

# Business Processes Modelling

## MPB (6 cfu, 295AA)

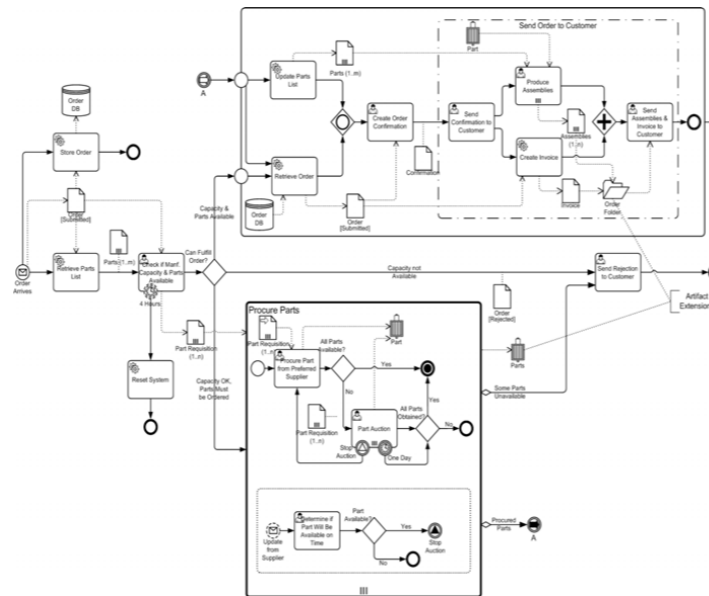
Roberto Bruni

<http://www.di.unipi.it/~bruni>

21 - BPMN analysis



# Object



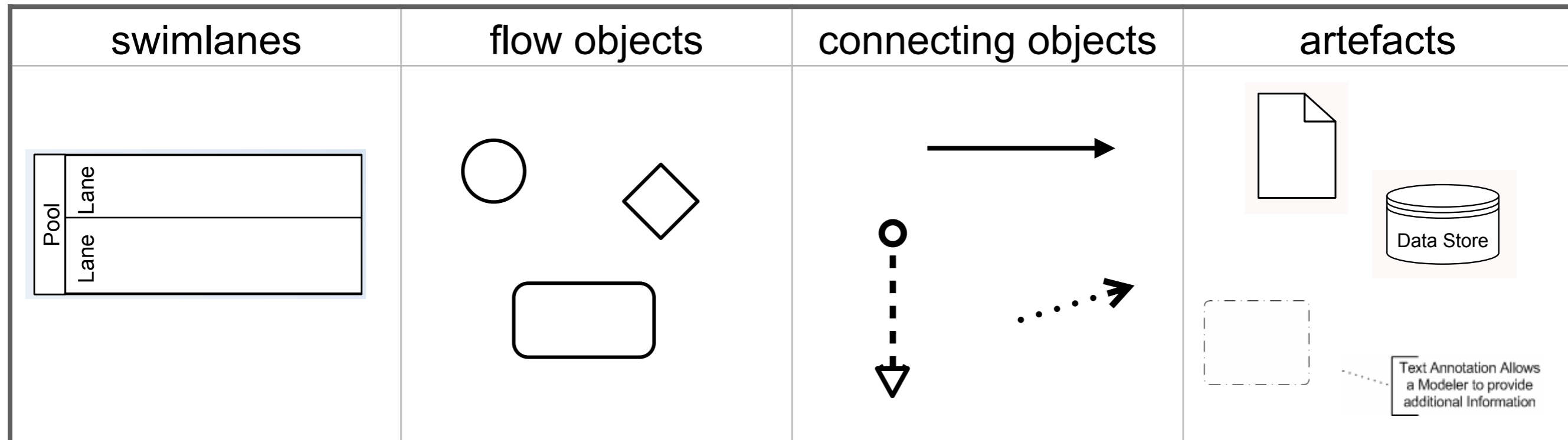
We overview the main challenges that arise when analysing BPMN diagrams with Petri nets

# BPMN Diagrams

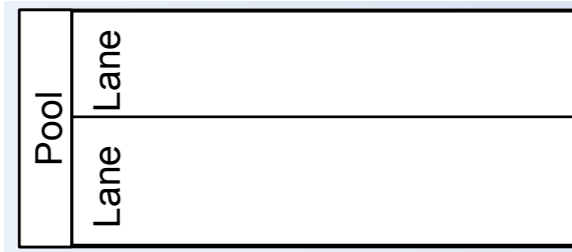
# Business process diagrams

BPMN defines a standard for **Business Process Diagrams (BPD)** based on **flowcharting technique**

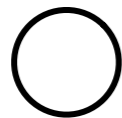
Four categories of elements



# BPMN vs EPC (roughly)



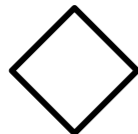
swimlanes



event



activity



gateway



sequence flow



message flow

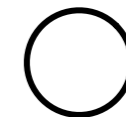
event



function



connector



control flow



## Activities

- Task**: A Task is a unit of work, the job to be performed. When marked with a **+** symbol it indicates a Sub-Process, an activity that can be refined.
- Transaction**: A Transaction is a set of activities that logically belong together; it might follow a specified transaction protocol.
- Event Sub-Process**: An Event Sub-Process is placed into a Process or Sub-Process. It is activated when its start event gets triggered and can interrupt the higher level process context or run in parallel (non-interrupting) depending on the start event.
- Call Activity**: A Call Activity is a wrapper for a globally defined Sub-Process or Task that is reused in the current process.

### Activity Markers

Markers indicate execution behavior of activities:

- +** Sub-Process Marker
- ↻** Loop Marker
- |||** Parallel MI Marker
- ≡** Sequential MI Marker
- ~** Ad Hoc Marker
- ⚡** Compensation Marker

### Task Types

Types specify the nature of the action to be performed:

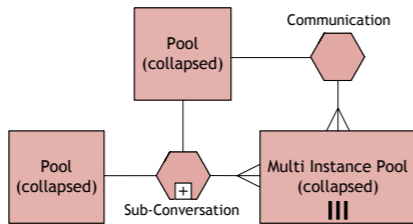
- ✉** Send Task
- ✉** Receive Task
- 👤** User Task
- 📄** Manual Task
- 📄** Business Rule Task
- ⚙️** Service Task
- 📜** Script Task

- Sequence Flow**: defines the execution order of activities.
- Default Flow**: is the default branch to be chosen if all other conditions evaluate to false.
- Conditional Flow**: has a condition assigned that defines whether or not the flow is used.

## Conversations

- Communication**: A Communication defines a set of logically related message exchanges. When marked with a **+** symbol it indicates a Sub-Conversation, a compound conversation element.
- Conversation Link**: A Conversation Link connects Communications and Participants.
- Forked Conversation Link**: A Forked Conversation Link connects Communications and multiple Participants.

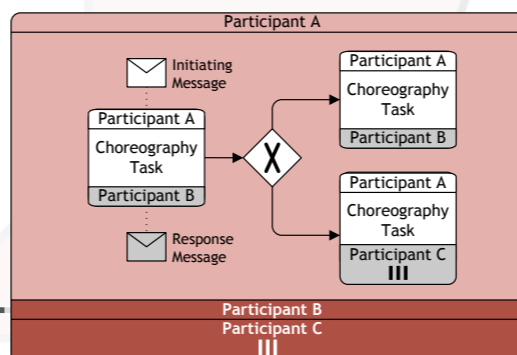
### Conversation Diagram



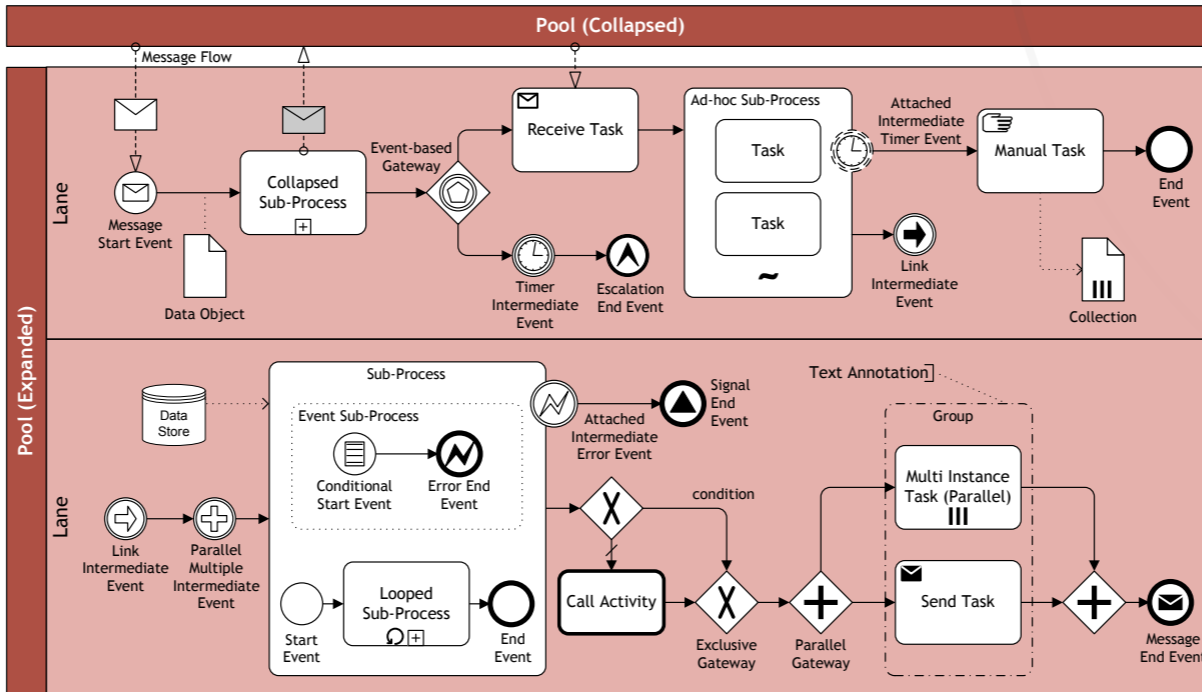
## Choreographies

- Participant A**: Choreography Task
  - Participant B**: Choreography Task
  - Participant C**: Choreography Task
- A **Choreography Task** represents an Interaction (Message Exchange) between two Participants.
- Multiple Participants Marker** denotes a set of Participants of the same kind.
- A **Choreography Sub-Process** contains a refined choreography with several Interactions.

### Choreography Diagram



### Collaboration Diagram



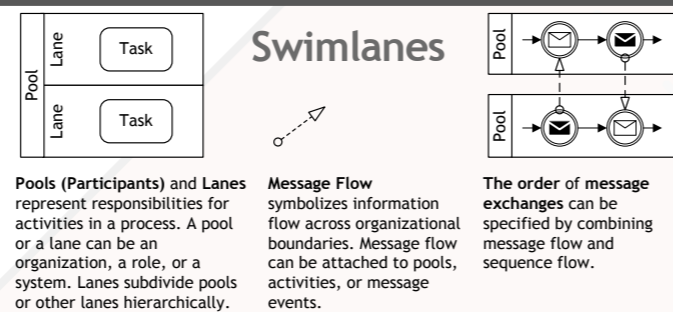
## Events

	Top-Level	Start	Intermediate	End
	Event Sub-Process Interrupting	Event Sub-Process Non-interrupting	Catching	Throwing
<b>None</b> : Untyped events, indicate start point, state changes or final states.	○	○	○	○
<b>Message</b> : Receiving and sending messages.	✉	✉	✉	✉
<b>Timer</b> : Cyclic timer events, points in time, time spans or timeouts.	🕒	🕒	🕒	🕒
<b>Escalation</b> : Escalating to an higher level of responsibility.	⬆️	⬆️	⬆️	⬆️
<b>Conditional</b> : Reacting to changed business conditions or integrating business rules.	📄	📄	📄	📄
<b>Link</b> : Off-page connectors. Two corresponding link events equal a sequence flow.	↔️			➡️
<b>Error</b> : Catching or throwing named errors.	⚡		⚡	⚡
<b>Cancel</b> : Reacting to cancelled transactions or triggering cancellation.	✖️		✖️	✖️
<b>Compensation</b> : Handling or triggering compensation.	⏪		⏪	⏪
<b>Signal</b> : Signalling across different processes. A signal thrown can be caught multiple times.	📡	📡	📡	📡
<b>Multiple</b> : Catching one out of a set of events. Throwing all events defined	⬆️	⬆️	⬆️	⬆️
<b>Parallel Multiple</b> : Catching all out of a set of parallel events.	⊕	⊕	⊕	⊕
<b>Terminate</b> : Triggering the immediate termination of a process.	⬛			⬛

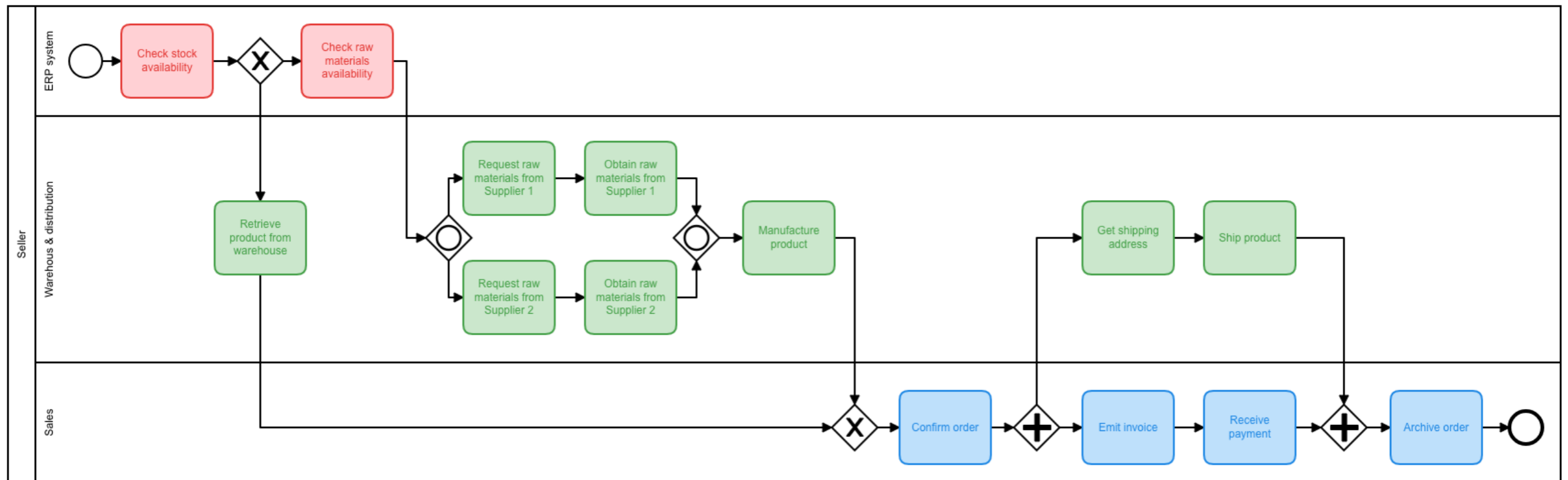
## Data

- Data Input**: A Data Input is an external input for the entire process. It can be read by an activity.
- Data Output**: A Data Output is a variable available as result of the entire process.
- Data Object**: A Data Object represents information flowing through the process, such as business documents, e-mails, or letters.
- Collection Data Object**: A Collection Data Object represents a collection of information, e.g., a list of order items.
- Data Store**: A Data Store is a place where the process can read or write data, e.g., a database or a filing cabinet. It persists beyond the lifetime of the process instance.
- Message**: A Message is used to depict the contents of a communication between two Participants.

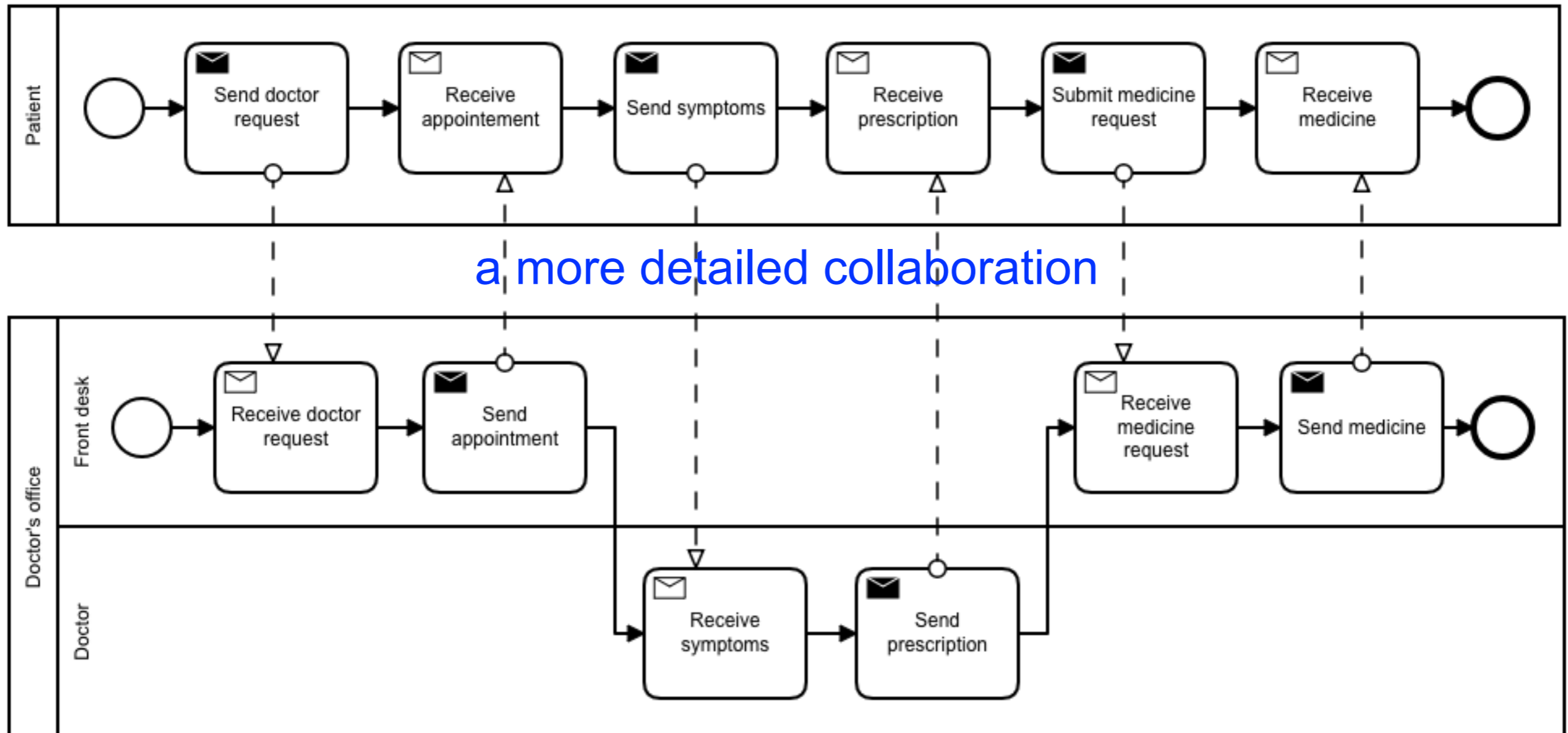
## Swimlanes



# Resources as lanes: order fulfillment

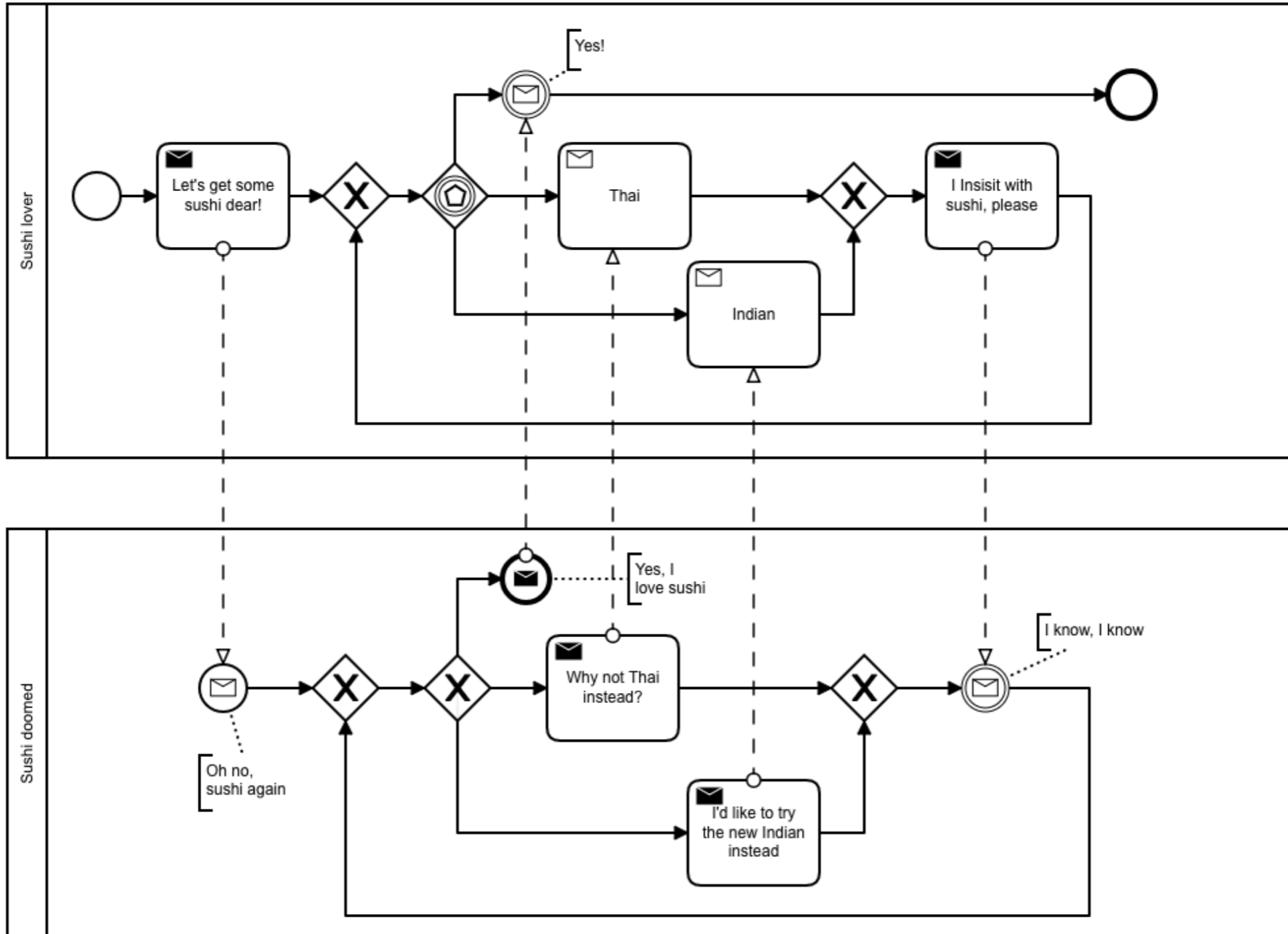


# From processes to collaborations





# A negotiation without choice



# BPMN Semantics

# BPMN formal semantics?

Many attempts:

Abstract State Machines (ASM)

Term Rewriting Systems

Graph Rewrite Systems

Process Algebras

Temporal Logic

...

