Methods for Business Modeling

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Contents

- Introduction
- Approaches to business modeling
- Formal methods for specification and analysis
- Software Tools
- Conclusions

About Methods for Business Modeling

- **Method** is well-considered (sophisticated) system of doing or arranging something.
- **Business Process** is a set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships.
- **Business Process Model** is the representation of a business process in a form which supports automated manipulation, such as modeling or enactment. The process definition consists of a network of activities and their relationships, criteria to indicate the start and termination of the process, and information about the individual activities, such as participants, associated data, etc.
- **Workflow** is the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules.

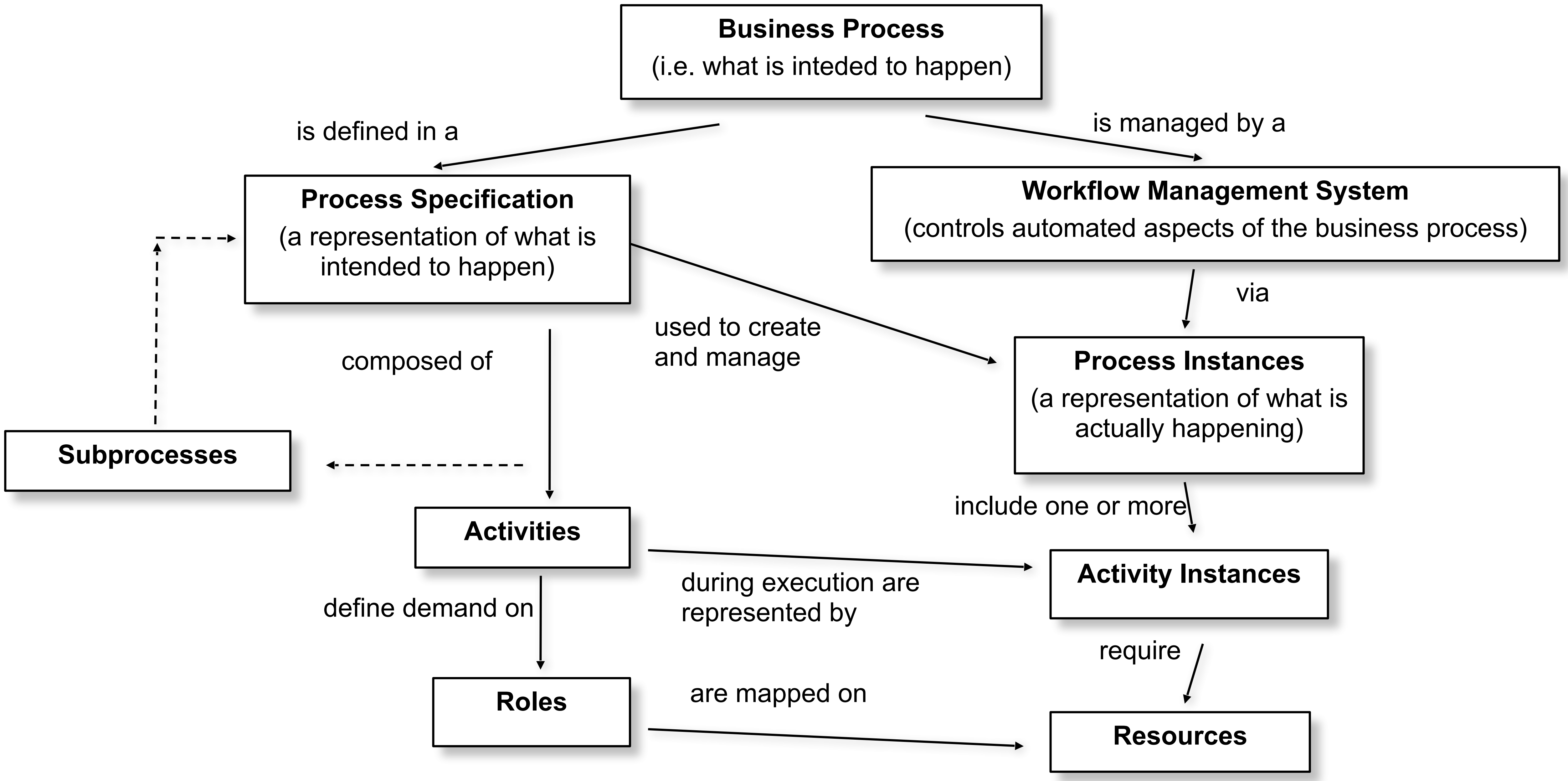
Methods for business modeling represent systematic way how to specify and analyze business processes.

Source: Workflow Management Coalition

Purpose of Business Modeling

- **Business Process Re-engineering (BPR)** - methods that support activities by which an enterprise reexamines its goals and how it achieves them, followed by a disciplined approach of business process redesign.
- **Enterprise Resource Planning (ERP)** - an information system that integrates all manufacturing and related applications for an entire enterprise. Business modeling is the first step in the software process of the ERP implemenation.
- **Workflow Management (WFM)** – generic software systems used for definition, management, enactment and control of business processes.

Ontology of Process Engineering



Business Process
(i.e. what is inteded to happen)

is defined in a

is managed by a

Process Specification
(a representation of what is intended to happen)

Workflow Management System
(controls automated aspects of the business process)

via

used to create and manage

composed of

Process Instances
(a representation of what is actually happening)

Subprocesses

include one or more

Activities

Activity Instances

during execution are represented by

define demand on

require

Roles

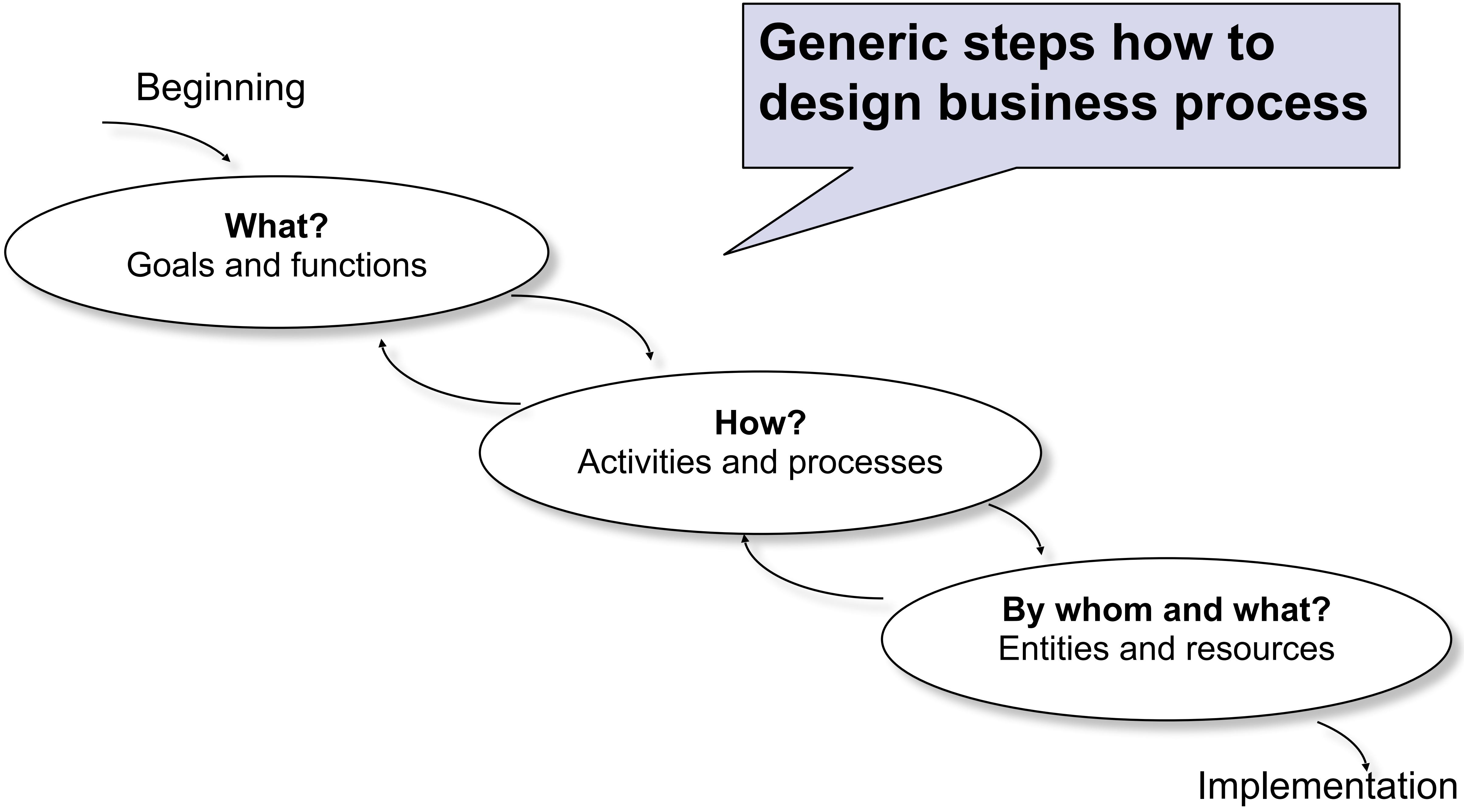
are mapped on

Resources

Approaches to Business Modeling

- Abstract framework to business process specification
- Functional specification based on IDEF
- Process specification using EPC
- Object-oriented approach to structural modeling
- Using UML for business modeling
- Meta-model of business process

Abstract Framework



Generic steps how to design business process

Beginning

What?
Goals and functions

How?
Activities and processes

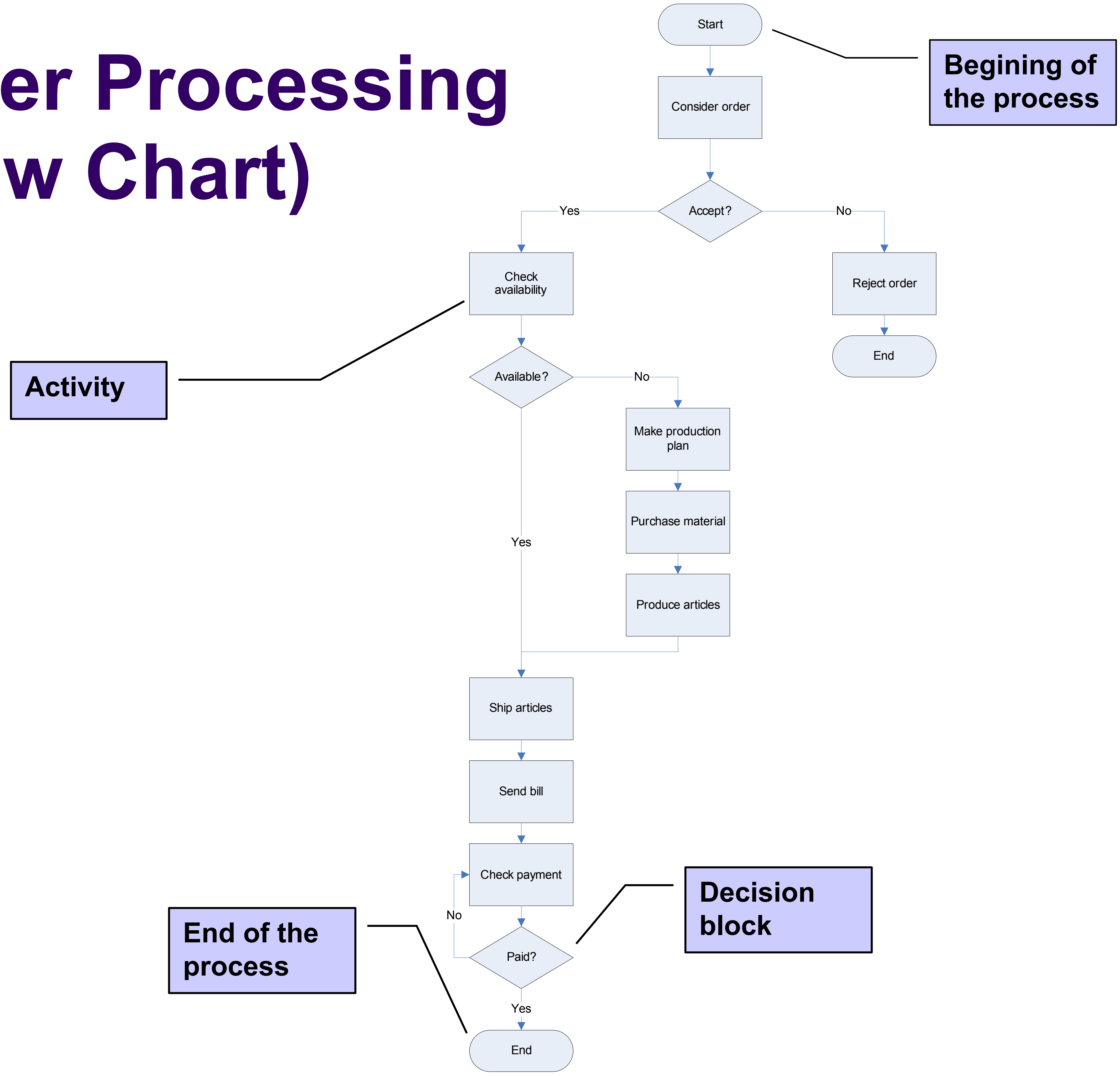
By whom and what?
Entities and resources

Implementation

Three Fundamental Abstractions

- **Functional View**. The functional view is focused on activities as well as on entities that flow into and out of these activities. That means how the input is transformed to the required output.
- **Behavioral View**. The behavioral view is focused on when and/or under what conditions activities are performed. The behavioral view captures the control aspect of the process model.
- **Structural View**. The structural view is focused on the static aspect of the process. It captures objects that are manipulated and used by a process as well as the relationships that exist among them.

Order Processing (Flow Chart)



Begining of the process

Activity

Decision block

End of the process

Integration DEFinition

- IDEF (Integration DEFinition language) is a software methodology and diagramming system developed by the US Department of Defense.
- **IDEF is used to produce a "function model"**. A function model is a structured representation of the functions, activities or processes within the modeled system or subject area.
- IDEF is based on SADT (Structured Analysis and Design Technique), developed by Douglas T. Ross and SofTech, Inc. In its original form, IDEF0 includes both a definition of a graphical modeling language (syntax and semantics) and a description of a comprehensive methodology for developing models.

IDEF Languages

- **IDEF0** is used to produce a "function model". A function model is a structured representation of the functions, activities or processes within the modeled system or subject area.
- **IDEF1** is used to produce information model that specifies structure and semantics of data.
- **IDEF2** is used to model dynamic aspects of the system, i.e. its behaviour.
- IDEFx other extensions (http://www.idef.com).

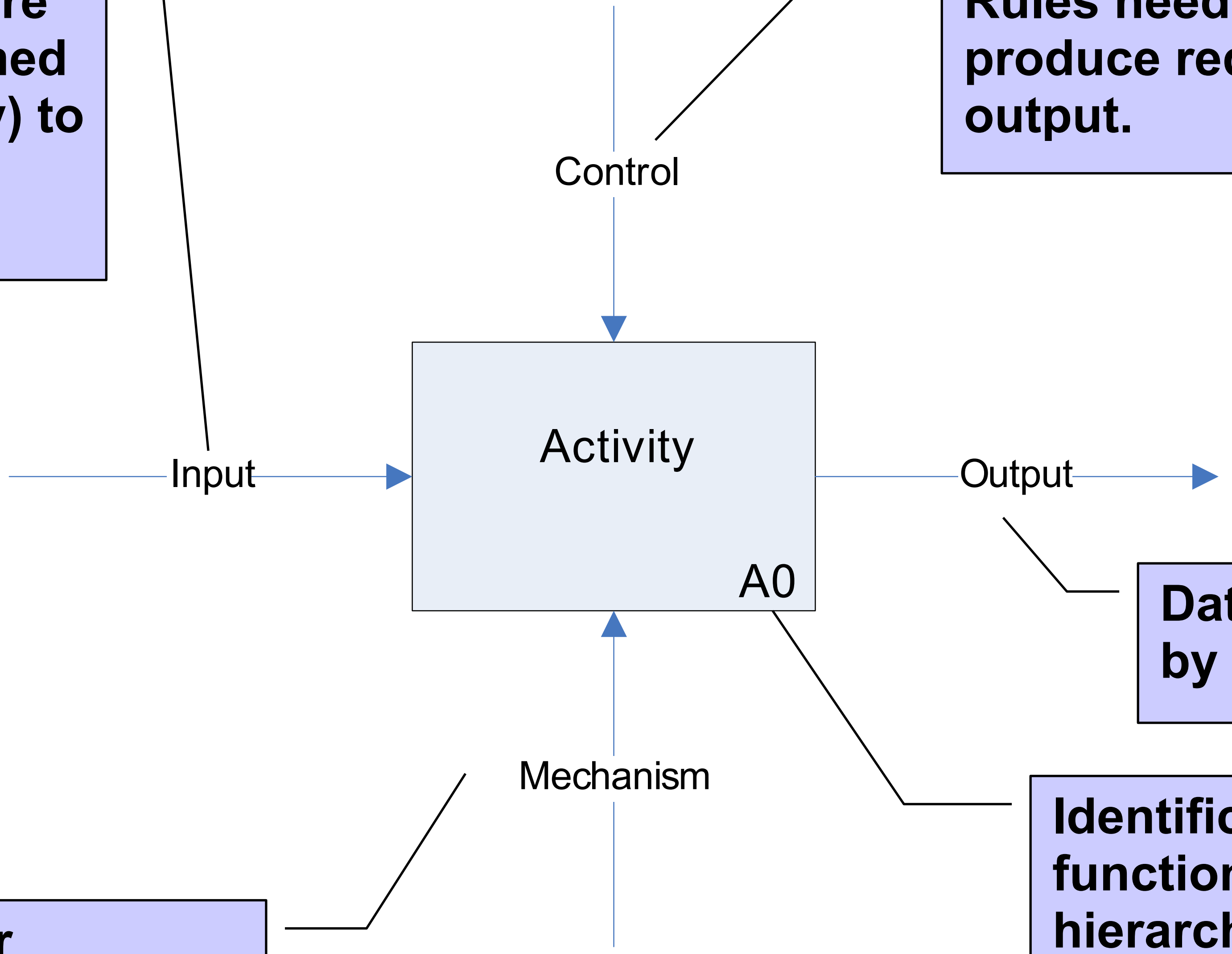
Basic Concepts of IDEF0

- As an analysis tool, IDEF0 assists the modeler in identifying the functions performed and what is needed to perform them.
- The IDEF0 model diagram is based on a simple syntax. Each activity is described by a verb based label placed in a box. Inputs are shown as arrows entering the left side of the activity box while the outputs are shown as exiting arrows on the right side of the box. Controls are displayed as arrows entering the top of the box and mechanisms are displayed as arrows entering from the bottom of the box. **Inputs, Controls, Outputs, and Mechanisms (ICOMs)** are all referred to as concepts.

Basic IDEF0 Syntax

Data or objects that are going to be transformed by a function (activity) to the output.

Rules needed to produce required output.



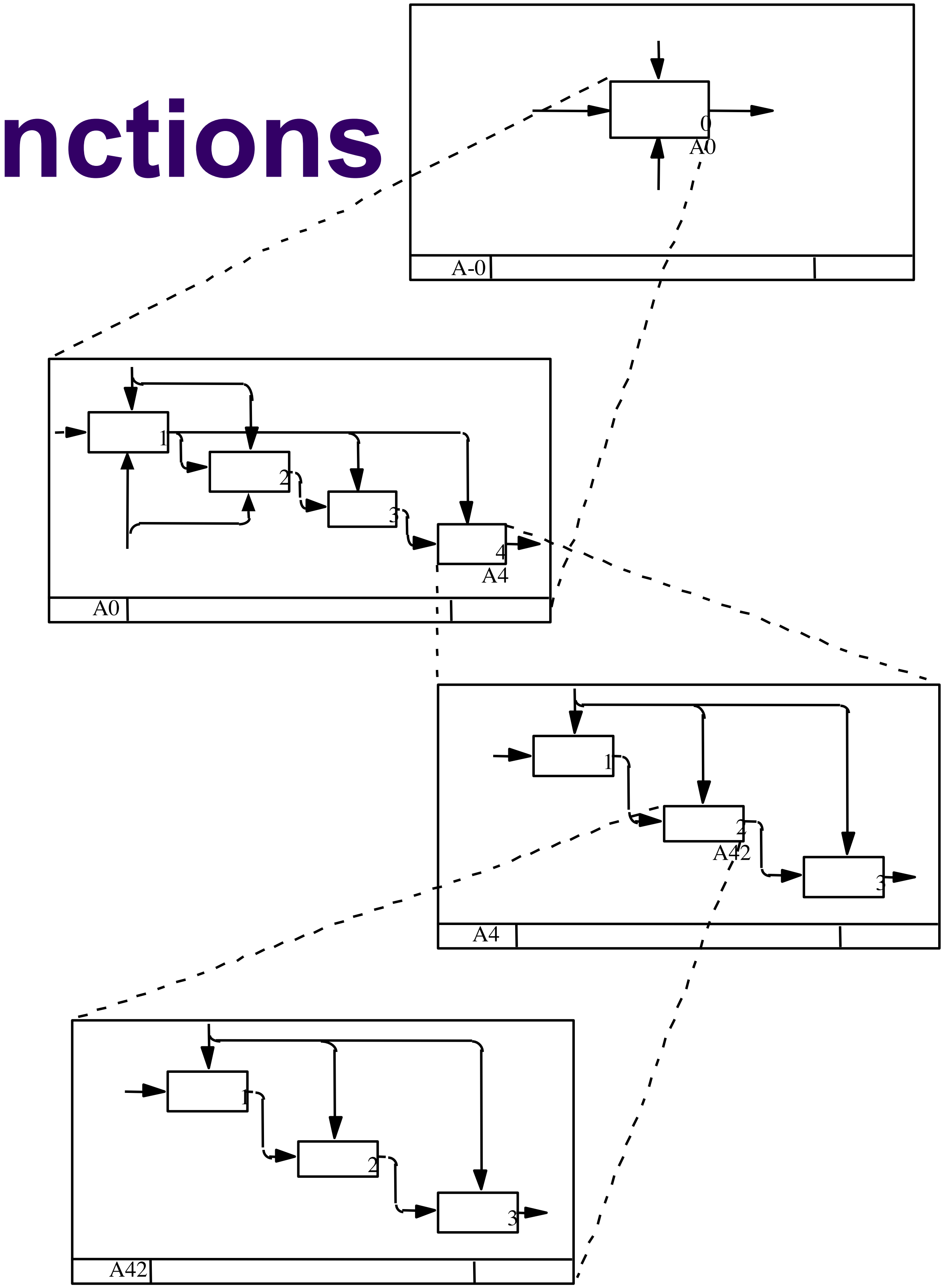
Data or objects produced by the function.

Identification of the function in the function hierarchy.

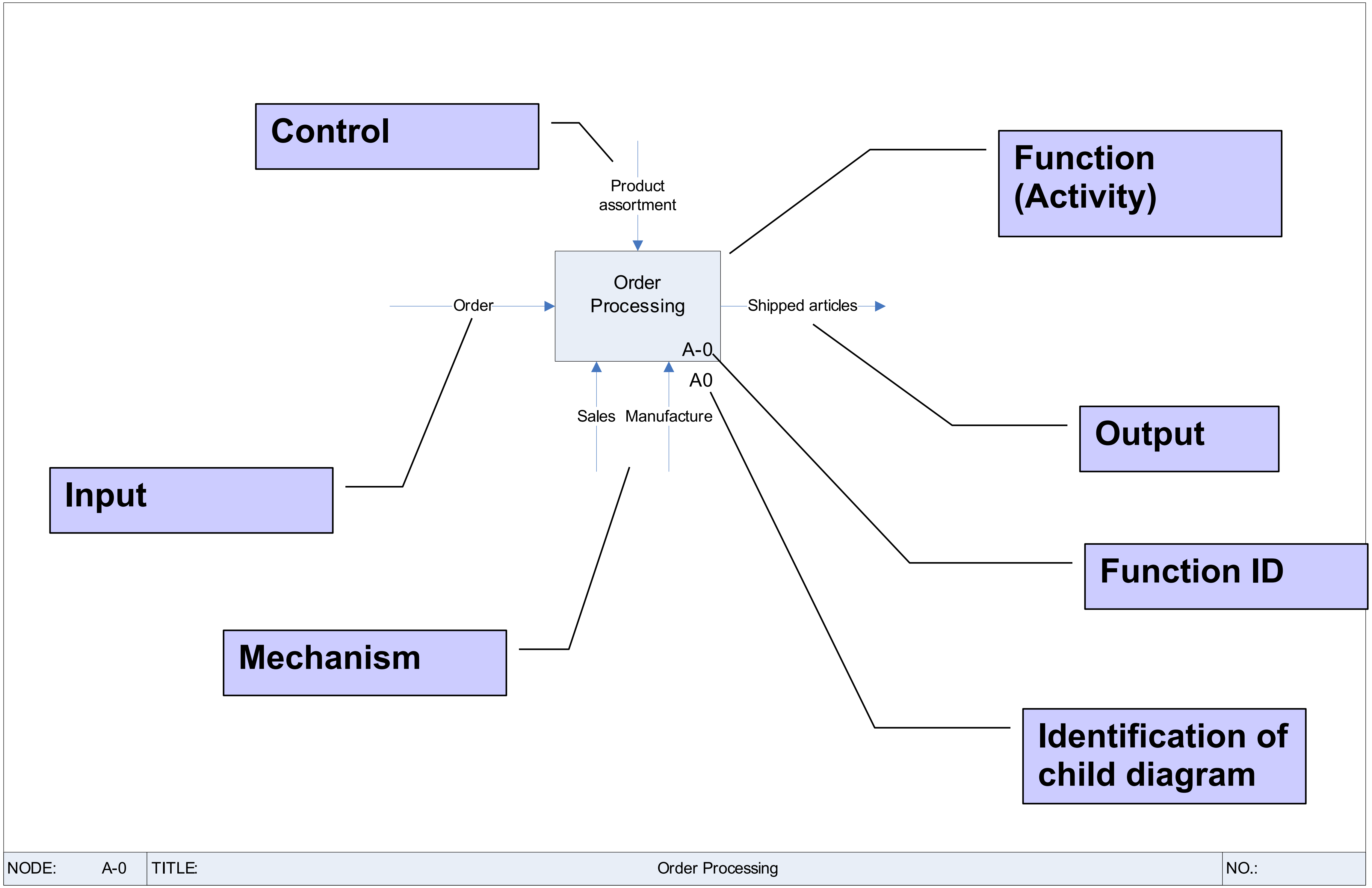
Sources needed for execution of the function.

