

MODELLO PER LA PRESENTAZIONE DEL PROGETTO DI RICERCA

a) **Titolo del progetto:**

Understanding Structural Limitations of Model-Driven Engineering Platforms: A Conceptual Framework and Empirical Survey

b) **PI:**

Alfonso Pierantonio

c) **Posizione accademica del proponente:**

Professore Ordinario

d) **Curriculum vitae del proponente (max 5000 caratteri – circa 2 pagine) con elenco delle pubblicazioni più significative (max 10) nel periodo 2021-25, relative al tema del progetto. Indicatori ASN 2024/26 alla scadenza del bando (solo per i progetti di ricerca) relativamente alla fascia superiore del Settore concorsuale e del Settore scientifico disciplinare di appartenenza.**

Alfonso Pierantonio is a Full Professor of Software Engineering at the University of L'Aquila (Italy), Department of Engineering and Information and Mathematical Sciences, where he coordinates the Software Engineering Research Group (SWEN). Since 2016, he has been Visiting Full Professor at Mälardalens University (Sweden). His research activity focuses on Model-Driven Engineering (MDE) and Language Engineering, with particular emphasis on co-evolution techniques, consistency management, bidirectionality, and the design and evaluation of advanced modeling tools and platforms.

His research also includes foundational work on the cognitive foundations of modeling tools, notably the journal article “The Cognitive Science of Modeling Tools” (Software and Systems Modeling), which provides the theoretical basis for the present project.

His recent research interests include the structural and cognitive aspects of modeling tools, the evaluation of modeling platforms, and the relationship between modeling languages, tooling infrastructures, and human reasoning processes. In this context, he has recently launched Jjodel, a research initiative aligned with the present project, conceived as a reflective modeling

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platform to support the analytical exploration of structural limitations in model-driven engineering and the study of their impact on modeling practices.

Alfonso Pierantonio has authored over 200 peer-reviewed scientific publications in international journals and conference proceedings and has collaborated with a broad international network of academic and industrial partners. He has been principal (or co-principal) investigator of several EU and industrial projects. He serves as Editor-in-Chief of the Journal of Object Technology and is a member of the editorial and advisory boards of Springer Software and Systems Modeling and Elsevier Science of Computer Programming, respectively. He has played a leading role in the international research community as General Chair of MoDELS 2023 and STAF 2015, Program Chair of ECMFA 2018, Program Chair of MODELS NIER 2026 and as a long-standing member of steering and organizing committees for major conferences in model-driven engineering and software languages. He has been invited as keynote speaker and invited lecturer at several international conferences, workshops, and summer schools in the areas of model-driven engineering and software languages, including a keynote at MODELSWARD 2025 (“Transparency of Tools: Beyond Usability in Modeling Tools”).

His scientific impact is reflected in the following bibliometric indicators:

- Google Scholar: h-index 40, 6,748 citations;
- Scopus: h-index 31, 3,532 citations.

Selected publications (2021–2025)

1. Pierantonio, A., Gozzano, S., & Mazza, M. (2026). The Cognitive Science of Modeling Tools. *Software and System Modeling*, to appear (Q1)
2. Bucchiarone, A., Di Rocco, J., Di Vincenzo, D., & Pierantonio, A. (2025). Modeling in Jjodel: Bridging Complexity and Usability in Model-Driven Engineering. *Software and Systems Modeling*, 1-25. (Q1)
3. Tolvanen, J.-P., Kelly, S., Di Rocco, J., Pierantonio, A., & Tinella, G. (2025). A framework for evaluating tool support for co-evolution of modeling languages, tools and models. *Software and Systems Modeling*, 24(2). (Q1)
4. Bettini, L., Di Salle, A., Iovino, L., & Pierantonio, A. (2024). Supporting reusable model migration with Edelta. *Journal of Systems and Software*, 212. (Q1)