**Petri nets**

(Usual difficulties with OR-join semantics)

# Sound BPMN diagrams

We can exploit the formal semantics of nets  
to give unambiguous semantics to  
BPMN process diagrams  
BPMN collaboration diagrams

We transform  
BPMN process diagrams to wf nets  
BPMN collaboration diagrams to wf systems

**A BPMN diagram is sound if its net is so**

We can reuse the verification tools  
to check if the net is sound

# Translation of BPMN to Petri nets

# From BPMN to Petri nets



Available online at [www.sciencedirect.com](http://www.sciencedirect.com)



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AND  
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## Semantics and analysis of business process models in BPMN

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# Simplified BPMN

a start / exception event has just one outgoing flow  
and no incoming flow

an end event has just one incoming flow  
and no outgoing flow

all activities and intermediate events have exactly  
one incoming flow and one outgoing flow

all gateways have either  
one incoming flow (and multiple outgoing)  
or one outgoing flow (and multiple incoming)

# Simplified BPMN

The previous constraints are no real limitation:

events or activities with multiple incoming flows:  
insert a preceding XOR-join gateway

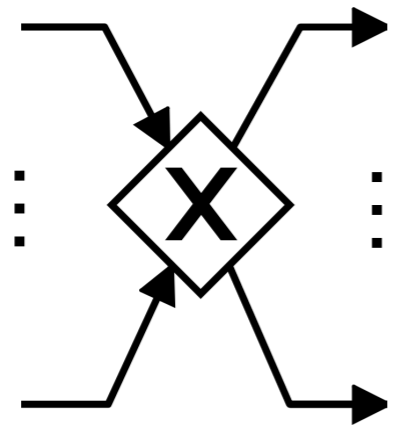
events or activities with multiple outgoing flows:  
insert a following AND-split gateway

gateways with multiple incoming and outgoing flows:  
decompose in two gateways

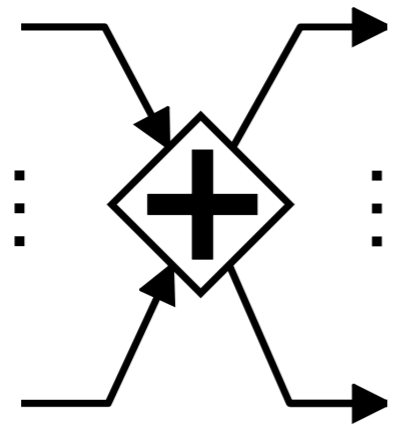
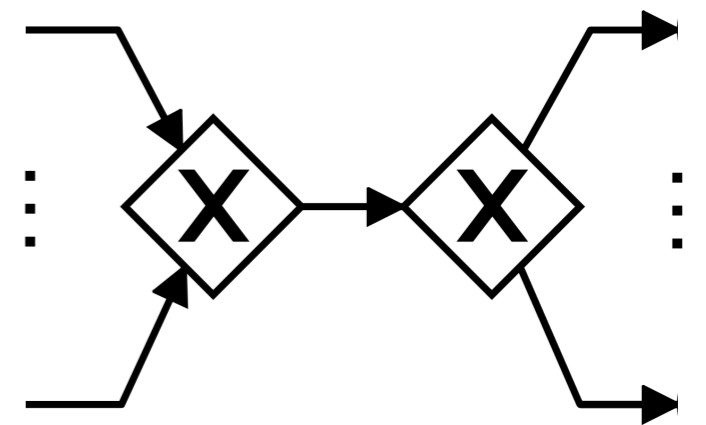
insert start / end events if needed



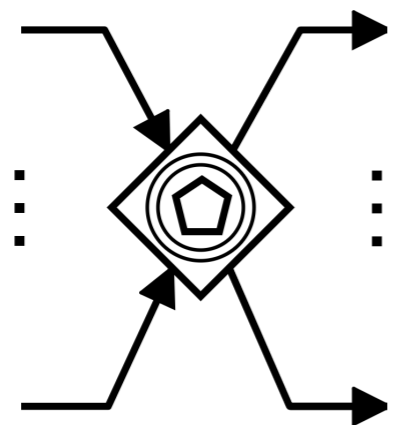
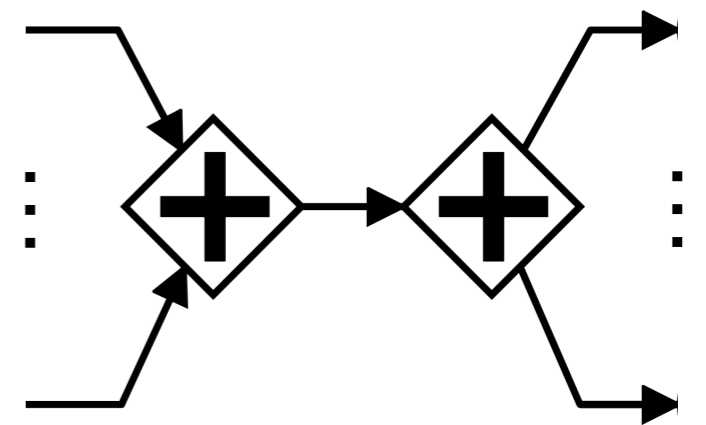
# Pay attention to gateways



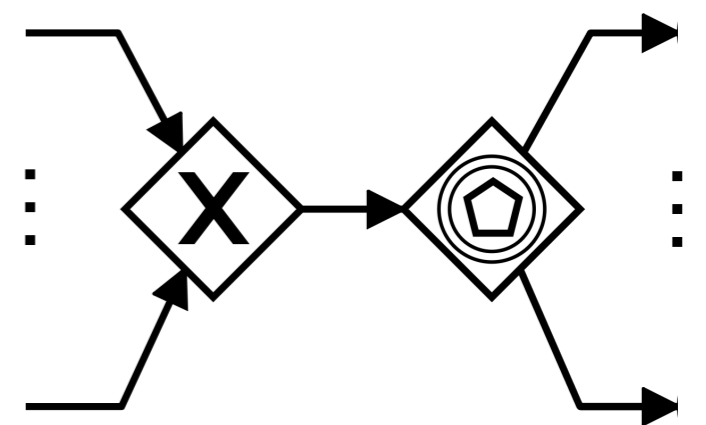
stands for



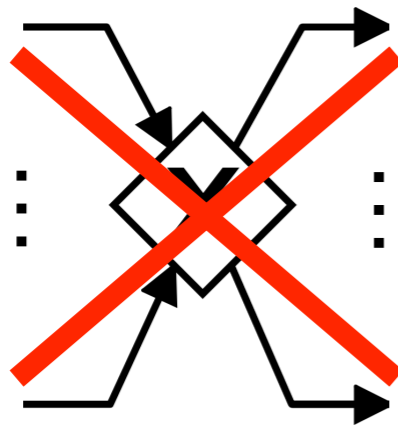
stands for



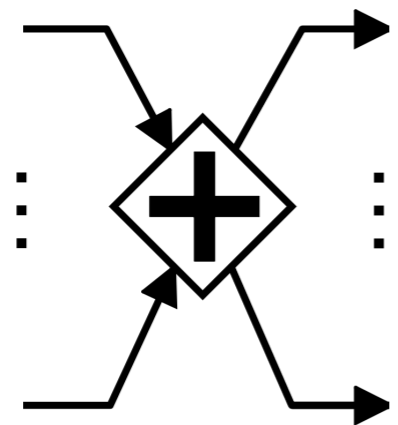
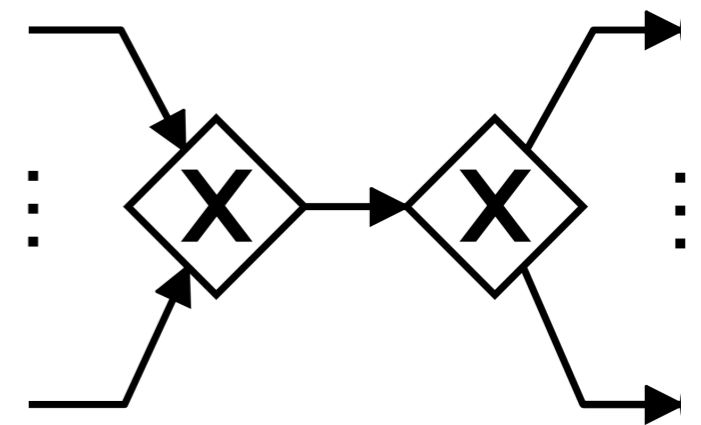
stands for



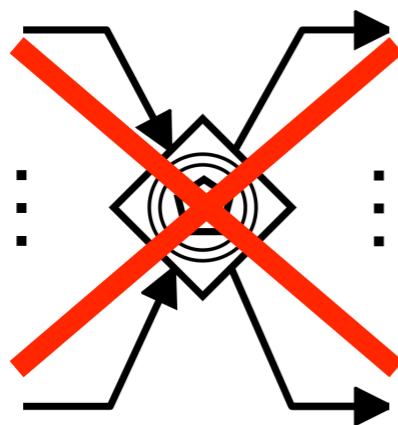
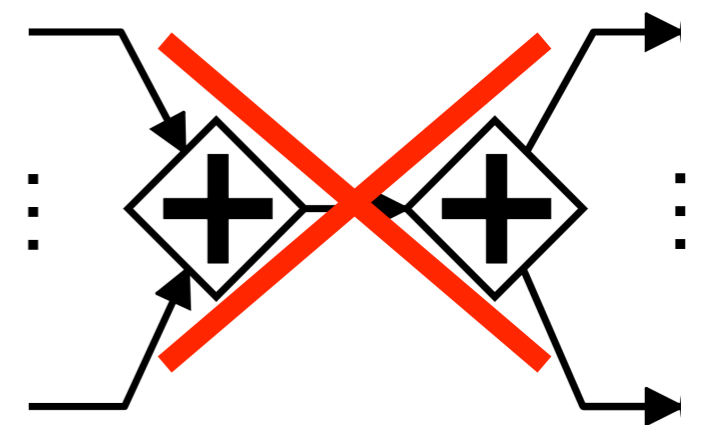
# My suggestions



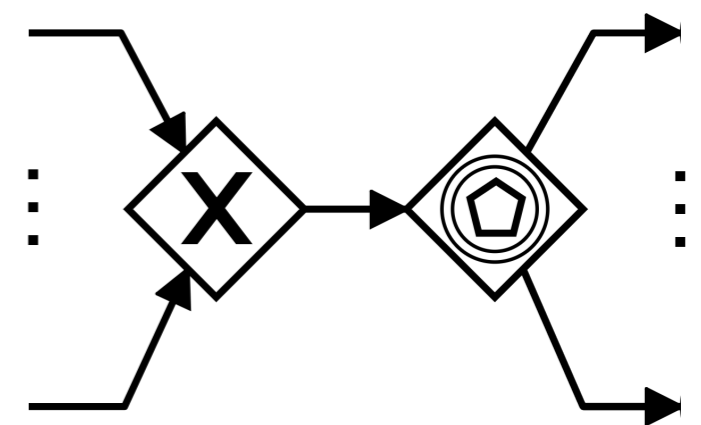
stands for



stands for



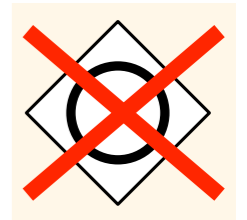
stands for



# Simplified BPMN

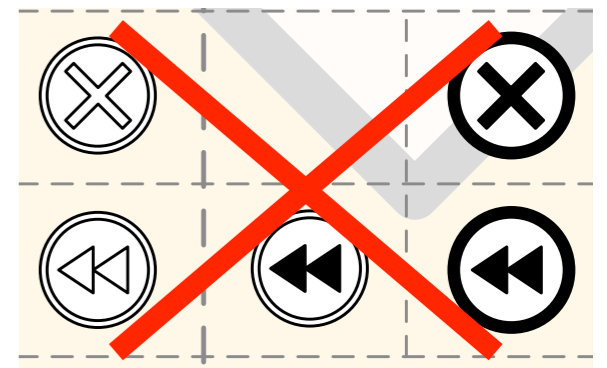
## Avoid OR-gateways

(all problems seen with EPC apply to BPMN as well)



## Limited form of sub-processing

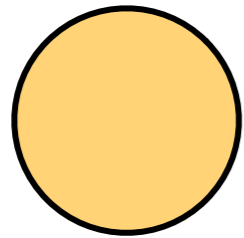
## No transactions and compensations



# The twist!

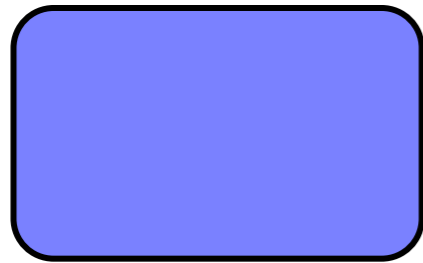
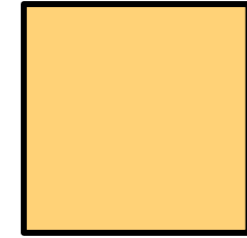
**BPMN object**

**net fragment**

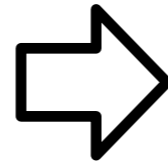


event

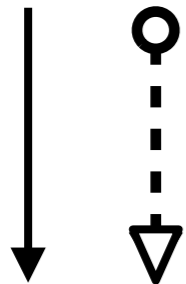
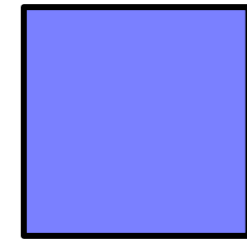
transition



activity

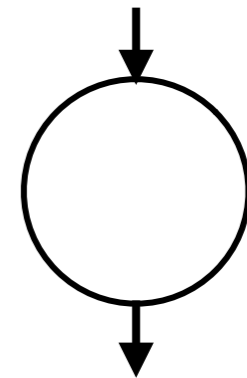


transition



sequence flow  
message flow

place



# Roughly

A place for each arc

one transitions for each event

one transition for each activity

one or two transitions for each gateway

...

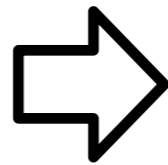
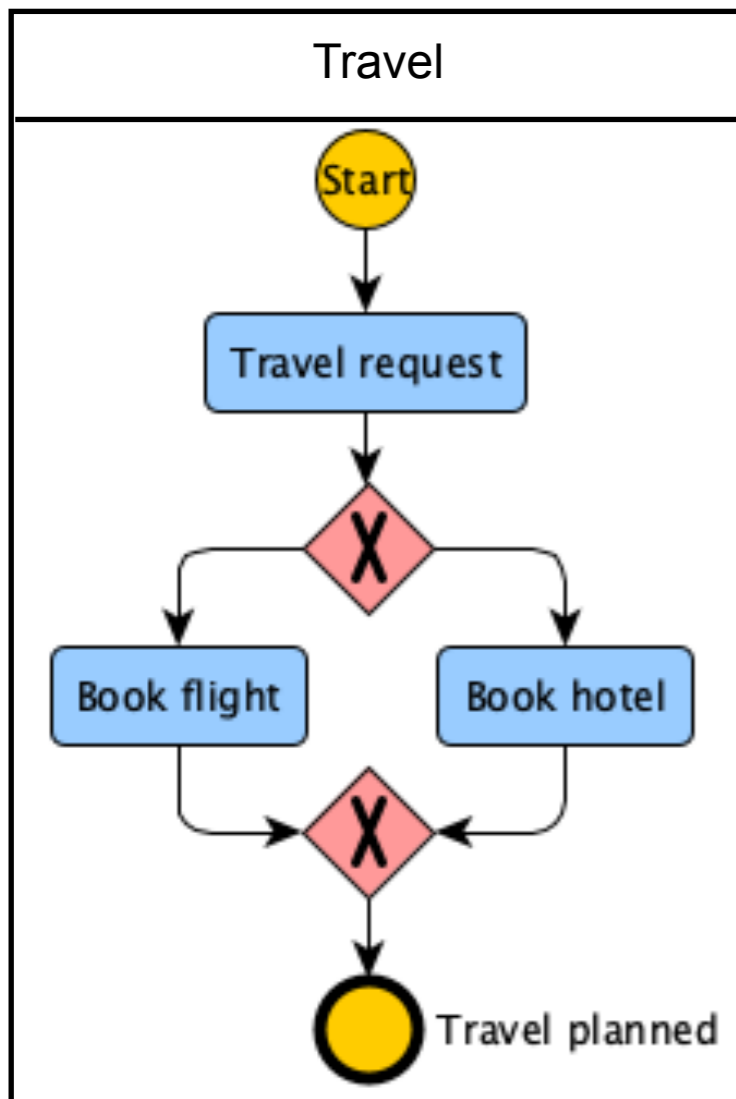
with some exceptions!

(start event, end event, event-based gateways, loops, ...)

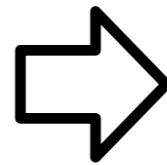
no dummy objects!

# The strategy

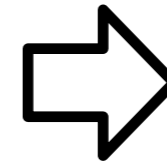
From BPMN process diagrams to wf nets in three steps



**Step 1**  
convert  
sequence flow  
message flow



**Step 2**  
convert  
flow objects

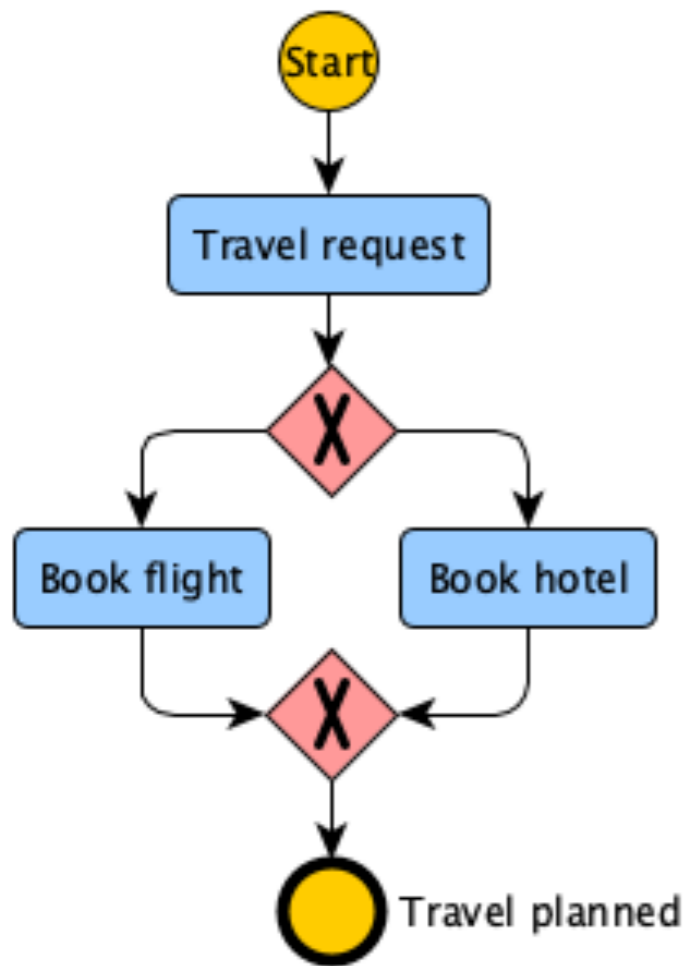


**Step 3**  
enforce  
initial place  
final place

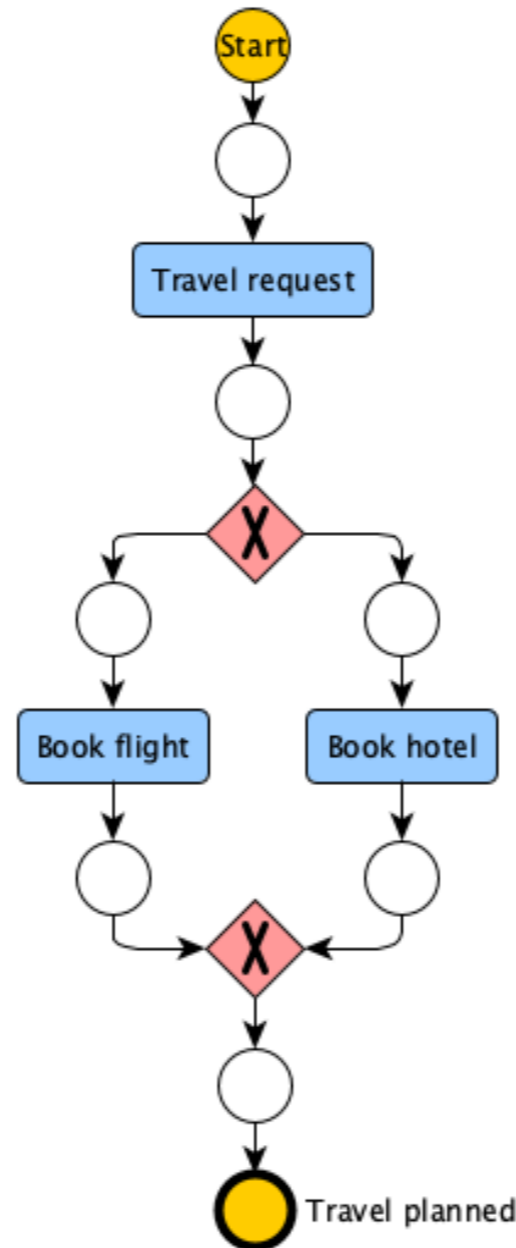


# Step 1: convert flows

We insert a place for each sequence flow and message flow

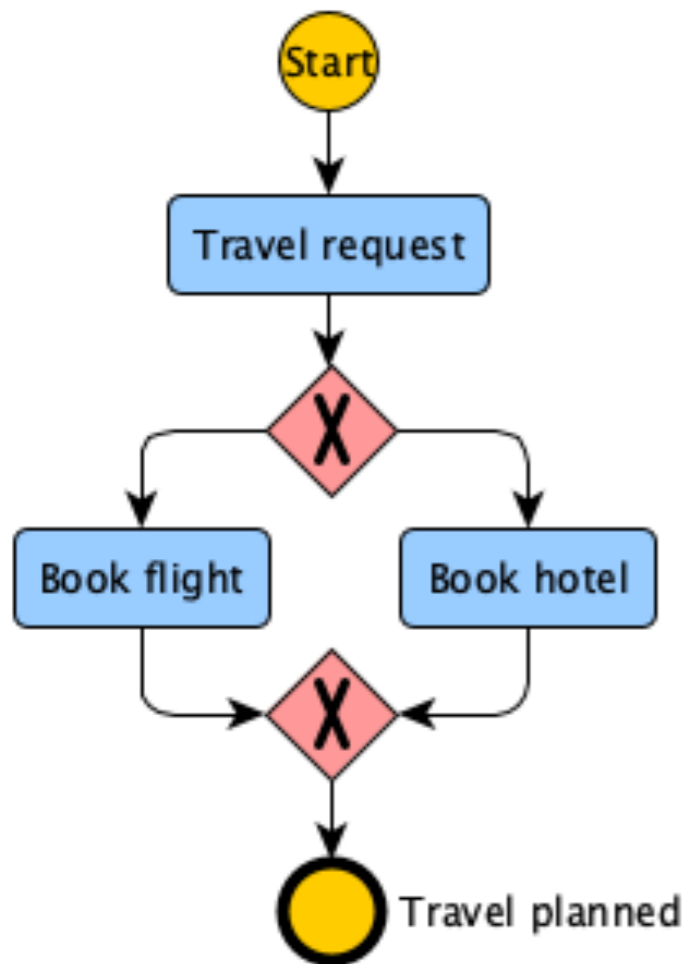


➔  
**Step 1**  
sequence flow  
message flow

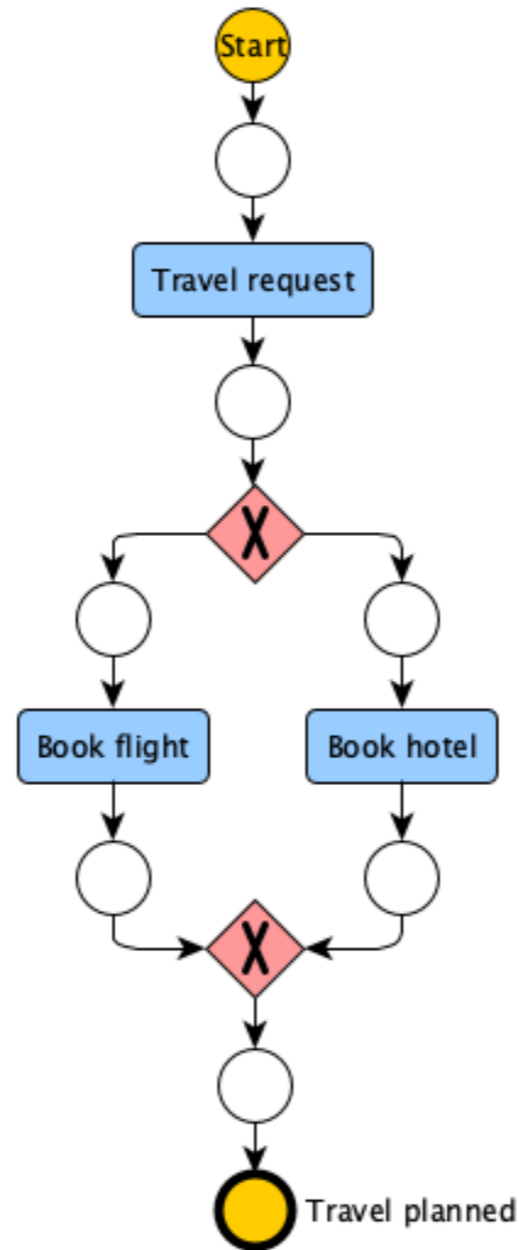
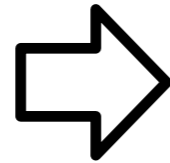


# Step 2: convert flow objects

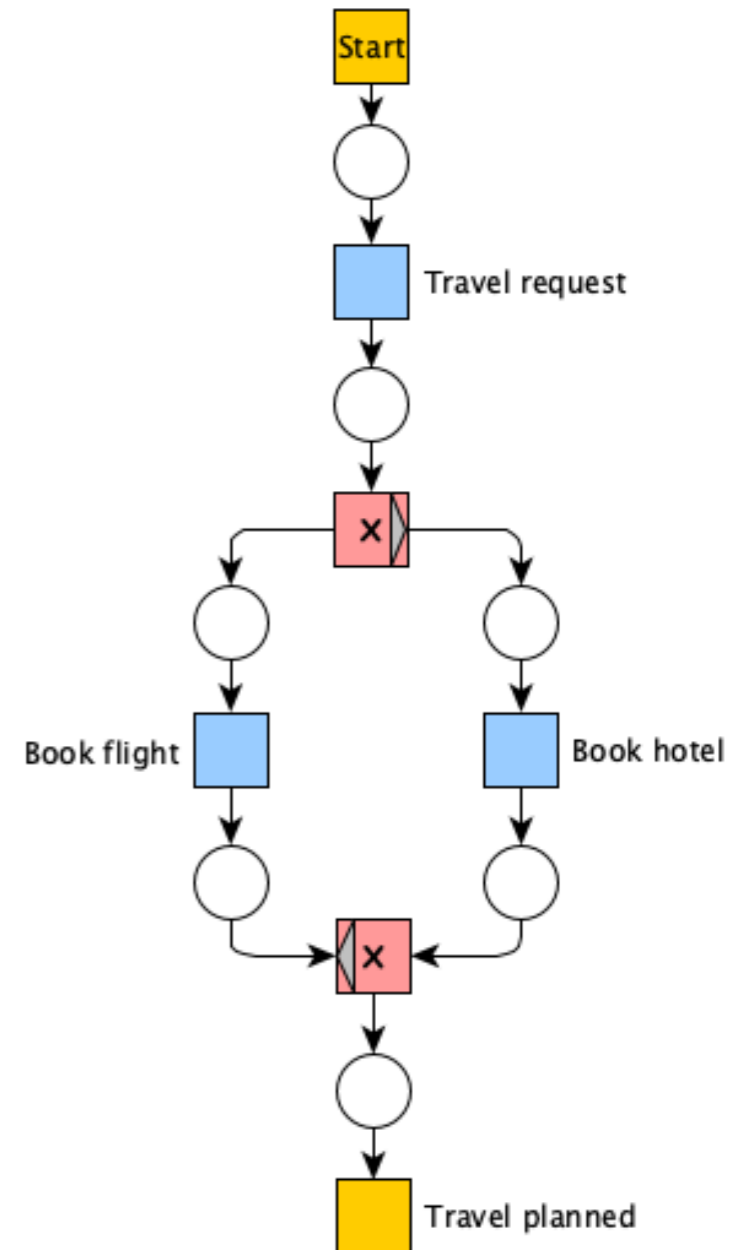
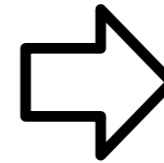
Then insert transitions



Step 1  
sequence flow  
message flow



Step 2  
flow objects

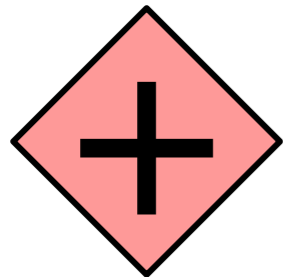




# Step 2: gateways

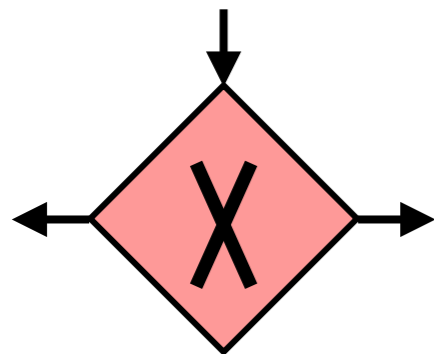
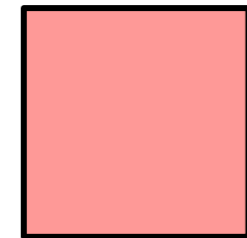
**BPMN object**

**net fragment**

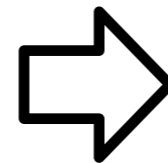


AND split / join

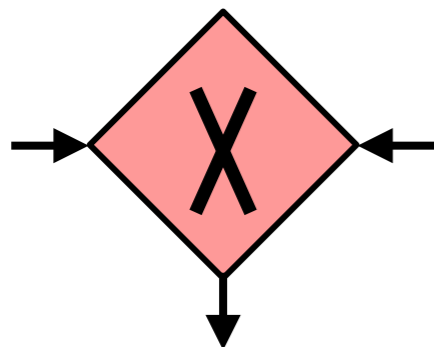
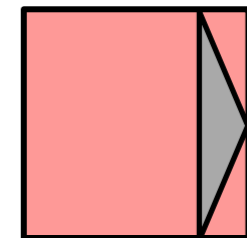
transition