Hierarchy of Functions

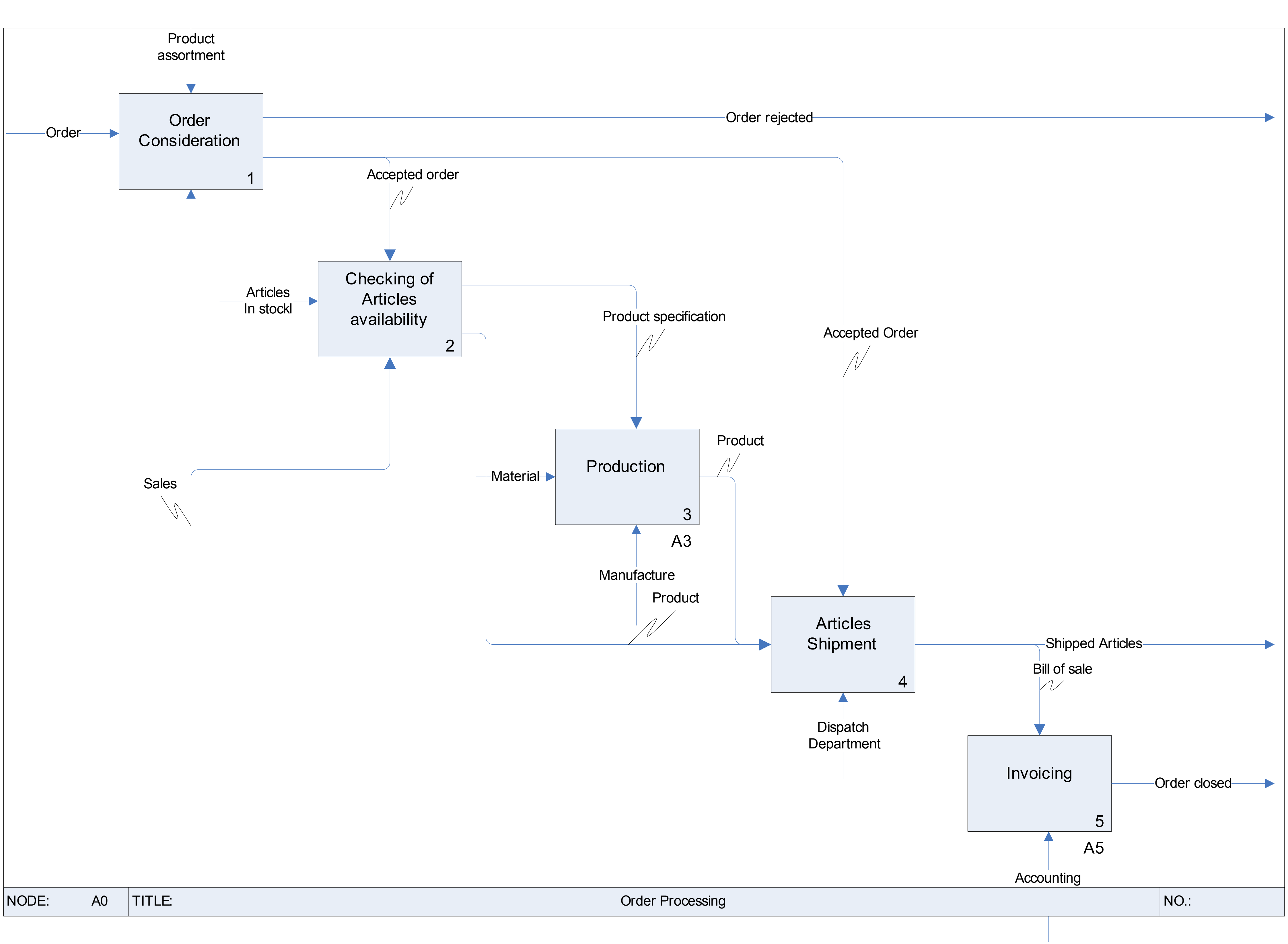
- Each model shall have a top-level context diagram, on which the subject of the model is represented by a single box with its bounding arrows. This is called the A-0 diagram.
- Every diagram but the context has from 3 to 6 functions.
- ICOMs may be interconnected.



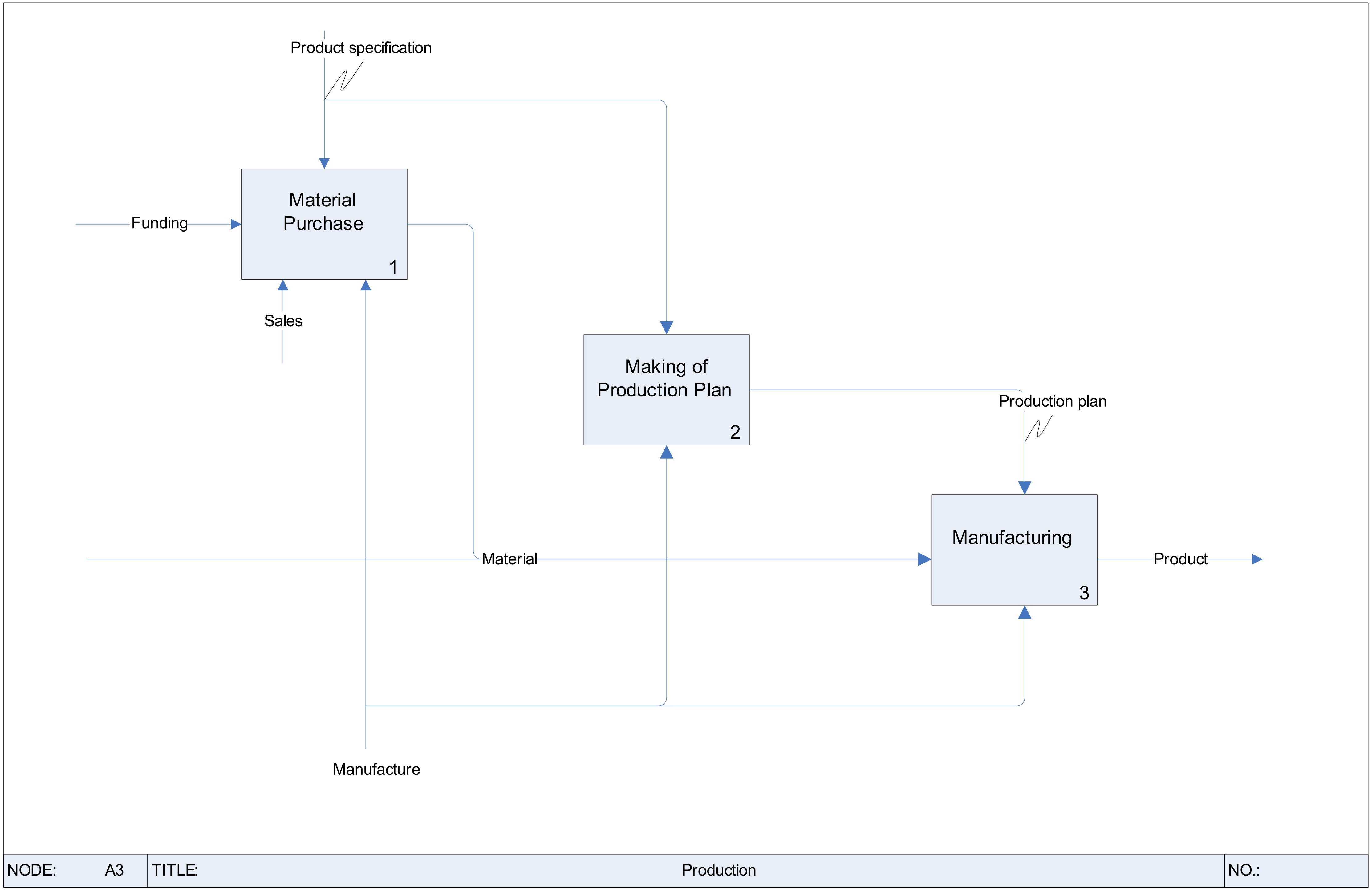
Context Diagram: Order Processing



A0: Order Processing



A3: Production



IDEF0 Pros and Cons

- **Positive aspects**
  - Methods is well formalized. The syntax and semantics is well defined.
  - Function specification enables to analyze even complex processes.
  - Methods is standardized by National Institute of Standards and Technology (USA).
- **Negative aspects**
  - IDEF0 is focused on functions and their decomposition. The time ordering is not explicitly expressed.
  - Complete specification of the process requires to employ other methods like IDEF1, IDEF2 ... This issue makes resulting specification too complex.

Exercise 1

- Create IDEF0 diagram for function *Invoicing*. Assume that this function consists only from two other functions: *Invoice sending* and *Payment checking*.

Process Specification Using EPC

- Event-driven Process Chains (EPC) are based on connecting events and action to the sequences which collectively realize a business objective.
- Event is the *precondition* for the activity. New event (*postcondition*) is generated when the activity is finished. It means that events defines the beginning and end of each activity.
- EPC diagrams are used in SAP R/3 (ERP/WFM) and ARIS (BPR).

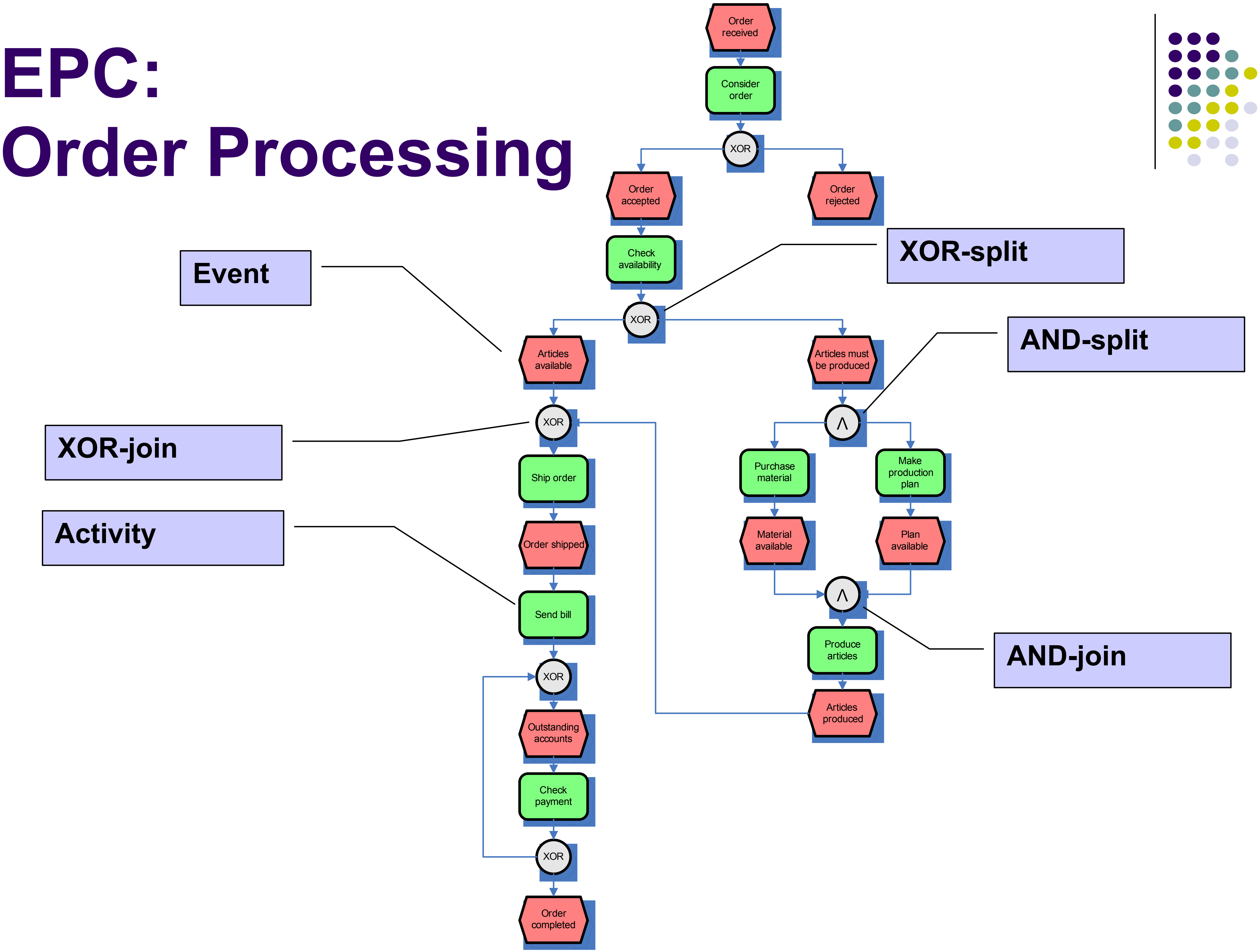
EPC Diagram Elements

- **Activities** are the basic building blocks that define what should be completed within the process execution.
- **Events** specify situations before and/or after the activity is executed. It means that event may represent an output condition of the one activity and an input condition for the other activity at the same time.
- **Connectors** are used to link together activities and events. This is a way how the flow of control is defined. EPC uses the following three types of connectors: ∧ (AND), ∨ (OR) and XOR (exclusive OR).

Semantics of Connectors

- **AND** is used either for *splitting* of the process to at least two concurrent process threads of execution or *joining* of concurrent threads to the one (synchronization point).
- **XOR** splits the process to just one optional thread of many possible ones.
- **OR** is used to split process to one, second or both possible threads of execution.

EPC:
Order Processing



Event

XOR-split

AND-split

XOR-join

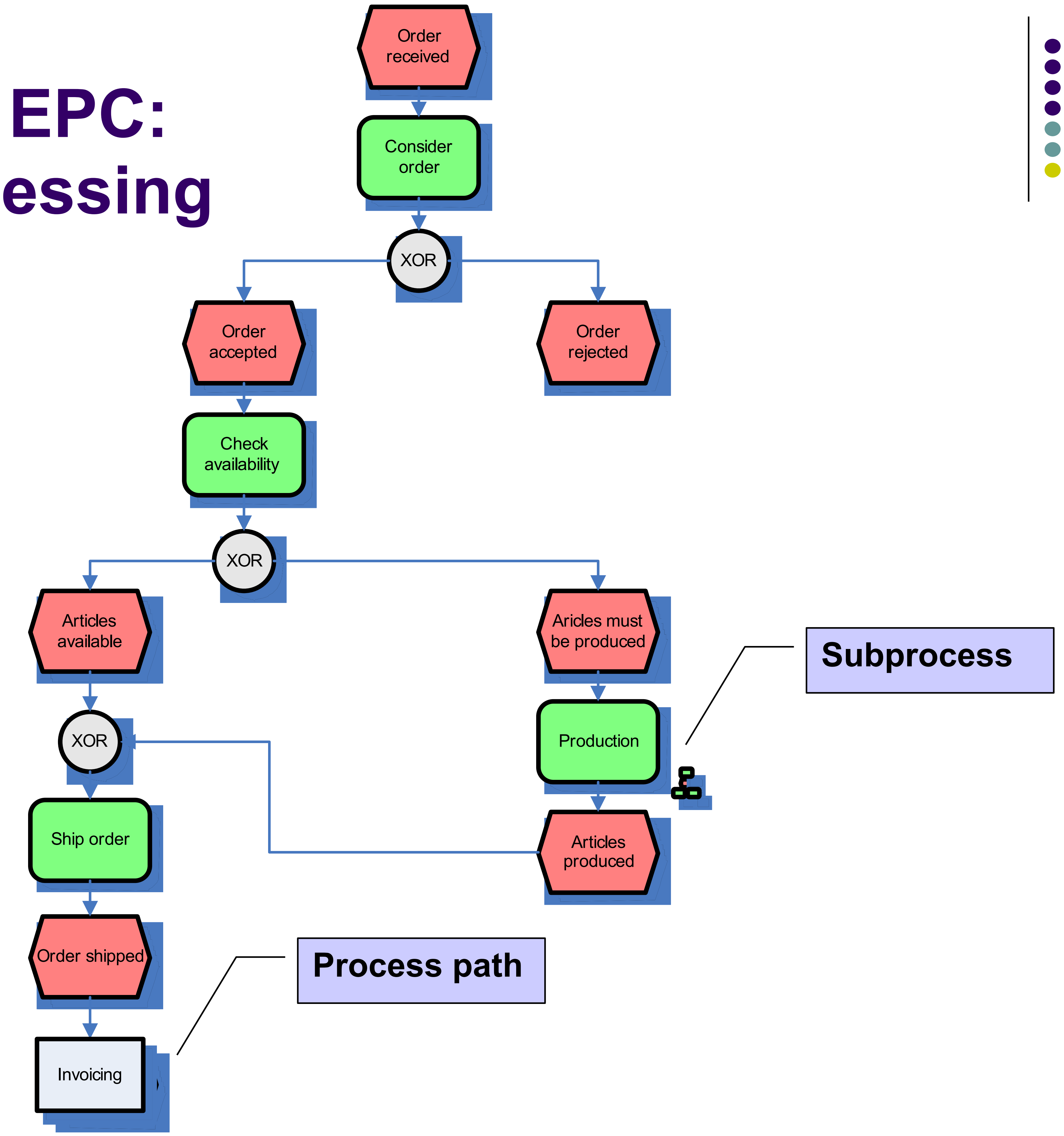
Activity

AND-join

Structured EPC

- Complex processes have to include subrocesses – **hierarchical decomposition**.
- **Process paths** represent the interface of the given process to another one (reference to another process).

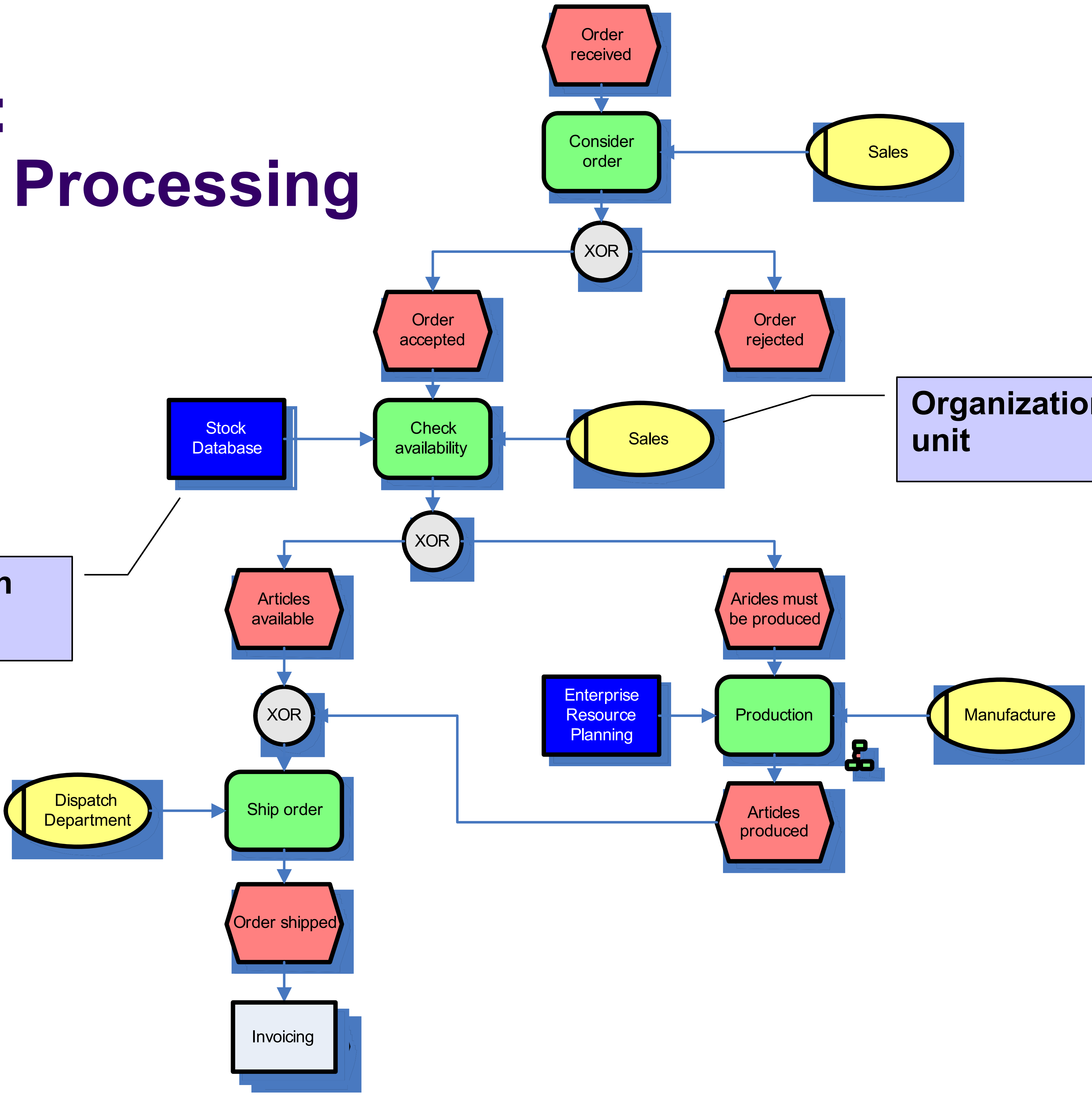
Structured EPC: Order Processing



Extended EPC (eEPC)

- Additional information is expressed in a process model
  - Organizational units responsible for activity execution
  - Information sources and material
  - ...

eEPC: Order Processing



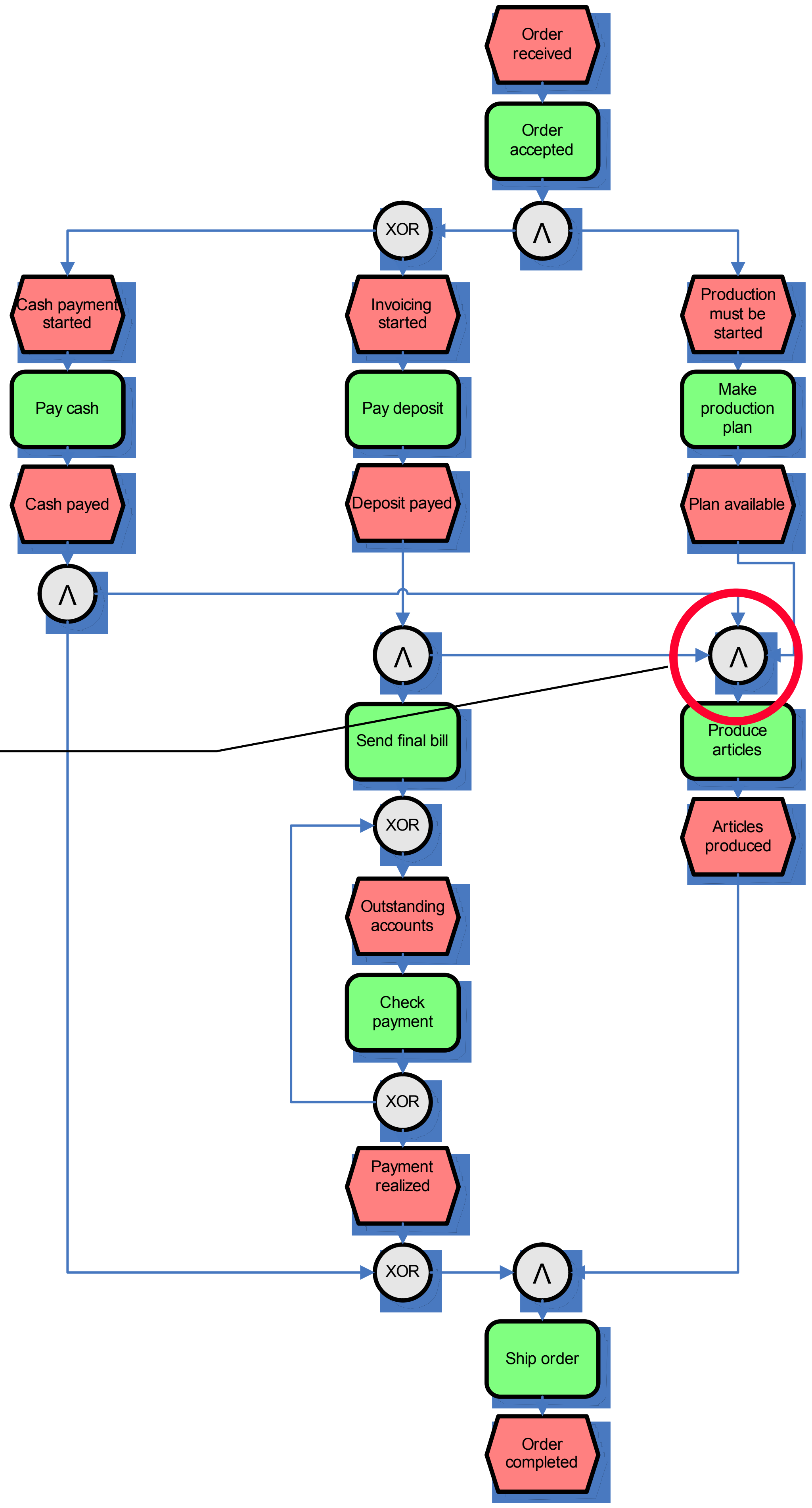
Organizational unit

Information sources

EPC Pros and Cons

- **Positive aspects**
  - Method provides simple but powerful abstraction based on chaining of event and activities that enables to model complex processes.
  - EPC is a part of widely accepted system like SAP and ARIS
- **Negative aspects**
  - Language for EPC diagrams is not formally defines. Syntax and semantics is not precise enough (e.g. OR has no obvious semantics assigned).
  - Missing formalism complicates portability of EPC between various software tools.

