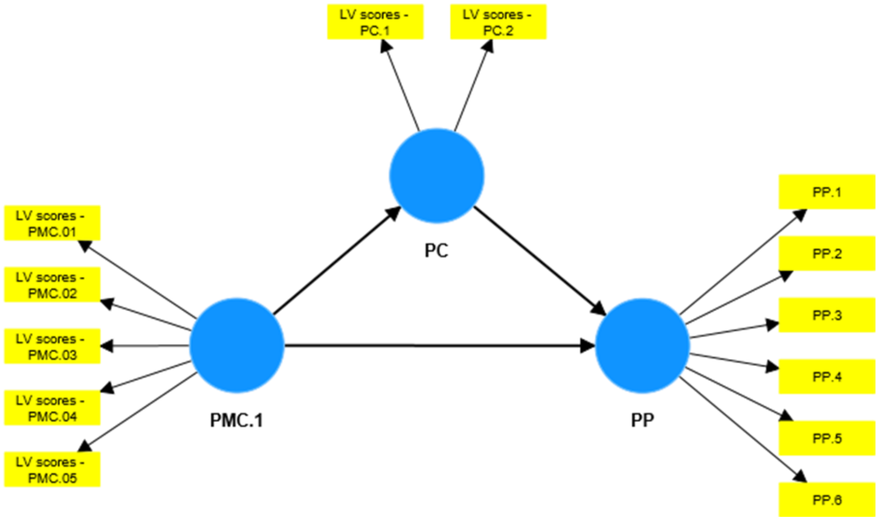

Figure 5: PLS-SEM for hypotheses testing for research question Q.2

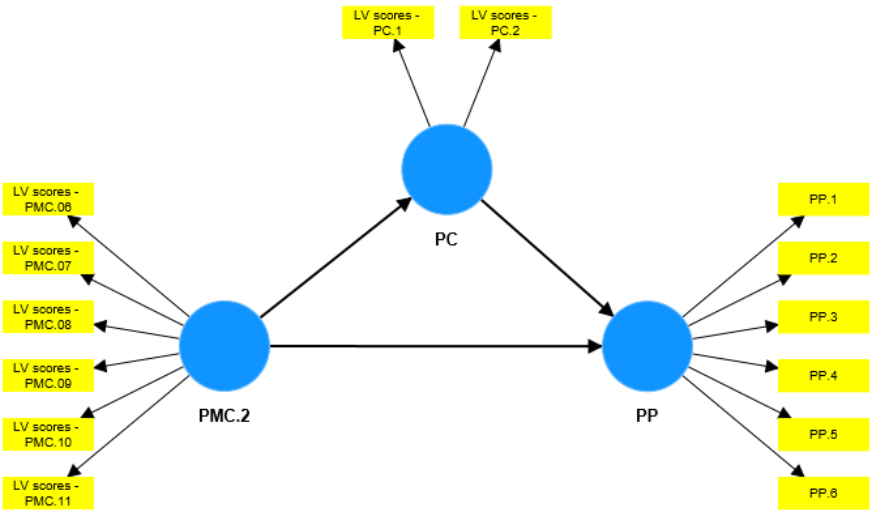

Figure 6: PLS-SEM for hypotheses testing for research question Q.3

The analysis employed three distinct models (Figures 4-9):

1. **Base Model (Q1)**: Full hierarchical structure
2. **Specialized Models (Q2-Q3)**:
    - Replaced PM competencies with:
        - Soft Skills & Personal Development scores (Q2)
        - Technical & Professional Competencies scores (Q3)

3. **Bootstrapping**: 5,000 subsamples with BCA confidence intervals (Gido, 2018)

Table 3: Bootstrap Parameters

Parameter	Setting
Subsamples	5,000
Confidence Interval	Bias-Corrected and Accelerated
Significance	Two-tailed ($\alpha = 0.05$)

Follow-up Analyses

Three supplemental investigations were conducted:

1. **Demographic Profiling** (Table 7):
   - Personal (gender, age, education)
   - Organizational (industry, position, size)
2. **Normality Testing**:
   - Kolmogorov-Smirnov and Shapiro-Wilk tests on transformed latent scores
3. **Model Refinement**:
   - Simplified PLS-SEM version to resolve mediation discrepancies
   - Multi-Group Analysis (MGA) to identify variance sources

This comprehensive approach ensured robust examination of the hypothesized relationships while addressing methodological complexities inherent in hierarchical construct analysis.