XOR split

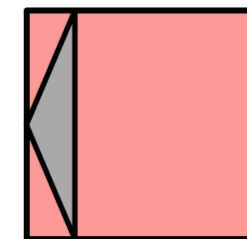


transition



XOR join

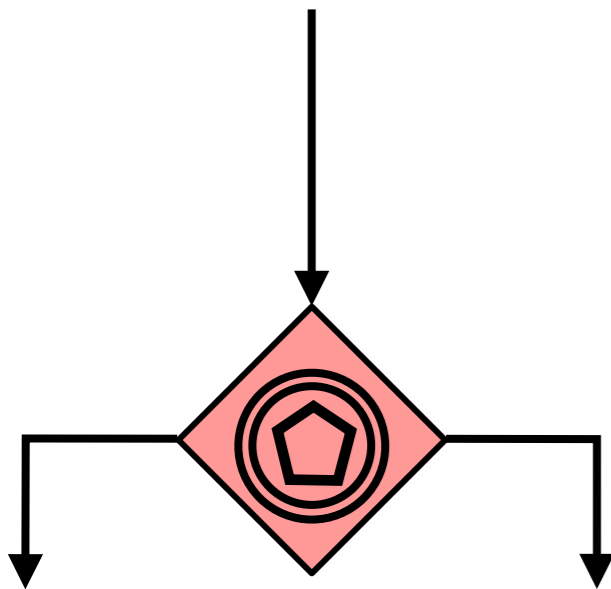
transition



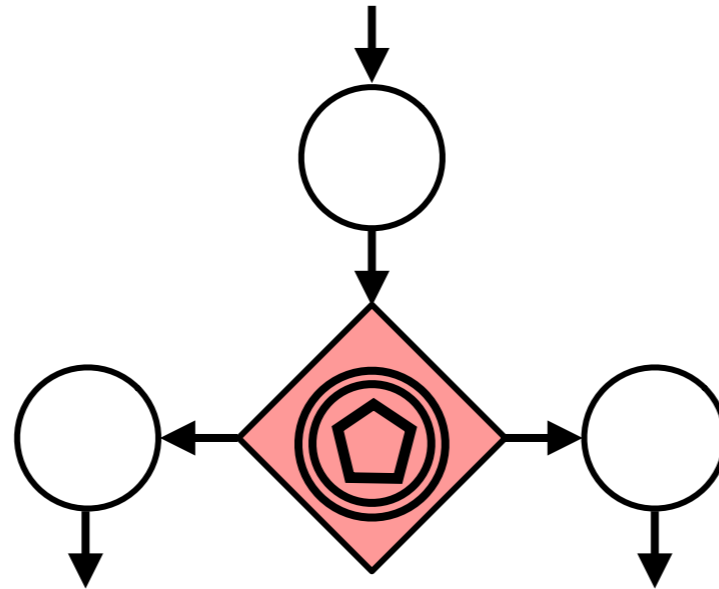
# Step 2: event-based

**BPMN object**

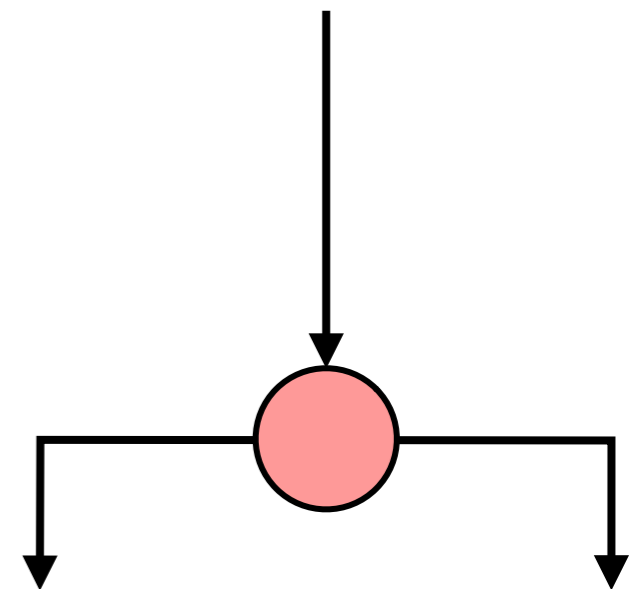
**net fragment**



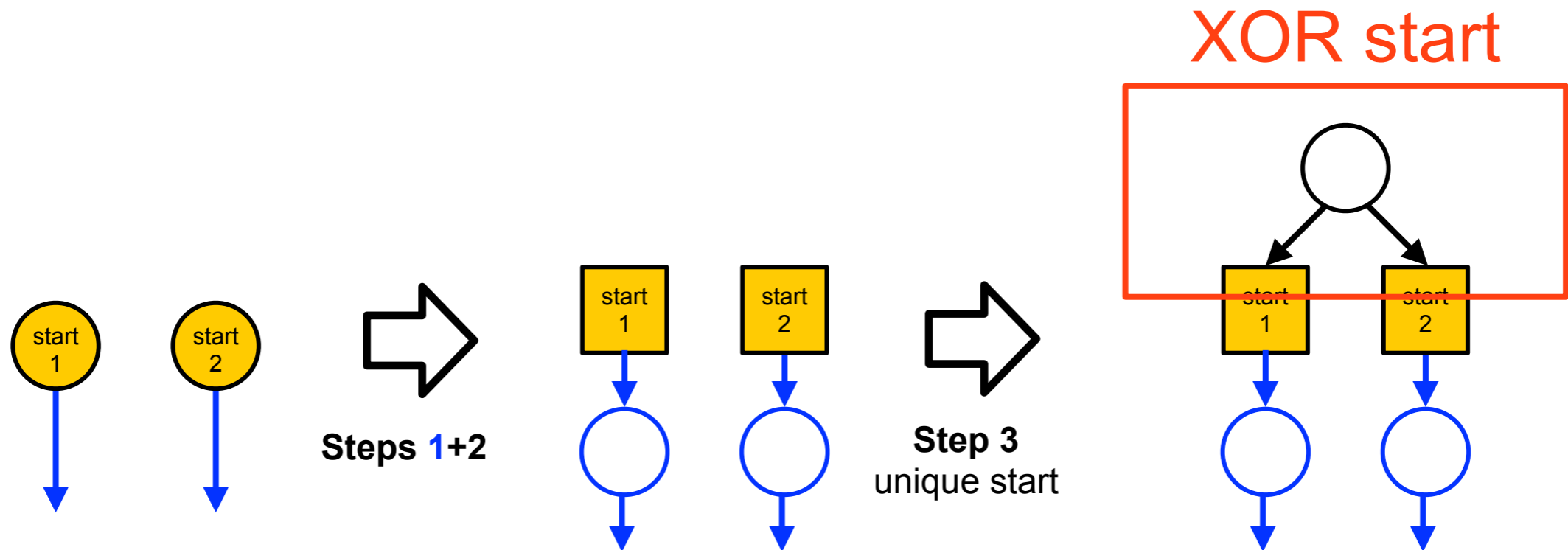
**Step 1**  
sequence flow  
message flow



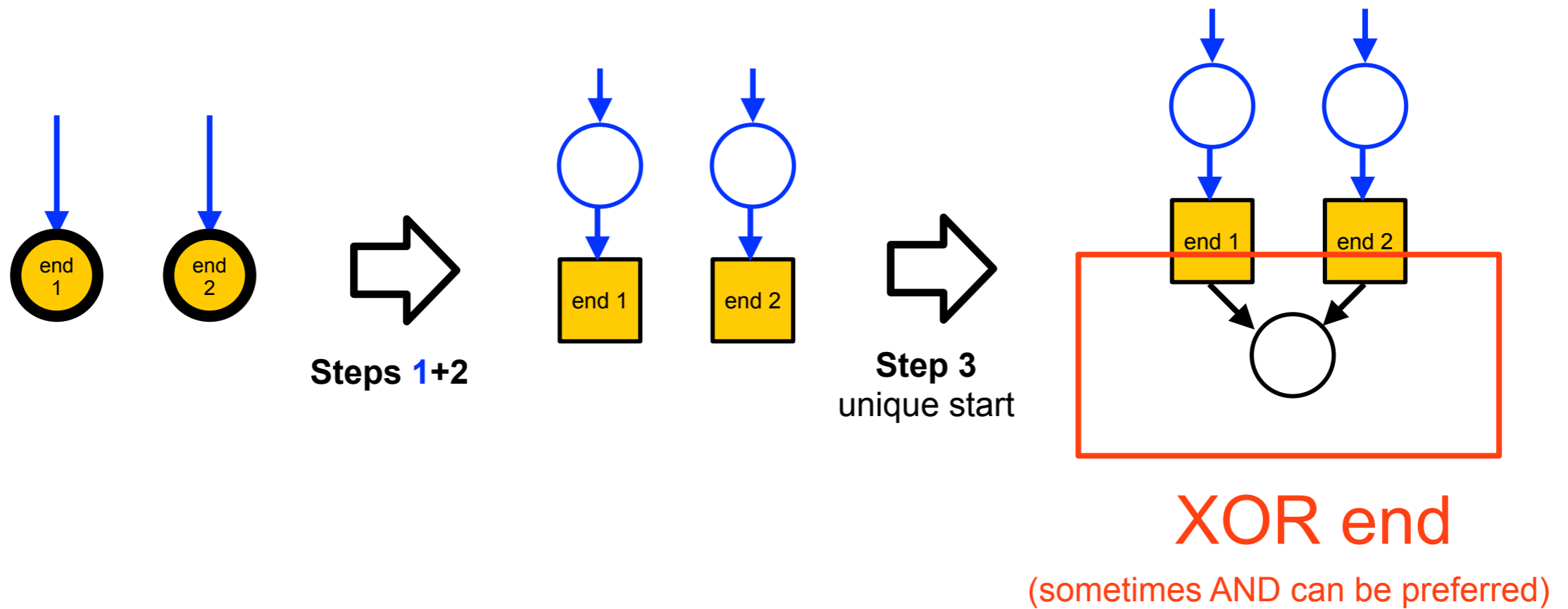
**Step 2**  
place fusion



# Step 3: add unique start

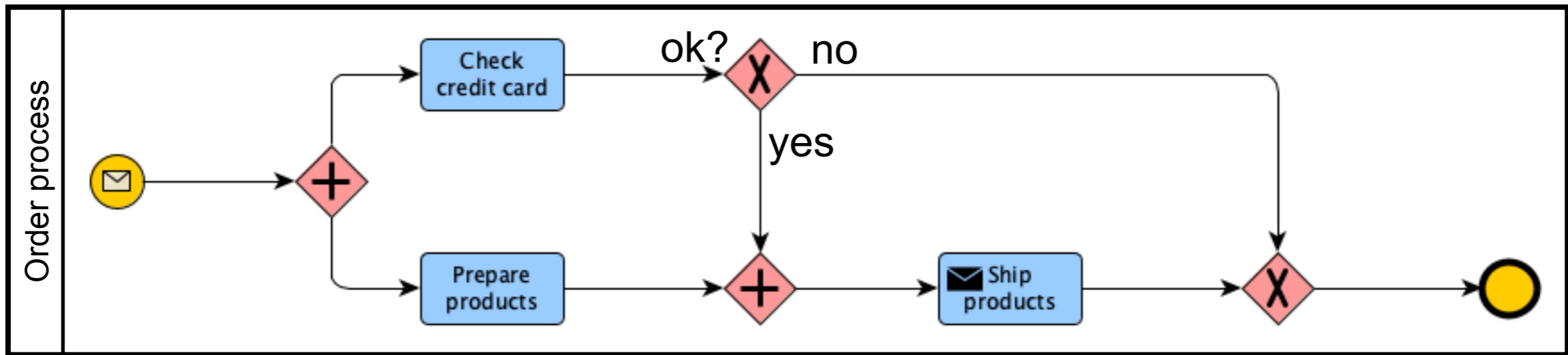


# Step 3: add unique end



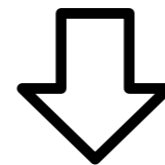
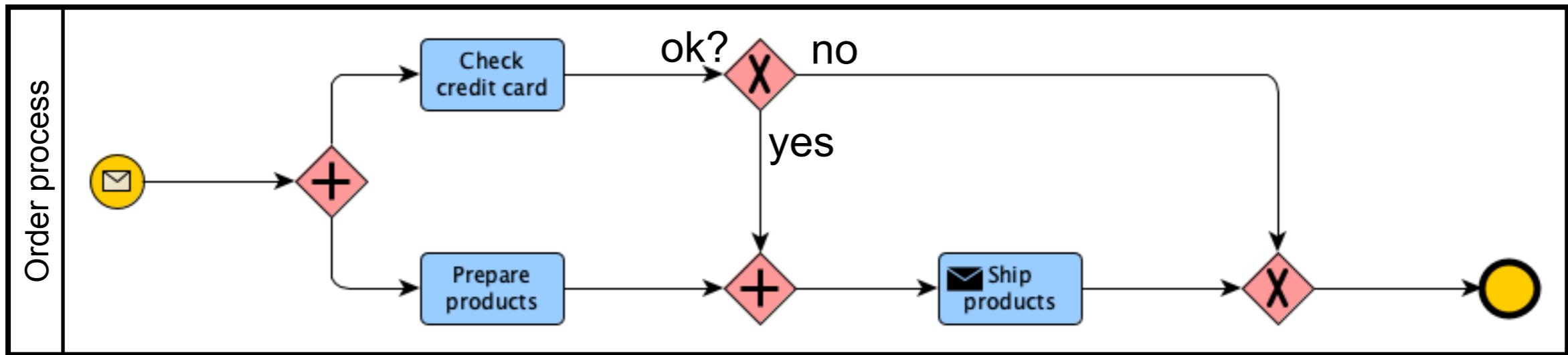
# Example: Order process

# Order process

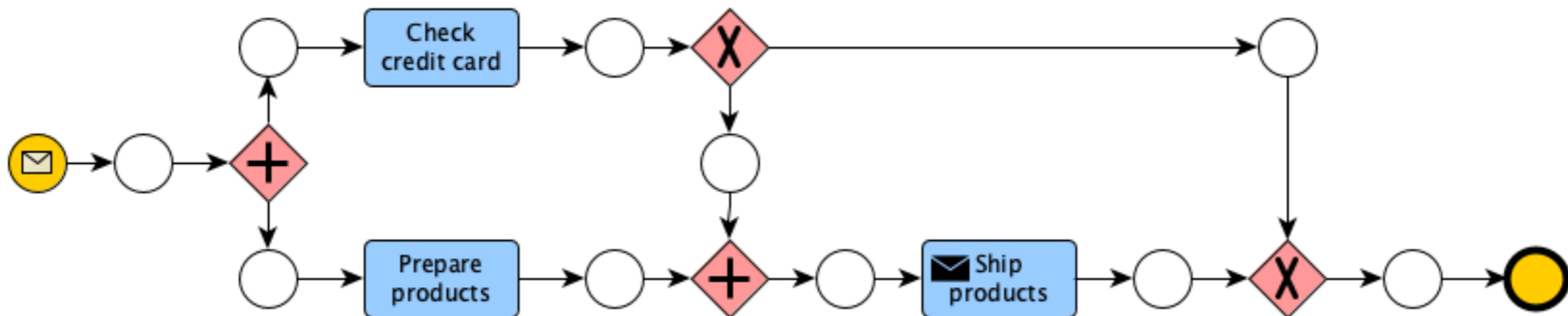


Sound?

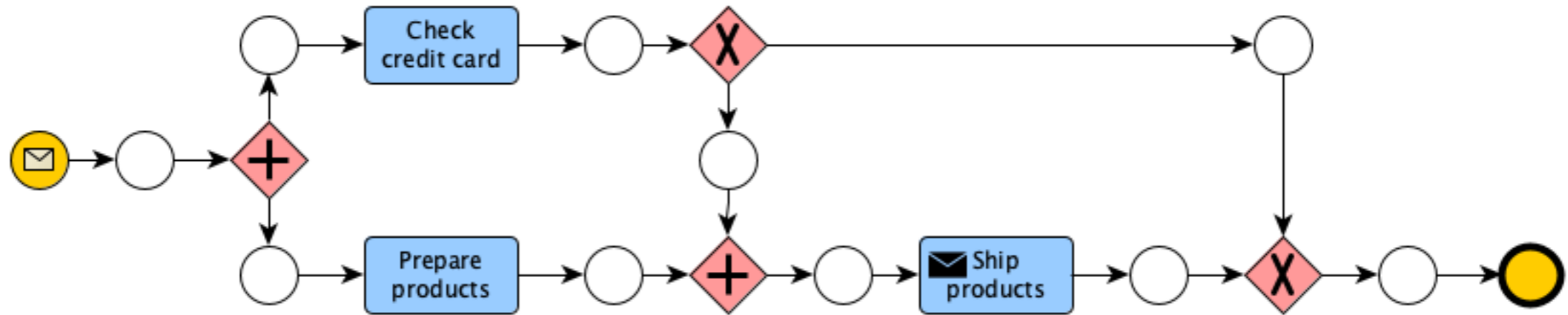
# Order process: step 1



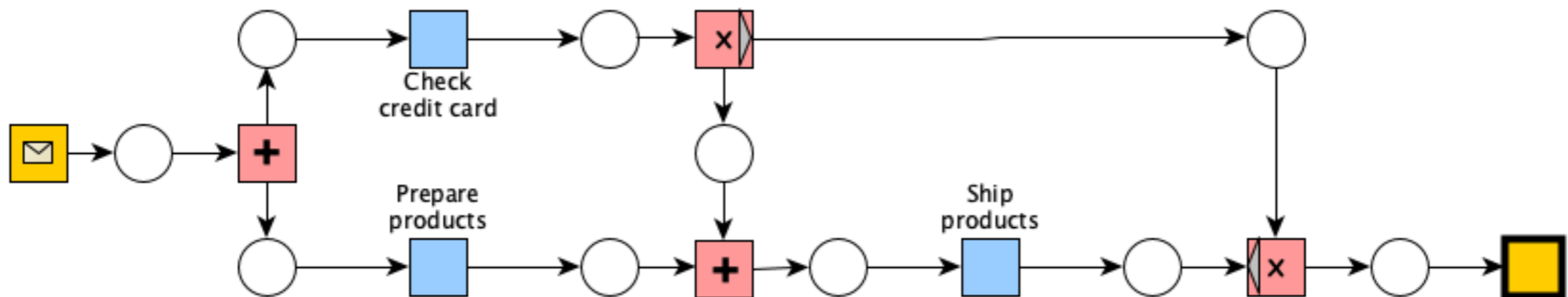
Step 1  
sequence flow  
message flow



# Order process: step 2

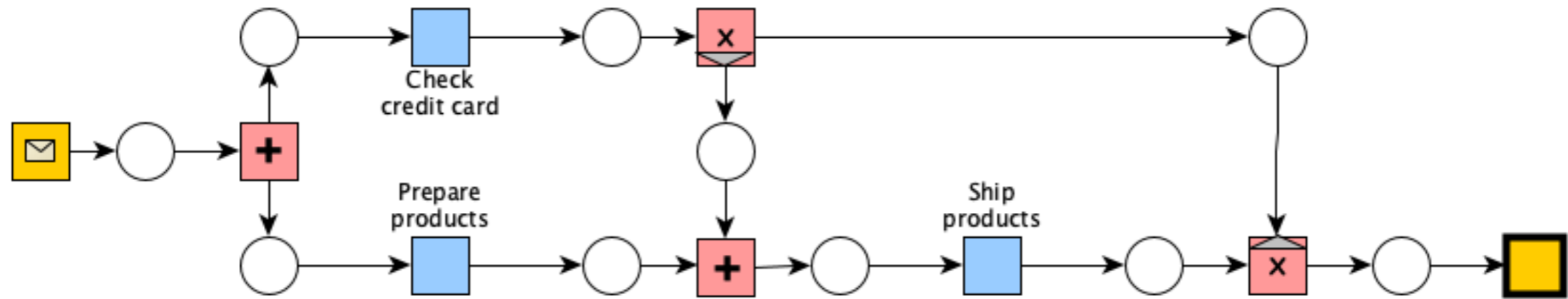


↓  
Step 2  
flow objects

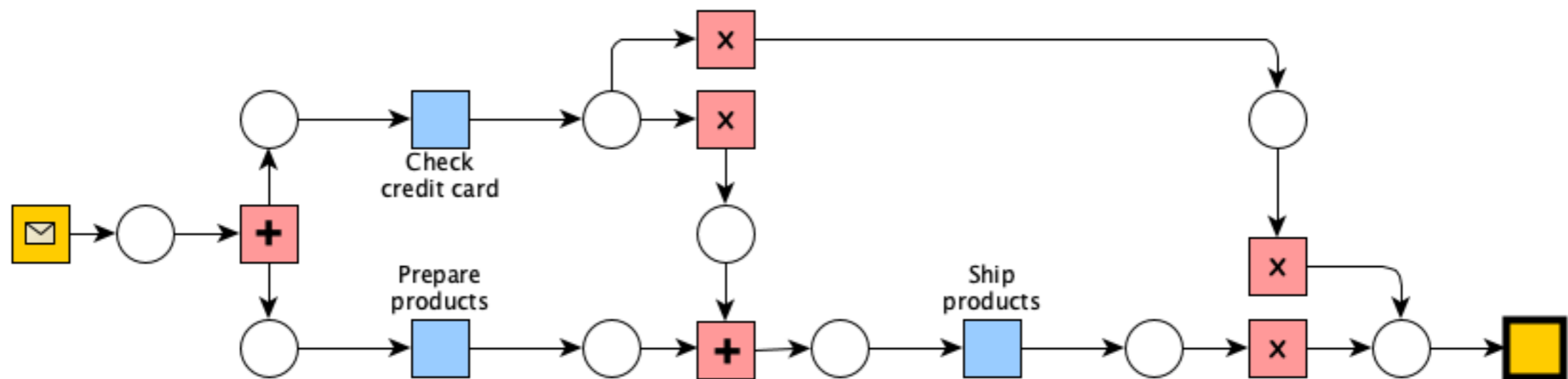




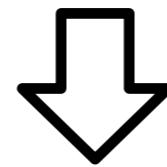
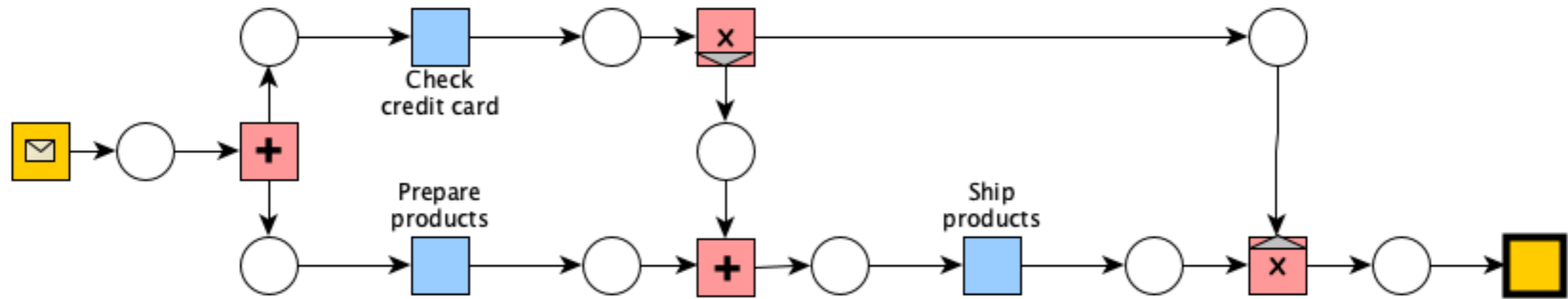
# Order process: (desugar)



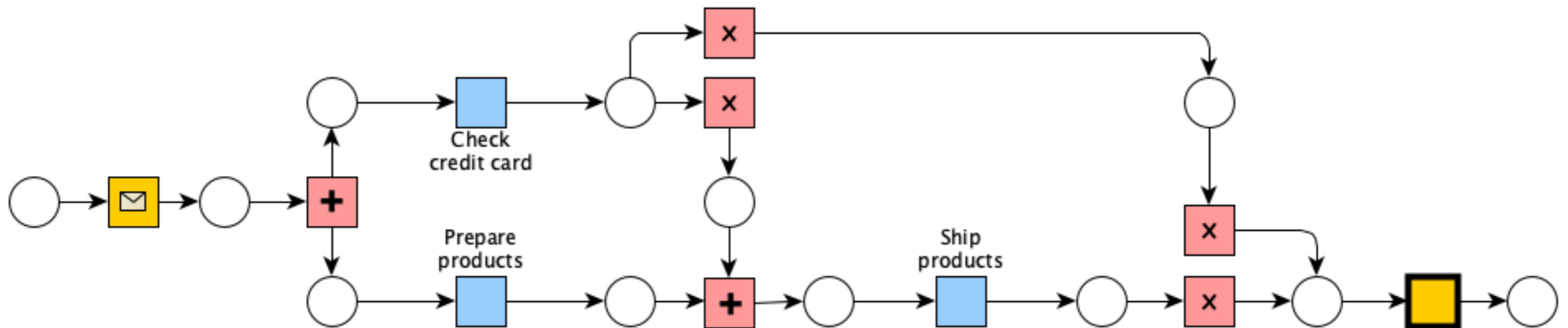
↓ desugar



# Order process: step 3

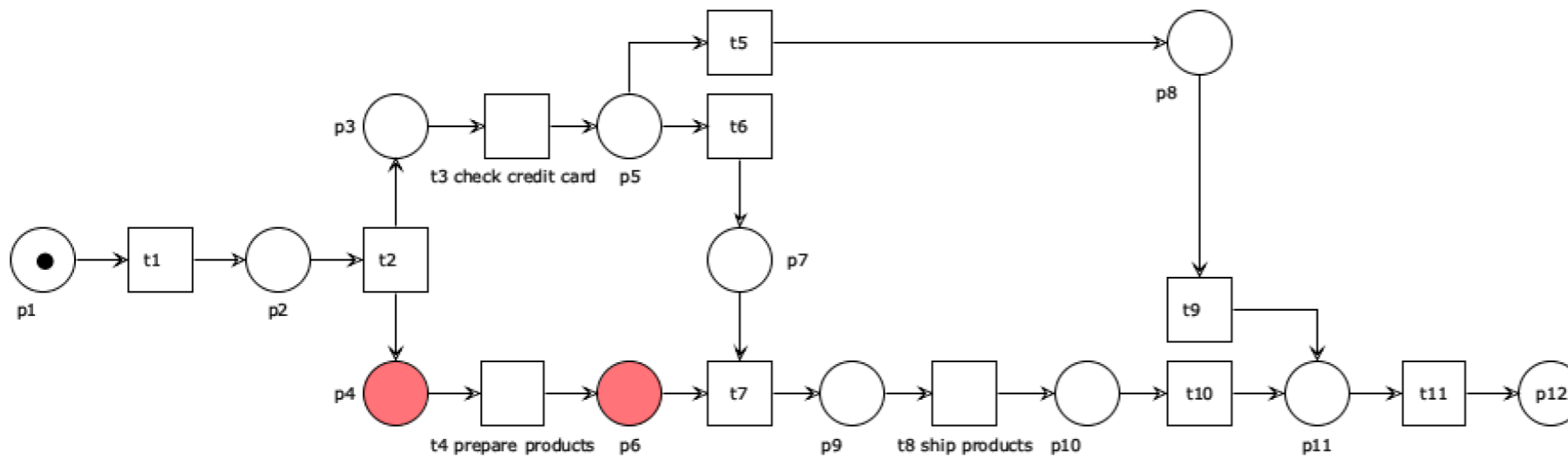


**Step 3**  
enforce  
initial place  
final place



# Soundness analysis

Not sound!