Faulty Process?



Process deadlock

Exercise 2

- Create Production subprocess with the respect to the following rules:
  - All needed material has to be purchased or only some material has to be purchased or in case that all material is in the stock no purchase is done.
  - Concurrently with potential material purchase the production plan is made.
  - Articles production can be started only in case that material and production plan are both available.

OO Approach to Structural Modeling

- **Object** is an entity with a well-defined boundary and identity that encapsulates state and behavior.
- **Class** is a description of a set of objects that share the same attributes, operations, methods, relationships, and semantics.
- **Object-oriented system** architecture is the structure of connected objects that define resulting behavior of the system through their communication (interactions).

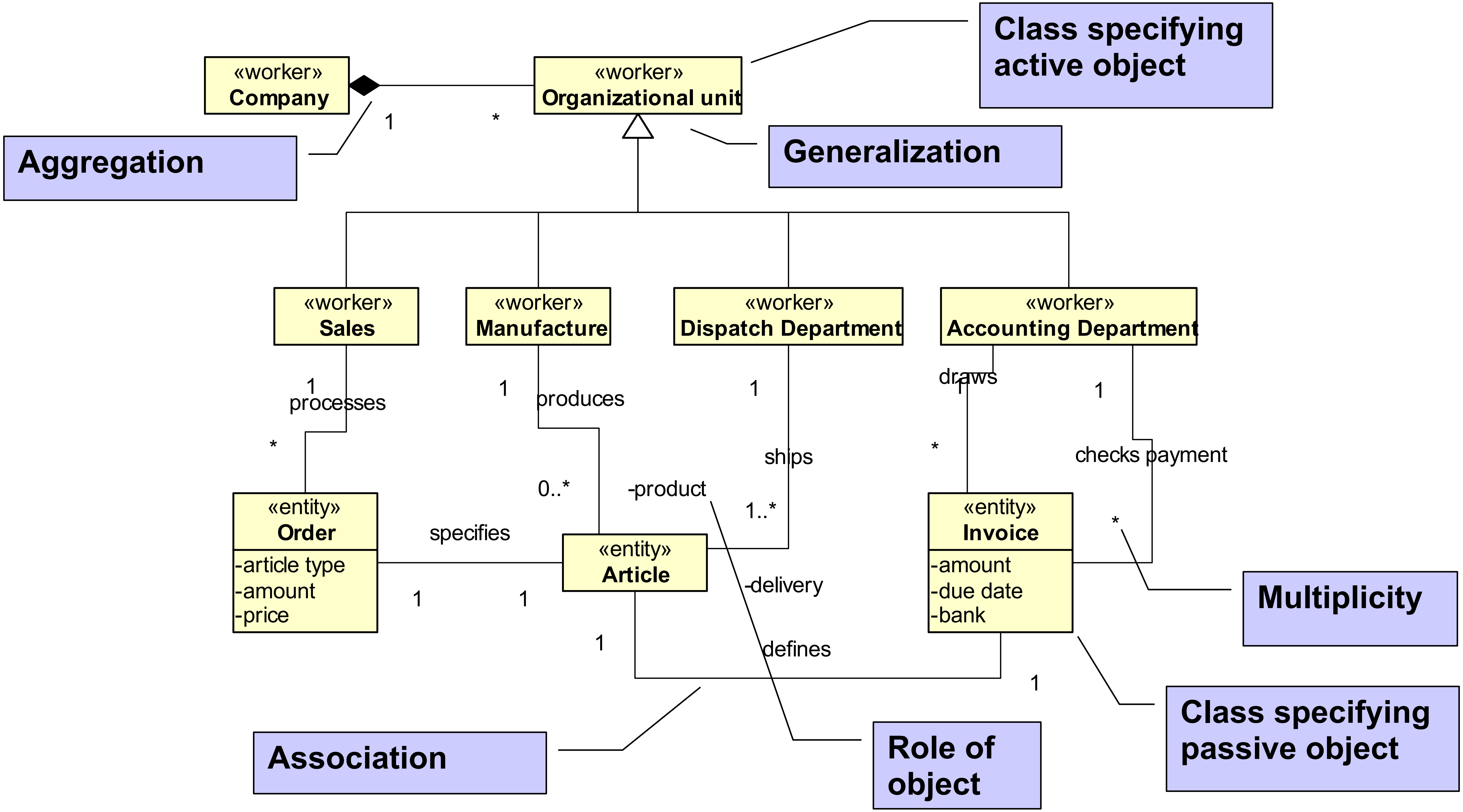
Object Model

- Structural model of the business process is specified by **class diagram** that consists of the following elements:
  - **Classes** representing active (*Workers*) and passive (*Entities*) objects.
  - **Relationships** among these classes that enable communication among their instances (objects).

Types of Relationships

- **Association** describes a group of links with common structure and common semantics (a Person works-for a Company). An association a bi-directional connection between classes that describes a set of potential links in the same way that a class describes a set of potential objects.
- **Aggregation** is the “part-whole” or “a-part-of” relationship in which objects representing the components of something are associated with an object representing the entire assembly.
- **Generalization** is the taxonomic relationship between a more general element (the parent) and a more specific element (the child) that is fully consistent with the first element and that adds additional information.

Object Model: Order Processing



Exercise 3

- Create class diagram defined by classes *Sales*, *Manufacture*, *Product* and *Material*. Describe the situation where *Sales* purchases *Material* that is required by *Product* to be produced. *Manufacture* produces the *Product* and uses the *Material* for this purpose.

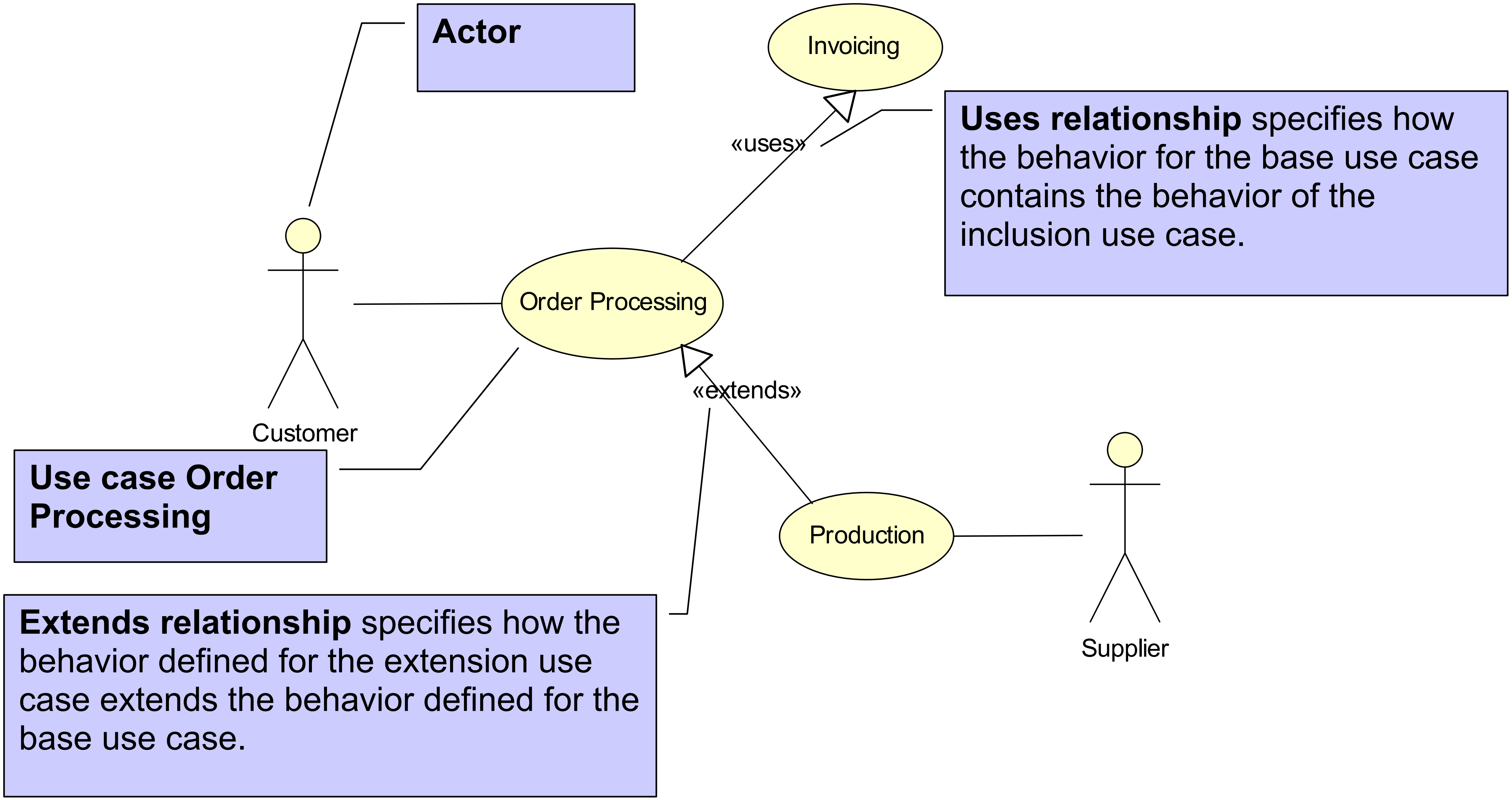
Using UML for Business Modeling

- The Unified Modeling Language (UML) is a standard language used to **visualize**, **specify**, **construct** and **document** the artifacts of a system.
- UML uses the following three diagram for purpose of business modeling:
  - Use case diagrams to specify functions of the system being modeled.
  - Activity diagrams to capture behavioral (control) aspect of business processes.
  - Class diagrams to specify structural properties of the system.

Functional View of the System

- **Use case** is the specification of a sequence of actions, including variants, that a system (or other entity) can perform, interacting with actors of the system.
  - **Use case diagram** shows the relationships among actors and use cases within a system.
  - **Actor** is coherent set of roles that users of use cases play when interacting with these use cases. An actor has one role for each use case with which it communicates.

Use Case: Order Processing



Actor

Uses relationship specifies how the behavior for the base use case contains the behavior of the inclusion use case.

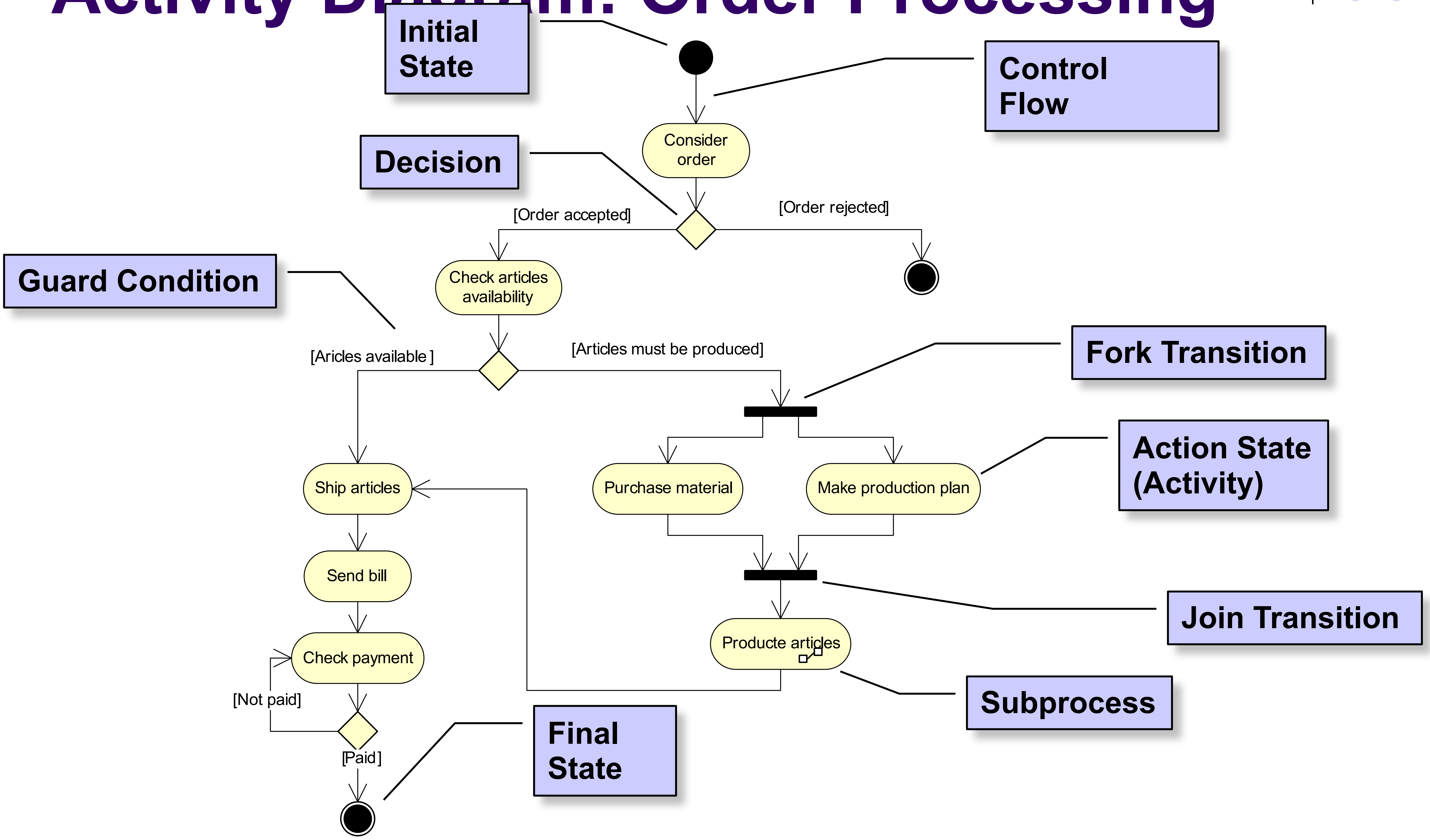
Use case Order Processing

Extends relationship specifies how the behavior defined for the extension use case extends the behavior defined for the base use case.

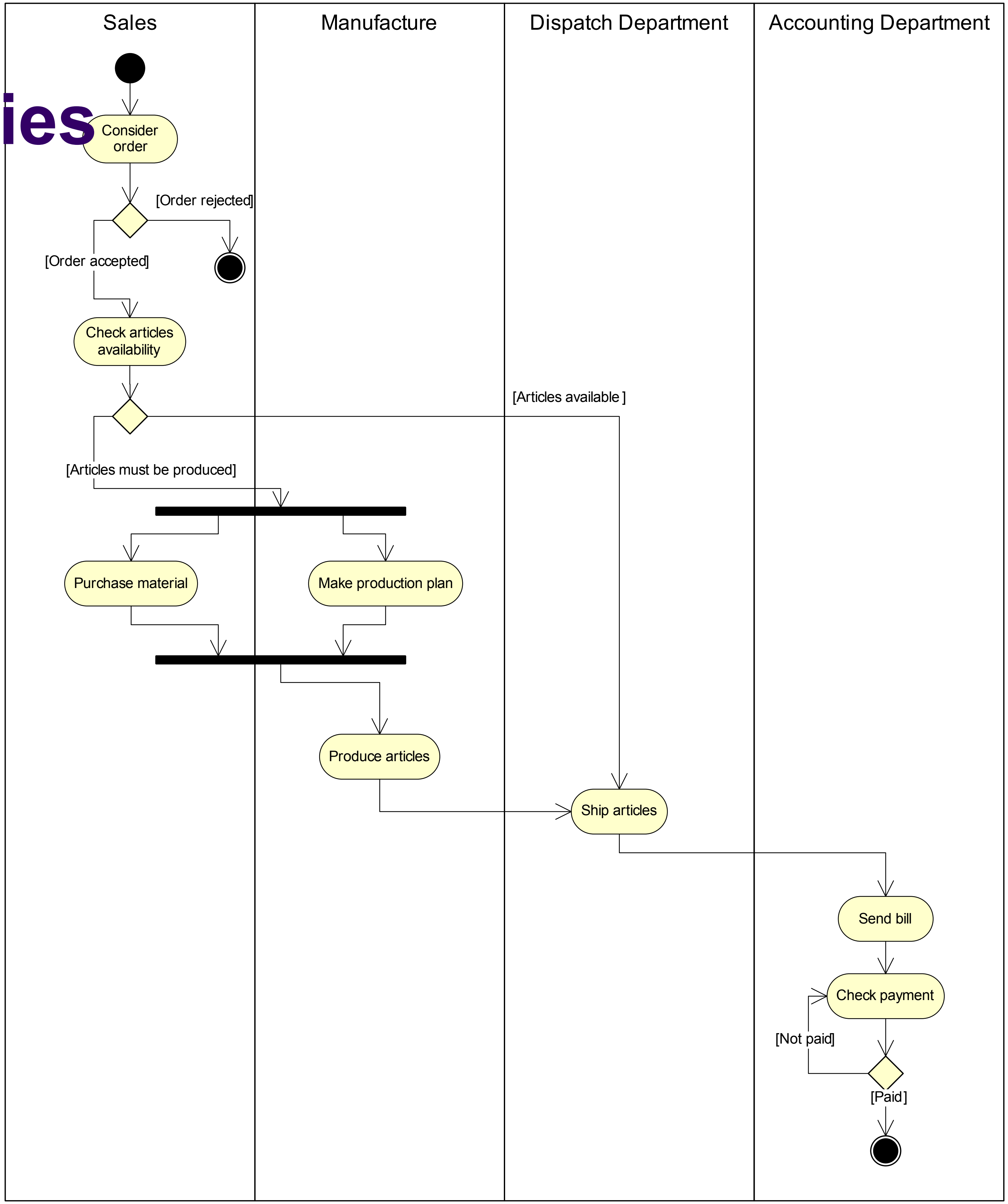
Control Flow

- **Activity Diagram** is a variation of a state machine in which the states represent the performance of activities and the transitions are triggered by their completion.
- The purpose of this diagram is to focus on **flows driven by internal processing**.

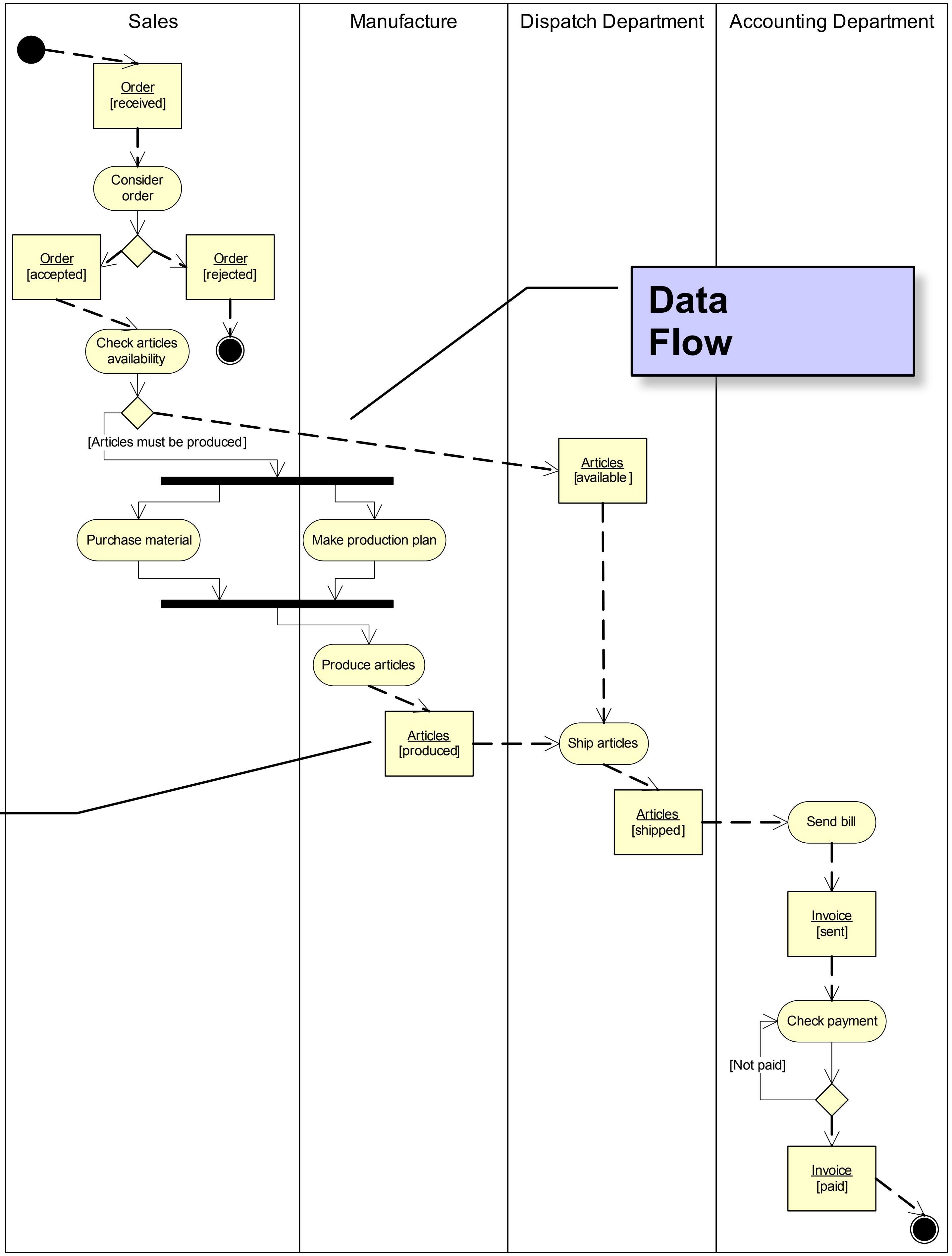
Activity Diagram: Order Processing



Responsibilities (Swimlanes)



Flow of Objects



Data Flow

Object in a given state

UML Pros and Cons

- **Positive aspects**
  - UML provides a large number of diagrams enabling to capture every aspects of the system being modeled.
  - The notation of UML is standardized and it is used by many software tools dedicated to software system design.
  - Since the primary focus of UML is to write software system blueprints it easy and straightforward to interconnect business modeling with the specification of information system.
- **Negative aspects**
  - UML is considered as a semi-formal method. The semantics is not precisely defined. It might be a problem to verify complex processes.

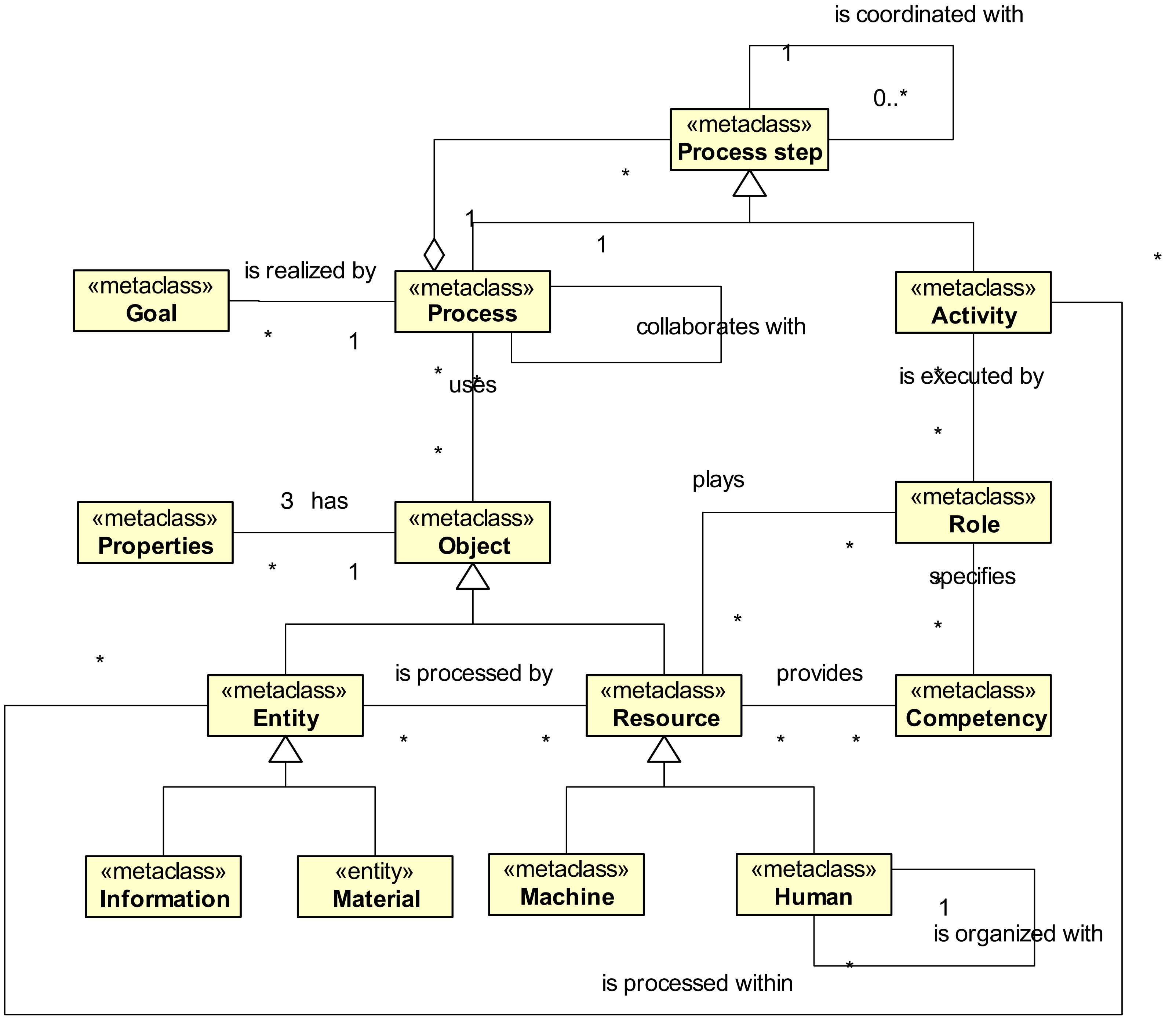
Exercise 4

- Define activity diagram for accounting department. Accountant issues the invoice and then he/she sends it to customer. In case that the total amount is higher than 5000 USD the invoice has to be authorized by a manager before it is sent.

