UNIVERSITÀ DI PISA

BUSSINESS PROCESS MODELLING
Project Report

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Contents

1 - Introduction

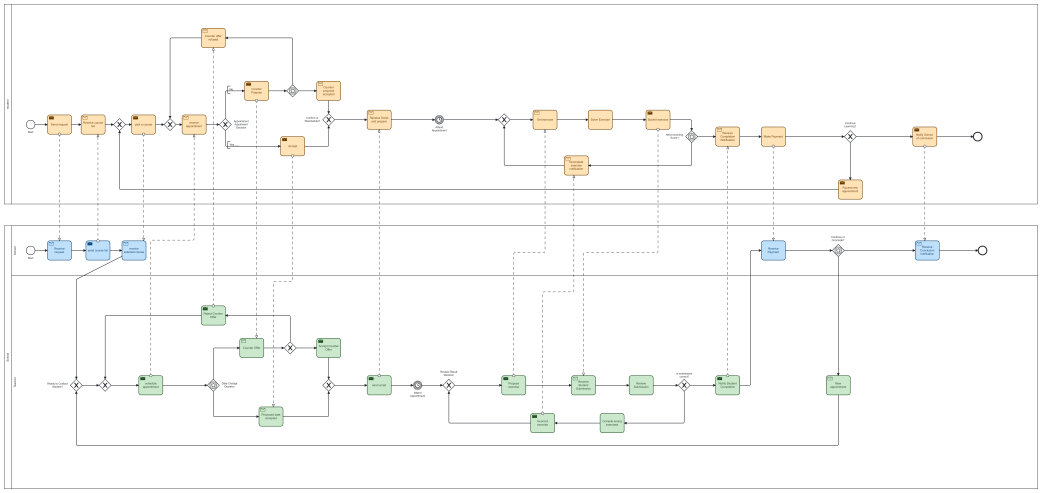
The goal of this project is to design and analyze a business process based on a real-world scenario involving an acting school. The modelling process involved creating a BPMN collaboration diagram and subsequently converting each participant's process into a Workflow Net (WF-net) using Petri net formalism. The project concludes with the integration of the individual WF-nets into a unified model and an assessment of its structural and behavioral properties.

2 - BPMN Design

The BPMN diagram was constructed as a collaboration model consisting of two distinct pools. The first pool represents the **Student**, and the second pool is subdivided into two lanes: one for the **School** and one for the **Teacher**. This design reflects the organizational structure and clarifies the division of responsibilities among the participants.

The model captures the full life cycle of interaction from the student's initial course request and lesson scheduling to script delivery, exercise performance, and the final decision to either continue or terminate the course.

The diagram was developed using Camunda Modeler, chosen for its ease of use and adherence to BPMN standards. Message flows were used between pools to represent asynchronous interactions, accurately modeling the communication dynamics of the real-world scenario.



3 - Workflow Net Transformation

Each pool in the BPMN model was individually translated into a Workflow Net (WF-net) using WoPeD. The transformation adhered to the standard three-step methodology for converting BPMN diagrams into Petri nets suitable for formal analysis:

1. **Convert Flows:** Every sequence flow and message flow in the BPMN model was replaced by a corresponding place in the WF-net. These places serve as control links between transitions, ensuring correct token flow.
2. **Convert Flow Objects:** Transitions were introduced for each BPMN flow object, including tasks, events, and gateways. Specific attention was given to accurately modeling control-flow behavior such as AND/XOR splits and joins, without introducing unnecessary dummy transitions.
3. **Enforce Initial and Final Places:** A single input place and a single output place were created to satisfy the definition of a WF-net. These unify multiple start or end events, where necessary, and establish the entry and exit points for process execution.

Prior to conversion, the BPMN diagrams were simplified to align with best practices. Each activity or intermediate event was ensured to have exactly one incoming and one outgoing flow, and each gateway was normalized to reflect either split or join behavior only. OR-gateways were deliberately avoided due to their semantic complexity.

The resulting WF-nets for both the Student and School modules were implemented in WoPeD and subjected to analysis. Each net satisfied the following properties:

- **Soundness:** Proper completion, option to complete, and absence of dead transitions were verified.
- **Safeness and Boundedness:** No place ever carried more than one token, and all reachable markings were finite.
- **Free-choice and Well-structuredness:** No structural violations were found in the individual nets.