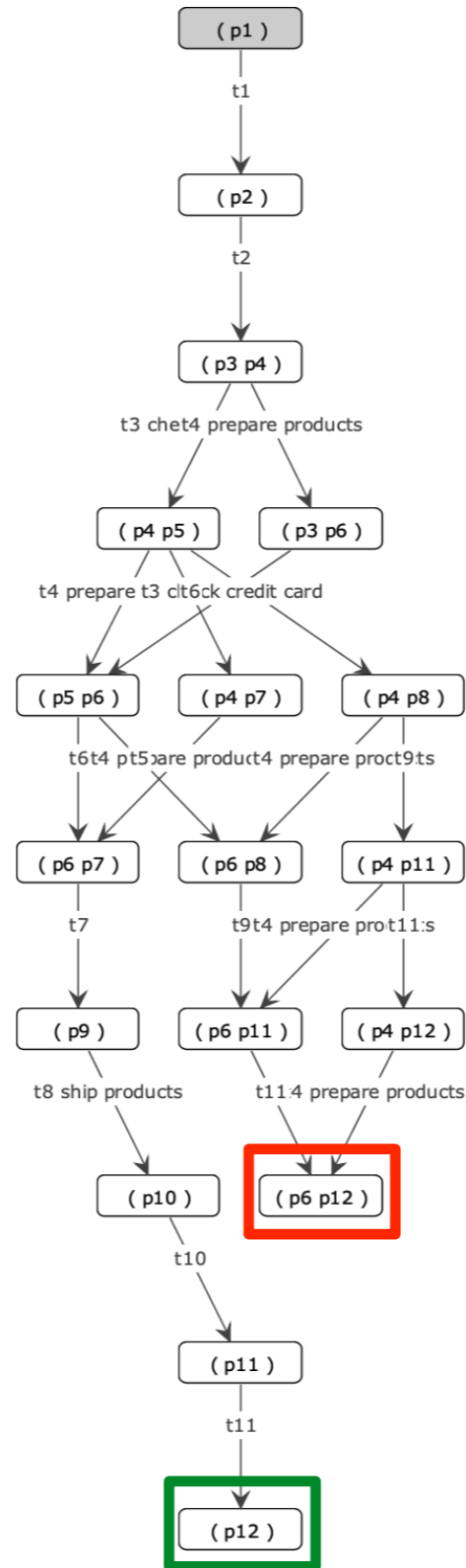


Semantical analysis

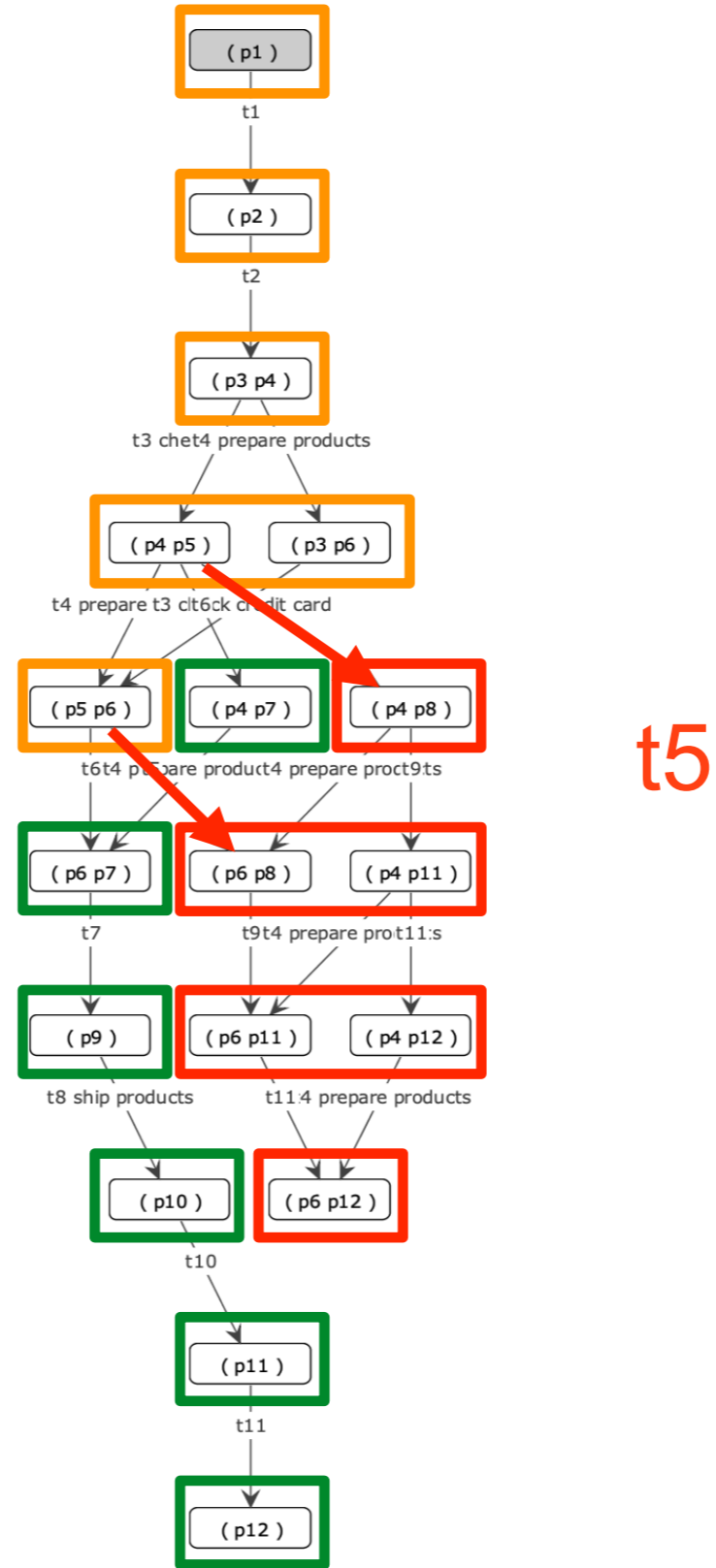
Wizard Expert

- Qualitative analysis
  - Structural analysis
    - Net statistics
      - Wrongly used operators: 0
      - Free-choice violations: 0
    - S-Components
      - S-Components: 1
      - Places not covered by S-Component
        - p4
        - p6
    - Wellstructuredness
      - PT-Handles: 1
      - TP-Handles: 1
  - Soundness
    - Workflow net property
    - Initial marking
    - Boundedness
      - Unbounded places: 2
        - p4
        - p6
    - Liveness

# Soundness analysis

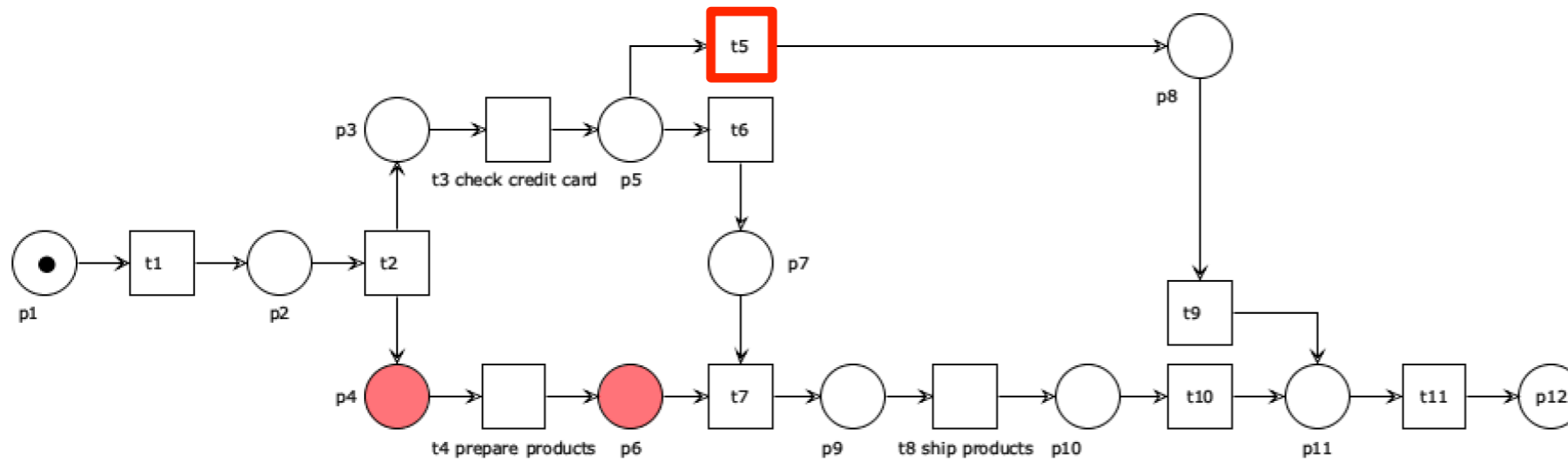


# Soundness analysis



# Soundness analysis

Not sound!



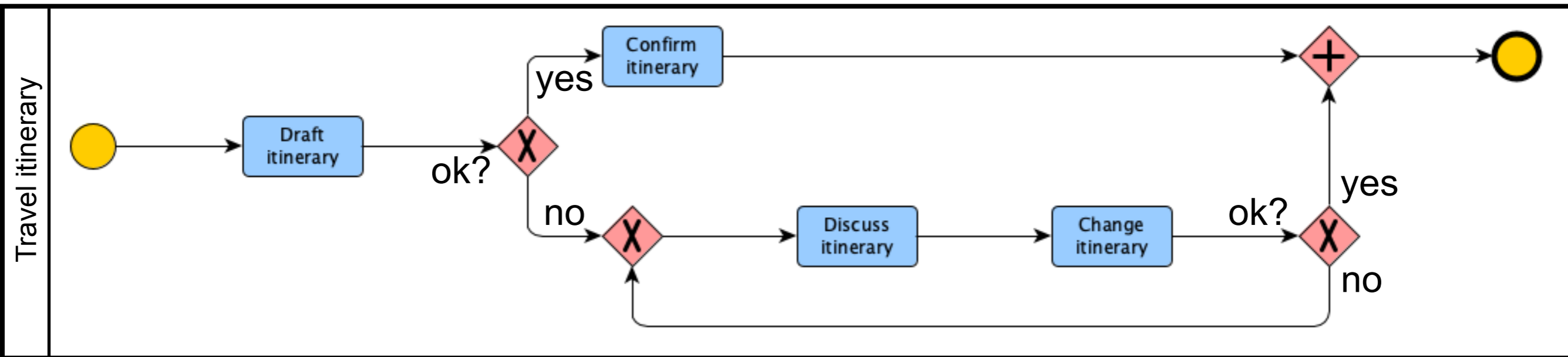
Semantical analysis

Wizard Expert

- Qualitative analysis
  - Structural analysis
    - Net statistics
      - Wrongly used operators: 0
      - Free-choice violations: 0
    - S-Components
      - S-Components: 1
      - Places not covered by S-Component
        - p4
        - p6
    - Wellstructuredness
      - PT-Handles: 1
      - TP-Handles: 1
  - Soundness
    - Workflow net property
    - Initial marking
    - Boundedness
      - Unbounded places: 2
        - p4
        - p6
    - Liveness

# Example: Travel itinerary

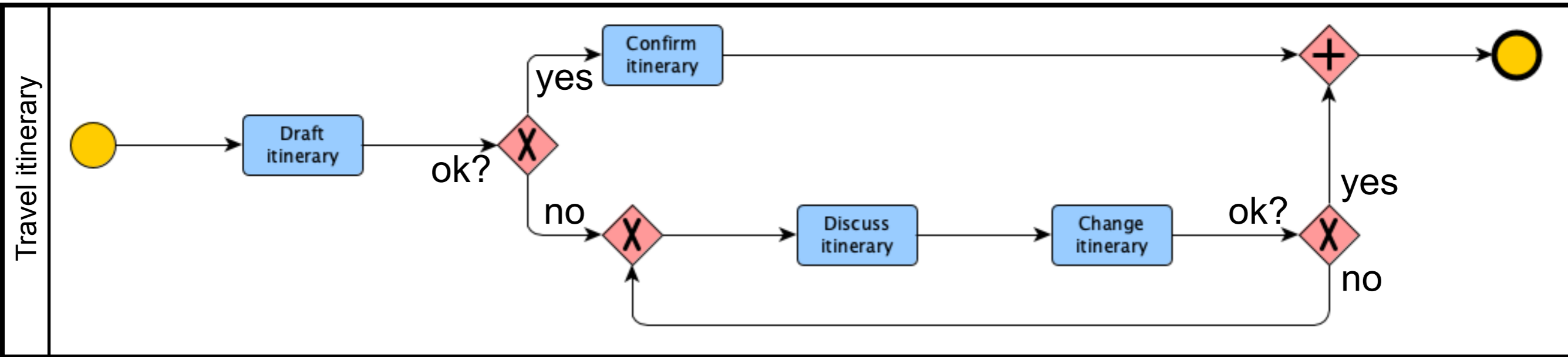
# Travel itinerary



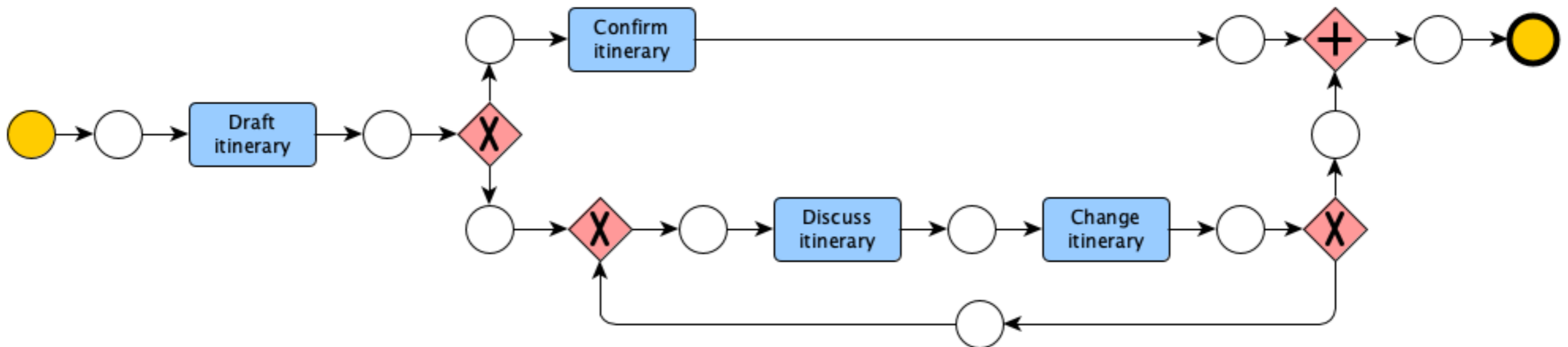
Sound?



# Travel itinerary: step 1

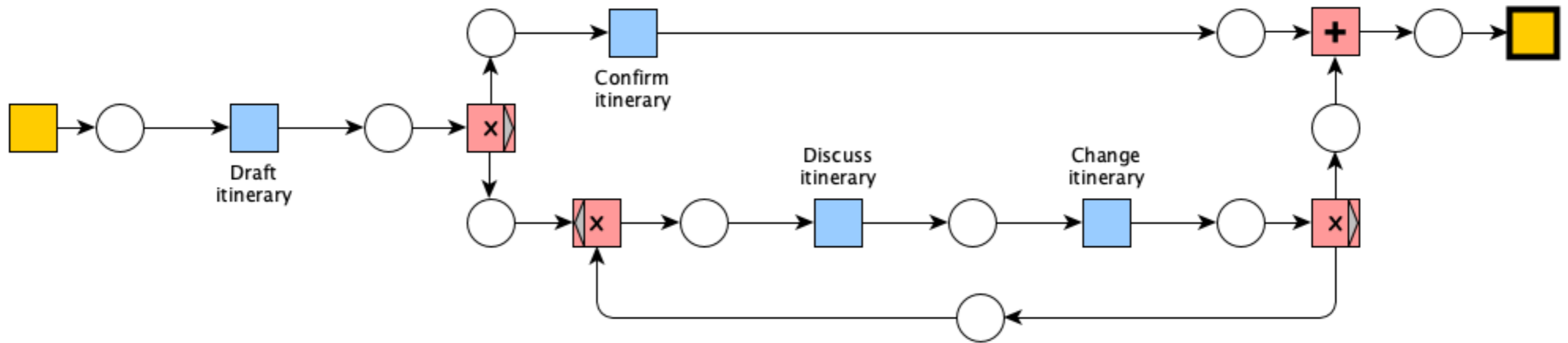


Step 1  
sequence flow  
message flow

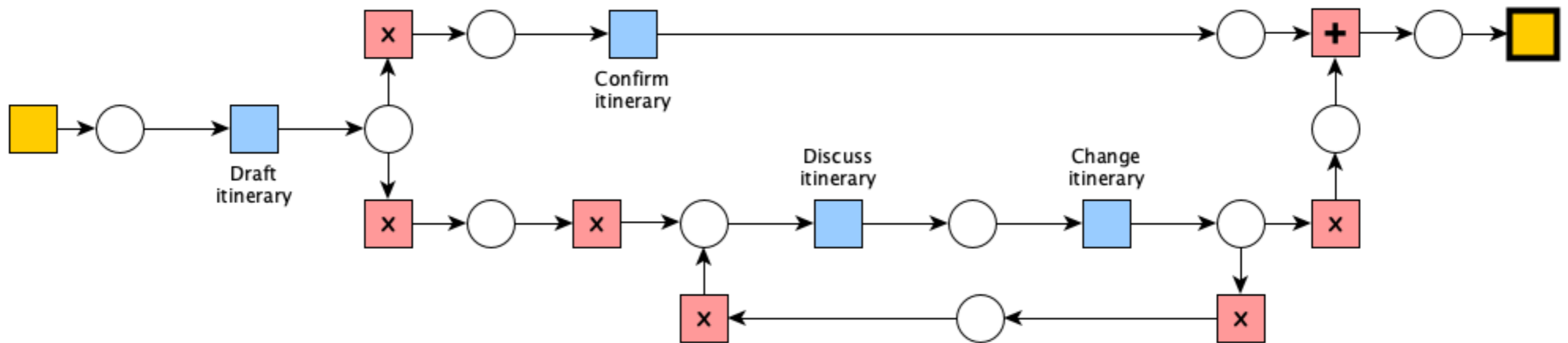




# Travel itinerary: (desugar)

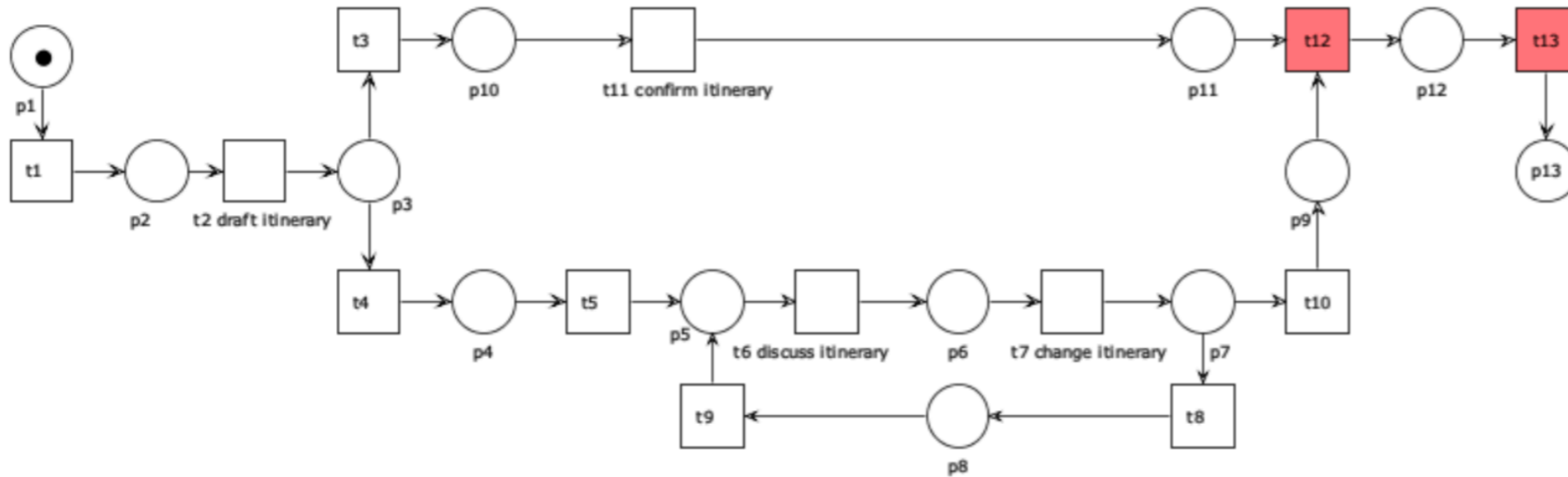


desugar





# Soundness analysis

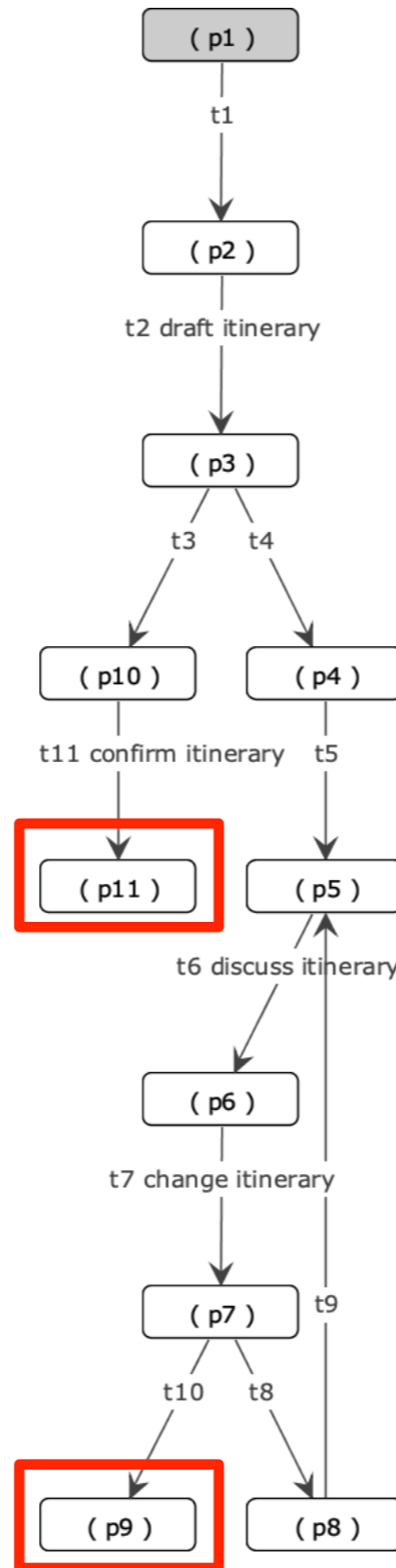


Not sound!

**Semantical analysis** [Wizard] [Expert]

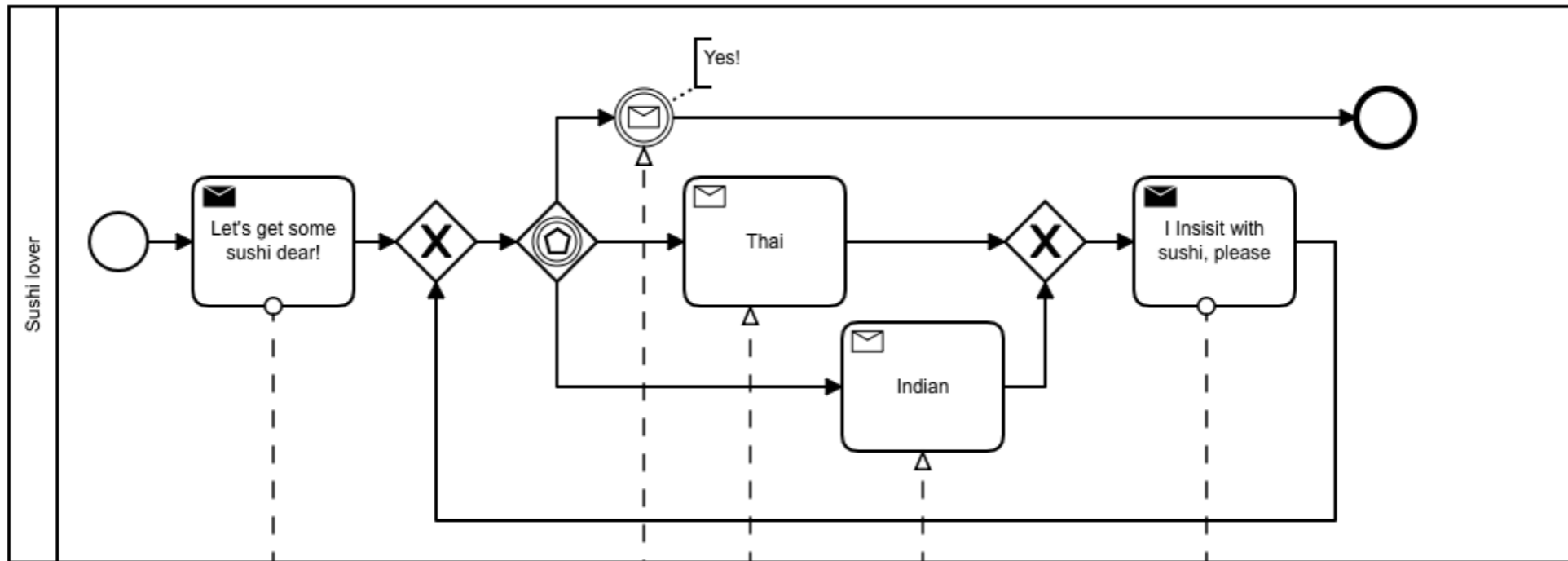
- Qualitative analysis
  - Structural analysis
    - Net statistics
      - Wrongly used operators: 0
      - Free-choice violations: 0
    - S-Components
      - S-Components: 0
      - Places not covered by S-Comp: 0
    - Wellstructuredness
      - PT-Handles: 1
      - TP-Handles: 0
  - Soundness
    - Workflow net property: ✓
    - Initial marking: ✓
    - Boundedness: ✓
    - Liveness
      - Dead transitions: 2
        - t13
        - t12
      - Non-live transitions: 13

# Soundness analysis

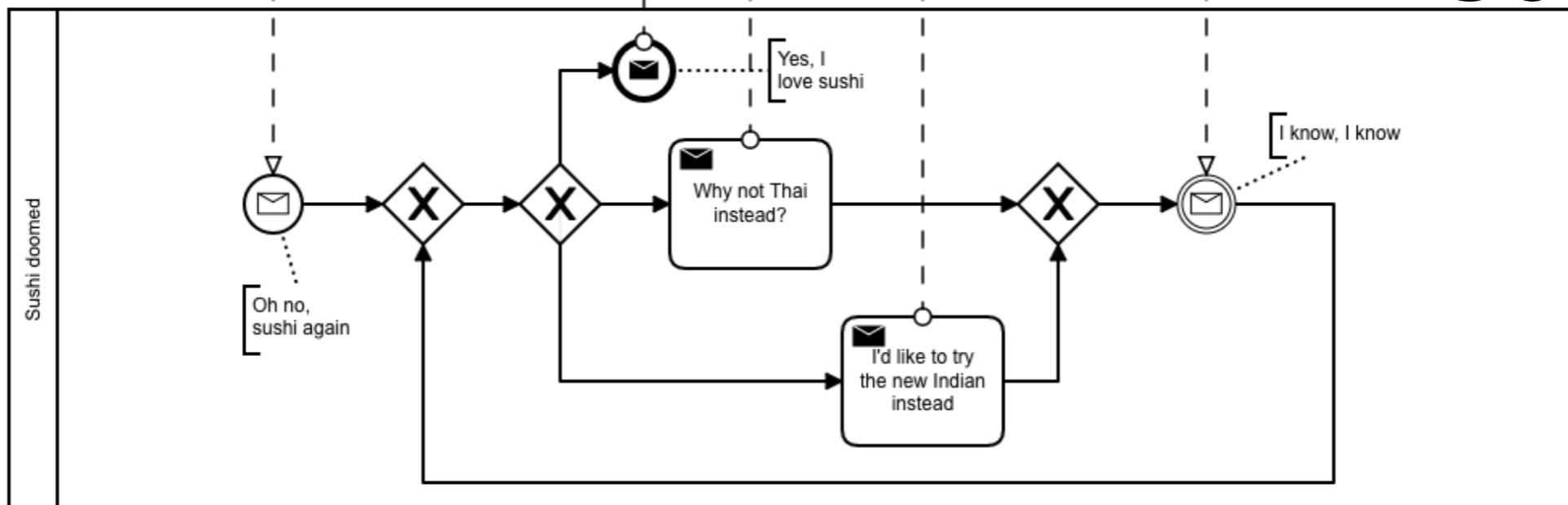


Example:  
Always sushi

# Always sushi

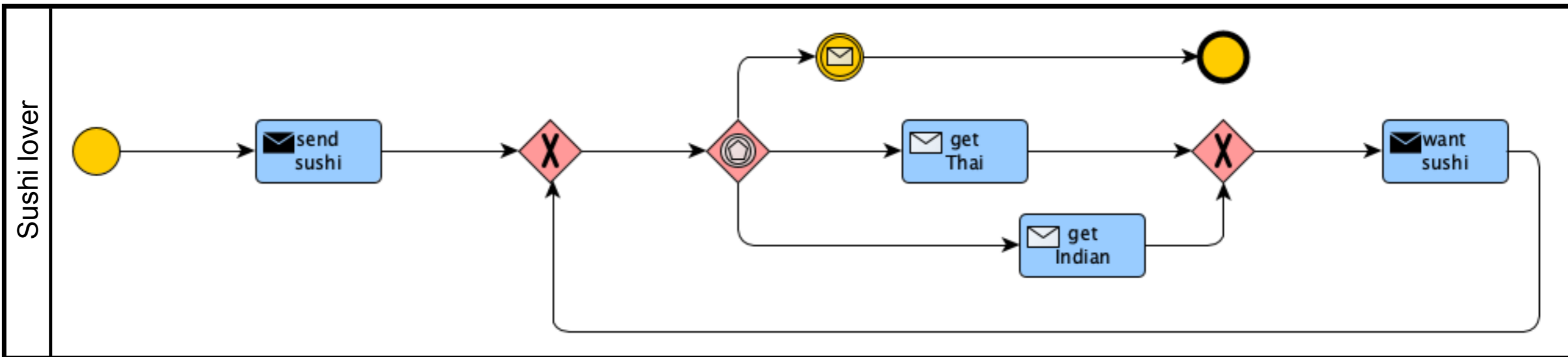


Sound?