Meta-Model Specification

- Meta-model is a model that defines the language for expressing a model.
- Business meta-model is a model for all above mentioned modeling approaches.

Business Process Meta-Model



Standards in BPM

- Specification language BPMN (Business Process Modeling Notation)
  - BPMN creates a standardized bridge for the gap between the business process design and process implementation.
  - BPMN defines a Business Process Diagram (BPD), which is based on a flowcharting technique tailored for creating graphical models of business process operations.
- Executable Languages: BPML (Business Process Modeling Language) and BPEL (Business Process Execution Language)
  - BPMN is supported with an internal model that enables the generation of executable BPEL.

Formal Methods

- Formal methods for specification and analysis
- Pi-calculus Overview
- Petri Nets and their properties
- Modeling processes by WF-Nets
- Analysis of business processes
- Fomalization and verification of informally specified processes

Formal Methods for Specification and Analysis

Techniques for the precise and unambiguous specification of business processes.

- Formal methods include
  - Formal specification
  - Specification analysis and proof
  - Transformational development
  - Process verification
- Language for formal specification has to have precise and unambiguous syntax and semantics.

Mathematical Representation of the Process

- Formal specifications are expressed in a mathematical notation with precisely defined vocabulary, syntax and semantics.
- Algebraic approach
  - The system is specified in terms of its operations and their relationships.
- Model-based approach
  - The system is specified in terms of a state model that is constructed using mathematical constructs such as sets and sequences.

Process Algebra: Pi-calculus

- The pi-calculus is a process algebra developed by Robin Milner.
- The pi-calculus is a successor of CCS (Calculus of Communicating Systems) language.
- The aim of the pi-calculus is to be able **to describe concurrent computations whose configuration may change during the computation**.
- The pi-calculus is a mathematical formalisms for describing and analyzing properties of concurrent computation.
- The pi-calculus is so minimal that it does not contain primitives such as numbers, booleans, data structures, variables, functions, or even the usual flow control statements (such as if... then...else, while...).

Names and Processes

- The **names** are ubiquitous in the language. They roughly corresponds to identifier in programming languages, and are generally noted in lowercase (*order*, *customer* ...).
  - Names are the only data **values** available in pure Pi-calcullus
  - Some names are used to transport other names – **channels**
- **Processes** represent the basic building blocks to describe behavior.
- Process expressions can be arranged either **sequentially** (using a simple dot .) or **concurrently** (using verical bar |).
- The Pi-calculus uses sum operator (+) to model nondeterministic **choice**.

Basic Communication

- There are two basic output and input actions:
  - Output action (**emission**) *c*!*x* means *send value x on channel c*
  - Input action (**reception**) *c*?(*x*) means *receive a value on channel c, binding that value to the name x* (**bound name**)
- Communicating processes:
  - Let's have two **concurrent processes** separated by verical bar |:

    c!*hello* . *d*?(*x*) | *c*?(*y*) . *d*!*y*

    The process on left is a **sequence** of two actions – the first one *c!hello* sends value *hello* along the channel *c*. A reception on *c* follows. The emission on the left is said to be **prefix** and what follows is a **continuation** of the process. The process on the right first listens on channel *c* and then reemits the same information (using the bounds name *y*) on the channel *d* (echoing process).
  - **Synchronization** is based on the rule that both an **emission prefix and a reception prefix must be matched** to exchange the information:

    c!*hello* . *d*?(*x*) | *c*?(*y*) . *d*!*y* → *d*?(*x*) | *d*!*hello*

    means one step **execution of the process (reduction)**. First the bound name *y* has been substituted by the name *hello* and then both prefixes disappeared (they were executed).

Process Abstraction

- Construct called **abstraction** allows to name behavior definitions. It is possible to use this name within process expression to model **calls** and **recursion**. This is the analogy to **function definitions** and **functions calls** in other programming languages:

  Sink(*c*) = *c*?(*x*) . *Sink*(*c*)

  means that process *Sink*(*c*) consumes all values transmitted to it on channel *c*. Here c is a bound name in a function definition that will be instantiated to an explicit channel for each actual use of the function.

  Source(*d*) = (*d*!*hello* . *d*!*world* . *Source*(*d*)) + (*d*!*hi* . *d*!*all* . *Source*(*d*))

  produces infinite sequence of pairs *hello world* and *hi all*. Both pairs can interleave arbitrarily because choise is nondeterministic.
- **Restriction** operator (*new c*) *P* creates a new and unique name *c* local to a process expression *P*:

  (*new com*) *Source*(*com*) | *Sink*(*com*)

runs forever, transmitting a sequence of pairs *hello world* and *hi all* on channel *com*. Every *hello* is followed by *world* as well as *hi* is followed by *all*.

Syntax of Pi-calculus

Prefixes	α ::=	$a!x$	**Output action (emission)**
		$a?(x)$	**Input action (reception)**
Processes	P ::=	0	**Nil – no action is performed**
		$\alpha.P$	**Prefix**
		$P + P$	**Choice**
		$P \mid P$	**Parallel**
		$(new\ x)\ P$	**Restriction**
		$A(y_1, ..., y_n)$	**Identifier**
Definitions		$A(x_1, ..., x_n) = P$	Definition can be thought of as a **process declaration**, x_1, ..., x_n as formal parameters, and the identifier $A(y_1, ..., y_n)$ as an invocation with actual parameters y_1, ..., y_n.

Example: Order Processing

- **Definitions:**
  Purchase(*customer*,*order*) = *customer*!*order* . *customer*?(*bank*, *bill*) . *bank*!*bill*
  // Send order along a customer channel, wait for bank where to pay bill and pay a bill

  Sale(*client*) = *client*?(*specification*) . *client*!<*swissbank*,*invoice*>
  // Wait for specification from client and send him/her invoice and bank connection

- **Execution**
  (*new steve*, *bmw*)
  Purchase(*steve*, *bmw*) | *Sale*(*steve*)

  steve!*bmw* . *steve*?(*bank*,*bill*) . *bank*!*bill* | *steve*?(*specification*) . *steve*!<*swissbank*,*invoice*>
  →
  steve!*bmw* . *steve*?(*bank*,*bill*) . *bank*!*bill* | *steve*?(*bmw*) . *steve*!<*swissbank*,*invoice*>
  →
  steve?(*bank*,*bill*) . *bank*!*bill* | *steve*!<*swissbank*,*invoice*>
  →
  steve?(*swissbank*,*invoice*).*swissbank*!*invoice* | *steve*!<*swissbank*,*invoice*>
  →
  swissbank!*invoice* | 0

- **Reconfiguration of the process**
  (*new steve*, *mary*, *bmw*, *honda*)
  Purchase(*steve*, *bmw*) | *Purchase*(*john*, *honda*) | *Sale*(*steve*) | *Sale*(*mary*)

Order Processing Revised

- **Definitions:**

Purchase(*customer*,*order*) = *customer*!*order* . *customer*?(*bank*,*bill*) . *bank*!*bill* . *customer*?(*product*)
// Send order along a customer channel, wait for bank where to pay bill, pay a bill and wait for a product

Sale(*client*) = *client*?(*spec*) . (*spec*! | (*bmw*? . *BMW*(*client, spec*) + *honda*? . *Honda*(*client,spec*))
// if spec = bmw then BMW(client, bmw) or if spec = honda then Honda(client, honda)

BMW(*client,spec*)
= (*production*!<*client*,*spec*> . *client?(car)* | *client*!<*swiss*,*invoice*>) . *swiss*?(*payment*) . *client*!*car*
// Produce specified car , send an invoice to the client, wait for payment and then ship a car

Honda(*client*,*spec*)
= (*warehouse*!<*client*, *spec*> . *client?(car)* | *client*!<*nomura*,*invoice*>) . *nomura*?(*payment*) . *client*!*car*
// Find specified car , send an invoice to the client, wait for payment and then ship a car

Production() = *production*?(*client*, *specification*) . (*client*!*car* | *Production*())
// Wait for specification, start production for a client and continue waiting for a new specification

Warehouse() = *warehouse*?(*client*, *specification*) . (*client*!*car* | *Warehouse*())
// Wait for a specification, start searching the car for a client and continue waiting for a new specification

- **Execution**

(*new steve*, *bmw*, *mary, honda*)
Purchase(*steve*, *bmw*) | *Purchase*(*mary*, *honda*) | *Sale*(*steve*) | *Sale*(*mary*) | *Production*() | *Warehouse*()

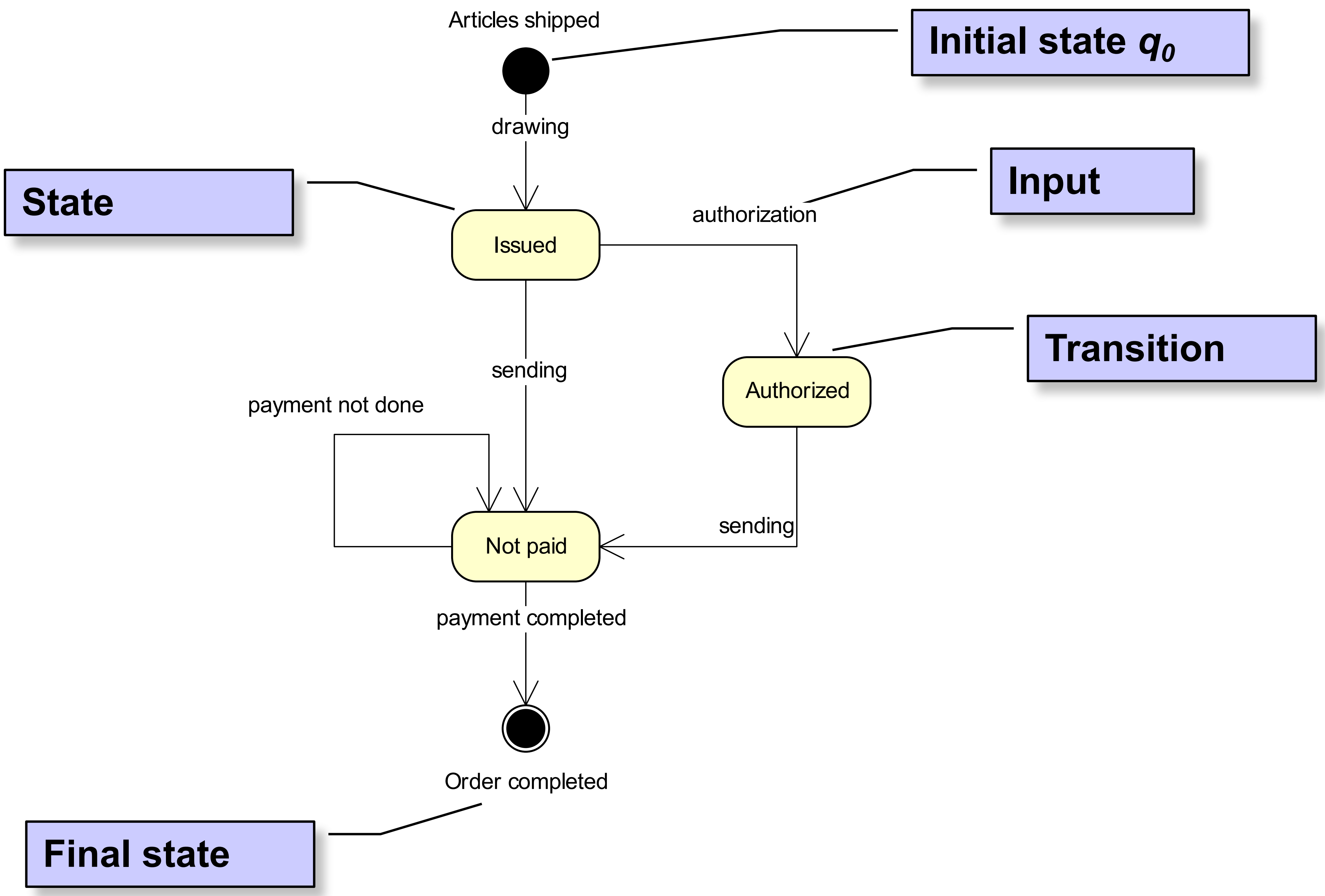
Finite Automata

- Finite automata are defined by
  - Q - finite set of states
  - I - finite set of inputs
  - $\delta: Q \times I \rightarrow Q$ - state transition function
  - q_0 - initial state
  - $F \subseteq Q$ - set of final states
- Visualization is based on statechart diagrams

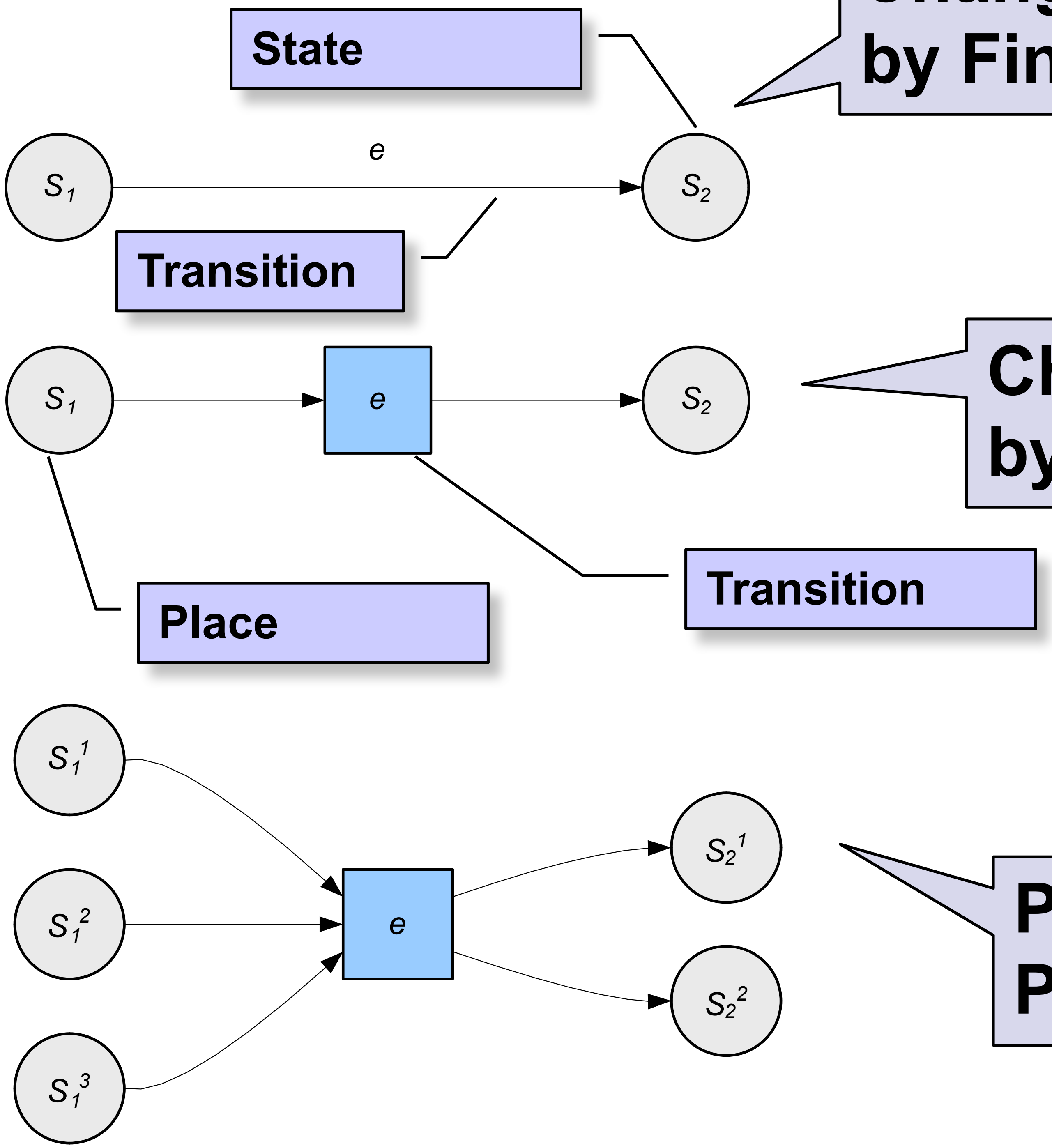
Formal Specification of Invoice States

- *Q* = {*Articles shipped, Issued, Authorized, Not paid, Order completed*}.
- *I* = {*drawing, authorization, sending, payment not done, payment completed*}.
- δ*(Articles shipped, drawing) = Issued,*
  δ*(Issued, authorization) = Authorized,*
  δ*(Issued, sending) = Not paid,*
  δ*(Authorized, sending) = Not paid,*
  δ*(Not paid, payment not done) = Not paid,*
  δ*(Not paid, payment completed) = Order completed.*
- *q0 = Articles shipped.*
- *F = {Order completed}.*

State Diagram: Invoicing



Introduction to Petri Nets



Change of state modeled by Finite Automata

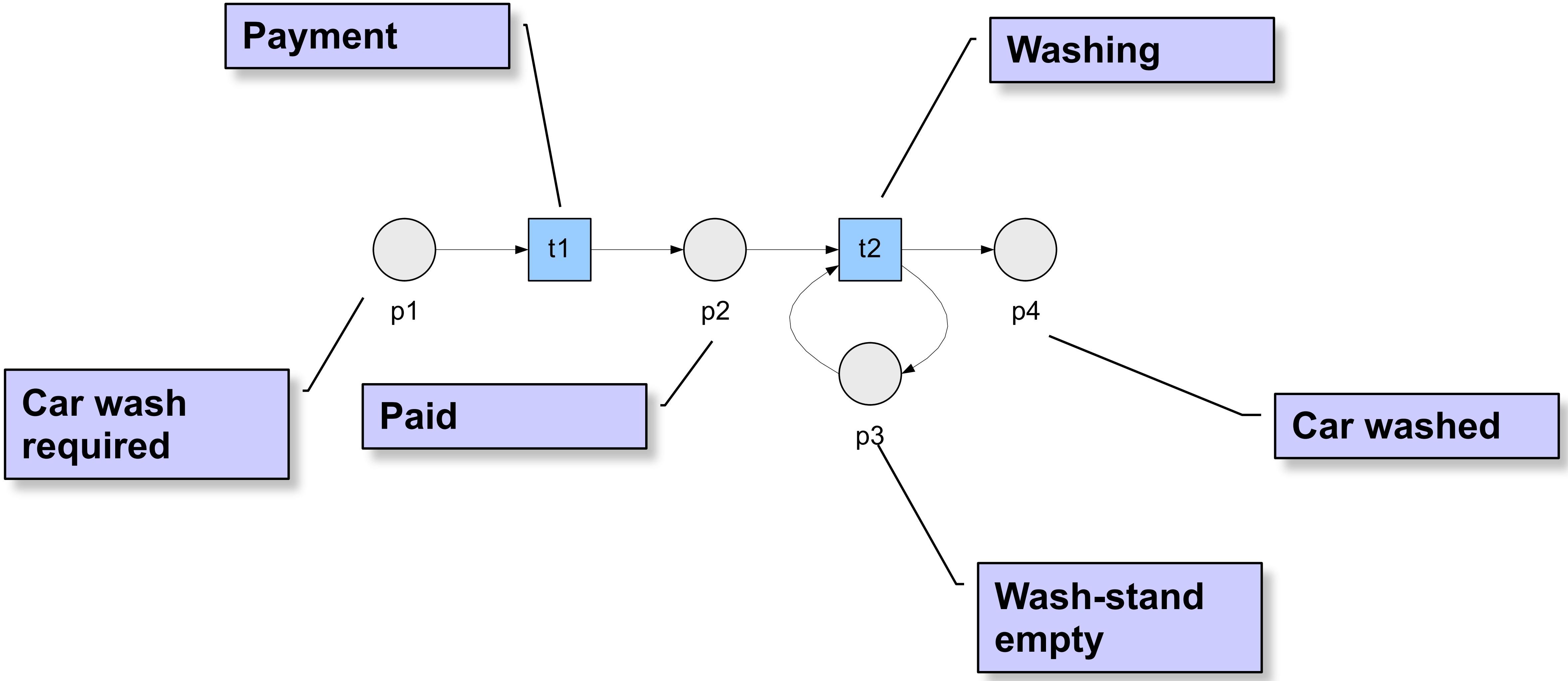
Change of state modeled by Petri Nets

Partial states modeled by Petri Nets

Petri Nets

- A ***Petri Net*** is a triple $PN = (P, T, F)$:
  - P is a finite set of places
  - T is a finite set of transitions $\left(P \cap T = \square\right)$
  - $F \;\square\; (P \times T) \square (T \times P)$ is a set of arcs (flow relation)
- A ***marking*** of a $PN = (P, T, F)$ – denoted by $M\!: P \rightarrow \mathbf{N}$ is a mapping which assigns a non-negative integer number of tokens to each place of the net.
- A marking M (distribution of tokens over places) is often referred as the state of a given Petri Net.
- Notation •t is used to denote the set of input places for a transition t. The notation t•, •p and p• have similar meanings, that is p• is the set of transitions sharing p as an input place.

Petri Net Model of Wash-stand



Payment

Washing

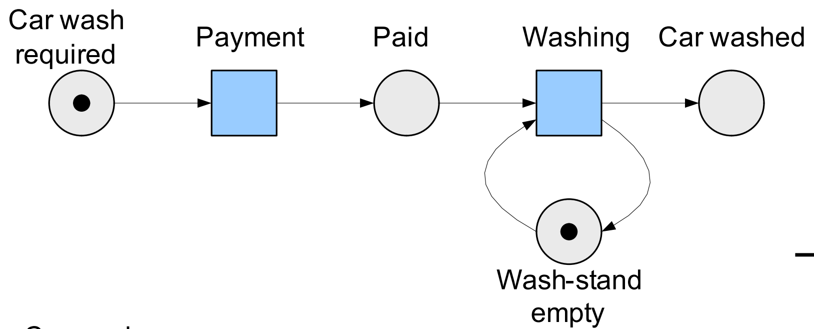
Car wash required

Paid

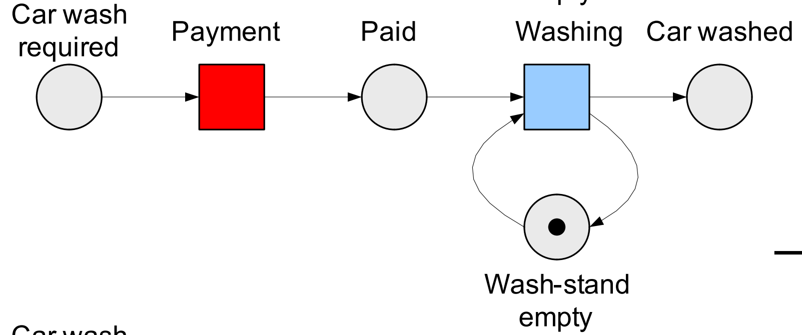
Car washed

Wash-stand empty

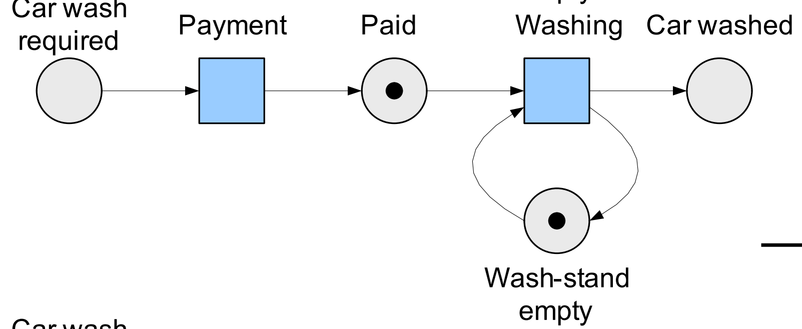
Process Simulation using Petri Net



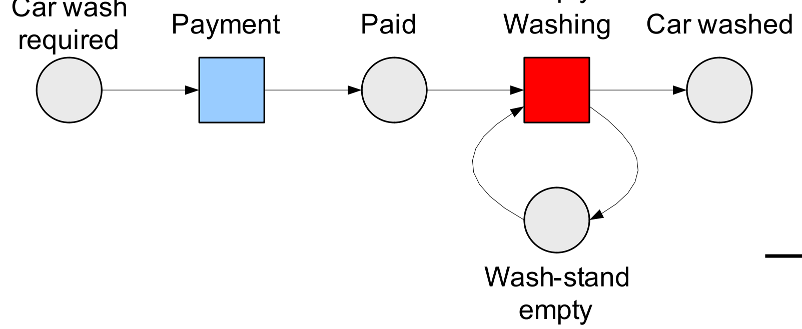
Initial state: tokens are in places *Car wash required* and *Wash-stand empty*.



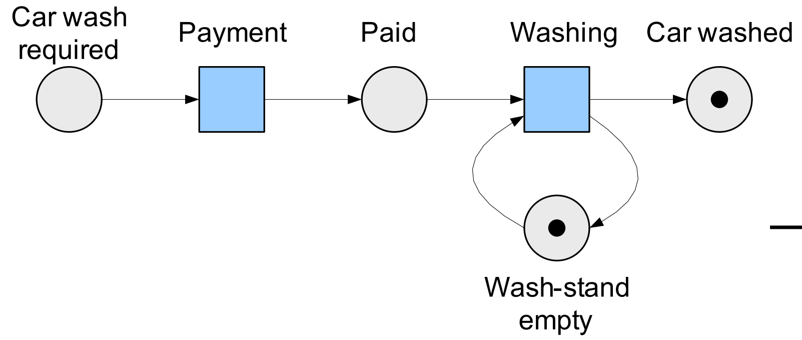
Transition *Payment* fired. Token is removed from the input place *Car wash required*.