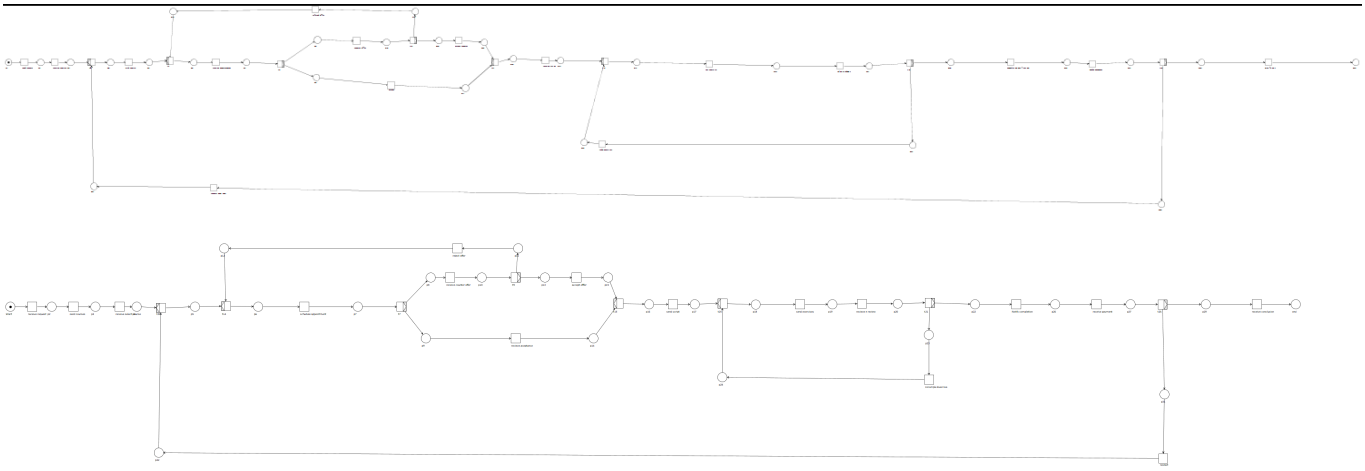
These findings confirm that both individual modules were structurally correct and behaviorally sound before being merged.

4 - Integration of Workflow Nets

Following the validation of the individual WF-nets, the Student and School modules were integrated into a single unified WF-net to represent the overall collaborative process. This integration required the introduction of intermediary places to coordinate transitions that depend on one another across the two modules. For instance, when a student issues a counter-offer, a dedicated place is used to enable only the corresponding teacher transition that responds to that counter-offer.

Additionally, XOR splits present in the BPMN model—originally represented as single transitions with multiple outgoing arcs—were desugared into a place followed by separate transitions. This transformation ensures that only one branch is selected based on the token flow, aligning with the exclusive decision logic intended in the process semantics.

While this modeling choice introduces free-choice violations (since transitions share input places but have distinct enabling conditions), it is deliberate. The aim is to restrict concurrent enablement and enforce conditional behavior. For example, if the student proposes a counter-offer, only the teacher's transitions to accept or reject that specific offer should be enabled—excluding unrelated branches. This mechanism accurately captures the real-world dependencies and enforces correct inter-role synchronization.



5 - Final Workflow Net Analysis

We checked the structural and behavioral analysis of the final model using WoPeD. The net includes:

- **Places:** 65
- **Transitions:** 57
- **Arcs:** 144
- **Operators:** 9

Soundness: The workflow net is fully sound, satisfying the properties of proper completion, option to complete, and no dead transitions.

Free-choice: The net has **4 free-choice violations**, where transitions share an input place but are not part of the same block, particularly in areas involving negotiation and synchronization. e.g The counter offer example explained earlier

Well-structuredness: The net has **112 PT-handles** and **120 TP-handles**, suggesting a moderately complex but manageable structure.

S-Components: All **63 places** are part of S-components, ensuring strong structural support and cyclic behavior.

Invariants: Positive S-invariants exist, validating token conservation. T-invariants are implied by loops and termination points, even if not explicitly computed.

Safeness: The net is safe. Each place holds at most one token in all reachable markings.

Reachability Graph Estimate: While a full reachability graph couldn't be generated, based on coverability and structural branching, the net is estimated to have over **500 unique states**.