2.3 Instrument Development

This study employed three validated measurement tools to assess the core constructs of project management competencies, project complexity, and project performance. Following rigorous adaptation and validation procedures, the final questionnaire was established.

2.3.1 Project Management Competencies Questionnaire (PMCQ):

The PMCQ, adapted from Sugden et al. (2021), evaluates project managers' competencies in alignment with PMI's framework (Institute, 2017). Originally developed for IT projects, the 33-item instrument demonstrated cross-industry applicability. Responses were collected on a 5-point Likert scale (1=Strongly Disagree to 5=Strongly Agree), with summative scores ranging from 33-165 indicating competency levels.

Psychometric properties:

Validity: AVE = 0.632, confirming discriminant validity (Rönkkö & Cho, 2022)

Reliability: Excellent internal consistency ($\alpha = 0.90$)

2.3.2 Complexity Assessment Tool (CAT):

The CAT operationalizes Maylor and Turner's (2017) complexity dimensions through 31 Likert-scale items. Total scores (31-155) inversely reflect perceived complexity, with lower scores indicating greater complexity.

Psychometric properties:

Validity: Established through expert consultation (Rönkkö & Cho, 2022)

Reliability: High internal consistency ($\alpha = 0.90$) (Qiu et al., 2016)

2.3.3 Project Success Questionnaire (PSQ):

Adapted from Saharan et al. (2020), the 14-item PSQ measures success across usability, sustainability, and satisfaction dimensions (Banihashemi et al., 2017). Scores range from 14-70, with higher values indicating greater success.

Psychometric properties:

Validity: AVE = 0.642 meets discriminant validity thresholds (Rönkkö & Cho, 2022)

Reliability: Exceptional internal consistency ($\alpha = 0.93$)

2.4 Ethical Considerations

The study strictly adhered to Belmont Report principles (2022), implementing multiple safeguards:

Respect for Persons:

- Secure data collection via password-protected platforms
- Voluntary participation with informed consent
- Right to withdraw without consequence

Beneficence:

- Minimal risk protocol
- No sensitive or intrusive questions
- Data anonymization procedures

Justice:

- Equitable recruitment through self-selection randomization
- Transparent participation criteria

Ethical approval was obtained from the Hungarian University of Agriculture and Life Sciences, with all procedures conforming to institutional and disciplinary standards for social science research.

3 RESULTS

This study examined the relationship between project management (PM) competencies and project performance, with project complexity as a mediating variable. The research framework extended Binder's (2016) standard PM model, operationalizing constructs through validated instruments (Maylor & Turner, 2017; Banihashemi et al., 2017). Data analysis employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to test four theoretical models.

3.1 Sample Description

3.1.1 Sample Power and Size

A priori power analysis determined the minimum sample size using two approaches:

1. Faber and Fonseca's (2014) rule of 10 observations per indicator (n=220, based on 22 indicators).

2. G*Power analysis (Montgomery, 2021) with parameters:

- Effect size f^2=0.05
- α=0.05
- Power=0.91
- 22 predictors

Both methods converged on a required sample of 221. The final sample included 229 valid responses, ensuring adequate statistical power.

3.1.2 Sample Demographics

Participants represented diverse professional backgrounds:

Gender:	63% male, 37% female
Age:	Predominantly 31-50 years (78.16%)
Education:	52.4% held master's degrees
Experience:	80.78% had 5-25 years of industry experience
Roles:	53.71% in middle/supervisory positions

This distribution provided balanced perspectives across experience levels and organizational hierarchies.