Payment is finished. Token is put in place *Paid*. Transition *Washing* is enabled.



Transition *Washing* is fired. Tokens are removed from its input places.



Final state. Tokens are moved to *Car washed* and *Wash-stand empty* places.

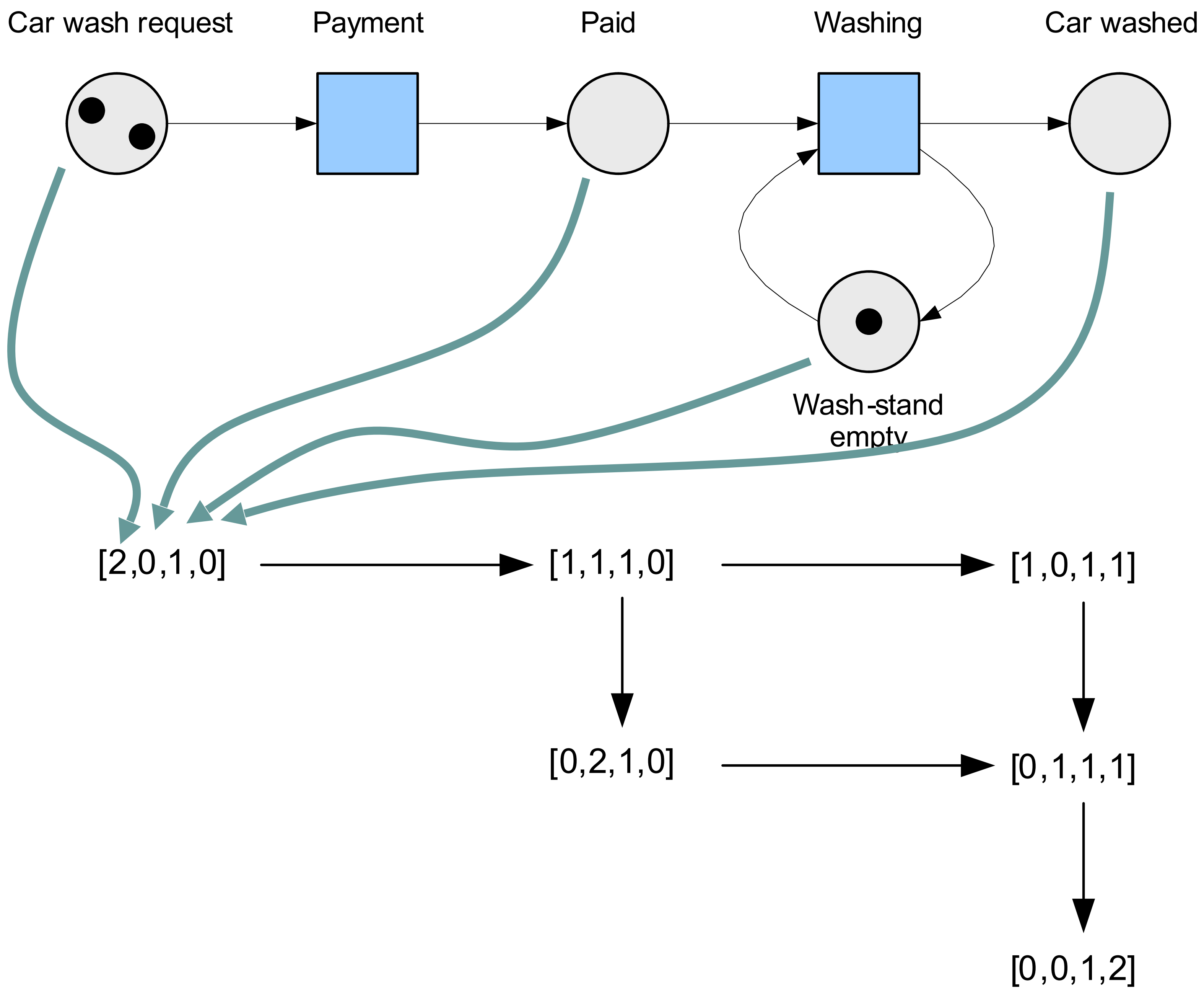
Formal Specification of Wash-stand

- Wash-stand Petri Net
  - $P = \{p1, p2, p3, p4\}$.
  - $T = \{t1, t2\}$.
  - $F = \{\langle p1, t1\rangle, \langle p2, t2\rangle, \langle p3, t2\rangle, \langle t1, p2\rangle, \langle t2, p3\rangle, \langle t2, p4\rangle\}$.
- Dynamic behavior – states reached during process execution
  1. $p1+p3$
  2. $p2+p3$
  3. $p3+p4$.

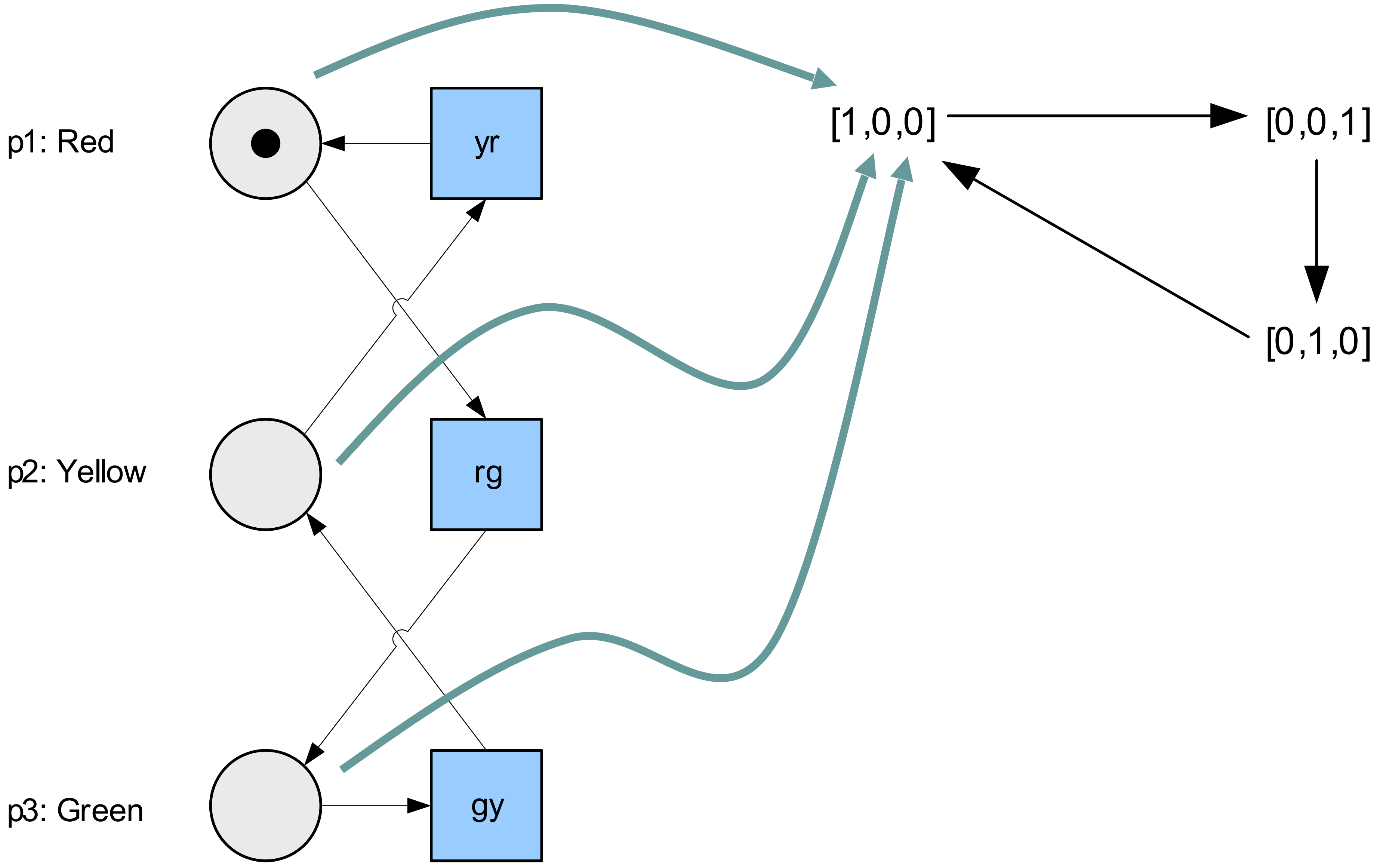
Significant Properties of Petri Nets

- We use (PN, M) to denote a Petri Net PN with an initial state M.
- For any to states M_1 and M_2, $M_1 \leq M_2$ iff for all $p \in P$: $M_1(p) \leq M_2\ (p)$, where $M(p)$ denotes the number of tokens in place p in state M.
- **Firing rule:** a transition t is said to be ***enabled*** iff each input place p of t contains at least one token.
- A state is M_n called ***reachable*** from M_1 iff there is a firing sequence that leads Petri Net from state M_1 to state M_n via a (possibly empty) set of intermediate states $M_2, \ \ldots M_{n-1}$.

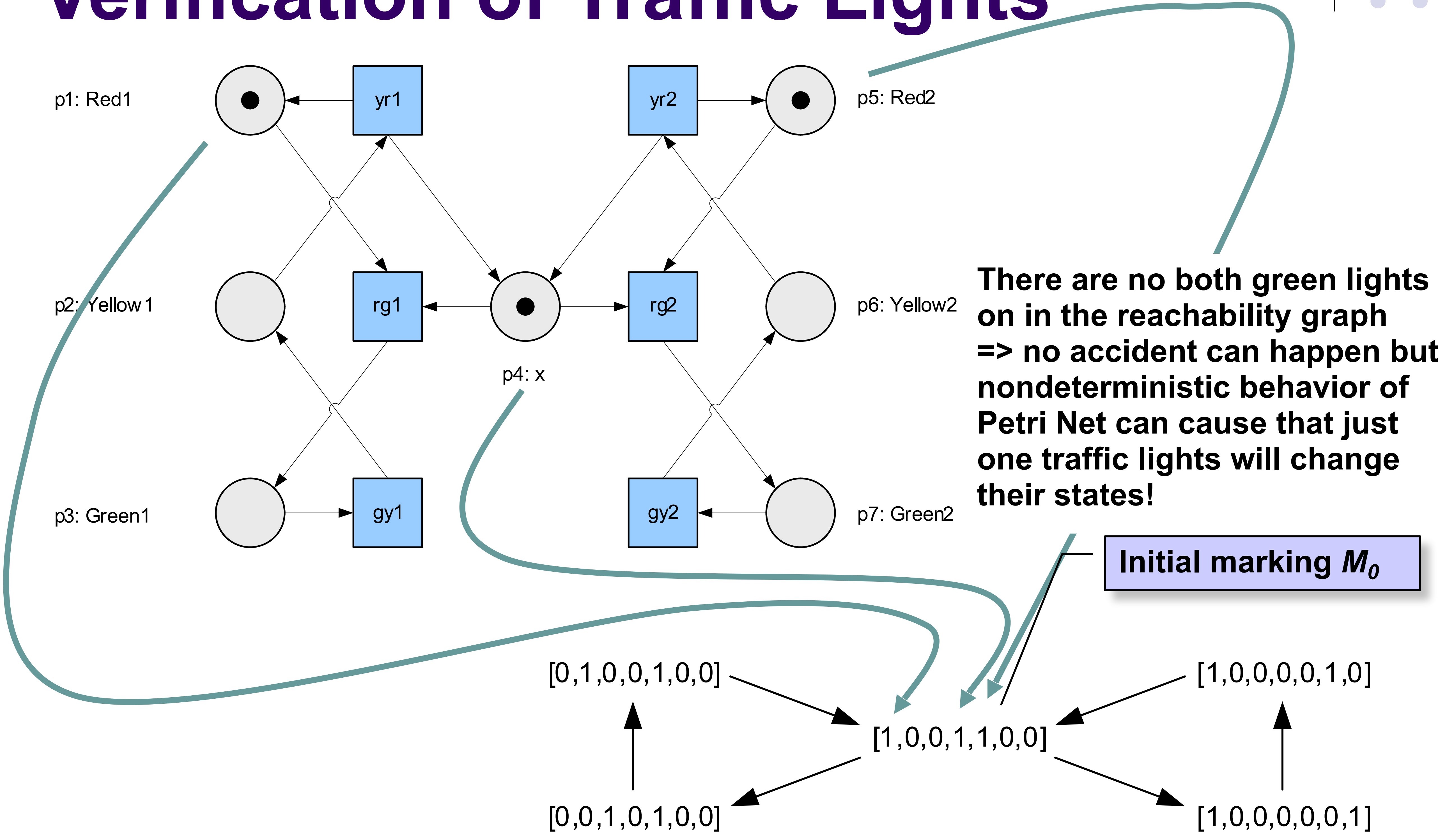
Reachability Graph of Wash-stand



Traffic Lights Petri Net



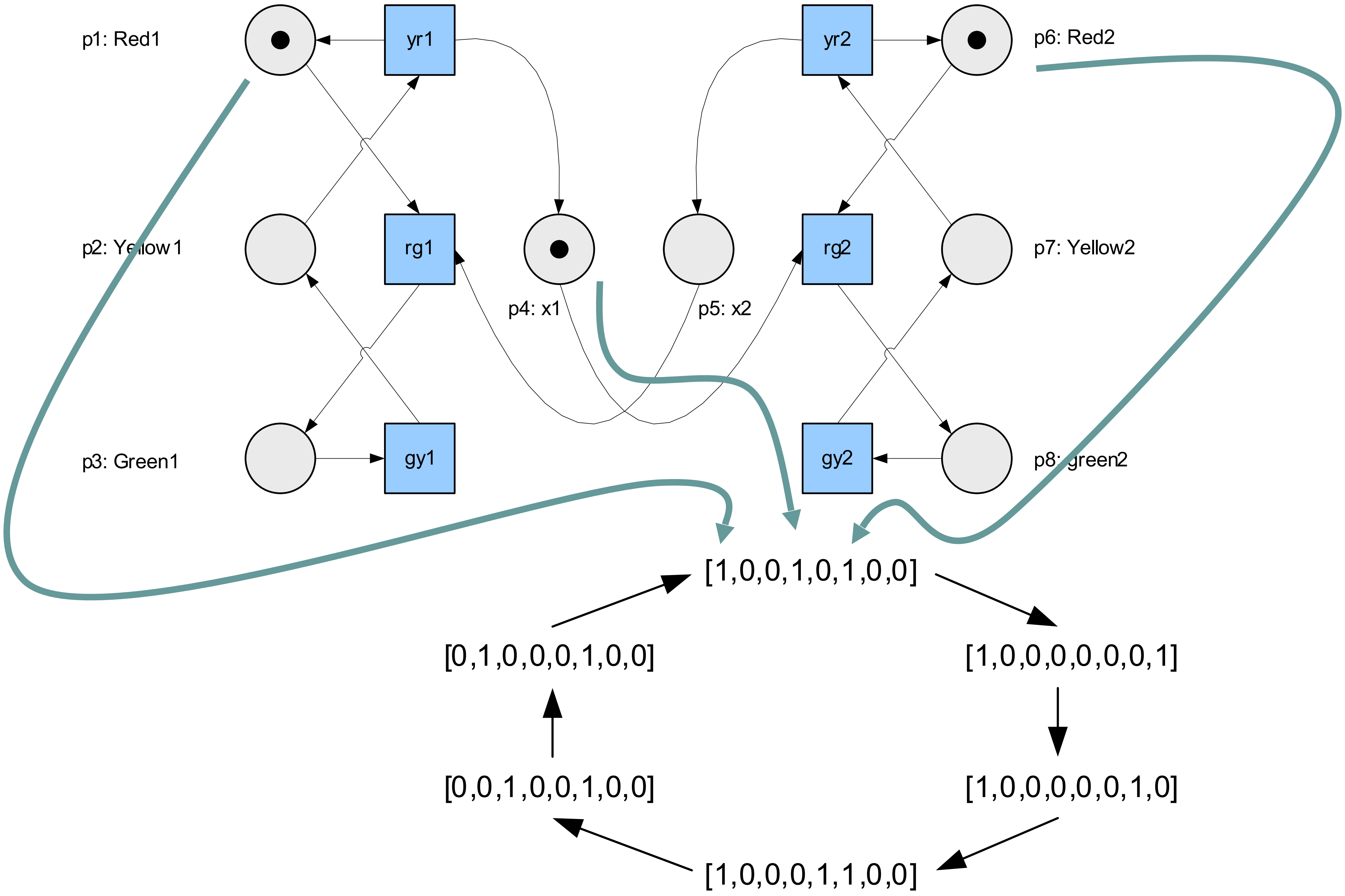
Verification of Traffic Lights



There are no both green lights on in the reachability graph => no accident can happen but nondeterministic behavior of Petri Net can cause that just one traffic lights will change their states!

Initial marking M_0

Correct Model of Traffic Lights



[1,0,0,1,0,1,0,0]

[0,1,0,0,0,1,0,0]

[1,0,0,0,0,0,0,1]

[0,0,1,0,0,1,0,0]

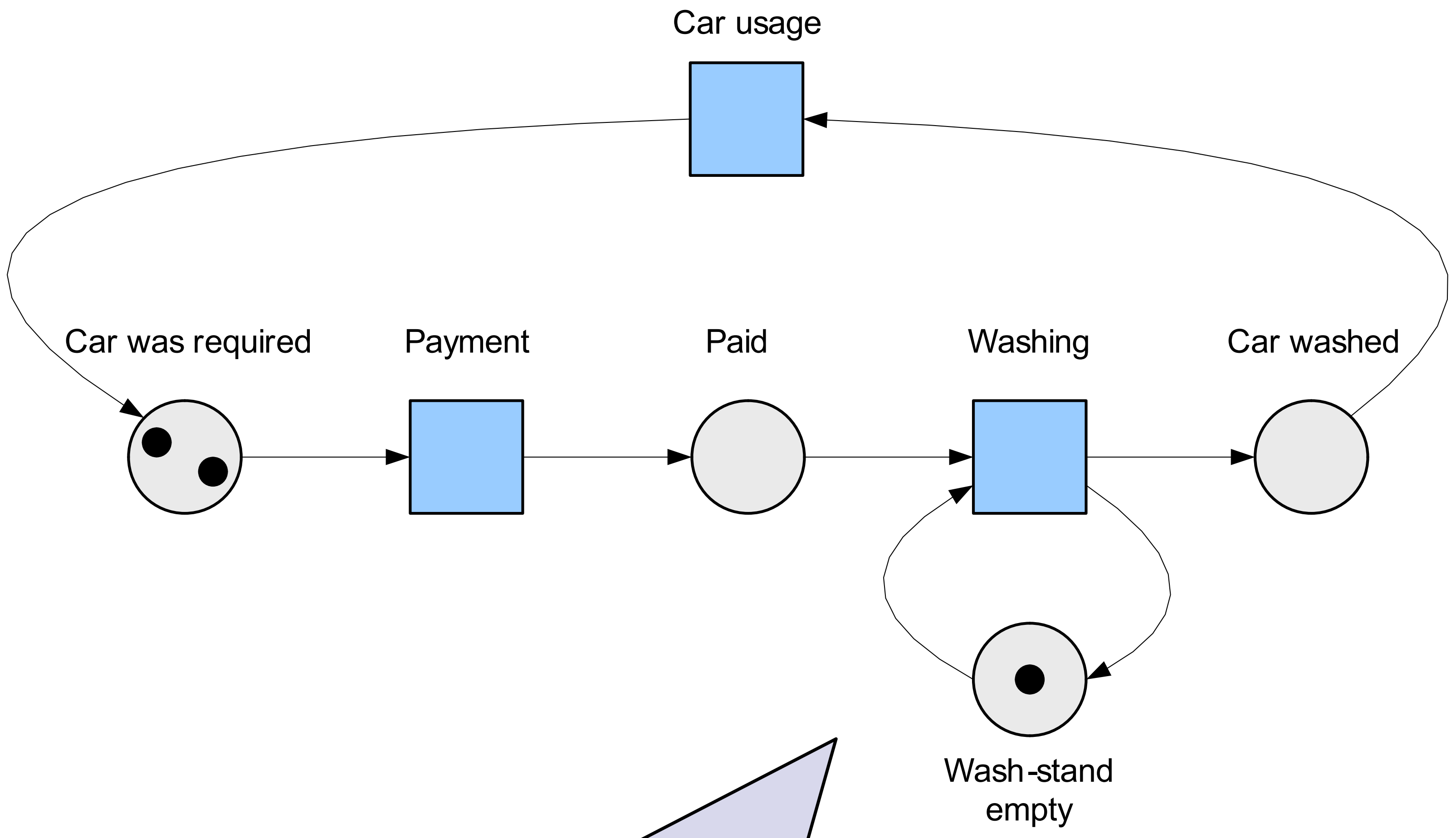
[1,0,0,0,0,0,1,0]

[1,0,0,0,1,1,0,0]

Liveness and Boundness

- A Petri Net (PN, M) is ***live*** iff for every reachable state M' and every transition t there is a state M'' reachable from state M' that enables t (=> every transition can fire arbitrarily many times).
- A Petri Net (PN, M) is ***bounded*** iff for each place there is a natural number n such that for every reachable state the number of tokens in place p is less than n. The net is ***safe*** iff for each place the maximum number of tokens does not exceed 1.

Live Petri Net

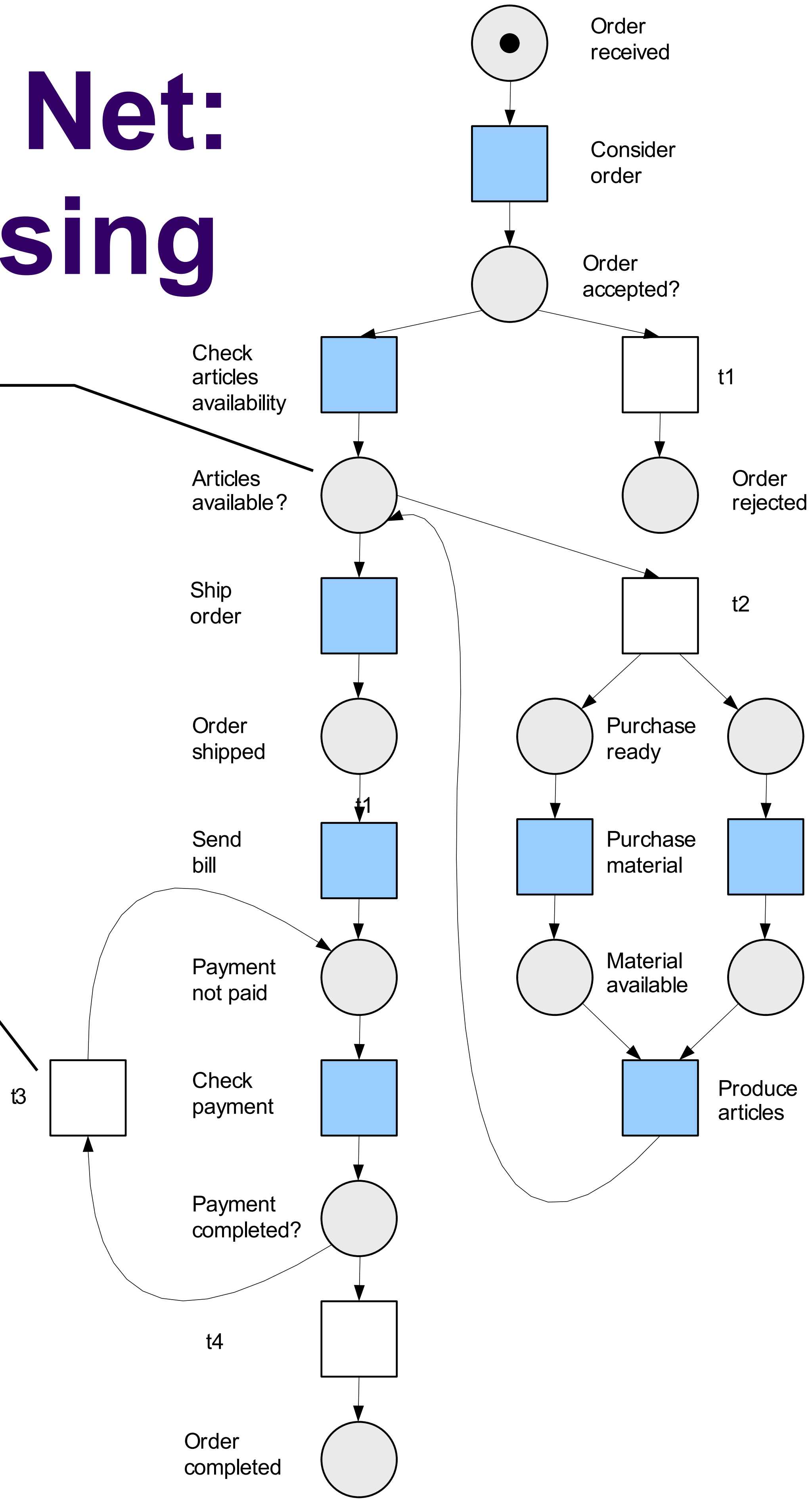


Every transition can fire arbitrarily many times.