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5. Eisenberg, M., Sahay, A., Di Ruscio, D., Iovino, L., Wimmer, M., & Pierantonio, A. (2024). Multi-objective model transformation chain exploration with MOMoT. *Information and Software Technology*, 174. (Q1)
6. Di Ruscio, D., Di Rocco, J., Nguyen, P. T., & Pierantonio, A. (2023). MemoRec: a recommender system for assisting modelers in specifying metamodels. *Software and Systems Modeling*, 22(1). (Q1)
7. Di Ruscio, D., Di Salle, A., Iovino, L., & Pierantonio, A. (2023). A modeling assistant to manage technical debt in coupled evolution. *Information and Software Technology*, 156. (Q1)
8. Sahay, A., Di Ruscio, D., Iovino, L., & Pierantonio, A. (2023). Analyzing business process management capabilities of low-code development platforms. *Software: Practice and Experience*, 53(4), 1036-1060. (Q2)
9. Di Ruscio, D., Kolovos, D., de Lara, J., Pierantonio, A., Tisi, M., & Wimmer, M. (2022). Low-code development and model-driven engineering: Two sides of the same coin? *Software and Systems Modeling*, 21(2). (Q1)
10. Bettini, L., Di Ruscio, D., Iovino, L., & Pierantonio, A. (2022). An executable metamodel refactoring catalog. *Software and Systems Modeling*, 21(5), 1689-1709. (Q1)

- e) Eventuali componenti del gruppo di ricerca (solo per i progetti di ricerca di base)
- f) Settore di ricerca ERC di riferimento per la proposta (indicare anche due sotto-settori)
- PE6 – Computer science and informatics
- PE6_14 – Systems and software
- PE6_10 – Modelling tools

- g) **Abstract** (max 1000 caratteri)

Model-Driven Engineering (MDE) platforms play a central role in the design of complex software-intensive systems, including cyber-physical and safety-critical ones, and in capturing domain knowledge through domain-specific artifacts. Despite decades of research, their effective adoption remains constrained by persistent difficulties that transcend individual technologies. This project investigates the structural limitations of contemporary MDE platforms from a conceptual and methodological perspective. Grounded in the view of MDE platforms as cognitive artifacts, it

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develops a conceptual framework identifying recurring limitations, including metamodel rigidity, challenges in model–metamodel co-evolution, limited support for incompleteness, and mismatches between modeling languages and practitioners’ cognitive processes. The framework builds on recurrent needs observed in MDE research and education and will be explored through a theory-driven survey of the international MDE community, complemented by analytical examination using Jjodel as a representative reflective modeling platform.

h) **Descrizione del progetto** (max 8.000 caratteri, compresi eventuali riferimenti bibliografici. È consentito inserire figure nella proposta. Le figure non concorrono alla determinazione del calcolo del numero dei caratteri.)

- a. Stato dell’arte
- b. Obiettivi
- c. Metodologia
- d. Piano di lavoro

Il progetto deve essere redatto in una sola lingua, a scelta tra italiano ed inglese.

a) **State of the art**

Model-Driven Engineering (MDE) platforms have long represented a cornerstone in the development of complex software systems, thanks to their ability to abstract, structure, and operationalize domain knowledge through models and domain-specific languages. Despite the maturity of the field and the availability of well-established platforms such as EMF, GMF, Sirius, or JetBrains MPS, the effective adoption of MDE remains limited and often confined to specific contexts.

The literature has investigated these limitations from multiple perspectives (Bucchiarone et al, 2020). On the one hand, research on structural and research challenges in MDE has highlighted recurring issues related to tool complexity, model/metamodel co-evolution (Cicchetti et al, 2008), and integration within industrial development processes (Bucchiarone et al, 2020). On the other hand, studies on the design of modeling languages and notations have shown how structural and syntactic choices directly affect comprehensibility and usability. In this respect, Moody’s work on the “Physics of Notations” provides a foundational theoretical basis, demonstrating how cognitively grounded principles can guide the construction of more effective visual notations (Moody, 2009).

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More recently, increasing attention to cognition in software engineering has led to comprehensive syntheses of decades of research, emphasizing the role of cognitive load, reasoning processes, and mental strategies in both professional practice and educational settings (Fagerholm, 2022). These aspects are particularly relevant in MDE, where both instructors and students are required to manage high levels of abstraction and conceptual complexity (Mazza, Gozzano, and Pierantonio; to appear). However, cognitive perspectives are still rarely integrated in a systematic way into the analysis of MDE platforms as complex socio-technical artifacts.