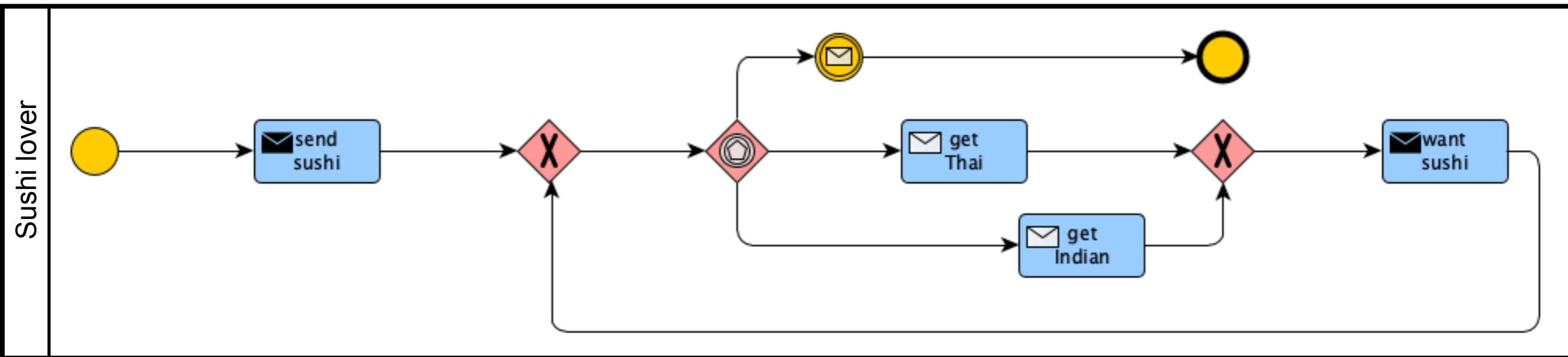


# Sushi lover

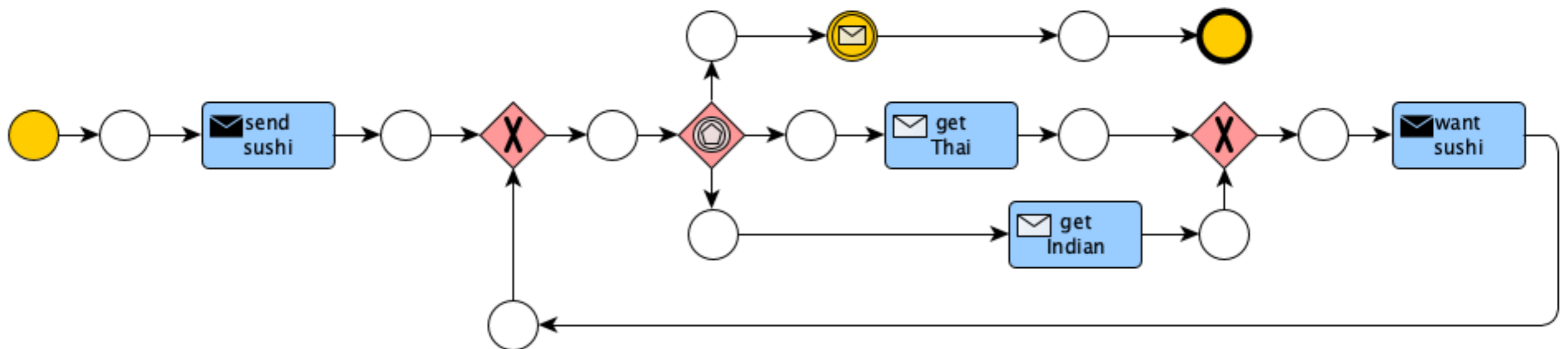


Sound?

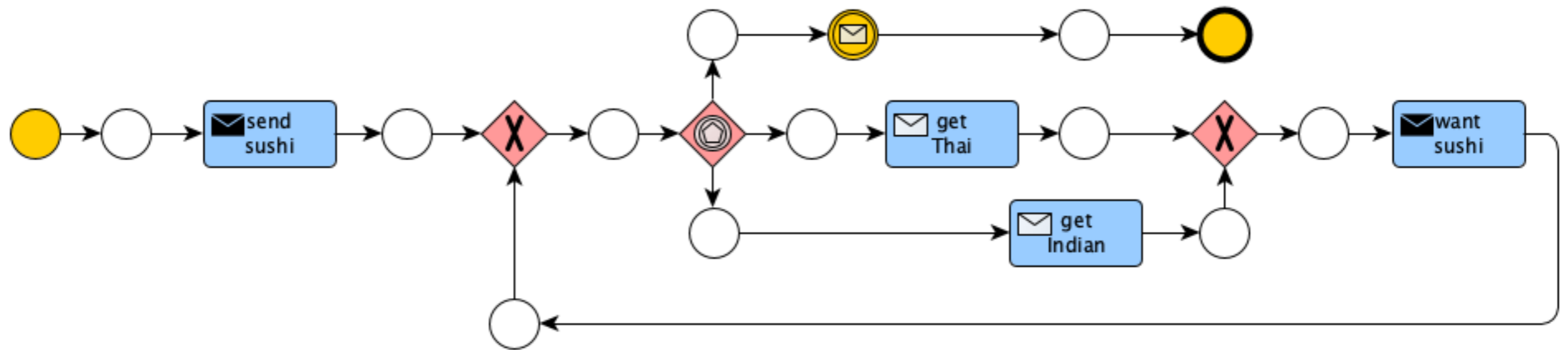
# Sushi lover: step 1



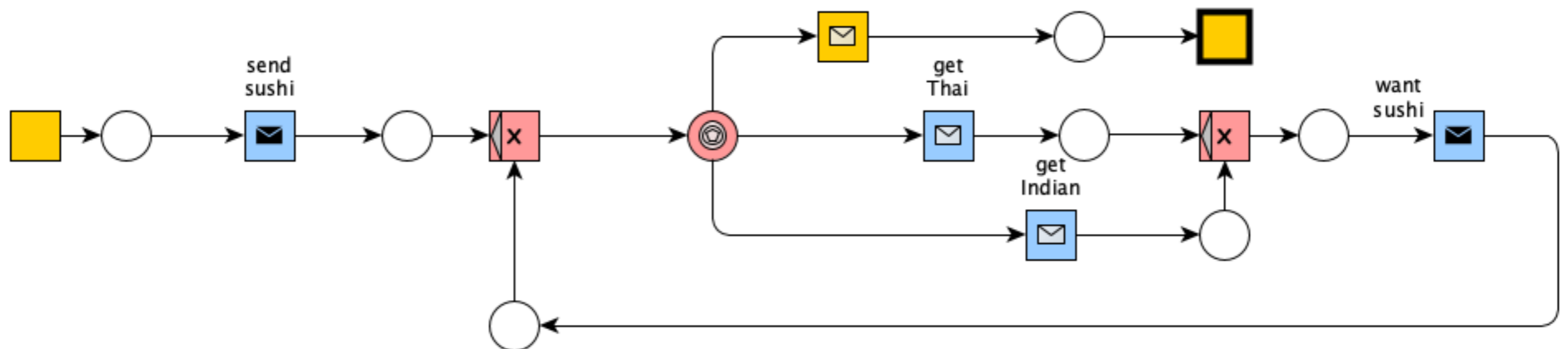
Step 1  
sequence flow  
message flow



# Sushi lover: step 2

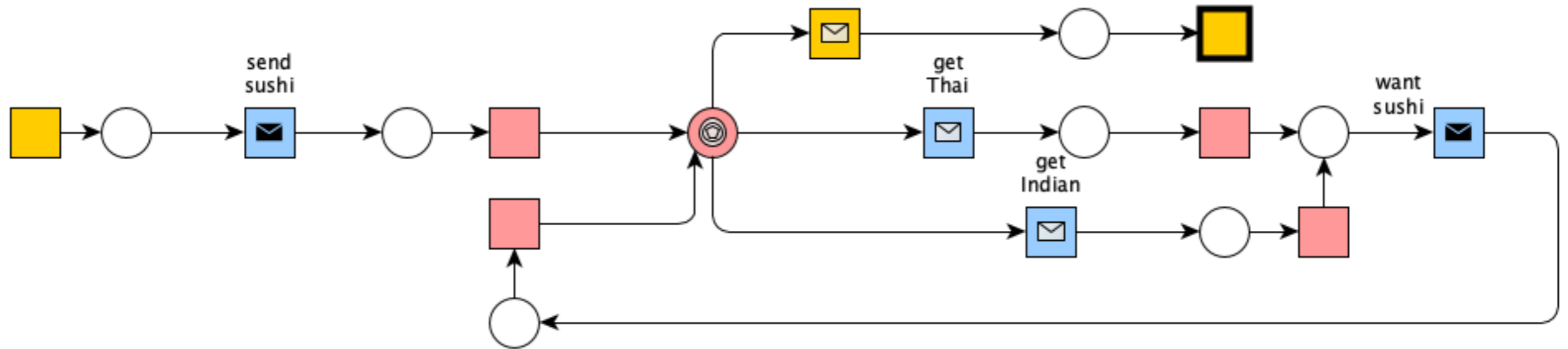


Step 2  
flow objects

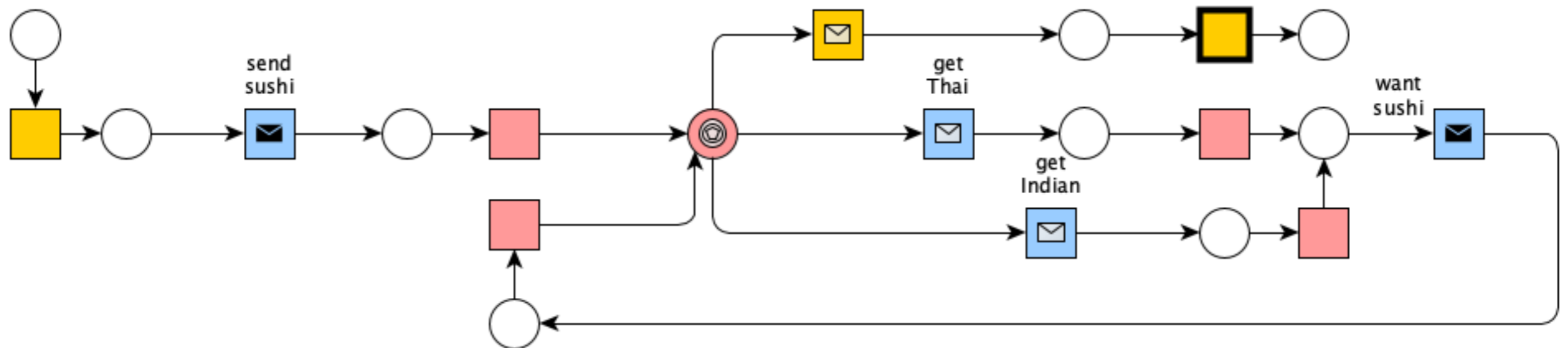




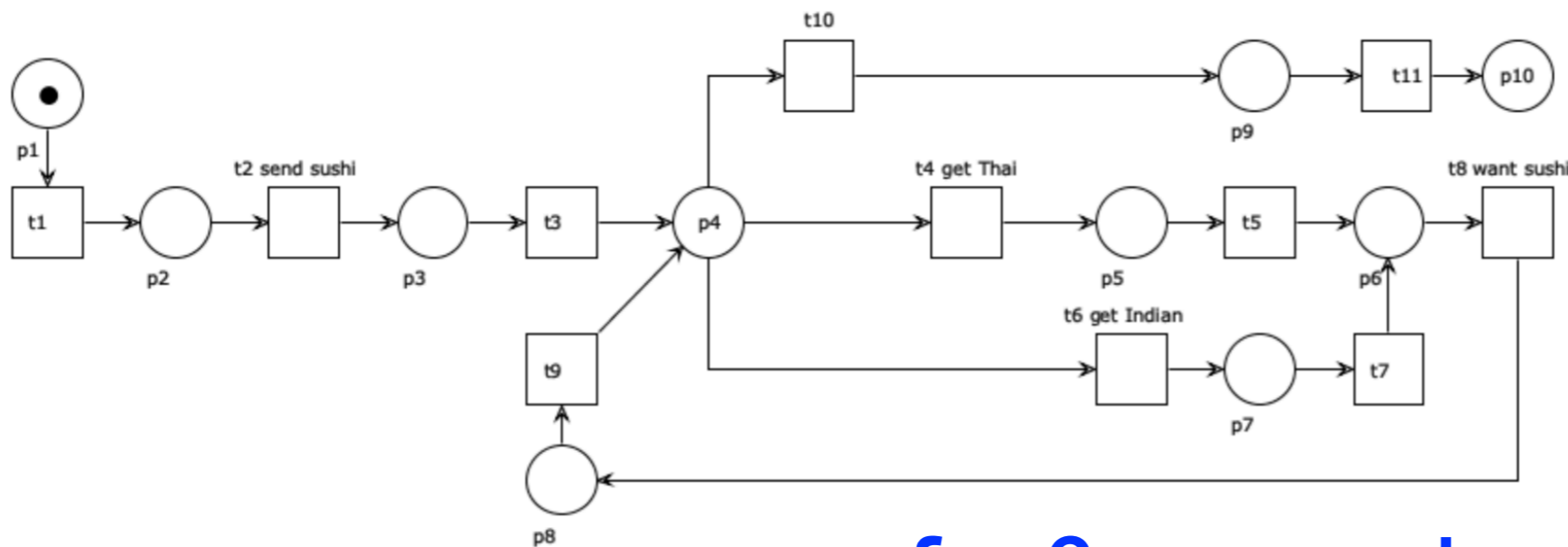
# Sushi lover: step 3



Step 3  
enforce  
initial place  
final place



# Soundness analysis



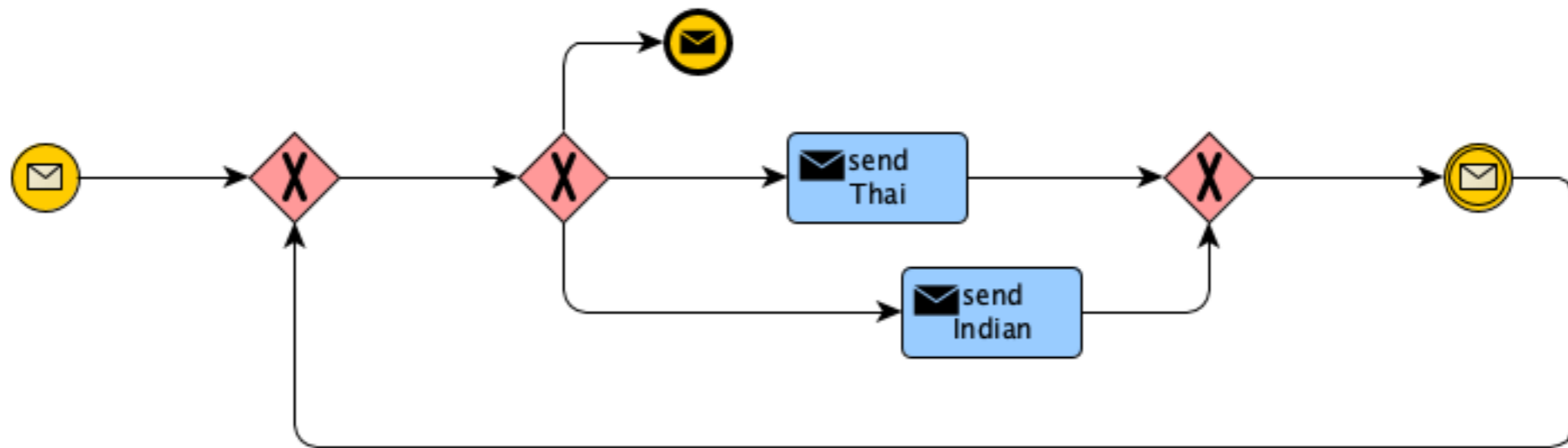
safe & sound  
(s-net)

Semantical analysis

Wizard Expert

- Qualitative analysis
  - Structural analysis
    - Net statistics
      - Wrongly used operators: 0
      - Free-choice violations: 0
    - S-Components
      - S-Components: 1
        - Places not covered by S-Comp
    - Wellstructuredness
  - Soundness
    - Workflow net property
    - Initial marking
    - Boundedness
    - Liveness

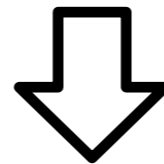
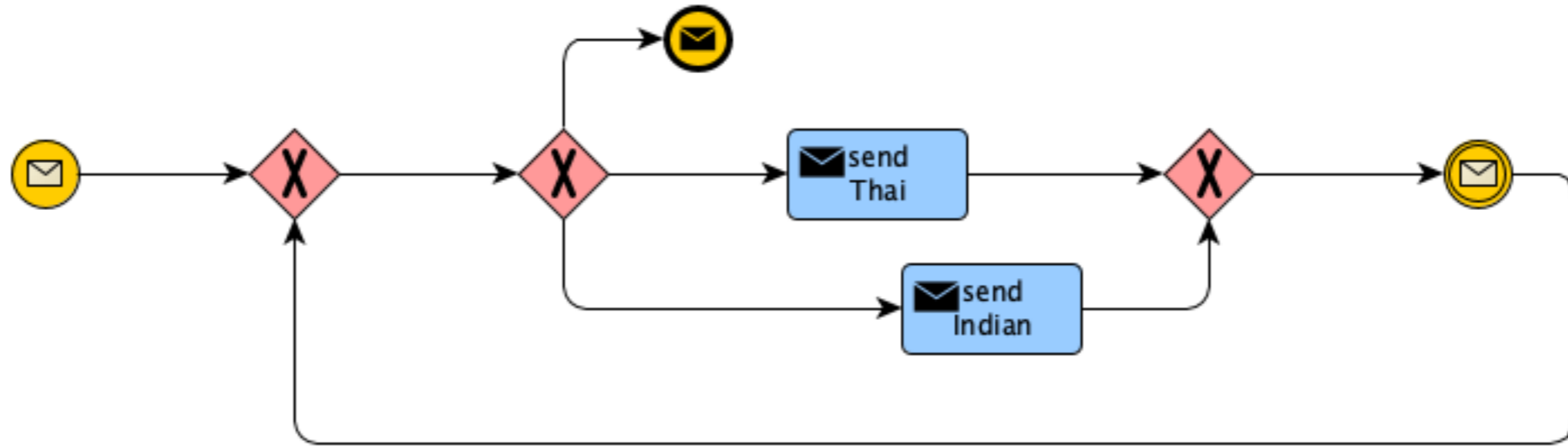
# Sushi doomed



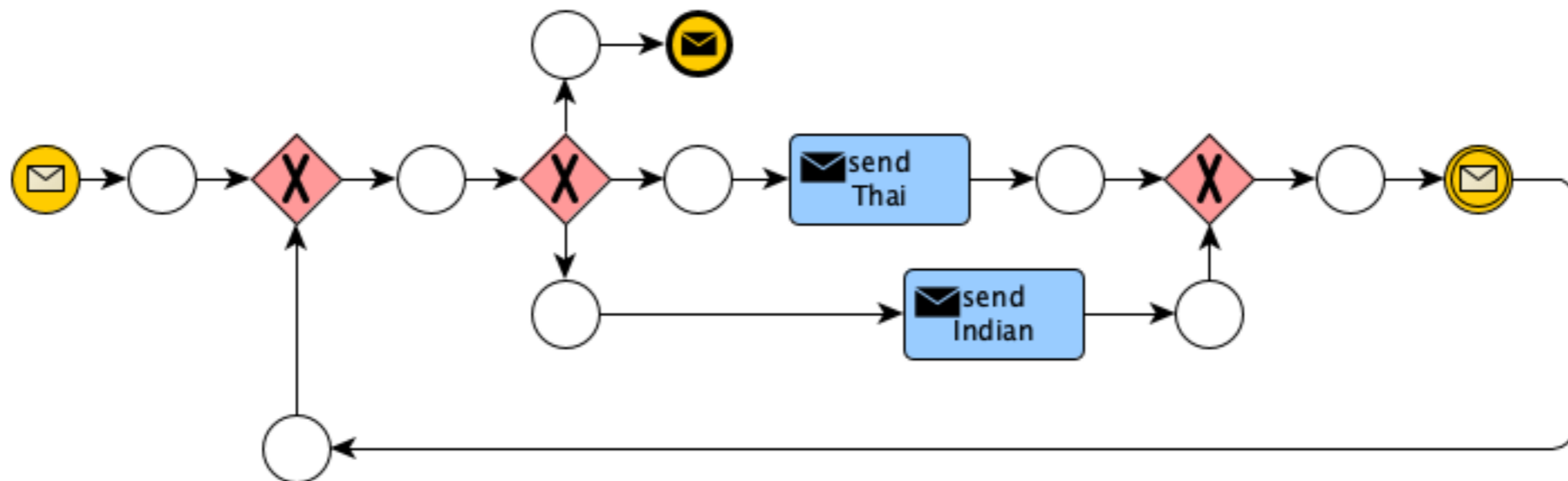
Sound?