Colored Petri Net: Order Processing

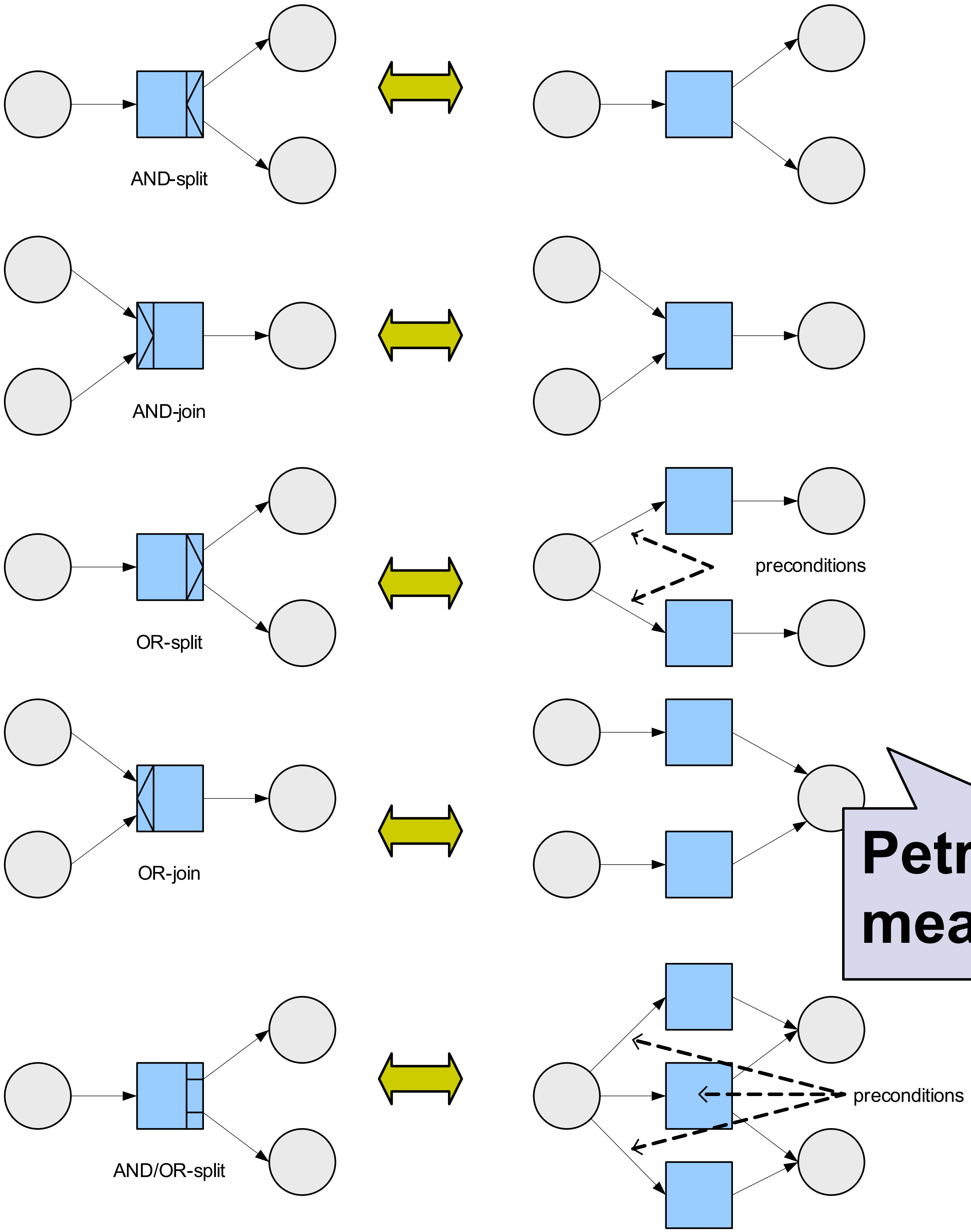
Token carries information needed for deterministic execution of Petri Net.

Empty transition required by Petri Net formalism.



Extended Notation

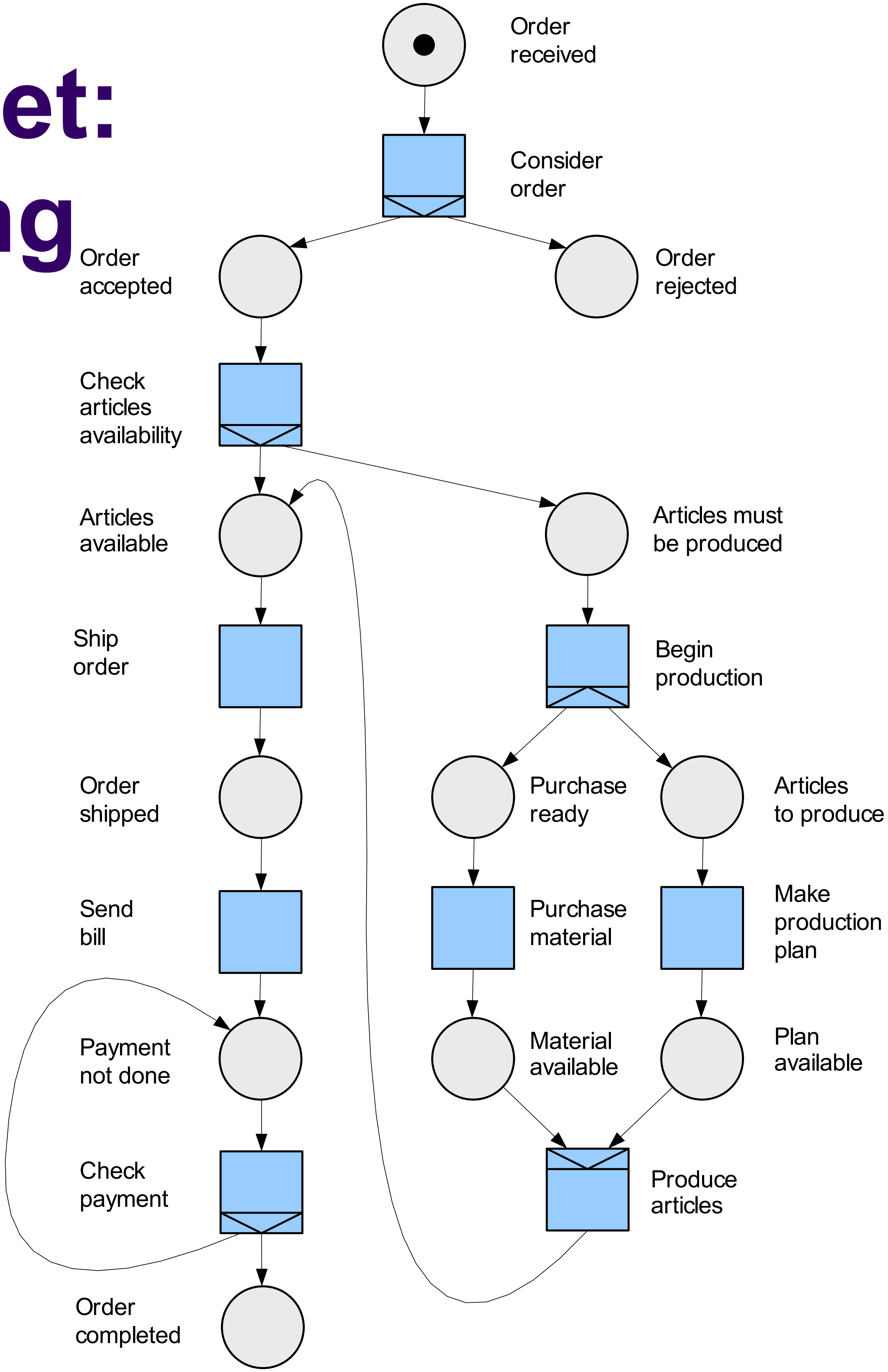
Notation



Petri Net meaning

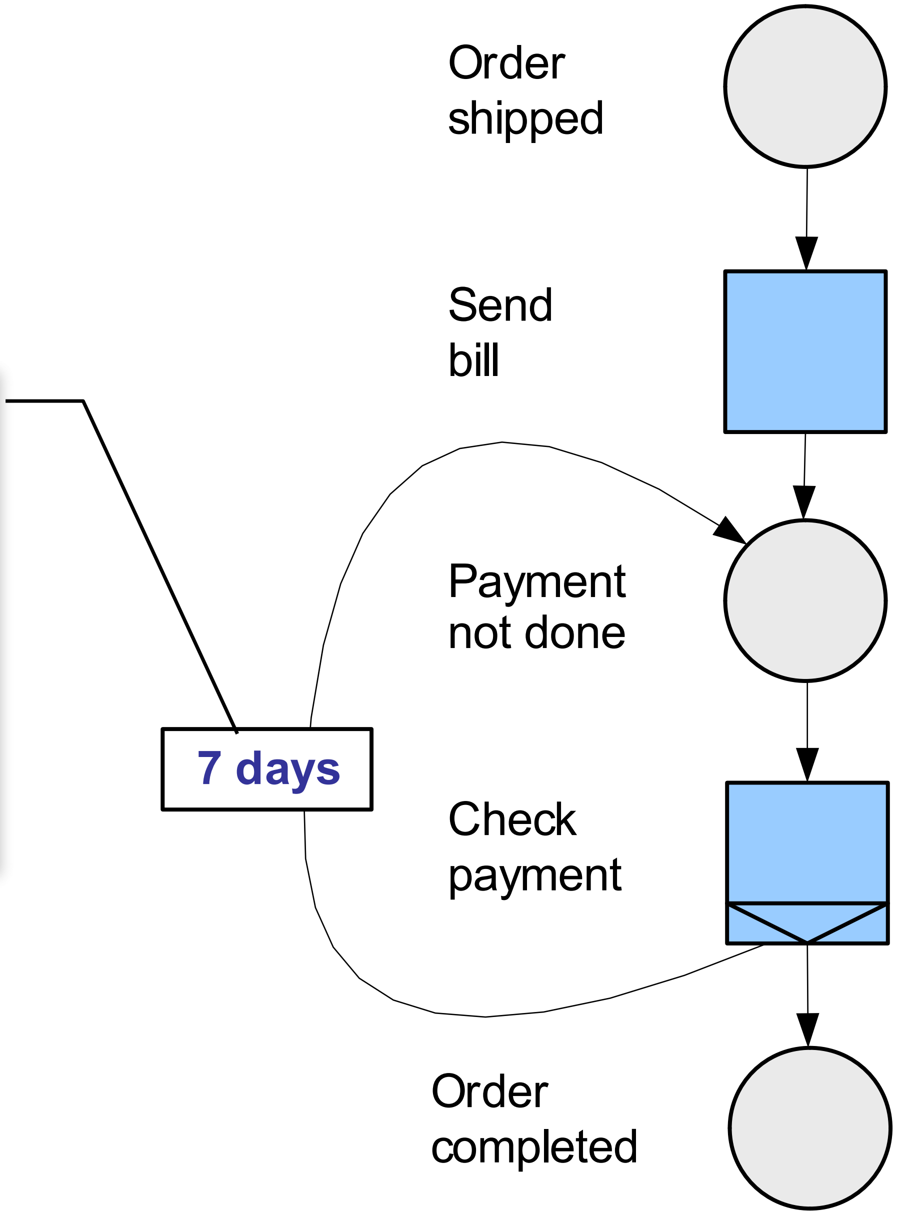
Modified Petri Net: Order Processing

Extended notation makes process model closer to reality while all properties of Petri Net theory is preserved.

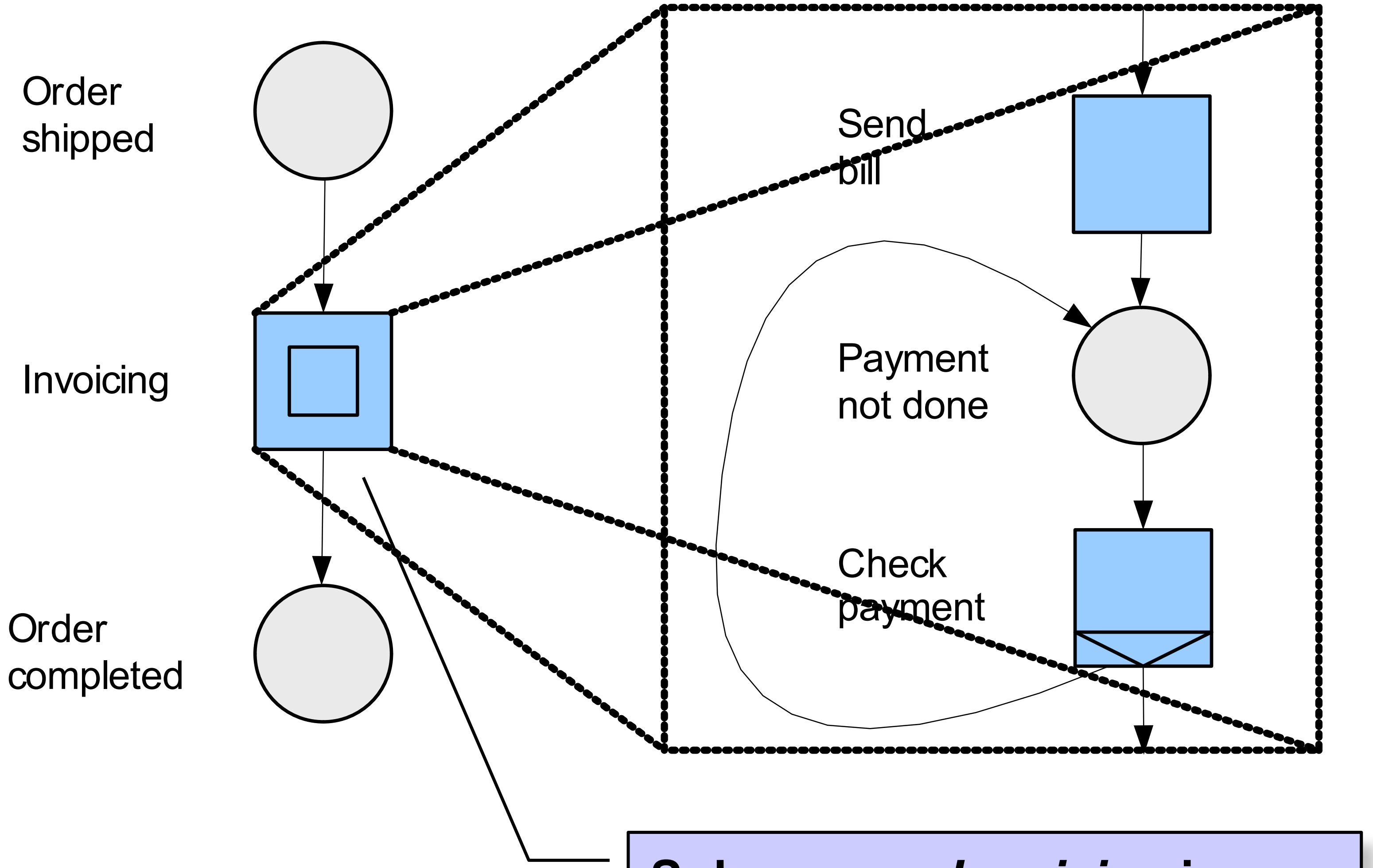


Temporal Extension

In case that *Check payment* was not successful token is moved to place *Payment not done* but it is consumed again after 7 days. The token was associated with *Time Stamp* 7 days delay.



Structuring Petri Nets



Subprocess *Invoicing* is substituted by refined Petri Net.

Exercise 5

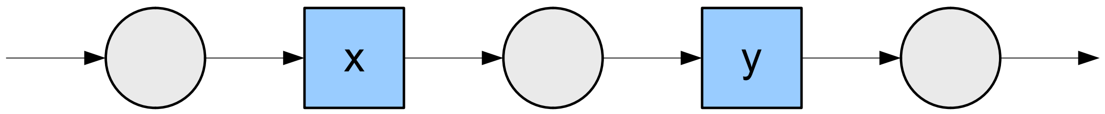
- Create Petri Net model of Traffic Lights where the yellow light is on when lights are switching from red to green and back from green to red.

Modeling Processes by WF-Nets

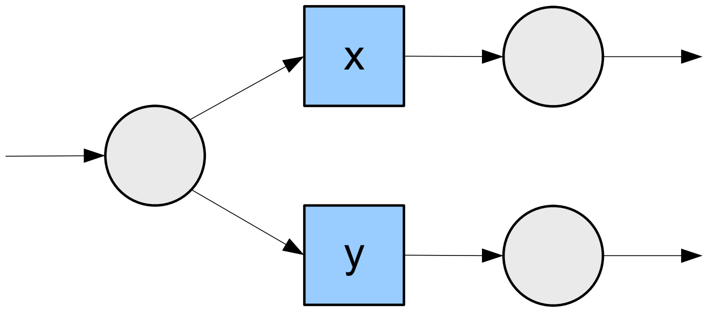
- A Petri net which models the control-flow dimension of a workflow, is called a Work-Flow Net (***WF-Net***).
- A Petri net $PN = (P; T; F)$ is a *WF-Net* if and only if:

1. There is one source place $i \in P$ such that $\bullet i = \emptyset$.
2. There is one sink place $o \in P$ such that $o\bullet = \emptyset$.
3. Every node $x \in P \cup T$ is on a path from i to o.

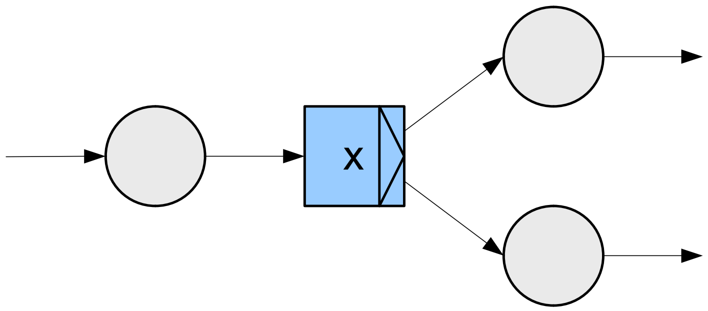
Workflow Structures



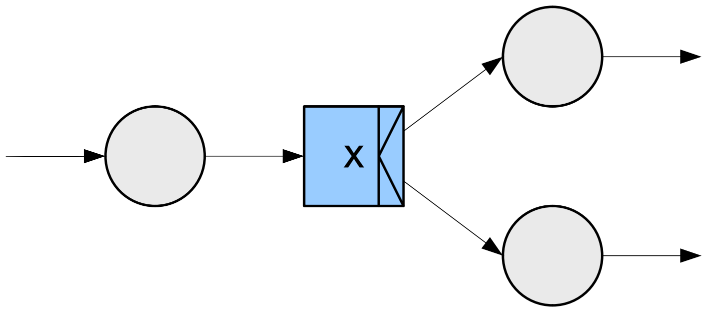
Sequence



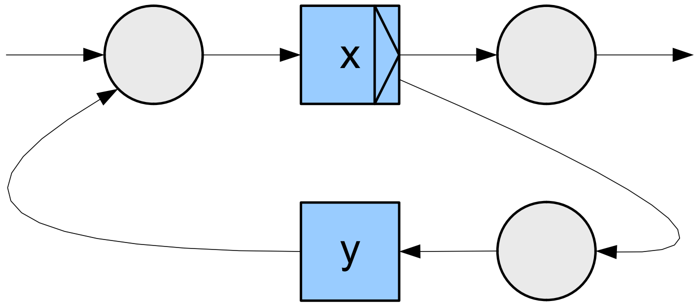
Implicit selection



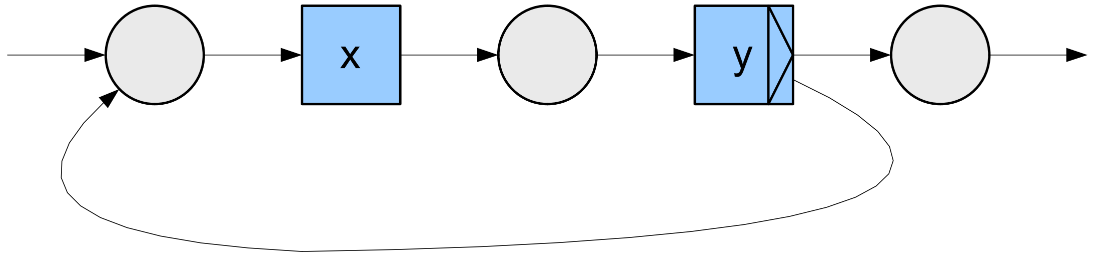
Explicit selection



Concurrency

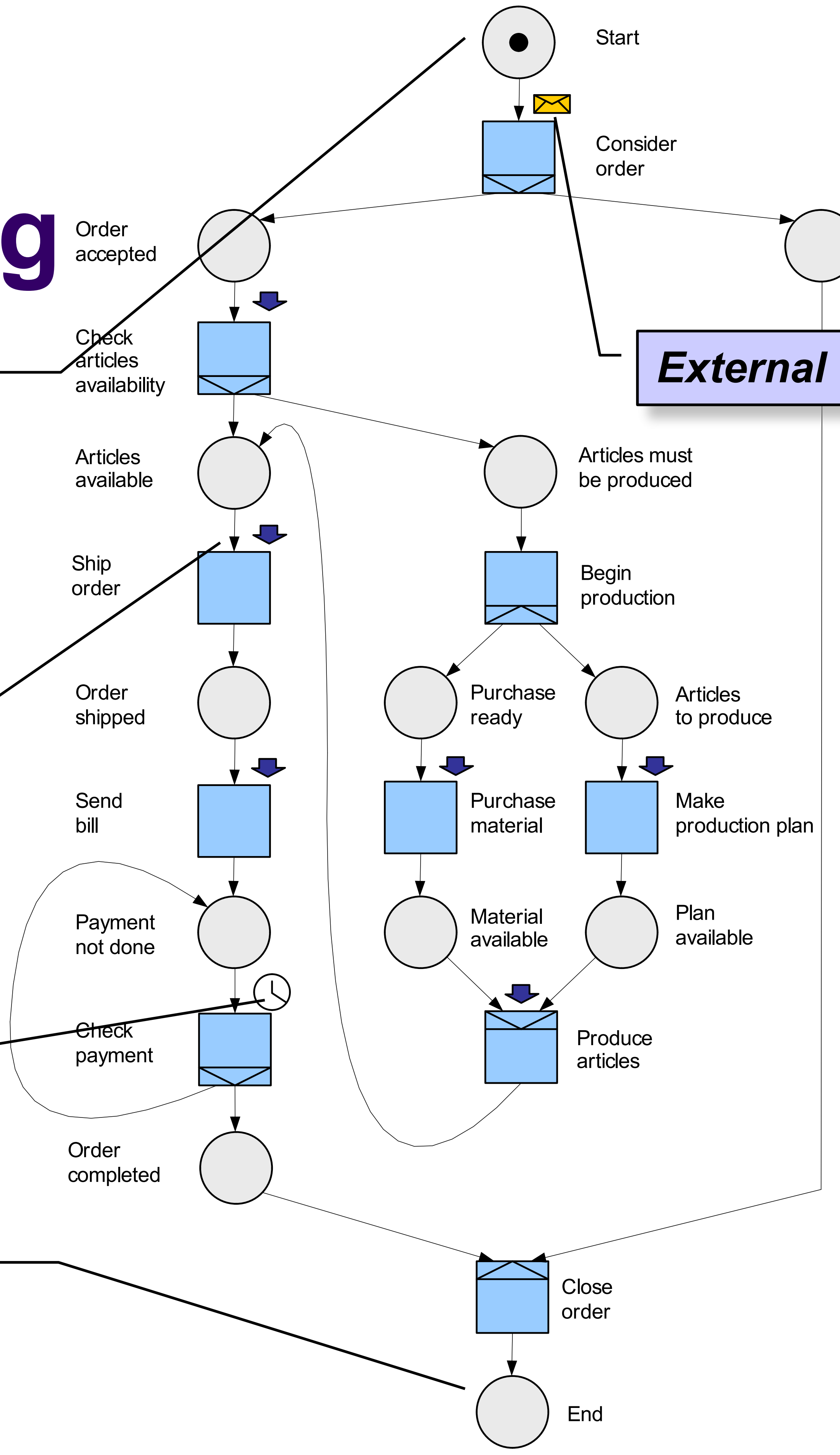


While-Do Loop



Repeat-Until Loop

WF-Net: Order Processing



Beginning of the process

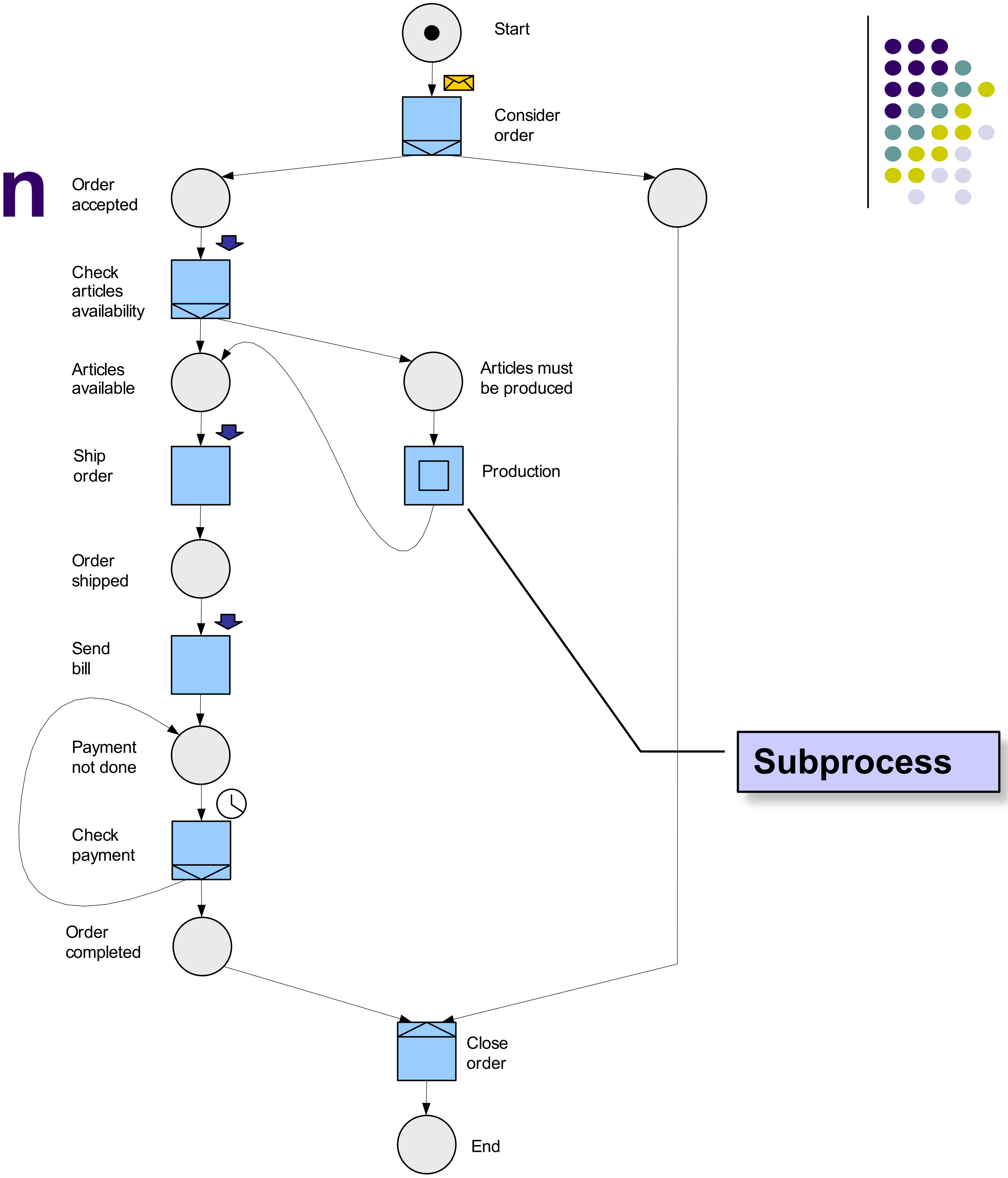
External event trigger

***Resource initiative* trigger**

***Time signal* trigger**

End of the process

Hierarchical Decomposition



Exercise 6

- Create WF-Net for the process of delivery service. Let’s have activities *Accept Order*, *Send Bill*, *Accept Payment*, *Ship Order* and *Cancel Order*. When the order is accepted the bill is sent to customer. In case that the payment is not received in a given time interval order is canceled. If payment is received in time then the order is shipped to customer.