Overall, the state of the art reveals a fragmentation between technological analyses of MDE platforms, studies on modeling notations, and results from cognitive science. What is currently missing is a unifying conceptual framework that interprets recurring difficulties as structural limitations shared across platforms and rooted in the way MDE tools support, constrain, or overload human cognitive processes.

Recent work has explicitly framed modeling tools as cognitive artifacts, investigating how their structural properties shape reasoning processes and cognitive load during modeling activities.

b) Objectives

The overall goal of the project is to contribute to research of base in model-driven engineering by providing a systematic understanding of the structural limitations of MDE platforms, interpreted through the lens of cognitive artifacts.

The project pursues the following scientific objectives:

- **O1:** To define a conceptual framework that identifies and organizes recurring categories of structural limitations in MDE platforms, including metamodel rigidity, challenges in model–metamodel co-evolution, limited support for incompleteness and ambiguity, and cognitive load induced by modeling languages and tools;
- **O2:** To empirically assess the relevance and pervasiveness of the identified limitations through a theory-driven survey targeting the international MDE research community, considering both research practice and teaching and learning contexts;

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- **O3:** To analyze selected limitations in depth through exploratory scenarios supported by Jjodel, used as a reflective modeling platform to study concrete interactions between tool structures, modeling practices, and cognitive processes.

c) Methodology

The project adopts a methodology that combines conceptual analysis with focused empirical investigation, in line with its exploratory and foundational nature.

In the first phase, a critical analysis of the literature on MDE platforms, modeling notations, and cognitive aspects of software engineering will be conducted. This analysis will lead to the definition of a conceptual framework capturing key categories of structural limitations and their expected implications for modeling activities, reasoning strategies, and cognitive load.

The framework will then be empirically grounded through a mixed-method survey, combining structured questions with open-ended items. The survey will primarily target MDE researchers and, in a selective manner, advanced practitioners involved in modeling and education. Rather than being purely descriptive, the survey will be explicitly designed to test hypotheses derived from the conceptual framework.

Finally, Jjodel (A. Bucchiarone et al.; 2025) will be employed both as an analytical case study and as a tool for constructing small exploratory scenarios, enabling an in-depth examination of how specific structural choices affect model evolution, expressiveness, and perceived cognitive effort. This triangulation will strengthen the validity of the results by combining community-wide evidence with tool-based analytical observations.

d) Work plan

Phase	Months	Activity
Phase 1	M1-M4	1. Conceptual framework construction <ol style="list-style-type: none">Literature review and definition of the conceptual frameworkFormalization of structural limitation categories
Phase 2	M5-M8	2. Empirical validation through survey

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- a. Design and pilot validation of the survey
 - b. Survey deployment and data analysis

Phase 3	M9-M10	3. Exploratory scenarios and analytical validation using Jjodel
Phase 4	M11-M12	4. Dissemination: synthesis of results and preparation of publications

Expected outputs include three scientific publications: one high-impact international publication and two medium-level publications, fully aligned with the objectives of the project.

References

- [1] Cicchetti, A., Di Ruscio, D., Eramo, R., & Pierantonio, A. (2008) Automating co-evolution in model-driven engineering. In 12th International IEEE enterprise distributed object computing conference. IEEE
- [2] Bucchiarone, A., Cabot, J., Paige, R. F., & Pierantonio, A. (2020). Grand challenges in model-driven engineering: an analysis of the state of the research. *Software and Systems Modeling*, 19(1), 5-13
- [3] Moody, D. (2009). The “physics” of notations: toward a scientific basis for constructing visual notations in software engineering. *IEEE Transactions on software engineering*, 35(6), 756-779
- [4] Fagerholm, Fabian, et al. “Cognition in software engineering: A taxonomy and survey of a half-century of research.” *ACM Computing Surveys* 54.11s (2022): 1-36
- [5] Bucchiarone, A., Di Rocco, J., Di Vincenzo, D., & Pierantonio, A. (2025). Modeling in Jjodel: towards bridging complexity and usability in model-driven engineering. *Software and Systems Modeling*, 1-25
- [6] Mazza, M., Gozzano, S. & Pierantonio, A. The Cognitive Science of Modeling Tools, *Software and Systems Modeling*, to appear