# Sushi doomed: step 1

Sushi doomed

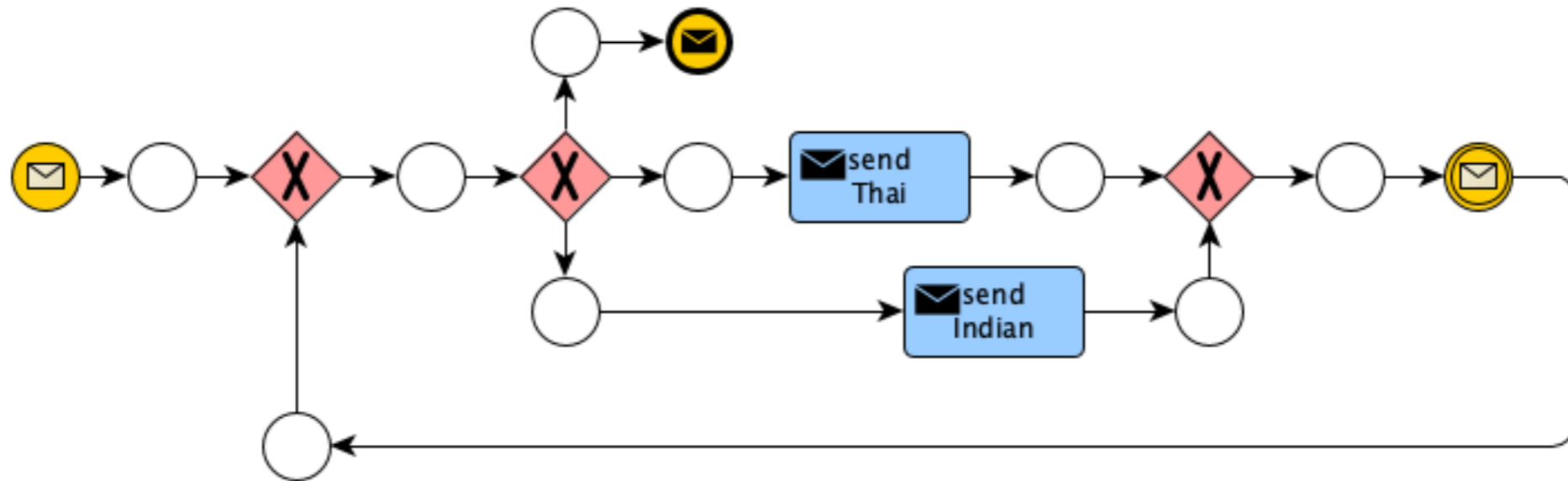


Step 1  
sequence flow  
message flow

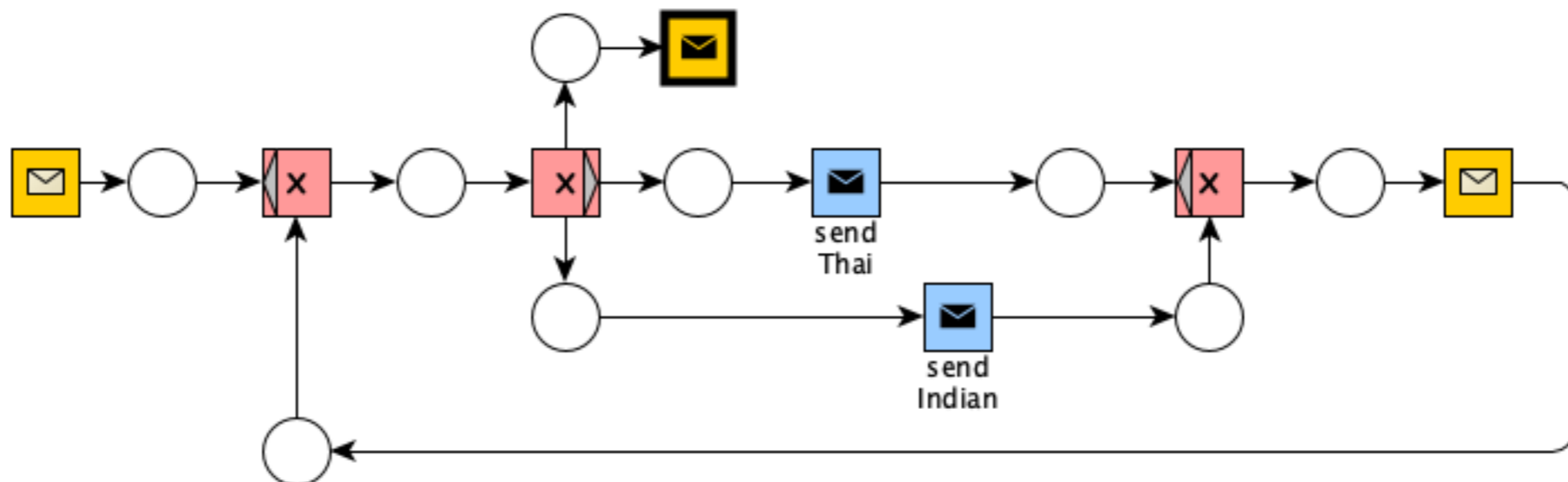




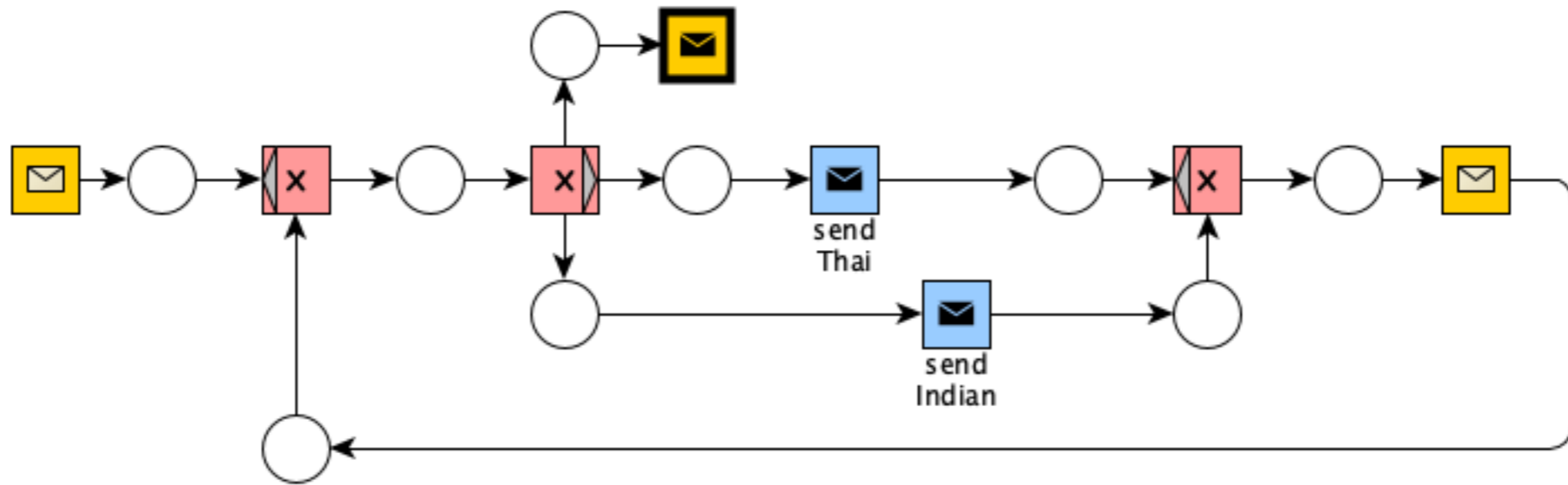
# Sushi doomed: step 2



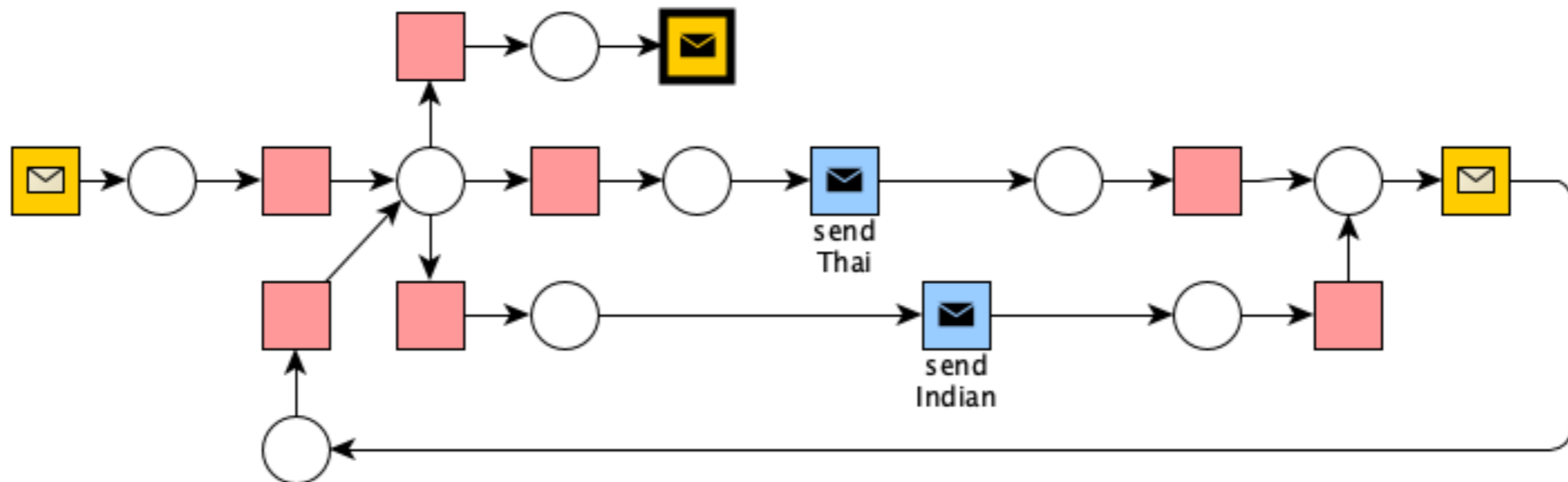
Step 2  
flow objects



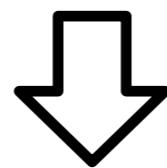
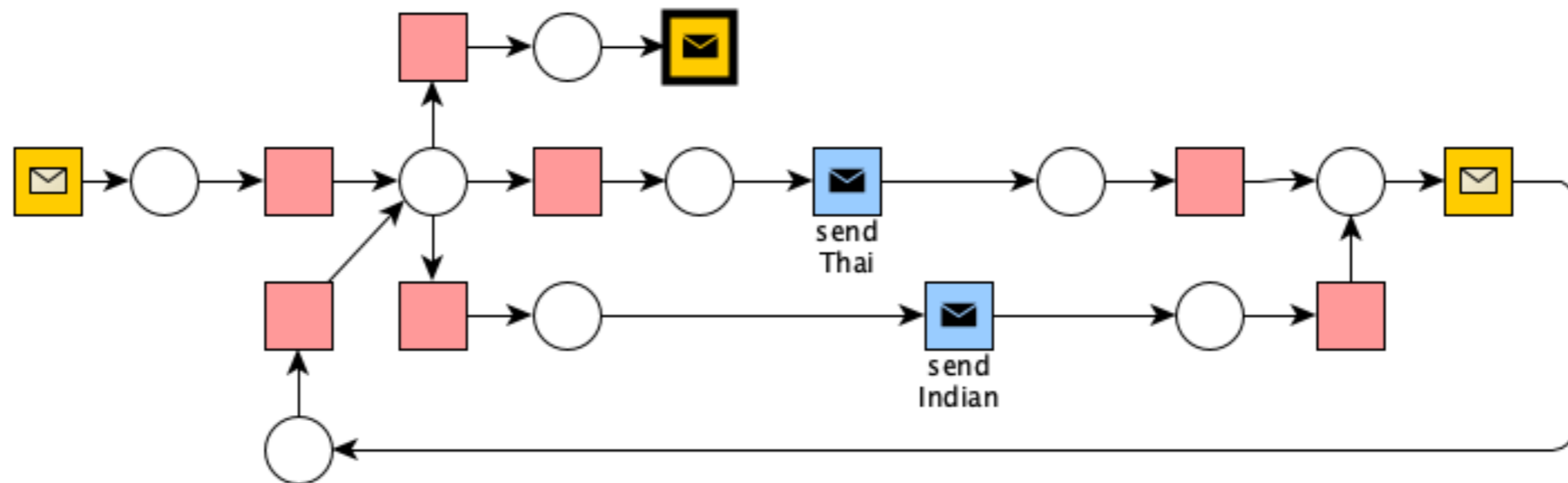
# Sushi doomed: (desugar)



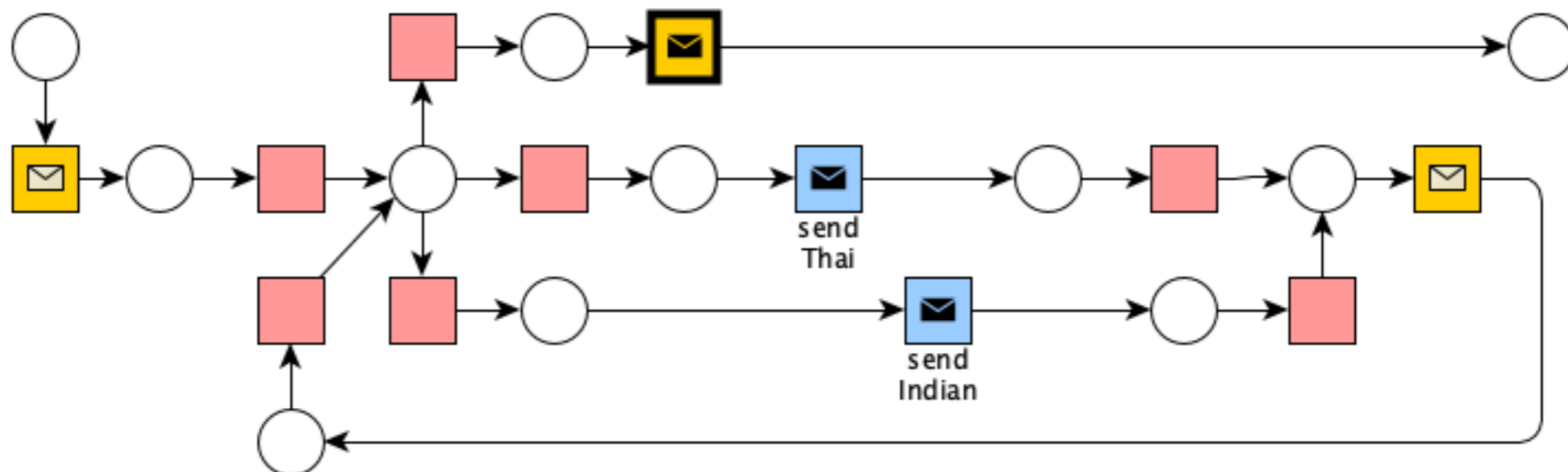
desugar



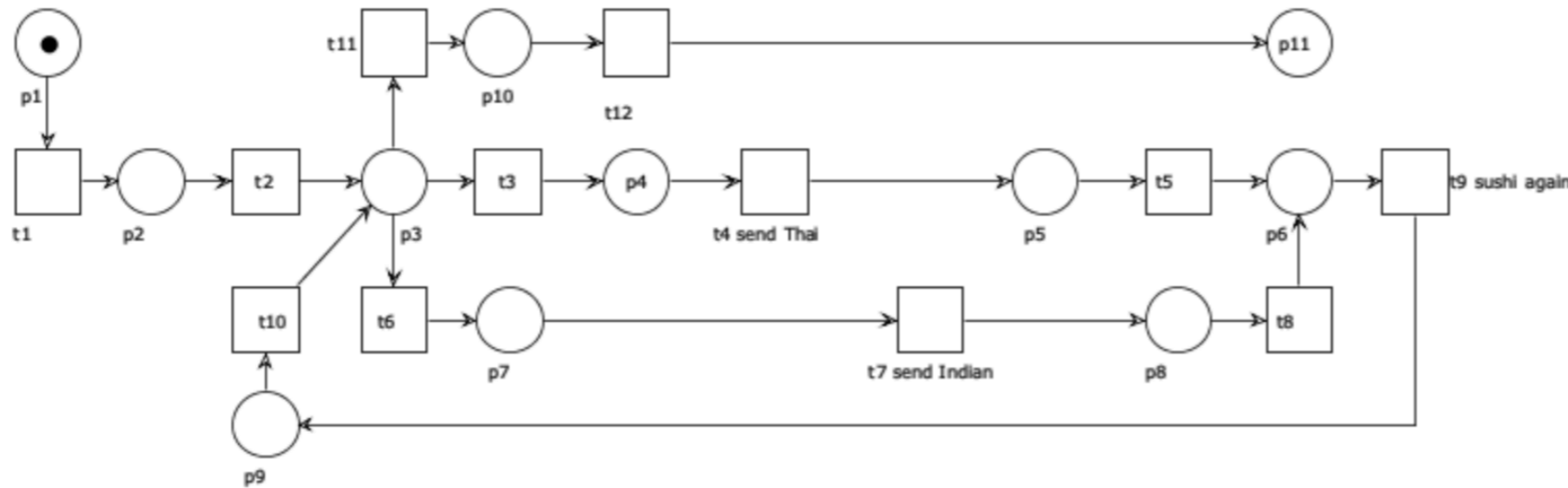
# Sushi doomed: step 3



**Step 3**  
enforce  
initial place  
final place



# Soundness analysis



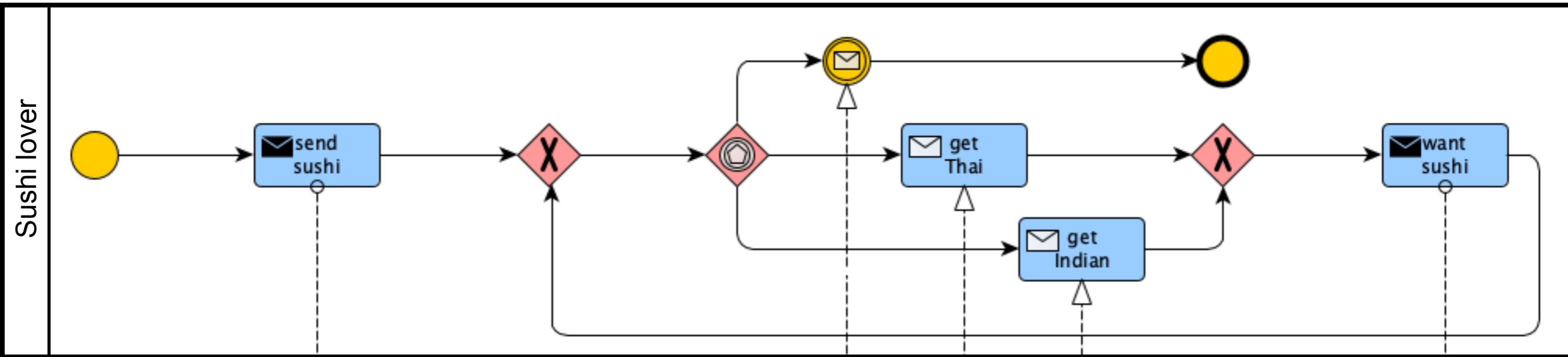
safe & sound  
(s-net)

Semantical analysis

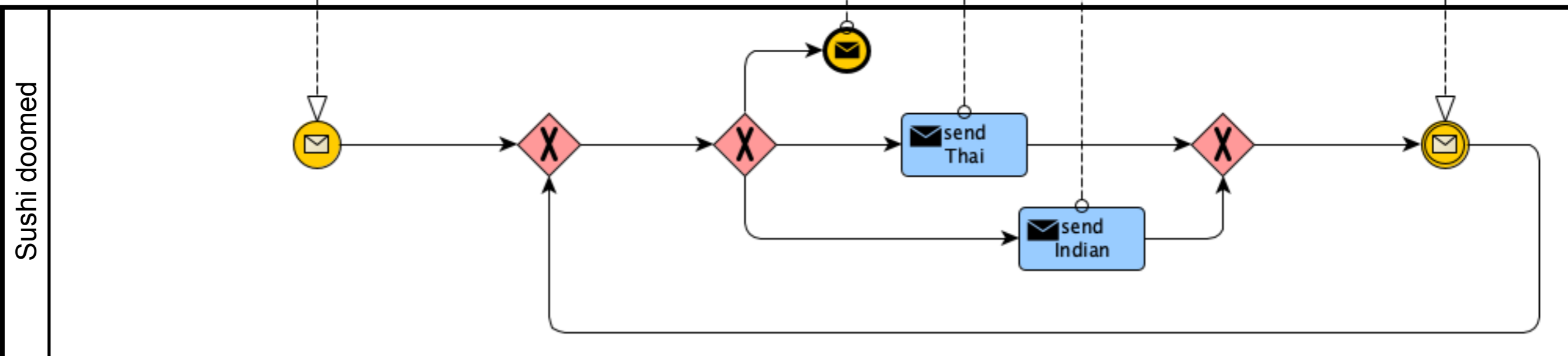
Wizard Expert

- Qualitative analysis
  - Structural analysis
    - Net statistics
      - Wrongly used operators: 0
      - Free-choice violations: 0
    - S-Components
      - S-Components: 1
      - Places not covered by S-Comp: 0
    - Wellstructuredness
      - PT-Handles: 0
      - TP-Handles: 0
  - Soundness
    - Workflow net property
    - Initial marking
    - Boundedness
    - Liveness

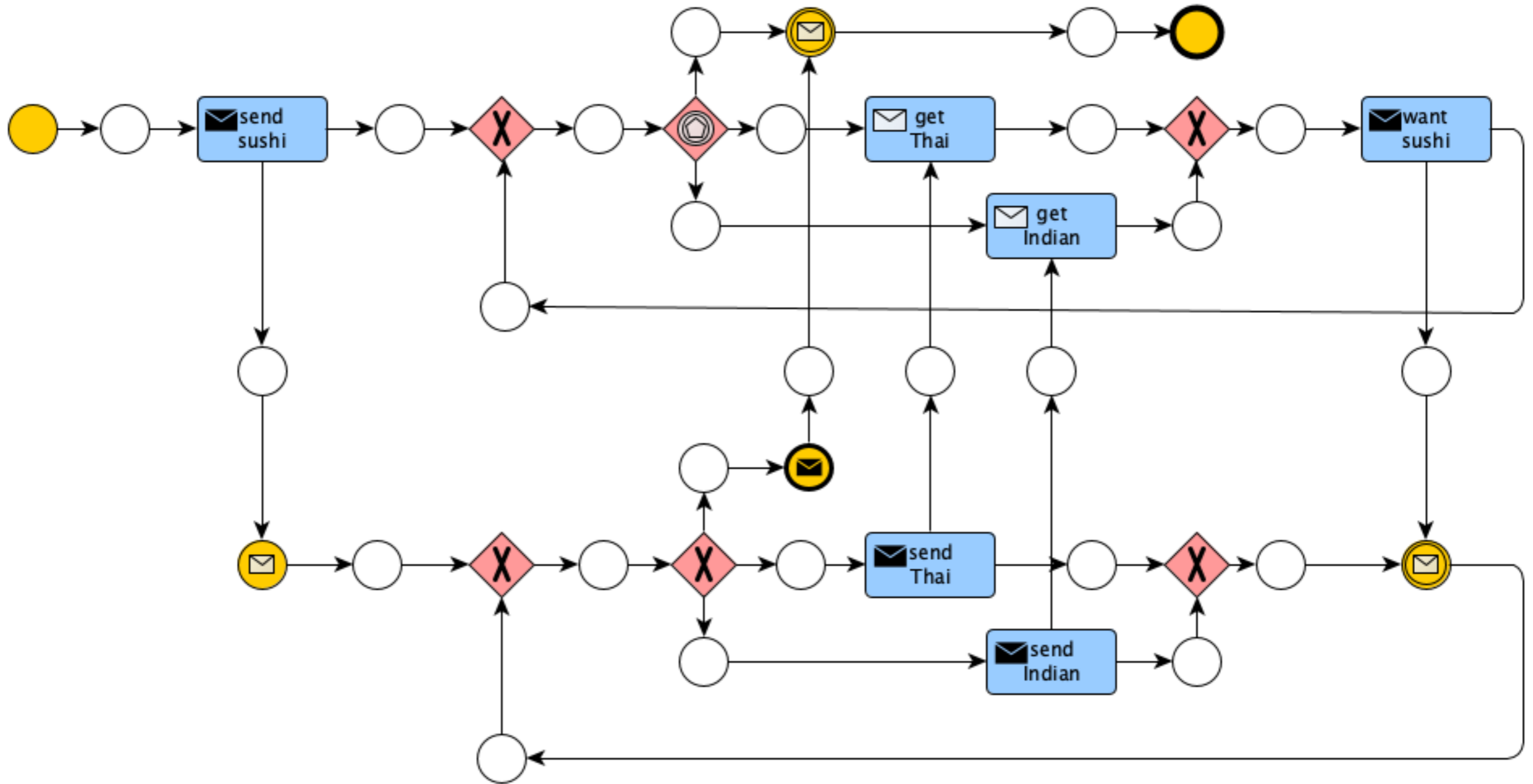
# Sushi system



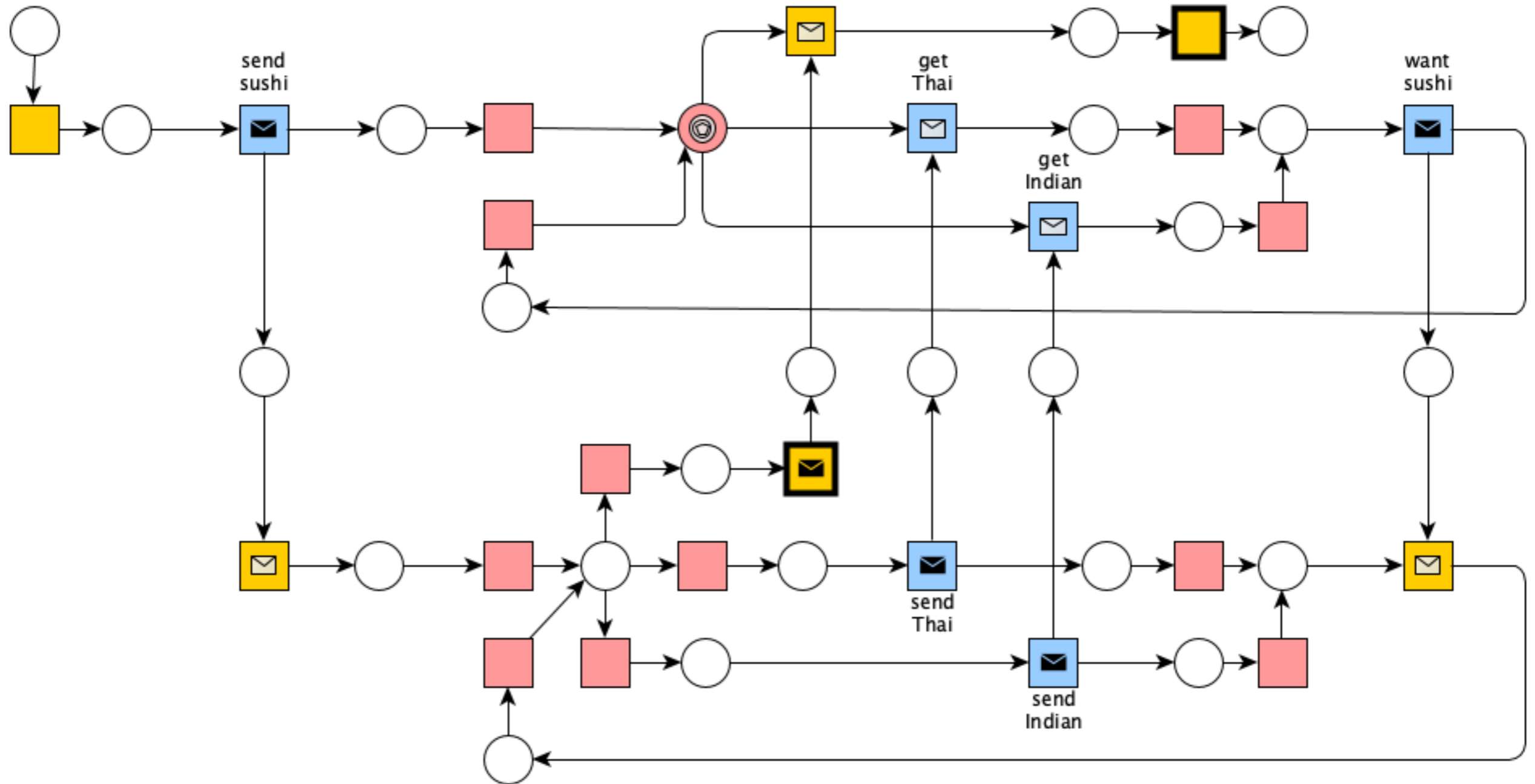
Sound?