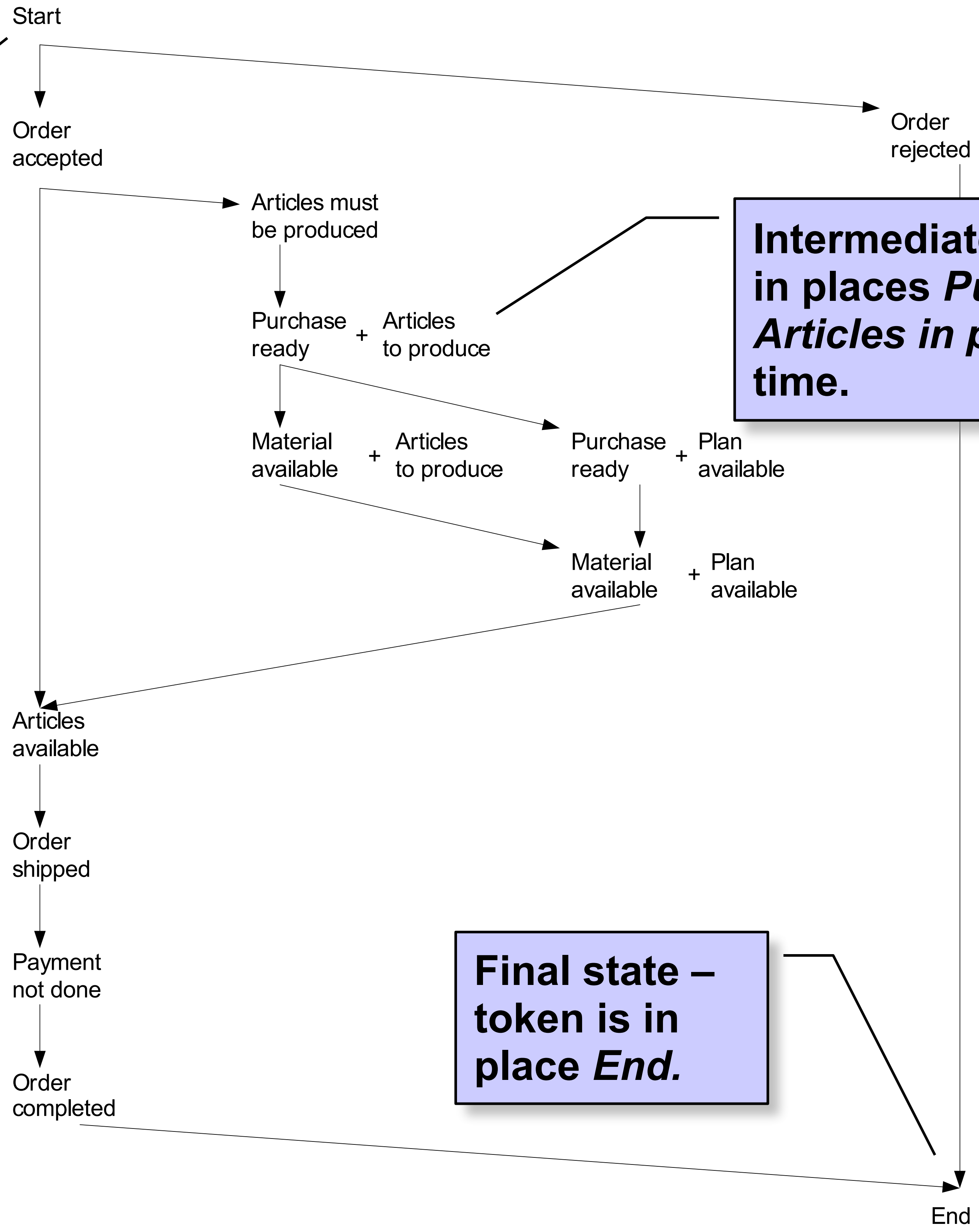
Analysis of Business Processes

- Analysis of business processes is based on analysis of properties inherent to Petri Nets:
  - reachability
  - liveness
  - boudness
  - and others …
- For the purpose of correct design of workflow property ***soudness*** was introduced.

Soudness

- A procedure modeled by WF-Net $PN = (P, T, F)$ is ***sound*** if and only if:
  - For every state M reachable from state i, there exists a firing sequence leading from state M to state o.
  - State o is the only state reachable from state i with at least one token in place o.
  - There are no dead transition in (PN, i).
- The first requirement states that starting from the initial state (state i), it is always possible to reach the state with one token in place o (state o). The second requirement states that the moment a token is put in place o, all the other places should be empty. Sometimes the term ***proper termination*** is used to describe the first two requirements. The last requirement states that there are no dead transitions in the initial state i.

Reachability Graph for Order Processing



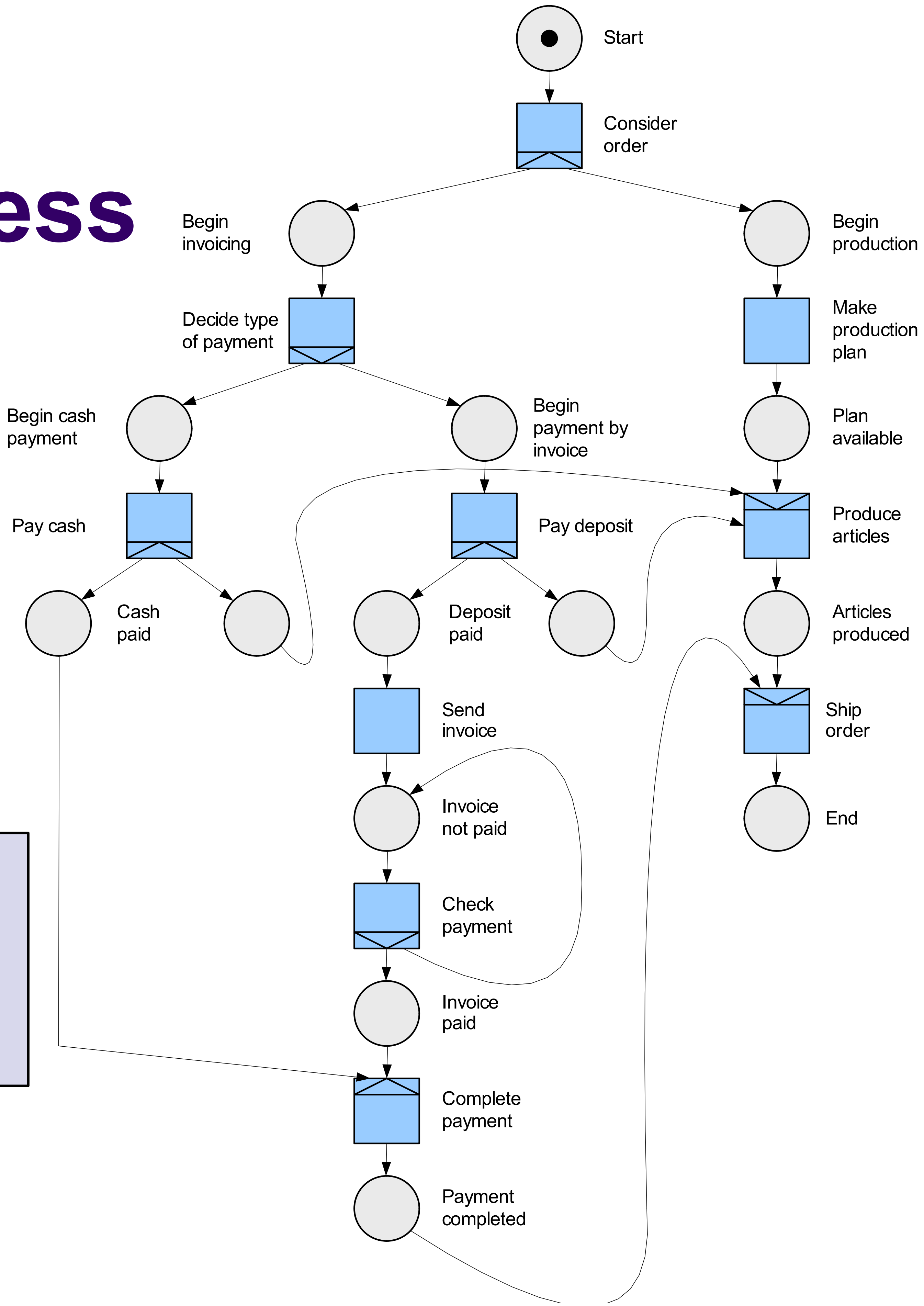
Start
Order accepted
Order rejected
Articles must be produced
Purchase ready + Articles to produce
Material available + Articles to produce
Purchase ready + Plan available
Material available + Plan available
Articles available
Order shipped
Payment not done
Order completed
End

Start state – token is in place *Start.*

Intermediate state – tokens are in places *Purchase ready* and *Articles in produce* at the same time.

Final state – token is in place *End.*

Faulty Process

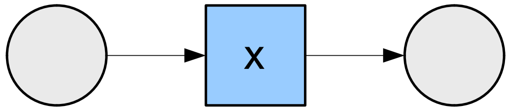


Construct reachability graph and find the problem(s).

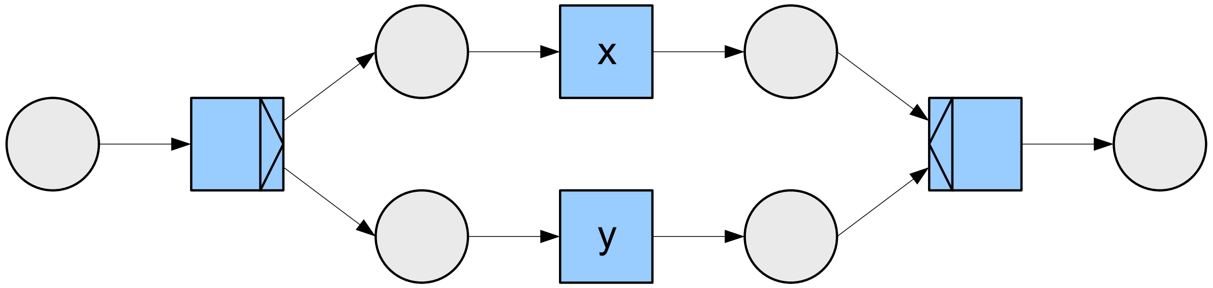
Verification of Soundness

- The first method how to determine *soudness* requires to add an additional transition t^* that connects start place i with end place o (short-circuited net). Based on that the soudness of of the WF-Net corresponds with two properties: *liveness* and *boundness* of short-circuited net. The issue is that verification of liveness and boudness requires computer tools for complex process models.
- The second method is based on the construction process of correct workflow nets. If we have two sound and safe WF-Nets WF_1 and WF_2 and we have transition t in WF_1 which has just one input and one output place, then we may replace task t in WF_1 by WF_2 and the resulting WF-Net is sound and safe again.
  - The safety is required because in case that input place of substituted transition t contains more than one token the inserted WF-Net does not need to be sound.

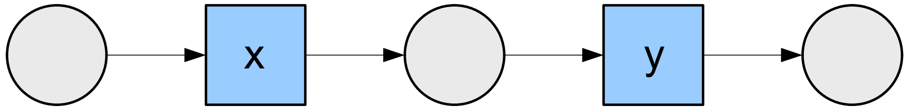
Sound and Safe Components



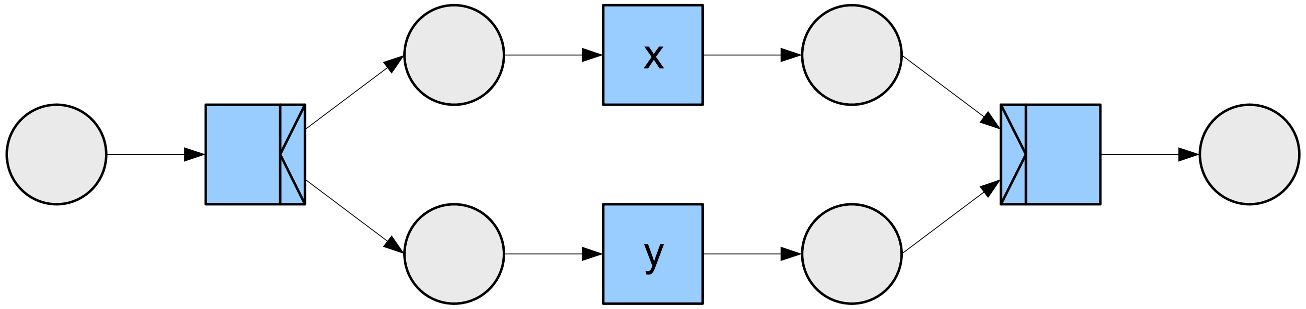
Basic block



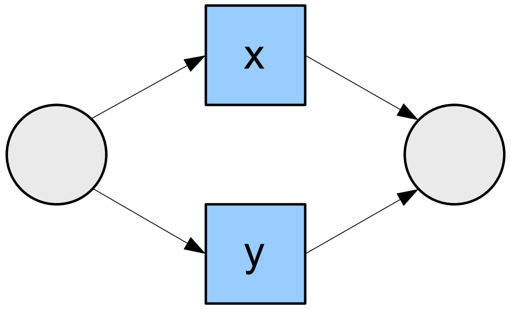
Explicit selection



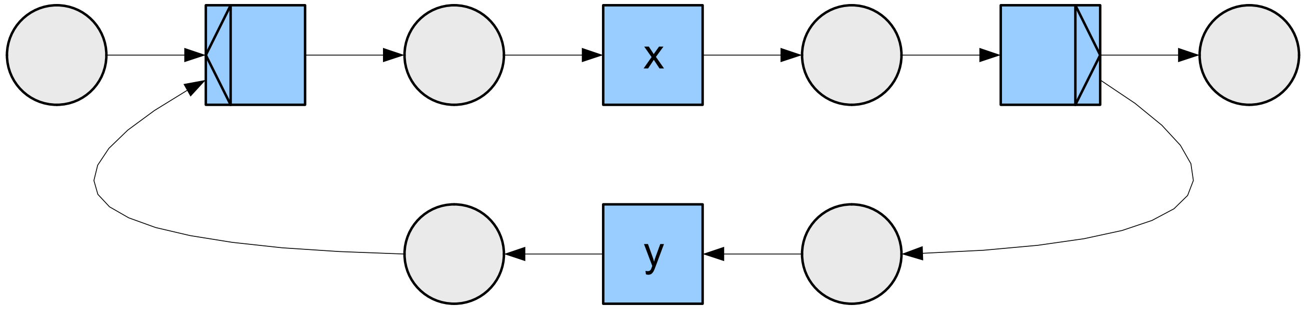
Sequence



Concurrency



Implicit selection

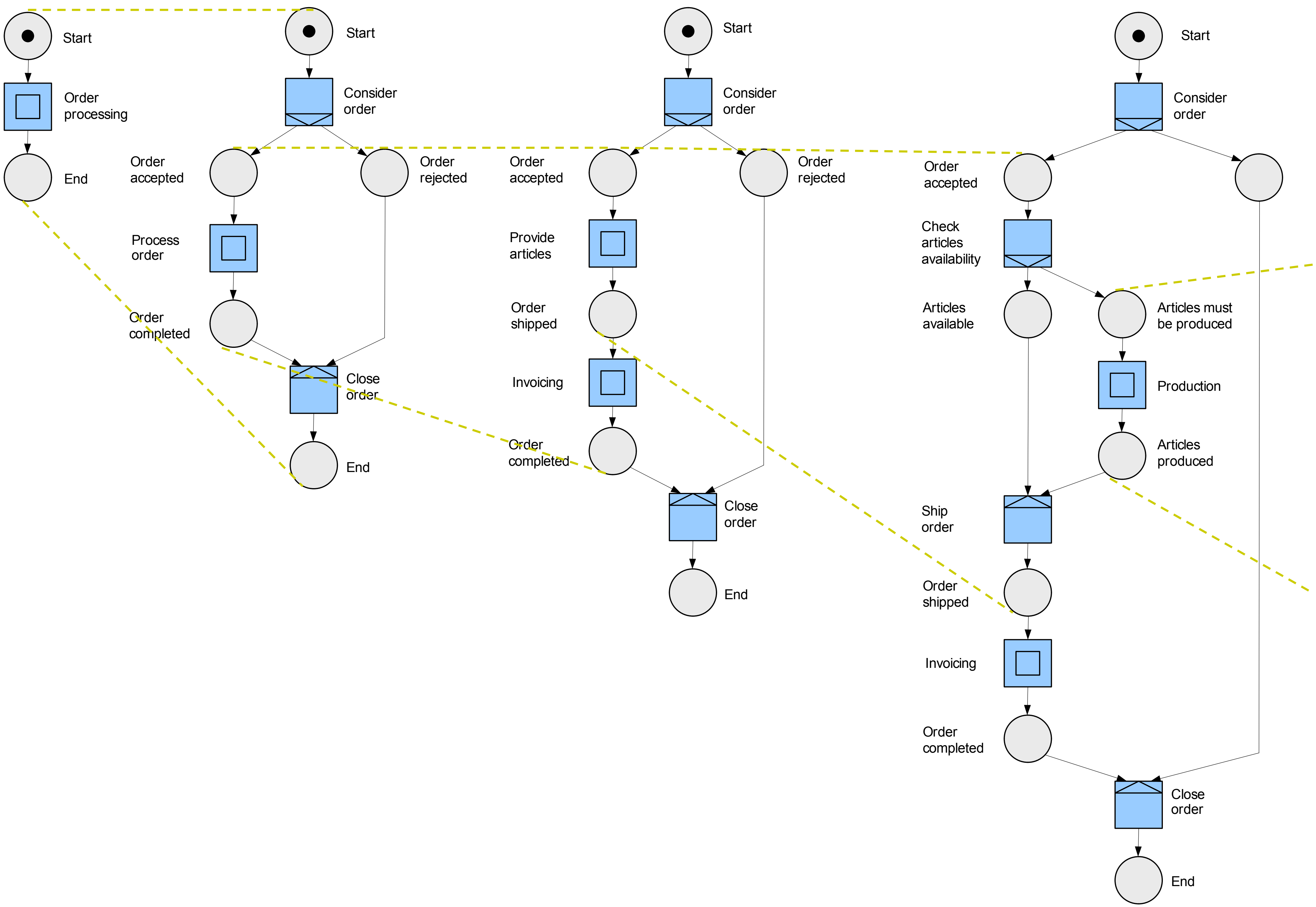


Loop

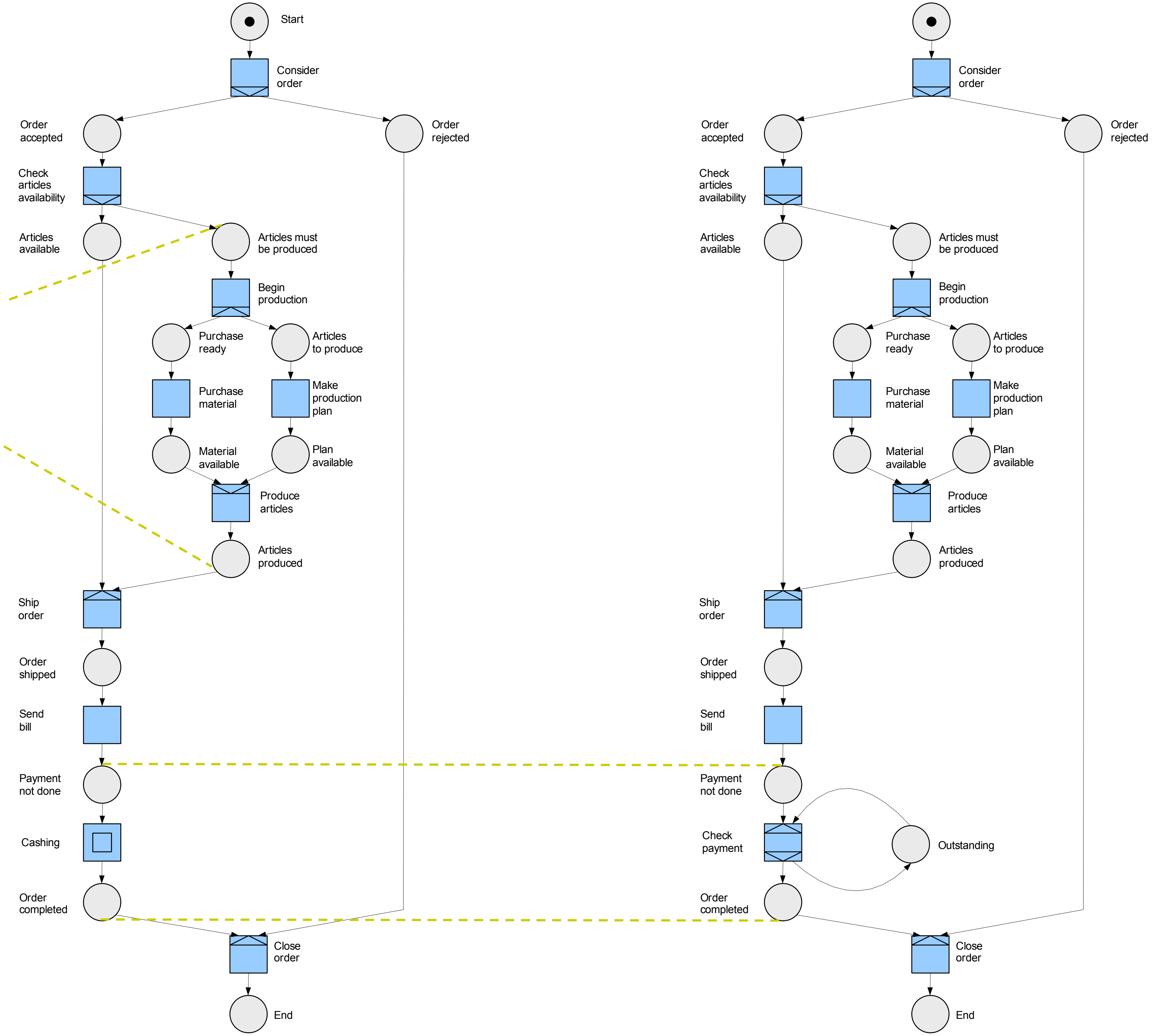
Well-structured WF-Nets

- ***Well-structured*** WF-Net contains balanced AND/OR-splits and AND/OR-joins. It means that two concurrent flows initiated by AND-split should not be joined by OR-join. Two alternative flows created via OR-split cannot be synchronized by AND-join.
- The main advantage of using well-structured nets is that sound and well-structured WF-Nets are also safe. It means that based on using of sound and well-structured components these components are also safe and we can build new sound and well-structured WF-Nets (and components).

Building Sound WF-Nets from Components



Building Sound WF-Net cont.