3.1.3 Descriptive Statistics

Descriptive Statistics & Data Normality

- **Project Performance**:
  - Mean scores indicate widespread agreement that projects met objectives.
  - ~98% of responses fell within the “agree” or “strongly agree” categories.
- **Project Management Competencies**:
  - Verbal communication scored highest; empathy scored lowest.
  - Moderate variability across skill use, signified by a standard deviation of around 0.95.
- **Project Complexity**:
  - Respondents reported low to moderate levels of perceived complexity; low variance in responses.
- **Normality Tests**:
  - Kolmogorov-Smirnov and Shapiro-Wilk tests flagged non-normal distributions, typical for Likert data.
  - This poses no concern for PLS-SEM, which is robust to such distributions.

3.1.4 Instrument Reliability and Structural Model Validity

Using SmartPLS4, we assessed:

- **Indicator validity**:
  - p-value < 0.05 and Variance Inflation Factor (VIF) < 5 for causal indicators.
  - Of 18 questionable indicators, 10 were removed for low outer loading (<0.50).

- **Construct validity**:
  - Nomological validity confirmed: all hypothesized paths were significant ($0.18 < f^2 < 0.4$).

Structural Model Evaluation

- **R^2 values**:
  - Project Complexity: $R^2 = 0.17$; Project Performance: $R^2 = 0.20$.
- **Effect sizes (f^2)**:
  - Project Complexity → Project Performance: $f^2 = 0.14$ (moderate)
  - Competencies → Performance: $f^2 = 0.02$ (small)

The model shows moderate explanatory power, suitable for exploratory research in this domain.

3.2 Hypothesis Testing

3.2.1 PLS-SEM Model M1: Hypothesis Testing and Mediation Analysis

Model M1 examined whether project complexity mediates the competencies–performance relationship:

- Path a (Competencies → Complexity): **$\beta = 0.41$, $t = 6.20$, $p < 0.001$**
- Path b (Complexity → Performance): **$\beta = 0.26$, $t = 1.80$, $p = 0.012$**
- Direct path c (Competencies → Performance): **$\beta = 0.35$, $t = 2.08$, $p = 0.037$**
- Indirect effect ($a \times b$): statistically significant; direct effect remained but was reduced.

Conclusion: Partial mediation supported—project complexity partially transmits effects of competencies to performance.

3.2.2 PLS-SEM Model M2 and M3: Advanced Mediation Testing

To explore competency types, models M2 and M3 were deployed:

- **Model M2**: Tested mediation of **Soft Skills & Personal Competencies** → Complexity → Performance.
  - Paths a and b were significant; the direct effect was non-significant.

- Conclusion: Full mediation by Complexity supported (βab significant, βc’ non-significant).

- **Model M3**: Tested mediation of **Technical & Professional Competencies** → Complexity → Performance.
  - Path a and b were significant; no direct effect remained.
  - Conclusion: Full mediation also supported.

3.3 Follow-up Analysis

To verify the consistency and robustness of Model M1, a streamlined version—**Model M1s**—was created by removing the third-level latent variables, allowing direct loading of first-order indicators onto the core constructs (**Project Management Competencies** and **Project Complexity**). This adjustment aimed to test whether simplifying the structure would significantly affect hypothesis testing outcomes.

3.3.1 Simple Structural Model

The simplification emerged following notable differences between Model M1 and subsequent models (M2 and M3), which separately assessed **Soft Skills & Personal Competencies** and **Technical & Professional Competencies**. These parallel examinations suggested potential structural limitations in the broader latent structure of Model M1.

- **Model M1s**: Directly maps first-order indicators to core constructs, removing intermediate latent levels.