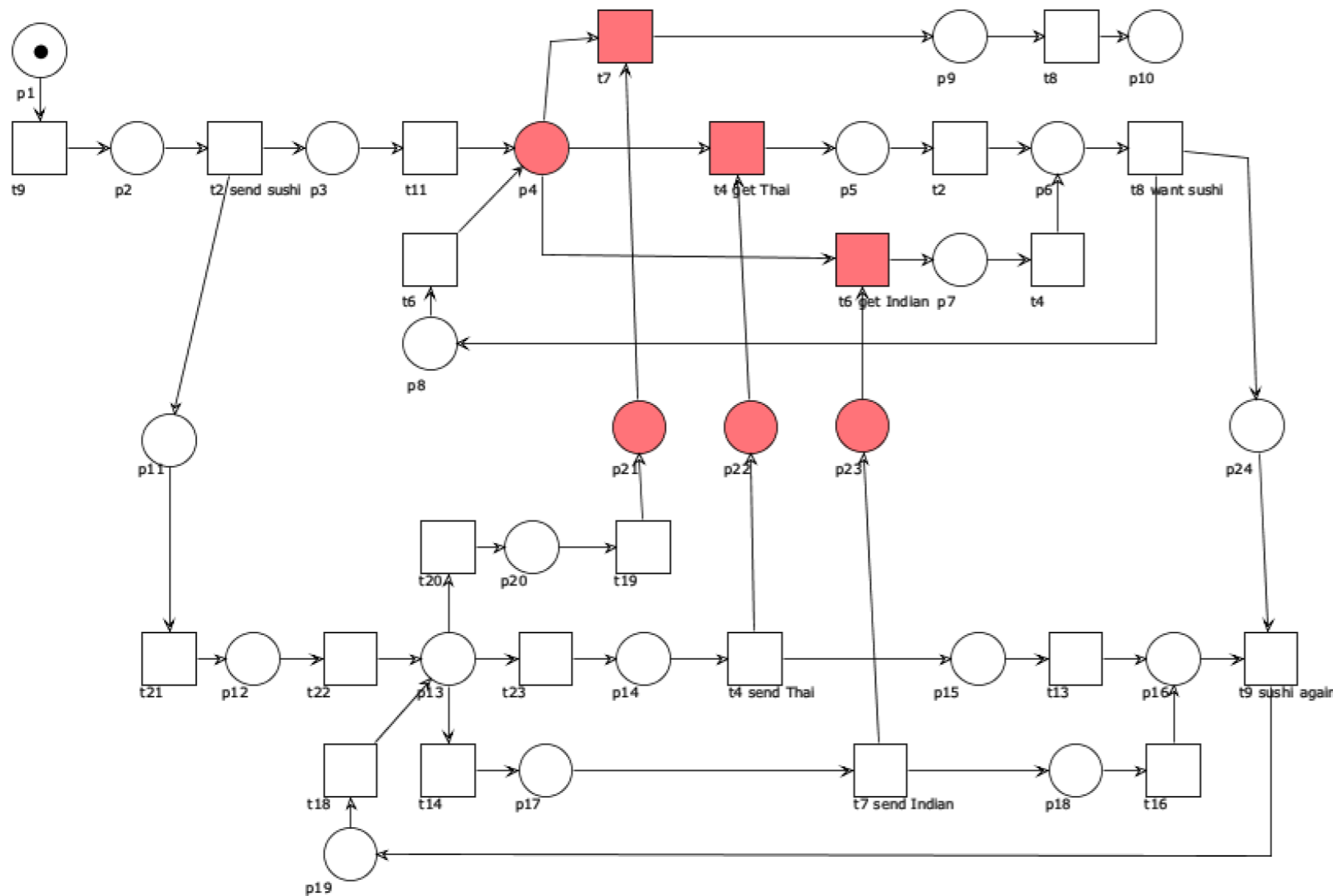
# Sushi system: step 1



# Sushi system: step 1+2+3



# Soundness analysis



## Semantical analysis

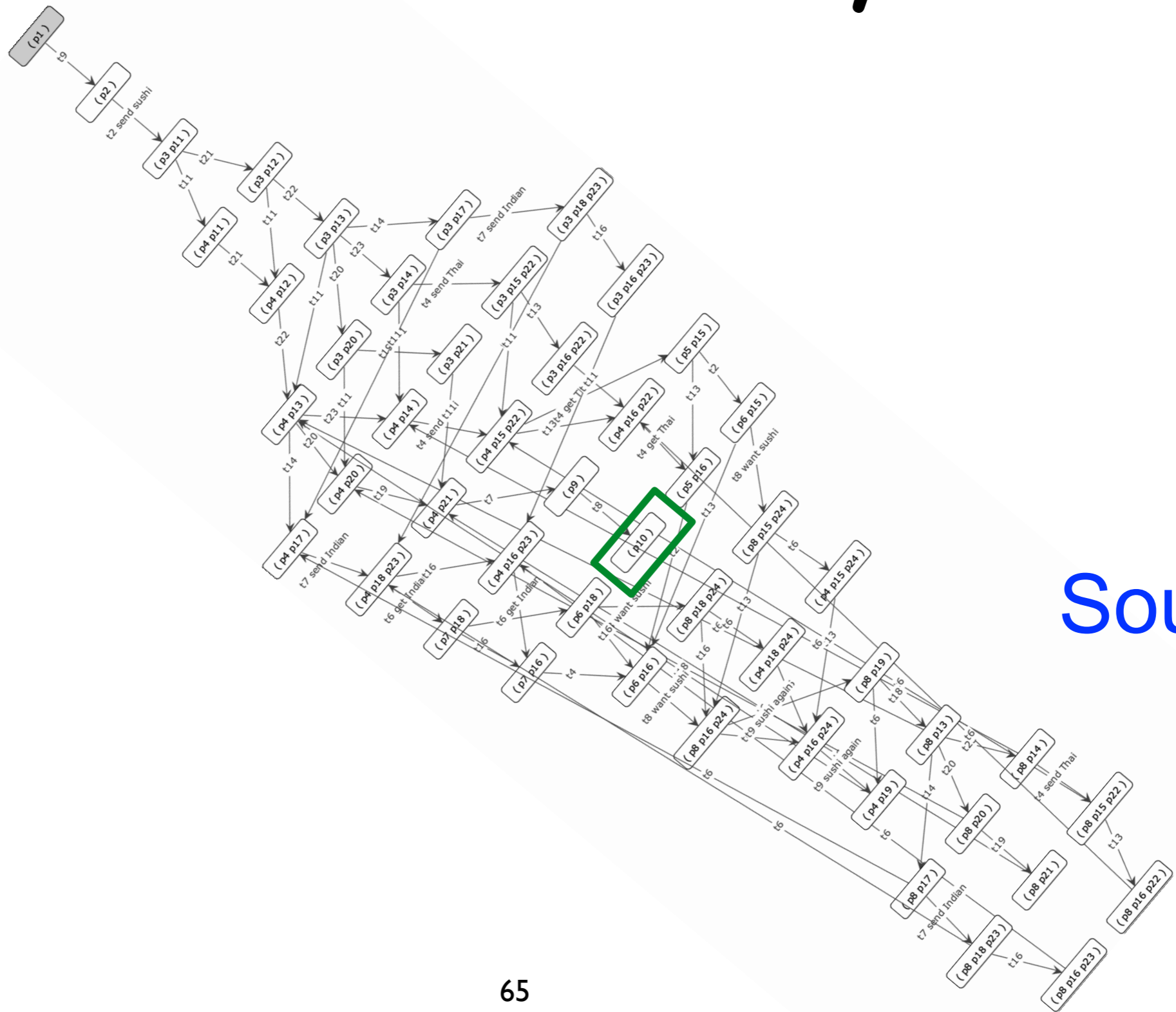
Wizard Expert

- Qualitative analysis
  - Structural analysis
    - Net statistics
      - Wrongly used operators: 0
    - Free-choice violations: 1
      - Free-choice violation group 1
    - S-Components
  - Wellstructuredness
    - PT-Handles: 8
    - TP-Handles: 14
- Soundness
  - Workflow net property
  - Initial marking
  - Boundedness
  - Liveness

Sound!



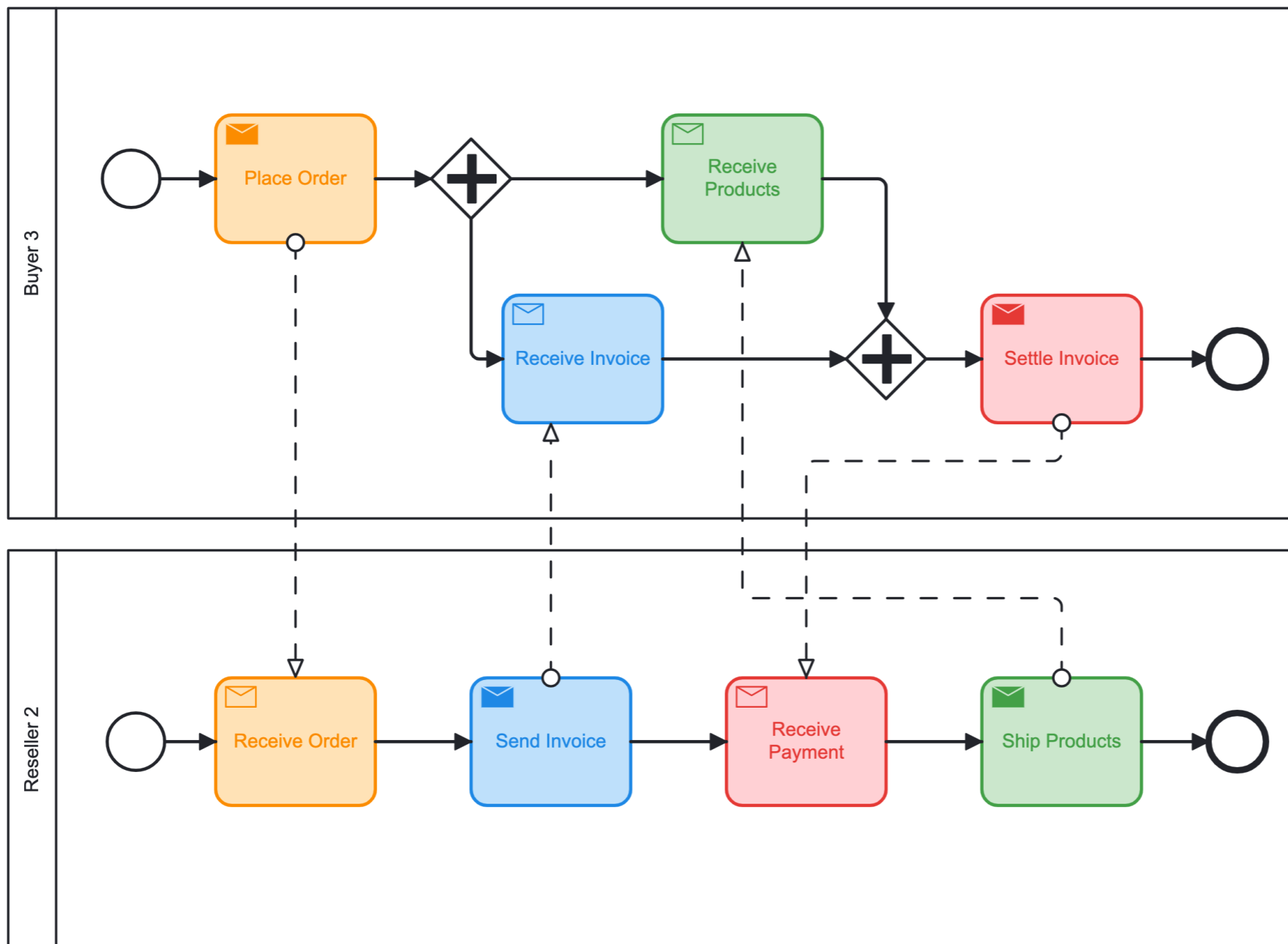
# Soundness analysis



Sound!

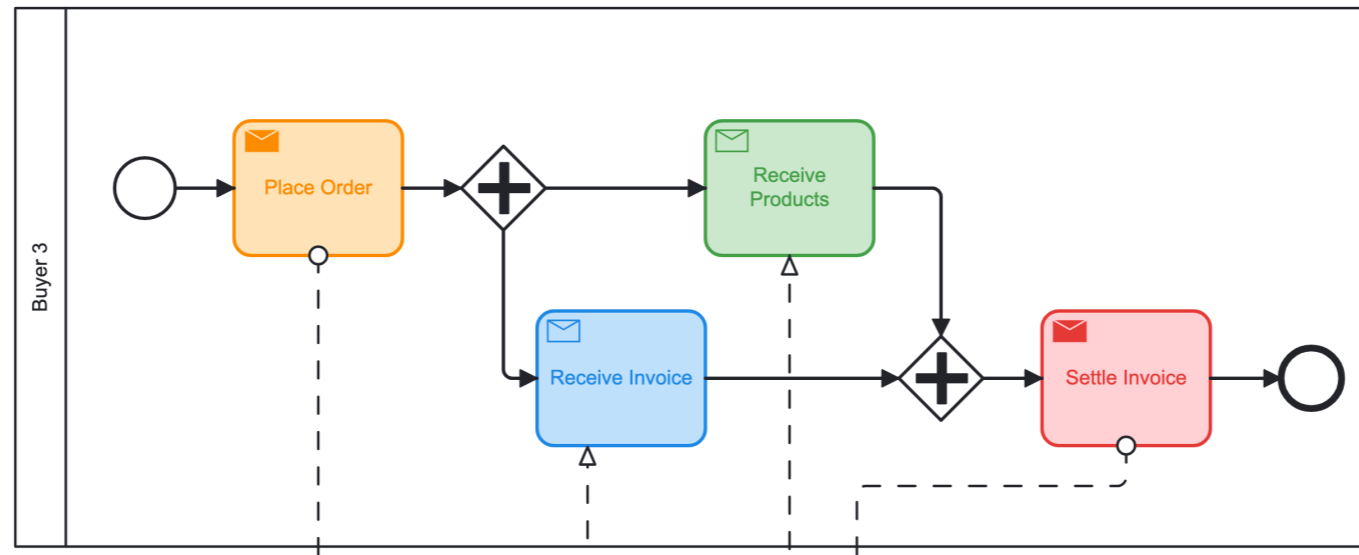
Example:  
Buyer - Reseller

# Buyer 3 and Reseller 2

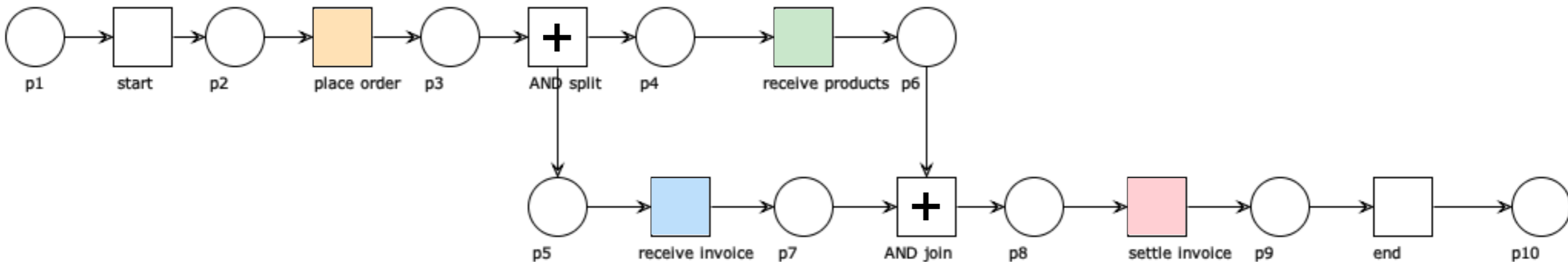


Sound?

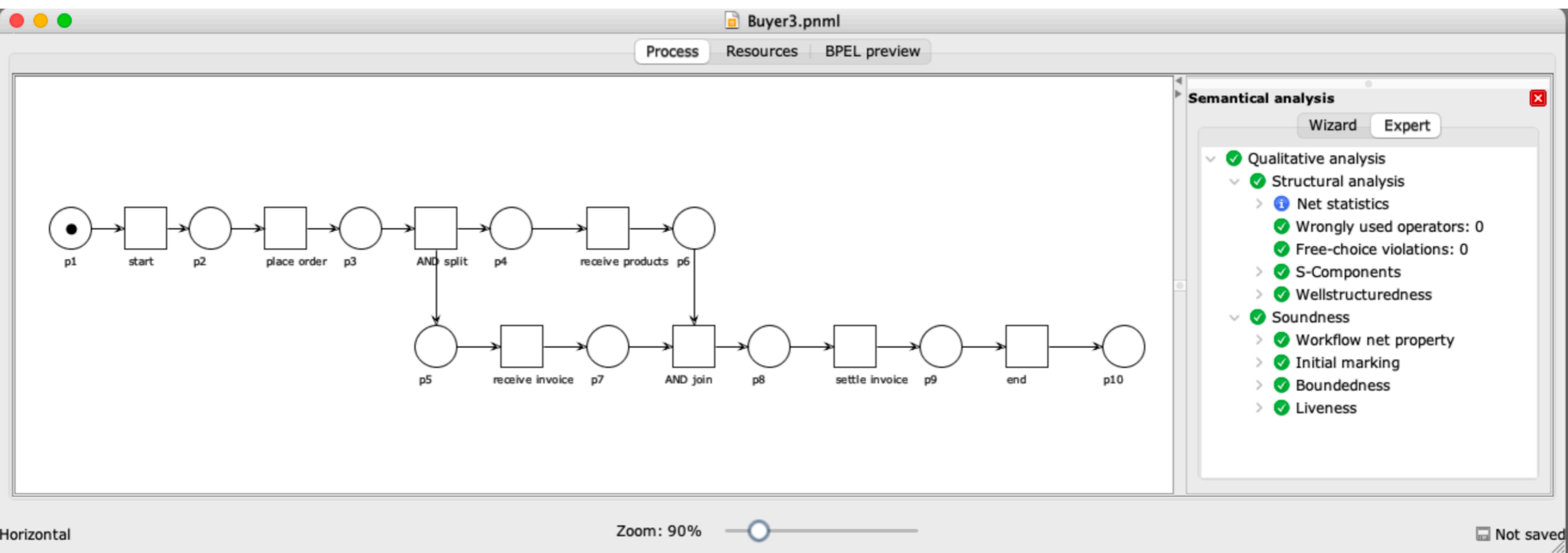
# Buyer 3 sound?



Step 1 + 2 + 3

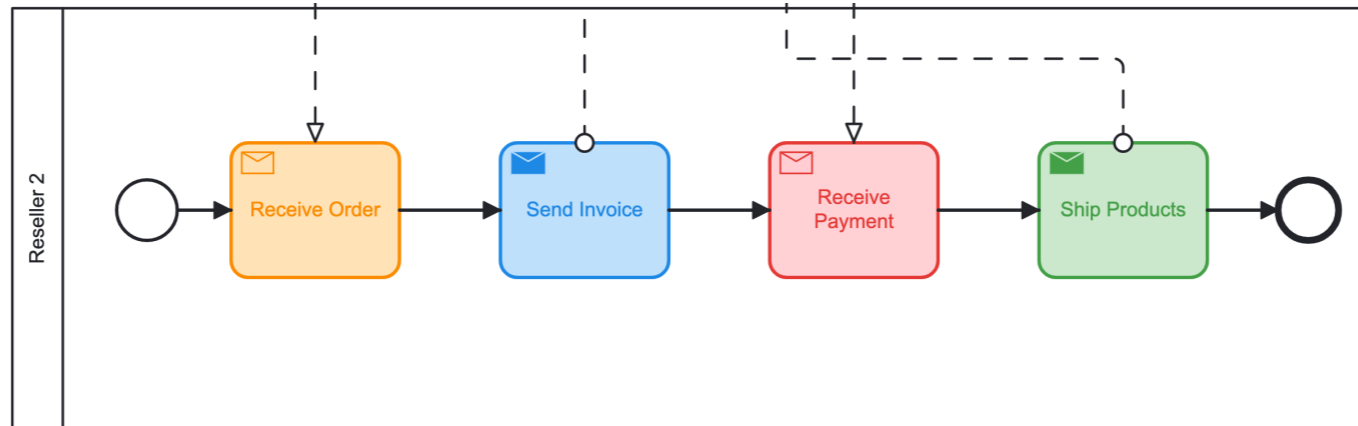


# Buyer 3 soundness analysis



Safe and sound!

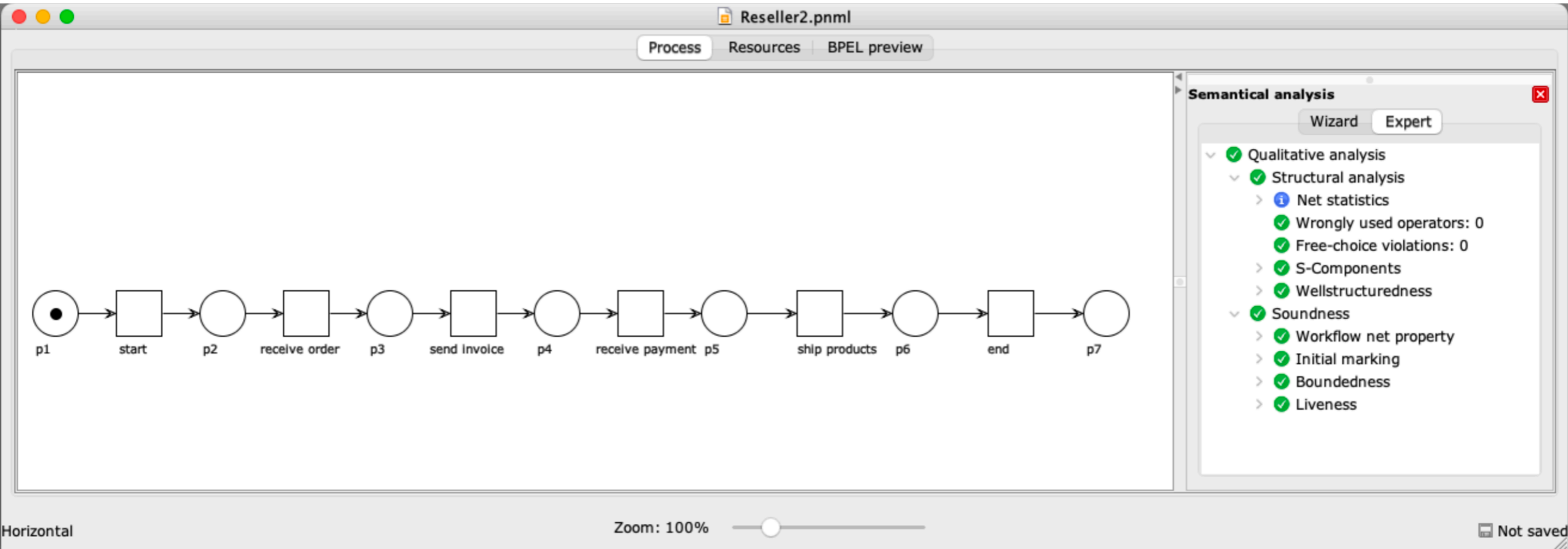
# Reseller 2 sound?



↓ Step 1 + 2 + 3

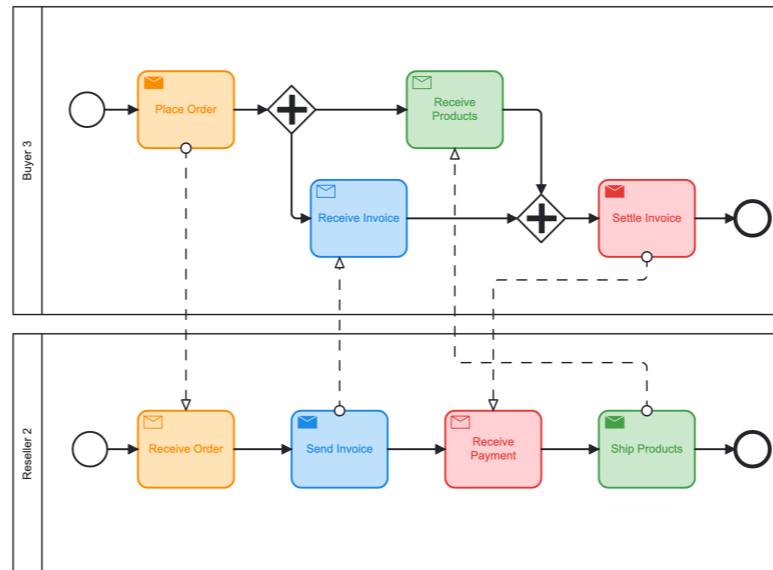


# Reseller 2 soundness analysis

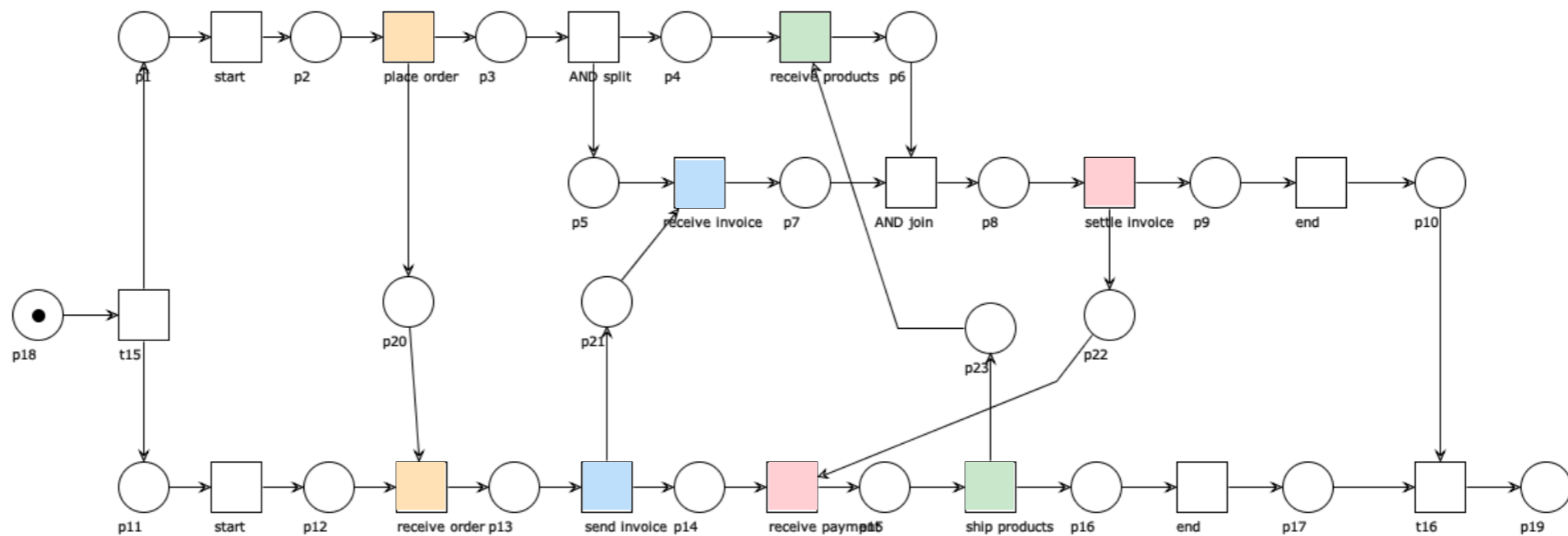


Safe and sound!