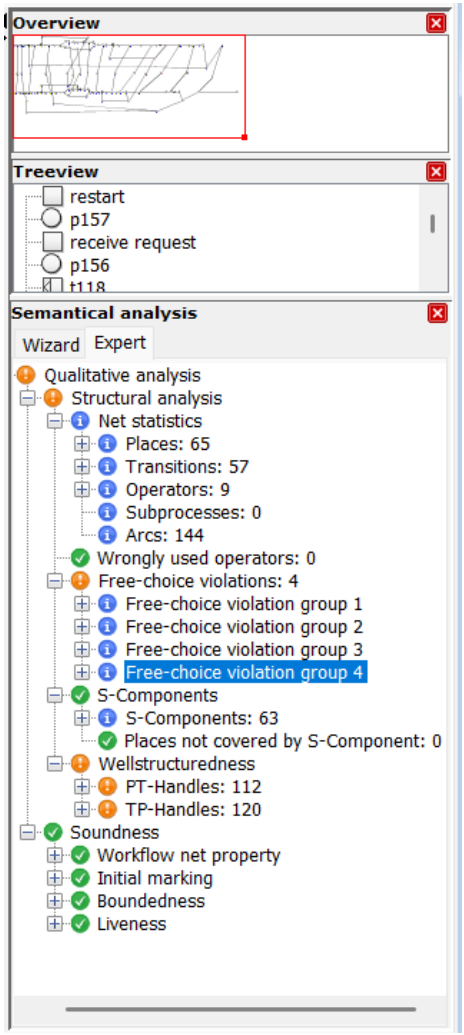


Figure 1: WoPeD structural analysis

6 - Coverability Analysis

Due to tool limitations, the reachability graph could not be extracted directly. Instead, we conducted a coverability analysis using WoPeD. But we know that since the net is bounded, the results of the reachability graph and the coverability graph are the same. Therefore, this method allows us to inspect possible system states and ensures that all transitions are eventually fireable under some execution sequence.

The coverability graph supports our verification of soundness and absence of deadlocks in the unified net. While exact state counts are unavailable, the graph shows all key behavioral paths and indicates correct termination in the final place.

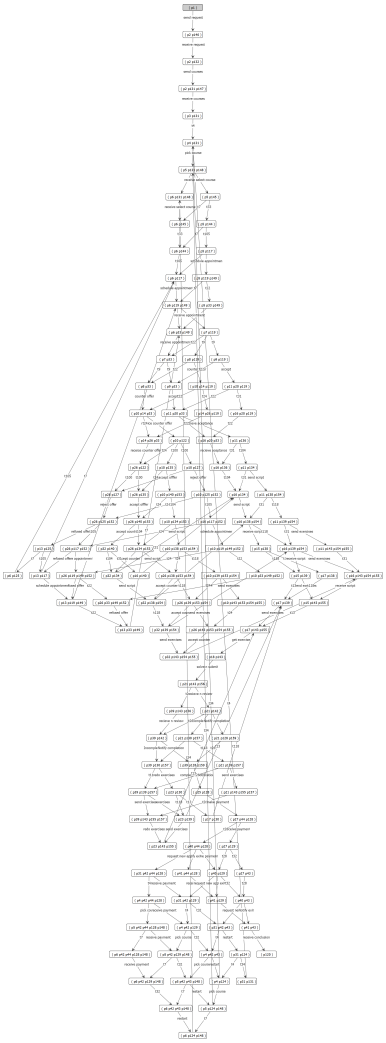


Figure 2: Coverability Graph of the Unified Workflow Net

7 - Conclusion

This project demonstrated a complete modelling cycle for a business process using BPMN and Petri net-based workflow nets. From abstract collaboration diagrams to formal WF-nets, the scenario was accurately captured and analyzed. The final unified net is sound, with a few acceptable violations of structural properties owing to the interactive nature of the process.

Future work may include refining the structure to eliminate free-choice violations and exploring automated synthesis of connectors based on behavioral dependencies.

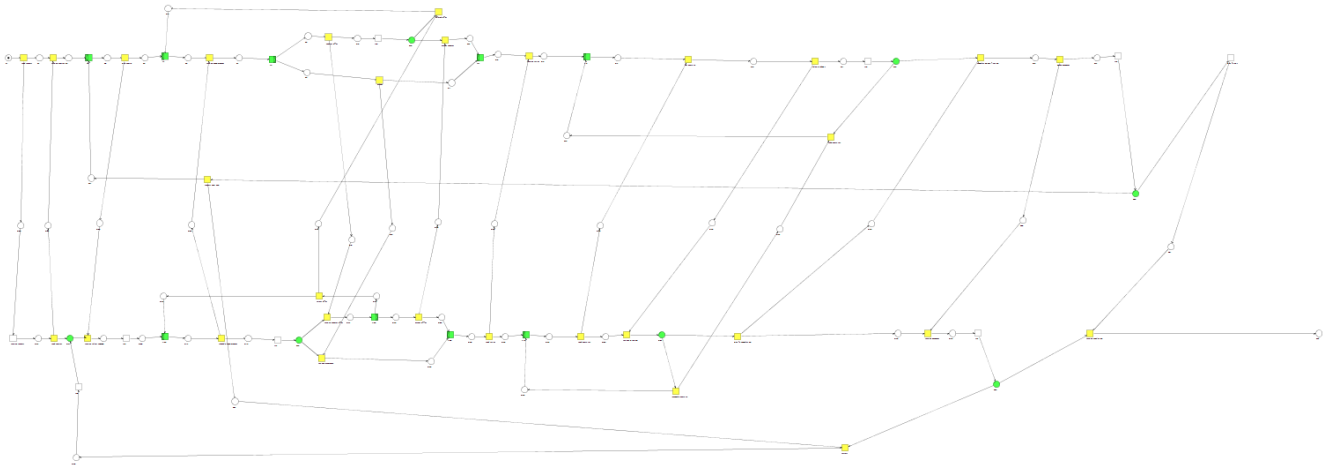


Figure 3: Unified Workflow Net