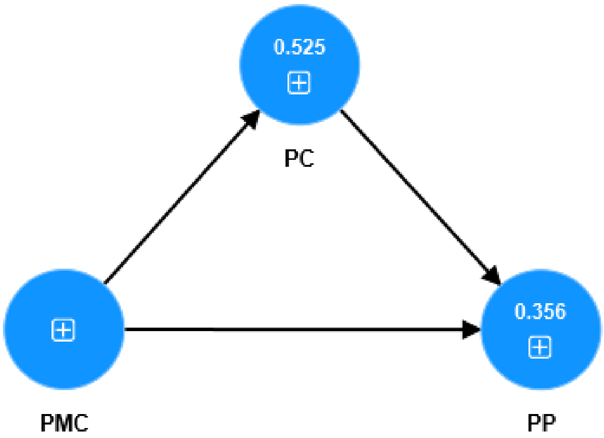

Figure 5: Simple Model (Follow-up Analysis) M1s-related indicators loaded directly on study constructs.

3.3.2 Predictive Power & Effect Size

Table 3: Model M1s (Follow-up Analysis) Coefficient of Determination R^2

Study Construct	**Model M1**		**Model M1s**	
	R^2	R^2 Adjusted	R^2	R^2 Adjusted
PC	0.174	0.171	0.526	0.524
PP	0.198	0.182	0.351	0.345

Table 4: Model M1s (Follow-up Analysis) Effect Size f^2

Study Construct	***Model M1***			***Model M1s***		
	PMC	*PC*	*PP*	*PMC*	*PC*	*PP*
PMC		0.011	0.021		1.111	0.195
PC			0.141			0.007
PP						

- **R² improvements**: PC increased markedly from 0.174 to 0.526; PP rose from 0.198 to 0.351.

- **Effect changes**: The influence of PMC on PC escalated from weak to strong (f^2: 0.011 → 1.111); PMC on PP changed from small to moderate (0.021 → 0.195); while PC → PP effect notably declined.

These shifts reflect greater explanatory clarity when latent constructs are simplified, aligning with Aria (2018) on model parsimony and interpretability.

3.3.3 Indicator Validity in M1s

- **Criteria**: p-value < 0.05 and VIF < 5 (Martinez Avila et al., 2021).
- **Findings**: Out of 120 indicators, 106 met at least one criterion. Several indicators showed weak outer loadings and were dropped, emphasizing the need for better measurement of latent constructs.

3.3.4 Hypothesis Testing via Bootstrapping

Bootstrap results for M1s reaffirmed mediation effects:

Table 5: Bootstrap results of paths of M1s

Hypothesis ID	Path code	Model Path	t-score	p-value
H1.1	*a*	*PMC»» PC*	9.090	0.000
H1.2	*b*	*PC»»» PP*	3.648	0.000
H1.3	*c*	*PMC»»» PP*	0.753	0.452

- **Indirect effect (PMC → PC → PP)**: Significant, supports mediation.
- **Direct effect (PMC → PP)**: Non-significant in simplified model, signifying **full mediation**.

3.3.5 Interpretation & Implications

1. **Construct Sensitivity**: Simplification boosted predictive power, suggesting overly complex latent frameworks may dilute effects.
2. **Measurement Refinement**: Indicator validity issues highlight potential misspecification; the model should be recalibrated with clearer variables.

Model Enhancement: Findings motivate exploration of alternate paths and inclusion of additional constructs to strengthen the predictive model and guide future iterations of project management theory.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Analysis of Sample Characteristics

Our participant pool featured a majority of male respondents (63%) and adults in the 31–50 age range (approximately 78%), reflecting experienced professionals. With 55% from software-related sectors and 45% from other industries, the sample captured diverse project environments. Most respondents held master's degrees (52%) and occupied mid-to-senior management roles, often supervising teams of fewer than 30. Their extensive field experience (predominantly 5–25 years) offers a robust foundation for understanding how competencies and complexity influence performance.

4.2 Results for Primary Research Questions

Model M1, based on established latent-level constructs, did not fully support mediation until first-order latent variables were removed, highlighting issues within the structural specification. Interestingly, as project complexity increased, the application of managerial competencies appeared to fall, suggesting a potential competency dilution in highly complex settings.

4.3 Results for Secondary Research Questions

Separate analysis of *Soft Skills & Personal Competencies* (Model M2) and *Technical & Professional Competencies* (Model M3) confirmed that project complexity indeed plays a mediating role. While effect sizes increased when models were flattened, the stability and generalizability of these paths remain unclear, pointing to the need for additional theoretical and empirical scrutiny.