# Buyer 3 + Reseller 2: sound?

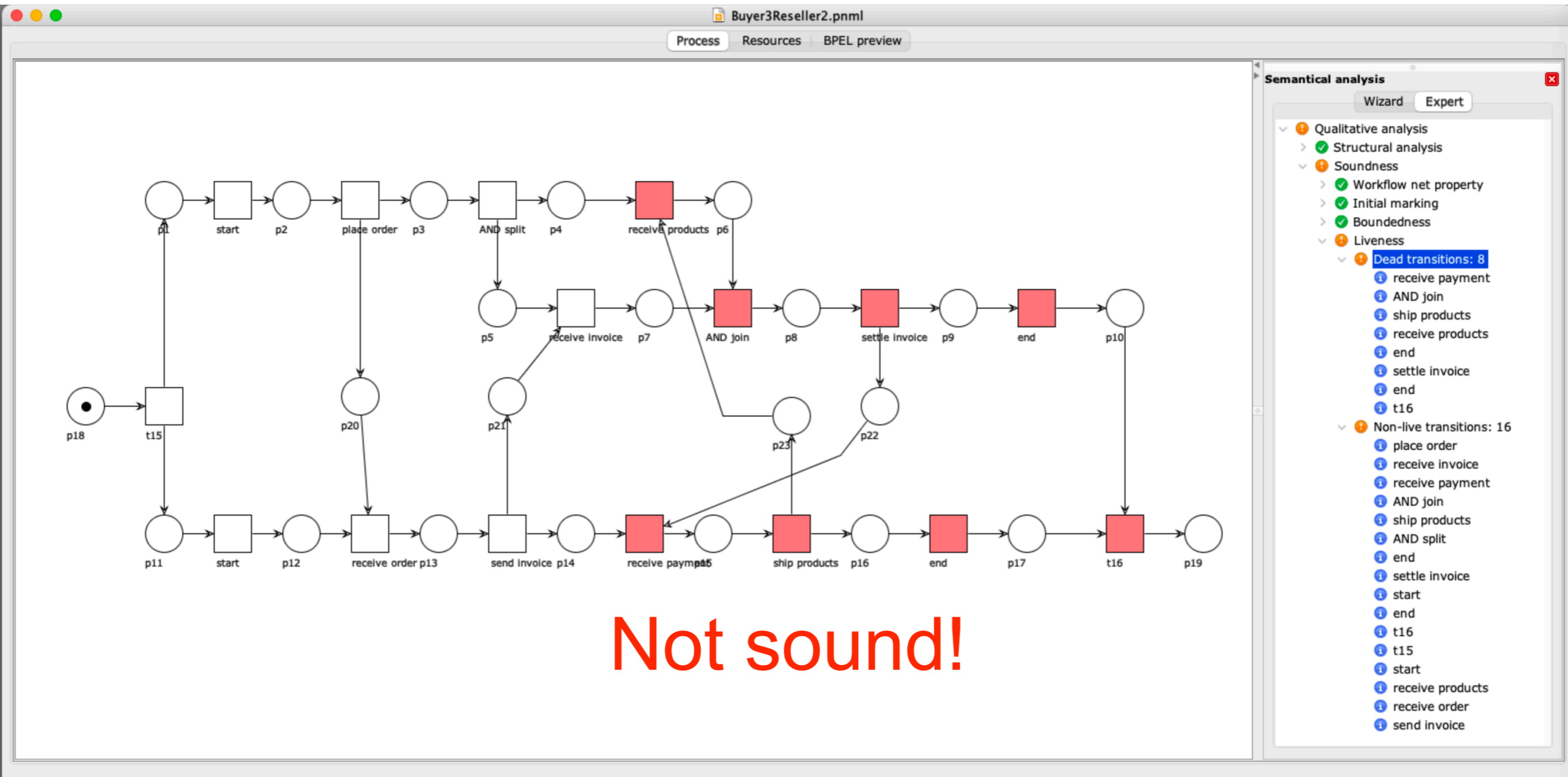


Step 1 + 2 + 3



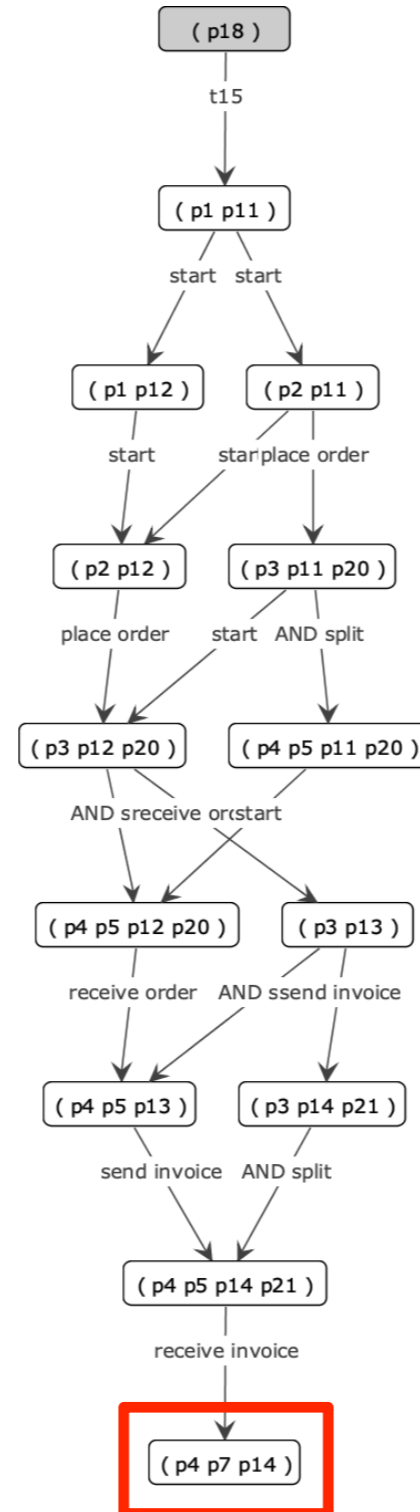


# Buyer 3 + Reseller 2: analysis



Not sound!

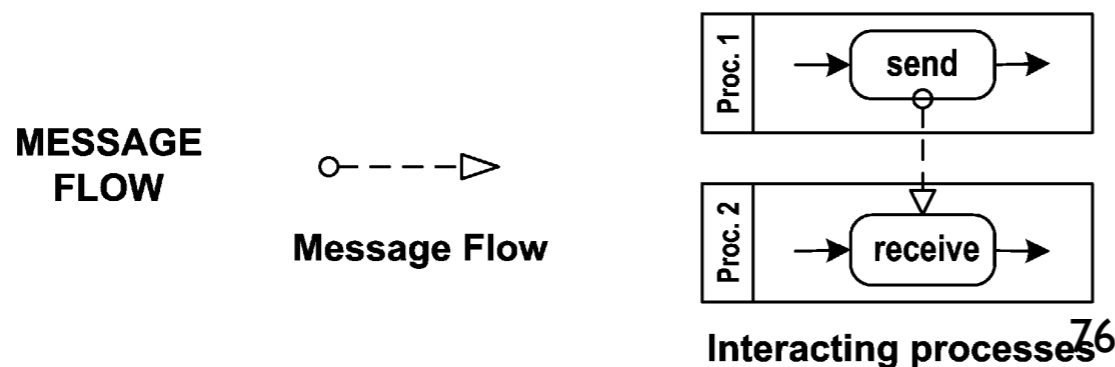
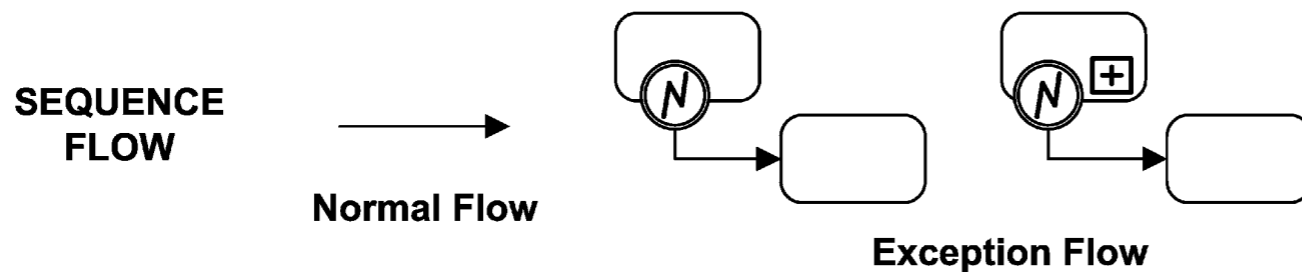
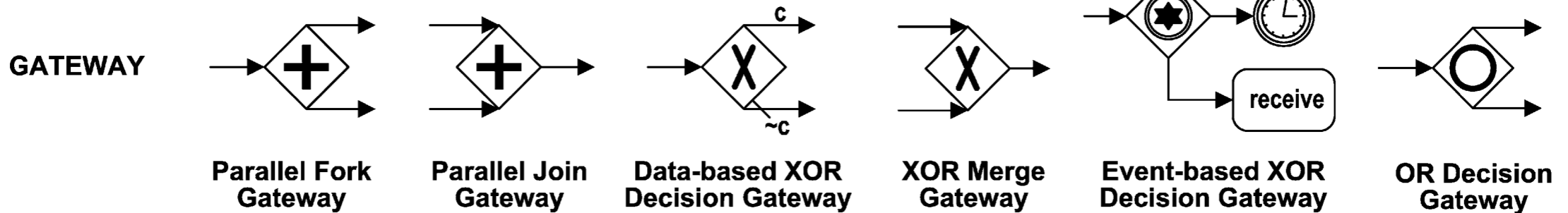
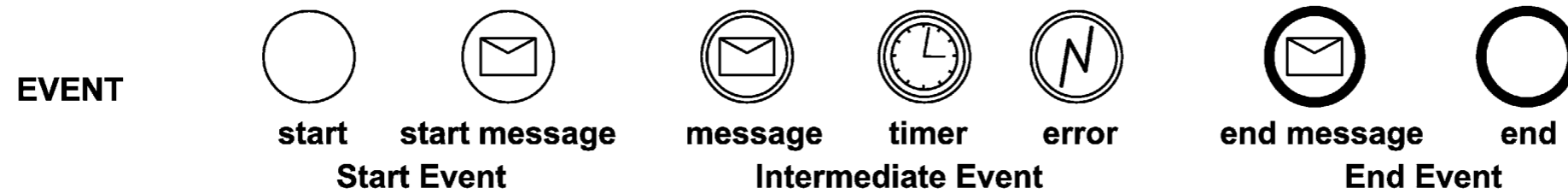
# Buyer 3 + Reseller 2: analysis



Not sound!

# Step 0: preprocessing BPMN diagrams

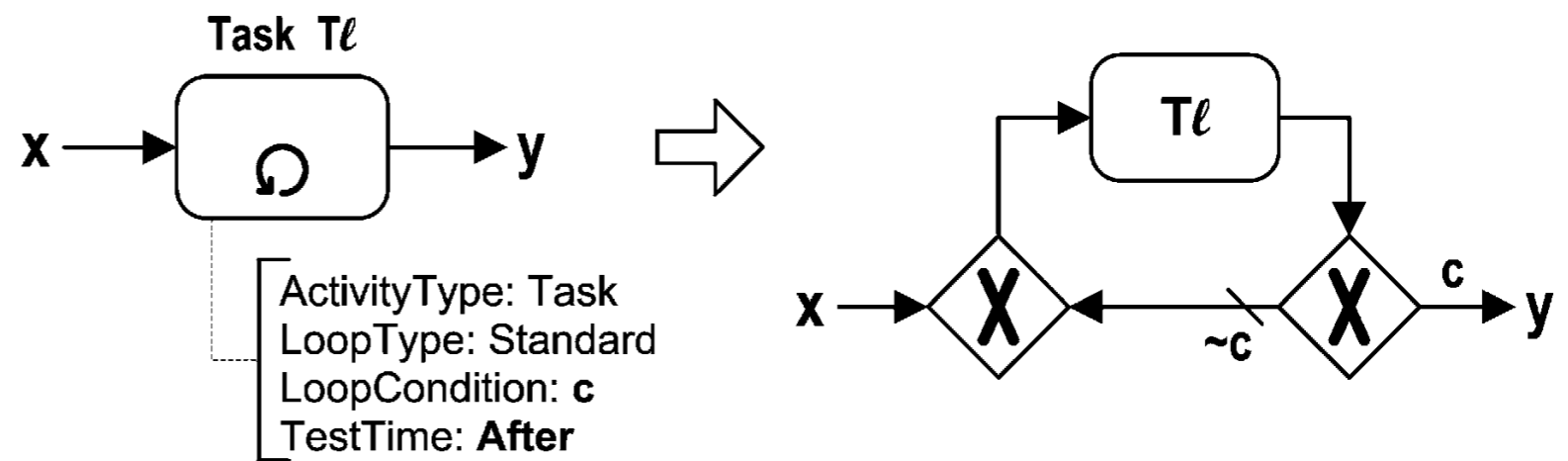
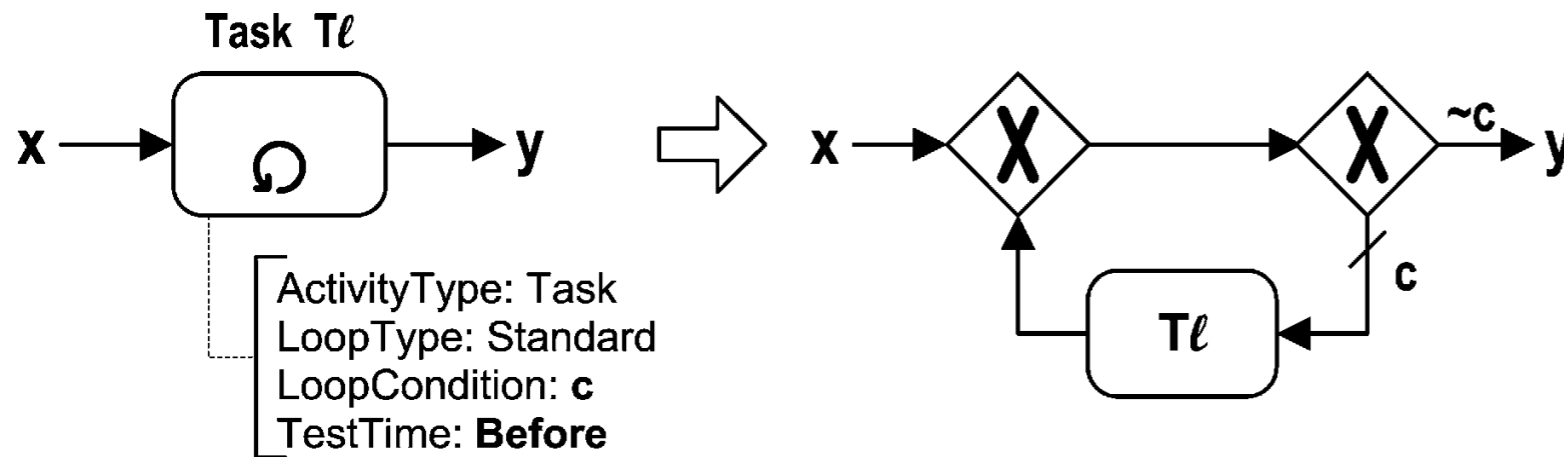
# Overview



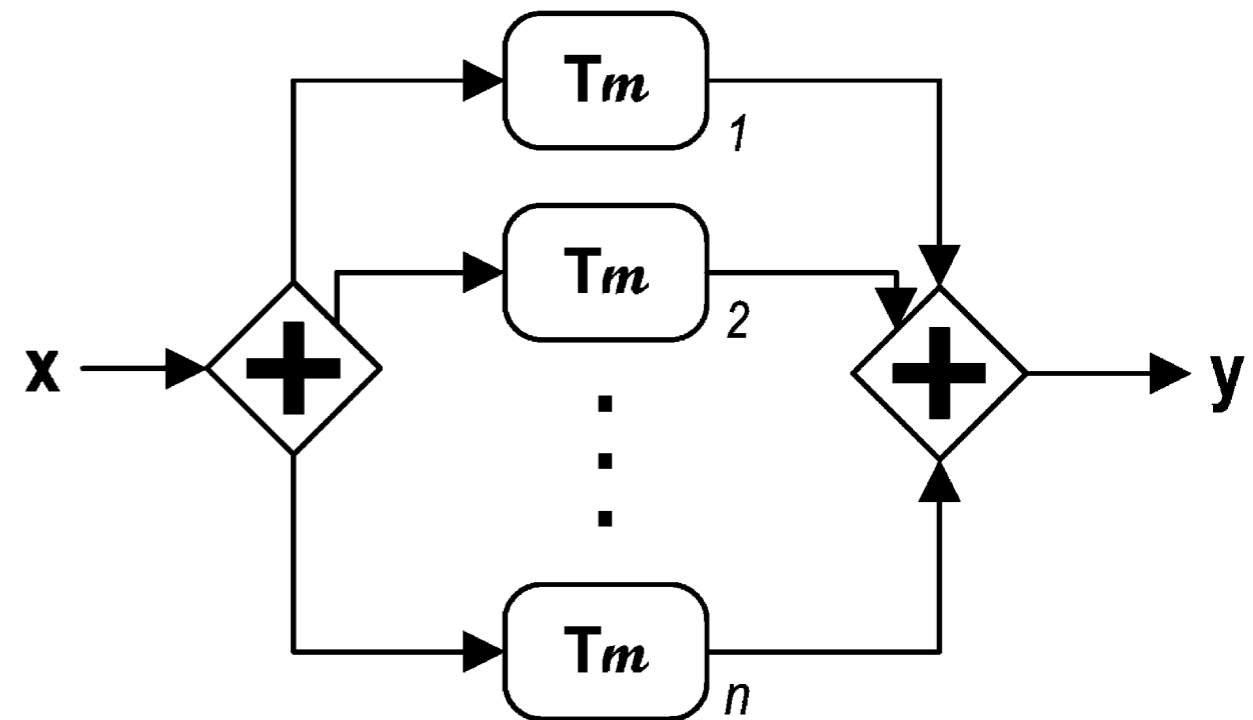
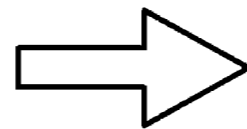
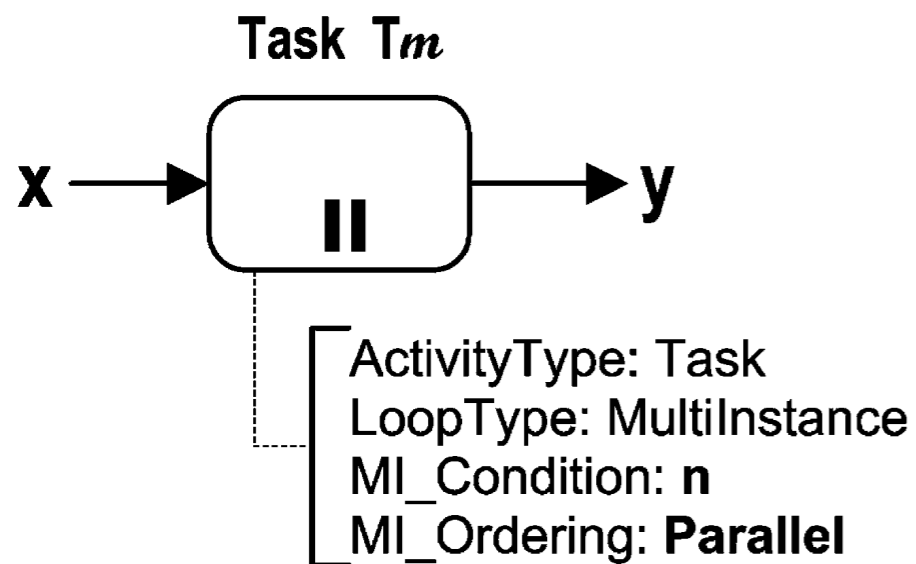
[ Note ]:

1. Apart from intermediate error events, intermediate message or timer events may also be the source of exception flows.
2. A message flow may link task to task, end event to task, task to start event, and end event to start event.

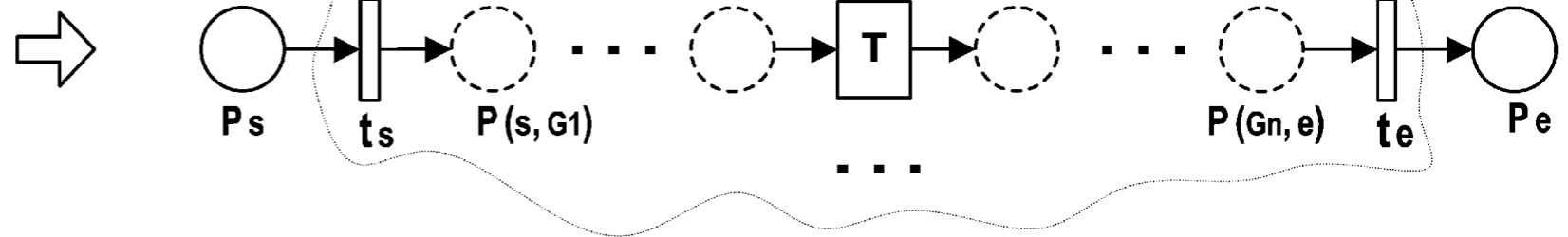
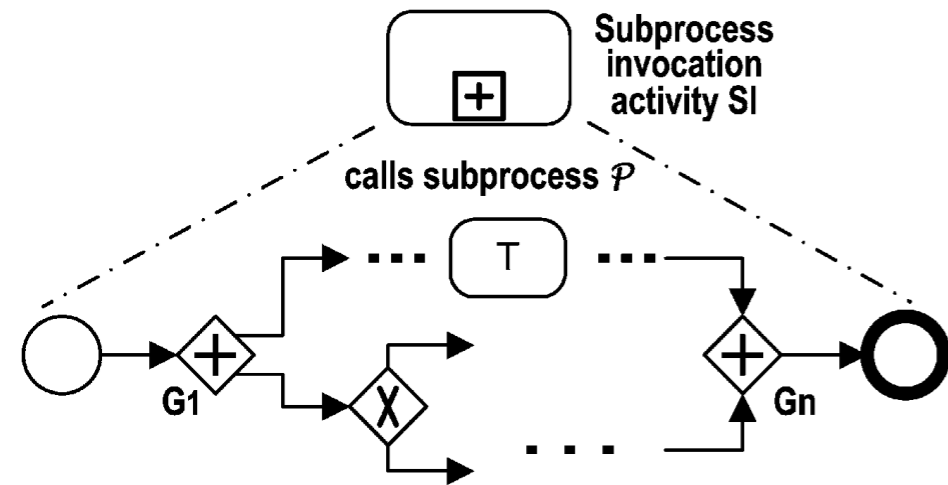
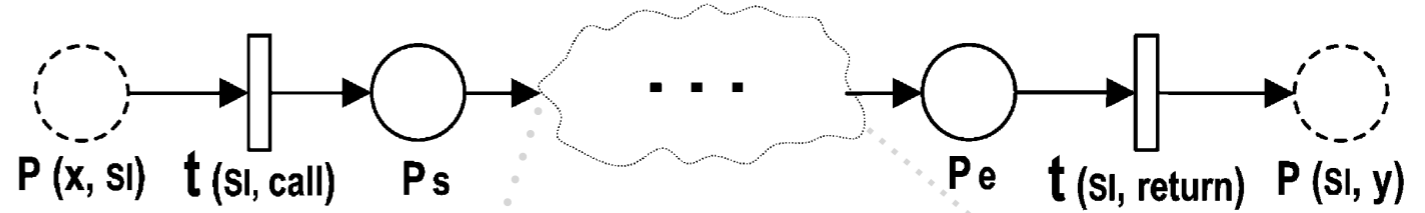
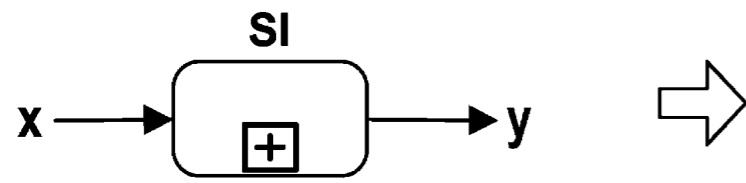
# Activity looping



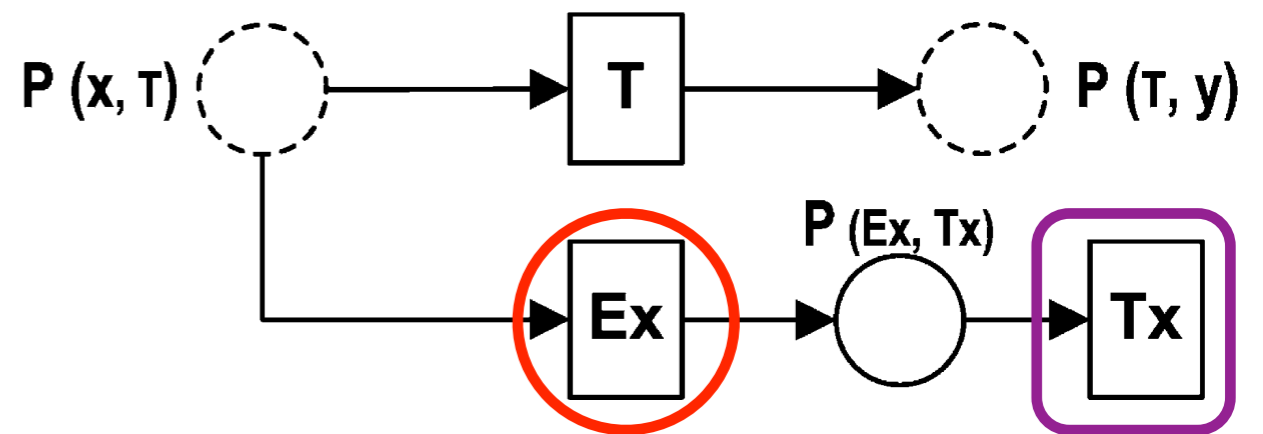
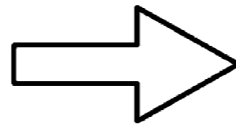
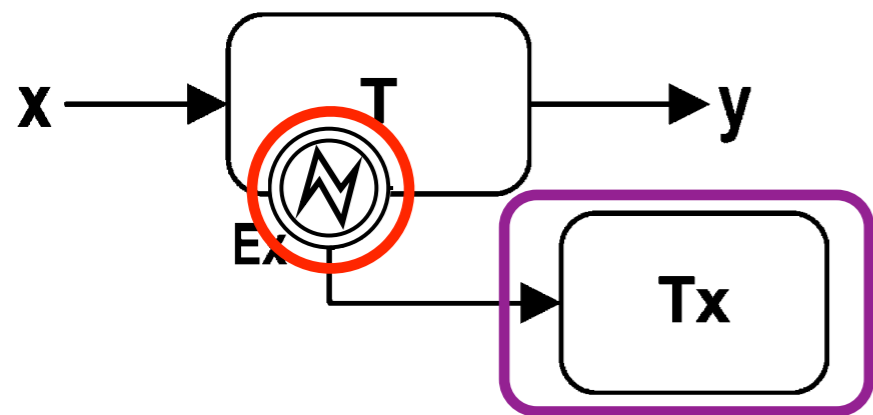
# Multiple instances (design-time bounded)



# Sub-processes



# Exception handling: single task





# Exception handling: sub-processes

accounts for  
separate execution  
of multiple instances