- i) **Elementi di originalità e innovazione della proposta e impatto in termini di rilevanza dell'avanzamento nella ricerca di base per la comunità scientifica di riferimento** (max 3000 caratteri)

The originality of the proposed research lies in its conceptual reframing of Model-Driven Engineering platforms as cognitive artifacts and in the systematic investigation of their

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limitations as structural rather than tool-specific issues. While existing studies often focus on individual languages, platforms, or technological shortcomings, this project advances the state of the art by identifying recurring limitations that emerge across different MDE environments and by interpreting them through a unified conceptual lens grounded in cognitive science and software engineering research.

A key innovative aspect of the proposal is the development of a conceptual framework of structural limitations that integrates insights from three traditionally separated research streams: (i) research on MDE platforms and tools, (ii) studies on modeling languages and visual notations, and (iii) cognitive and behavioral research in software engineering. By explicitly connecting these strands, the project addresses a gap in the literature highlighted by recent surveys and challenge papers, which call for deeper theoretical foundations and more explanatory accounts of the persistent difficulties in MDE adoption and use.

Methodologically, the project introduces an original combination of theory-driven empirical validation and analytical exploration using a reflective modeling platform. Rather than relying on purely descriptive surveys, the proposed empirical study is designed to test hypotheses derived from the conceptual framework, thereby strengthening the explanatory power of the results. The use of Jjodel as an analytical and exploratory instrument further contributes to innovation by enabling the examination of structural limitations in concrete yet controlled scenarios, without reducing the research contribution to the evaluation of a specific tool.

The expected impact on research of base is twofold. First, the project will provide the MDE research community with a validated conceptual taxonomy of structural challenges, offering a shared vocabulary and analytical reference point for future studies. Second, by clarifying the cognitive and methodological roots of long-standing issues, the project will support the development of more principled theories of modeling languages and tools. These outcomes are expected to influence subsequent foundational research in model-driven engineering, human-computer interaction for programming tools, and the cognitive science of software engineering, thereby advancing the theoretical understanding of how modeling technologies shape and constrain human reasoning in complex software development.

j) **Impatto del progetto in riferimento alle tematiche di genere** (facoltativo, max 3000 caratteri)

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While gender-related aspects are not the primary focus of the proposed research, the project acknowledges the relevance of gender-sensitive perspectives in the design, use, and evaluation of software engineering tools, particularly in cognitively demanding domains such as model-driven engineering.

By conceptualizing MDE platforms as cognitive artifacts, the project explicitly addresses factors related to cognitive load, comprehensibility, and reasoning effort. These aspects are known to play a role in shaping participation, learning outcomes, and long-term engagement in technical disciplines, including those where gender imbalances persist. Structural characteristics of modeling languages and tools that unnecessarily increase cognitive effort or favor specific reasoning styles may act as implicit barriers, especially in educational and early-career contexts.

The empirical component of the project will adopt an inclusive approach in the design and dissemination of the survey, paying attention to balanced representation, neutral language, and the avoidance of methodological biases. Where relevant, survey data will allow for exploratory analyses aimed at identifying whether certain perceived limitations disproportionately affect specific groups, including instructors and students at different career stages.

By contributing to a deeper understanding of how structural properties of MDE platforms influence cognitive processes, the project may indirectly support the development of more accessible and inclusive modeling technologies. In this sense, the proposed research aligns with broader institutional and European objectives on equality and inclusion, while remaining firmly grounded in research of base.

Piano di spesa

<i>Voce di spesa</i>	<i>Importo (Euro)</i>
Borse di ricerca (art.2 del Regolamento per il conferimento di borse di ricerca attualmente in vigore)	13,500
Rinnovo assegni di ricerca	
Materiali di consumo	
Attrezzature, strumentazioni, software	
Missioni	
Acquisto prodotti ritenuti necessari per la realizzazione del progetto (es. materiale librario, licenze per l'accesso a banche dati,	

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ecc.)	
Pubblicazioni, organizzazione di convegni e workshop	1,500