4.4 Conclusions for Research Question Results

1. Project complexity significantly mediates the link between PM competencies and performance, confirmed across different structural models.
2. Simplified models (flattened structures) produced larger, more consistent path coefficients, underscoring the importance of structural clarity.
3. A notable inverse correlation between complexity and competency usage suggests that complex settings may inhibit effective competency deployment. This offers practitioners a clear opportunity: enhancing and adapting competencies specifically for high-complexity contexts can support better project outcomes.

4.5 Limitations

1. **Measurement scope** – The complexity instrument used lacked coverage of emergent dimensions, limiting depth.
2. **Sampling bias** – Online, self-selective recruitment may not reflect the broader Hungarian project manager population.
3. **Instrument development** – Tools for measuring competencies and complexity are still evolving and lack universal standardization.
4. **Causal inference** – The non-experimental, cross-sectional design does not permit definitive causal claims.

4.6 Practical Implications

The proposed model can be used as a **diagnostic tool** to identify competency gaps under different complex conditions. For instance, high socio-political complexity requires stronger stakeholder skills, while technical complexity emphasizes analytical and technical competencies. Organizations can integrate the model into **training, assessment, and planning processes**, with a simplified version.

The study confirmed that project management competencies positively influence project outcomes but also revealed that rising project complexity can limit their effective use. These findings urge managers to pay greater attention to applying competencies in complex environments.

5.6 Future Research Directions

Future studies should adopt **longitudinal designs**, broaden the industry and regional scope, and further refine **complexity measurement tools**. Overall, the study validates project complexity as a **mediator** of competencies and performance, while highlighting the need for more refined models for practical use.

5 NEW SCIENTIFIC RESULTS

This doctoral research contributes to the evolving body of knowledge in project management by deepening the understanding of how project complexity mediates the relationship between project management competencies and project performance, particularly within the context of Hungarian organizations. Through empirical investigation and advanced modeling techniques, I present the following new scientific results:

1. Validation of Project Complexity as a Mediator

I proved that project complexity functions as a mediating factor linking project management competencies to project performance outcomes. Building on the theoretical frameworks of Geraldi (2021) and Maylor & Turner (2017), I concluded that complexity significantly shapes how competencies translate into successful project execution. This mediating effect refines the understanding of project dynamics and reinforces complexity theory as a relevant perspective in project-based research.

2. Enhanced Model Structure Supporting Mediation Hypothesis

I tested multiple model structures (M1, M1s, M2, and M3) using Partial Least Squares Structural Equation Modeling (PLS-SEM) and concluded that the mediation hypothesis remains robust across different configurations. I proved that simplified models without hierarchical latent variables (particularly Model M1s) yielded stronger path coefficients. This demonstrates that overly complex model structures may obscure relationships, and I identified the value of iterative model testing for improving best practices in evaluating complex constructs.

3. Inverse Relationship Between Complexity and Competency Application

I identified a negative relationship between project complexity and the utilization of project management competencies. I concluded that as project complexity increases, the application of competencies tends to decrease. This challenges the conventional assumption that more complex projects demand higher competency deployment. I proved that project managers may face barriers in fully applying their competencies in highly complex environments, which has critical implications for project performance.

4. Sector-Based Insights into Competencies and Complexity

I analyzed data across both software and non-software industries and proved that the interaction between competencies and complexity differs by sector. I concluded that sectoral characteristics influence how competencies are applied and perceived. This finding contributes to contextualizing project management practices and lays the groundwork for developing industry-specific competency frameworks.

5. Refinement of Complexity Measurement Tools

I critically evaluated existing complexity measurement instruments and proved that widely used tools, such as the Complexity Assessment Tool (CAT), fail to account for emergent complexity. I concluded that a refined multidimensional approach is necessary to capture structural, socio-political, and emergent aspects of complexity. This contributes to advancing instrument development and supports methodological innovation in complexity research.

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