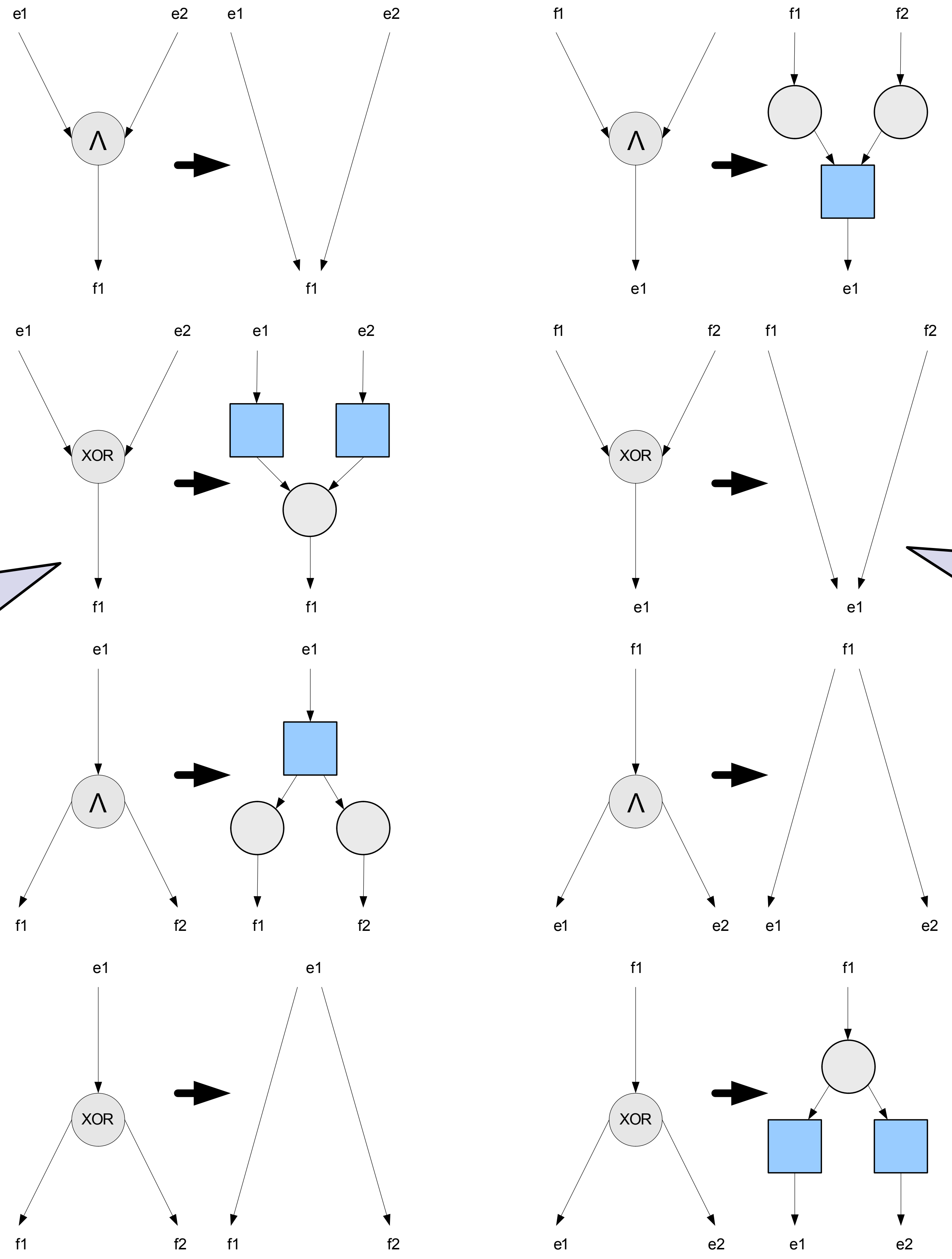
Formalization and Verification of Processes

- Key issues of formal methods:
  - Formal methods reduce number of errors in process specification but the mathematical representation requires more time to obtain results.
  - Formal methods are hard to scale up to large systems.
  - The main area of their applicability is critical systems. In this area the use of formal methods seems to be cost-effective.
- Formalization of informally defined processes:
  - The idea is to combine formal methods with diagrammatic languages like EPC or UML.

EPC Formalization

- An ***event-driven process chain*** is a five-tuple $EPC = (E, F, C, T, A)$:
  - E is a finite set of events,
  - F is a finite set of functions,
  - C is a finite set ogf logical connectors,
  - $T : C \rightarrow \{\square, XOR, \square\}$ is a function which maps each connector onto a connector type,
  - $A \,\square\, (E \times F) \,\square\, (F \times E) \,\square\, (E \times C) \,\square\, (C \times E) \,\square\, (F \times C) \,\square\, (C \times F) \,\square\, (C \times C)$ is a set of arcs.
- Next step is to define **rules of how the EPC model can be transformed to WF-Net**.
- Resulting WF-Net can be verified using standard methods and tools applicable to Petri Nets.
- Building of EPC diagrams can employ well-structured components as well as constructing WF-Nets.

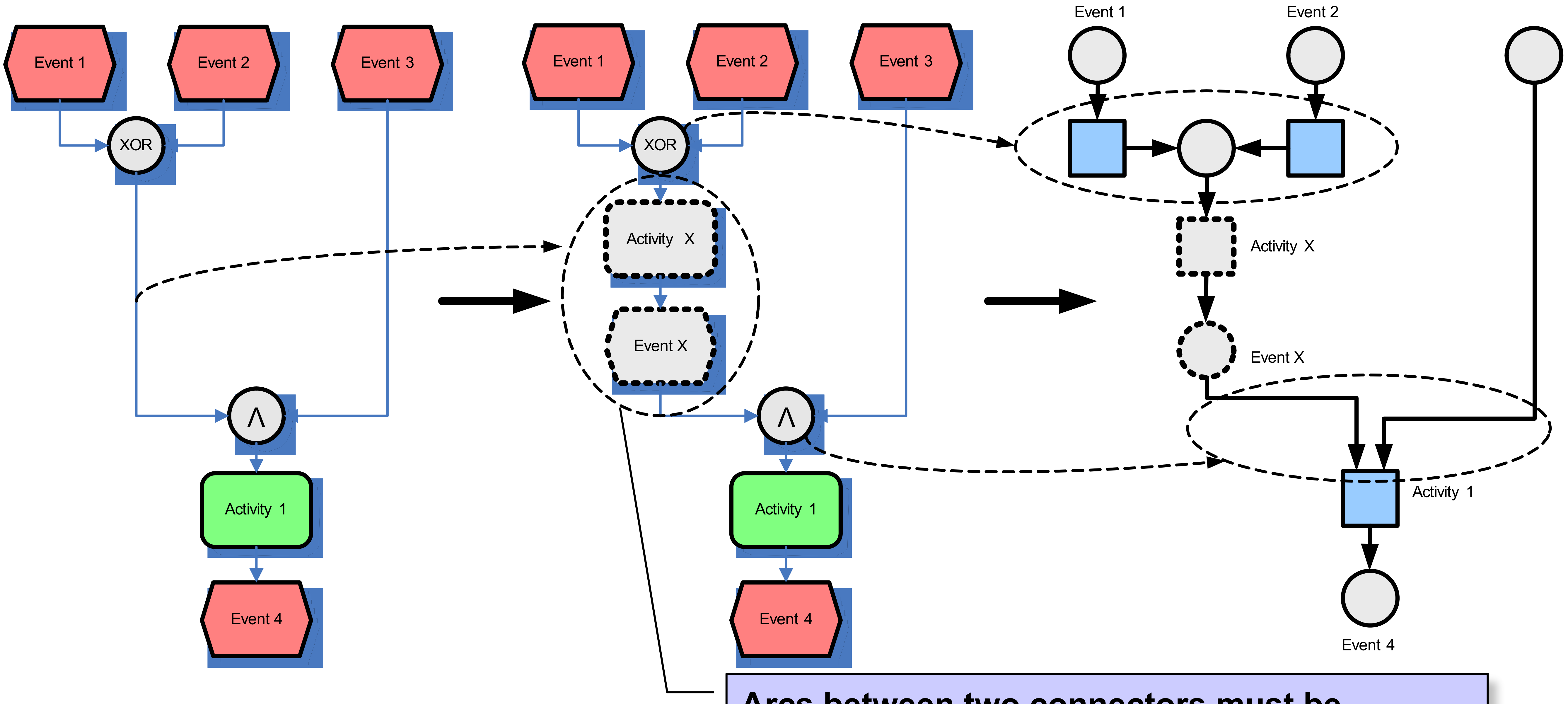
Mapping Connectors on Petri Nets



Connecting Events to Activities

Connecting Activities to Events

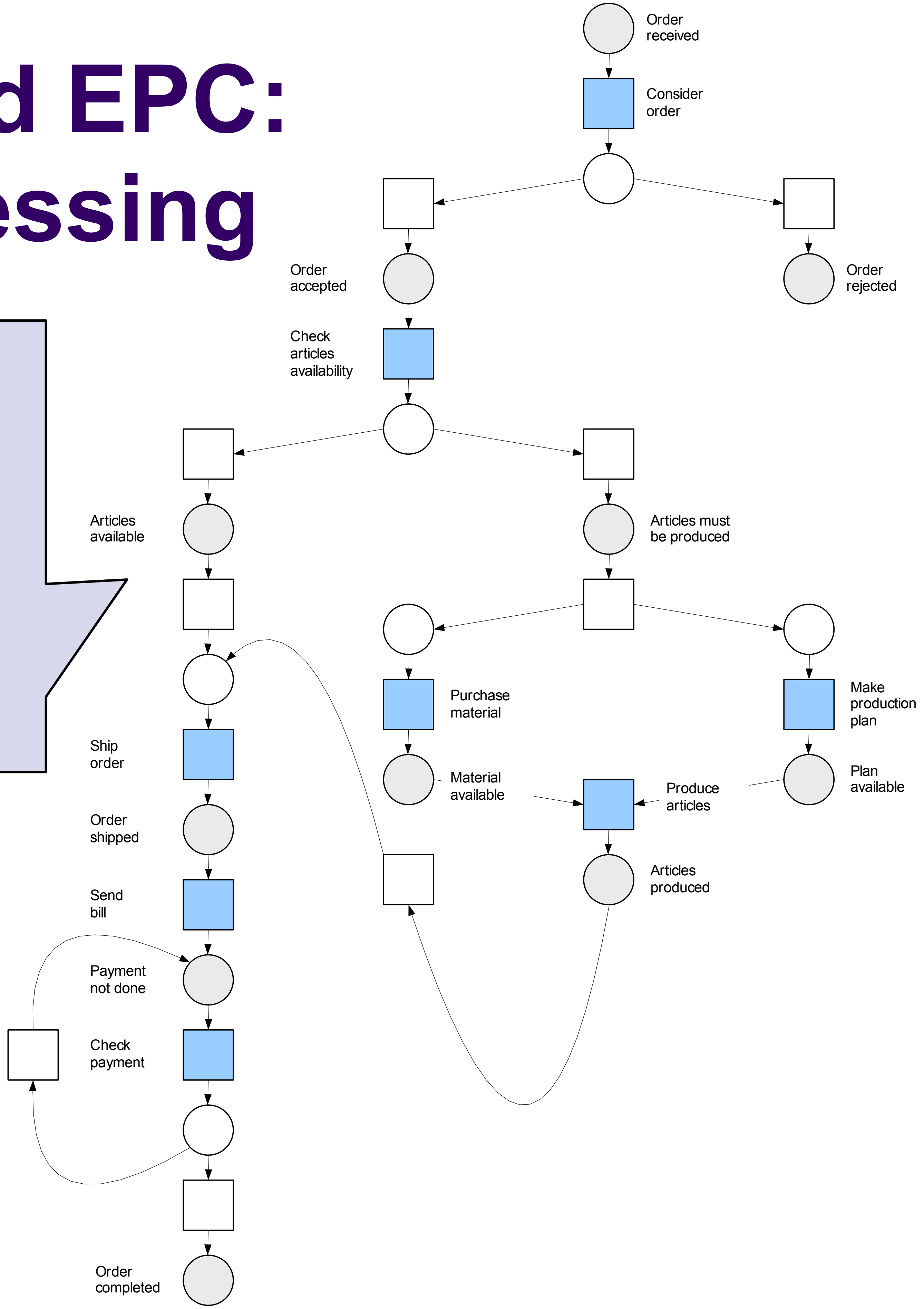
Transformation of EPC Model to Petri Net



Arcs between two connectors must be replaced by events and functions before the EPC is mapped onto a Petri Nedt.

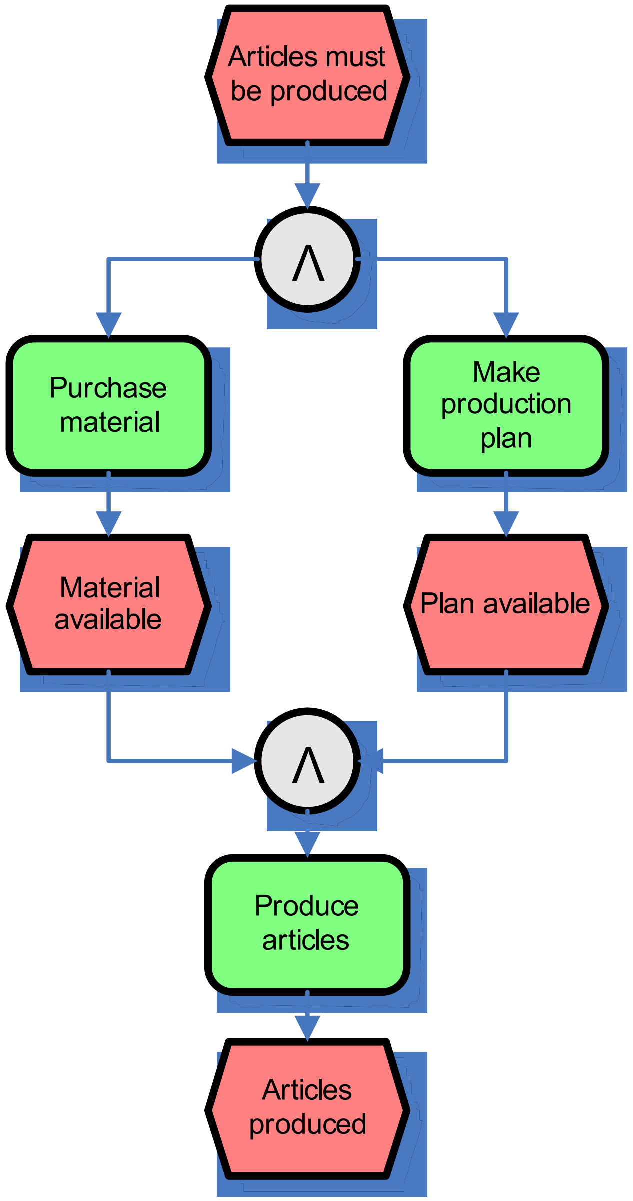
Transformed EPC: Order Processing

Uncolored (fictive) places and transition were added to Petri Net because of transfromation process.



Exercise 7

- Transform the give process model specified in EPC diagram to Petri Net. Is this process sound?



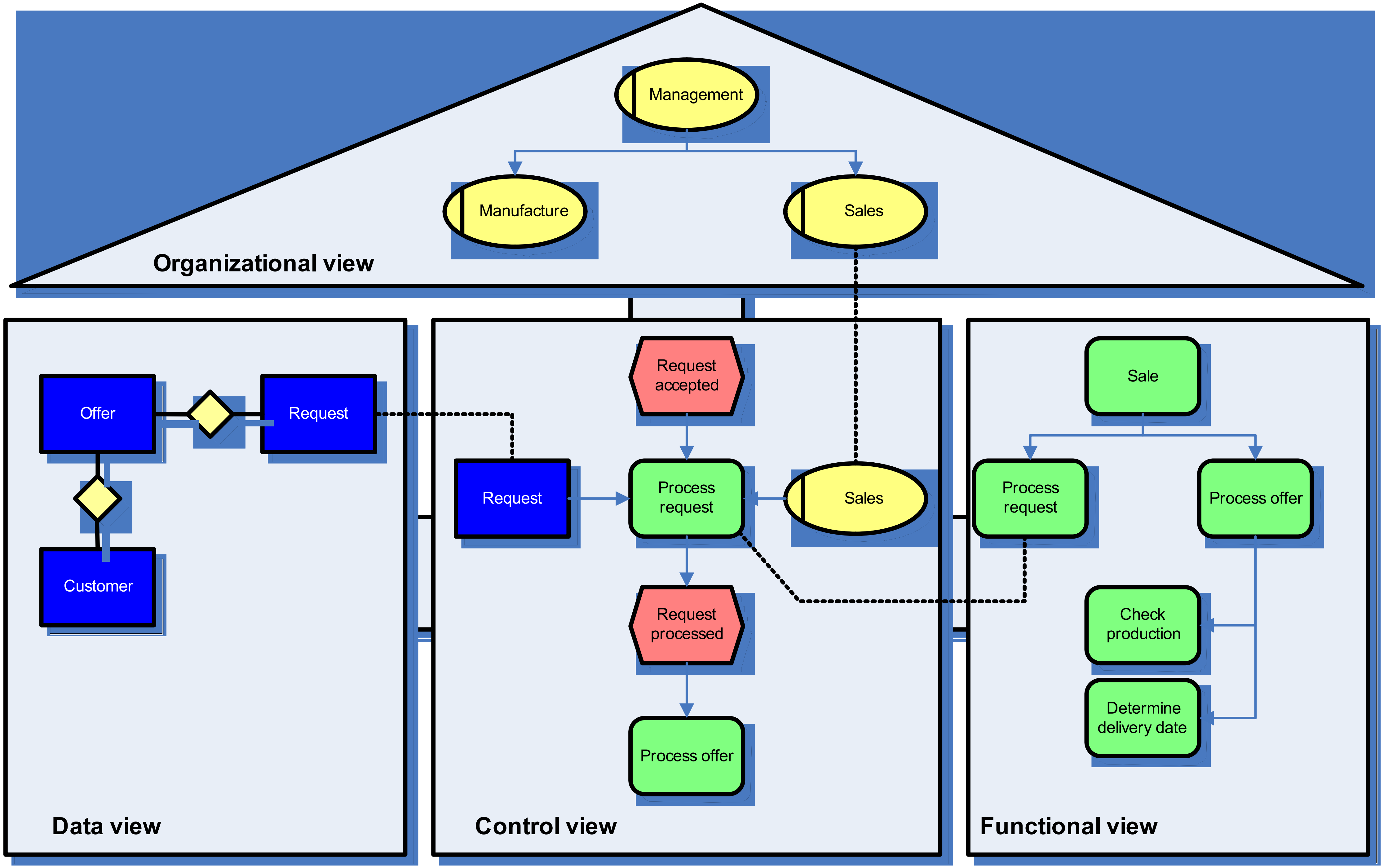
Software Tools

- ARchitecture of Integrated Systems (ARIS)
- Business Process Studio (BP Studio)

Architecture of Integrated Systems

- **Conceptual Framework** that helps to describe organizations: their organizational structure, their processes and their resources in terms of people and information systems.
- **Software tool** that helps to apply the conceptual framework. The software tool helps to electronically describe organizations in a consistent manner and analyze them in some respects.
- More at … http://www.ids-scheer.com

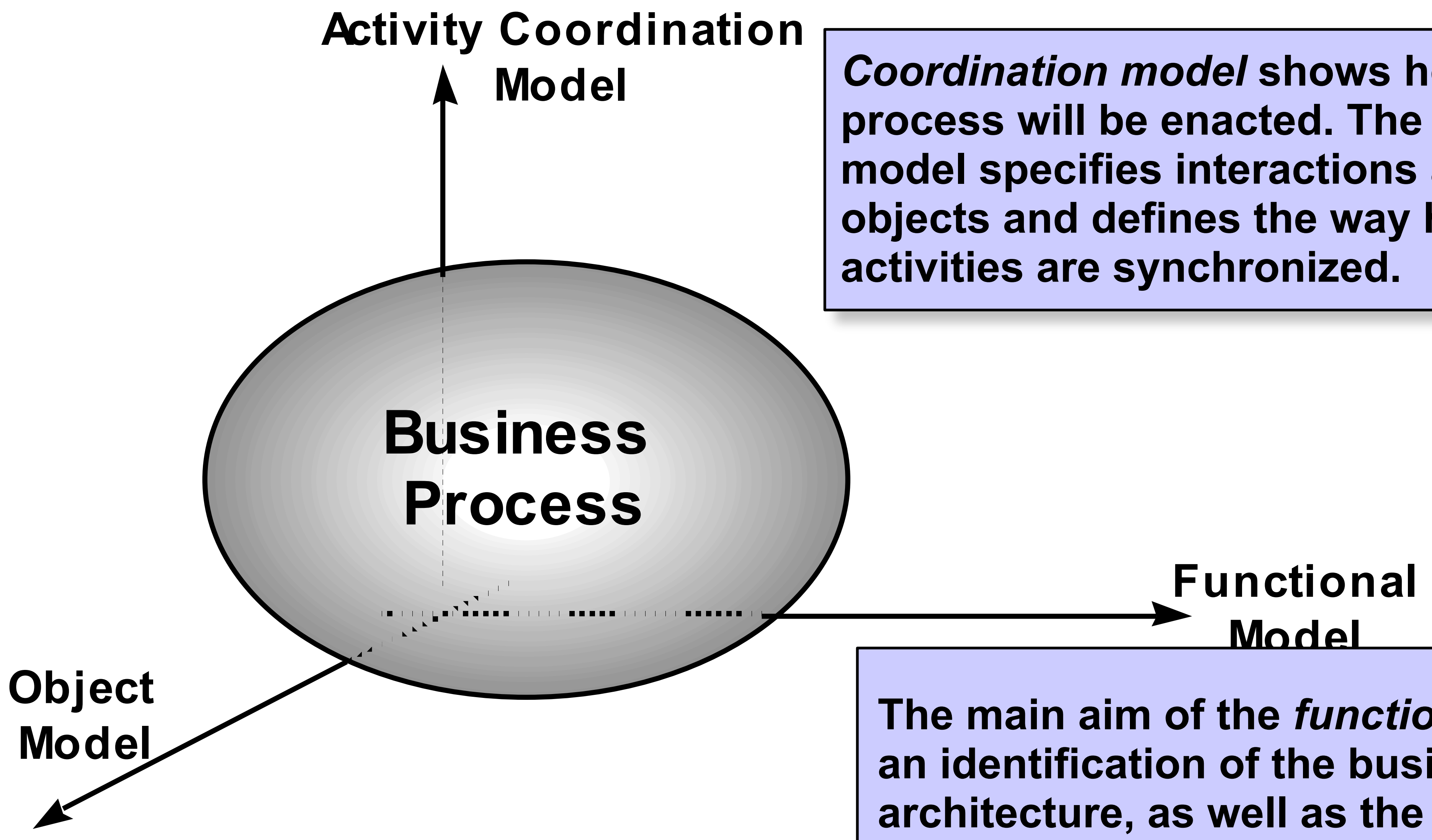
ARIS Framework



Business Process Studio

- BPStudio is user friendly, so domain experts without a special knowledge of information technology can use it.
- BPStudio is based on a formal approach (Petri Nets) that enables analysis, simulation, and later execution of a built model (workflow engine).
- BPStudio is focused on concurrency as a primary and inherent property of any business process
- Download … http://vondrak.cs.vsb.cz/download.html

Three Aspects of Business Modeling

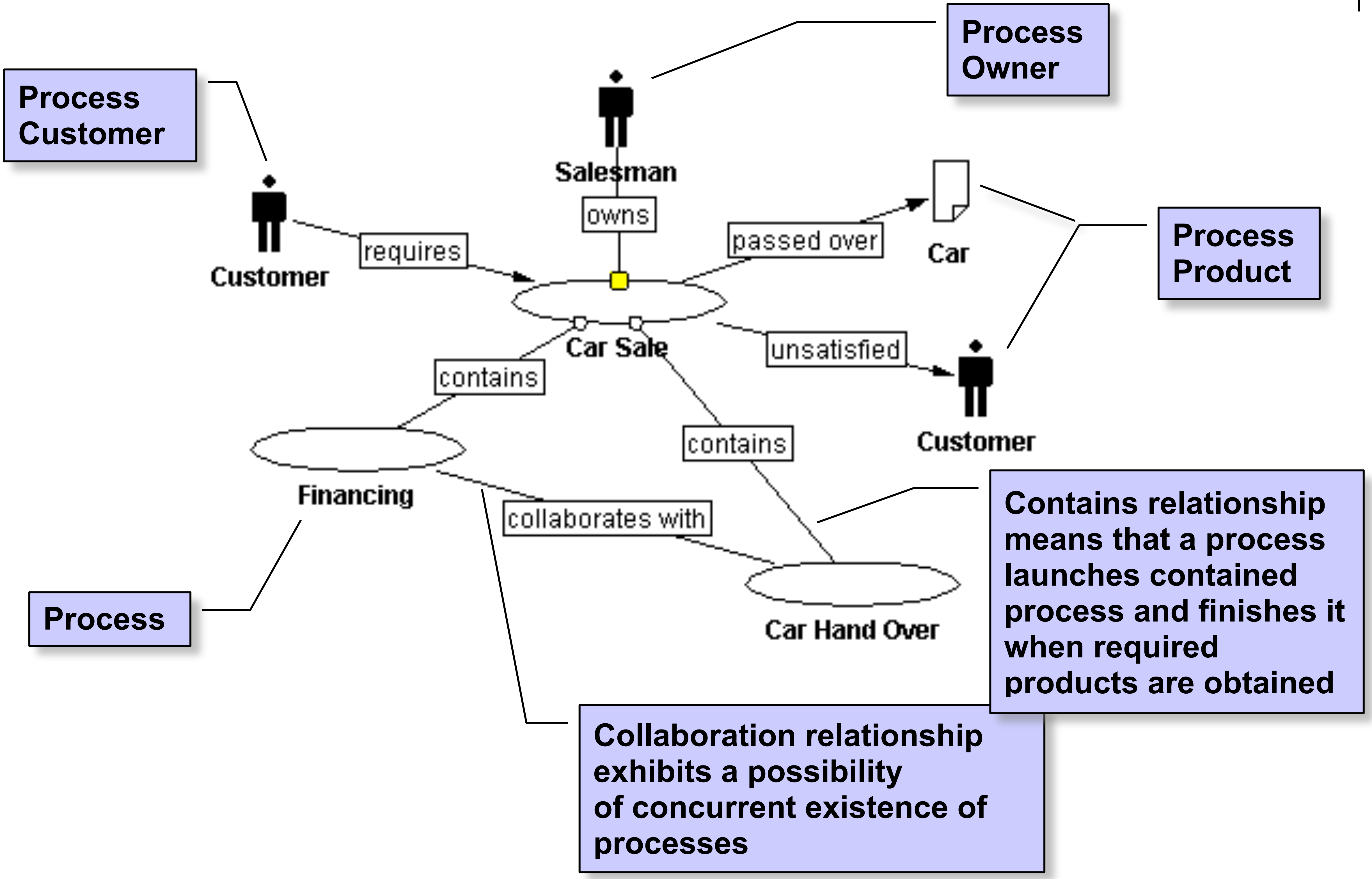


Coordination model shows how the process will be enacted. The coordination model specifies interactions among objects and defines the way how all these activities are synchronized.

The main aim of the *functional model* is an identification of the business process architecture, as well as the identification of process customers and products.

Object model identifies static structure of all entities (objects) that are essential for the enactment of the process.

Functional Model: Car Sale



Process Customer

Process Owner

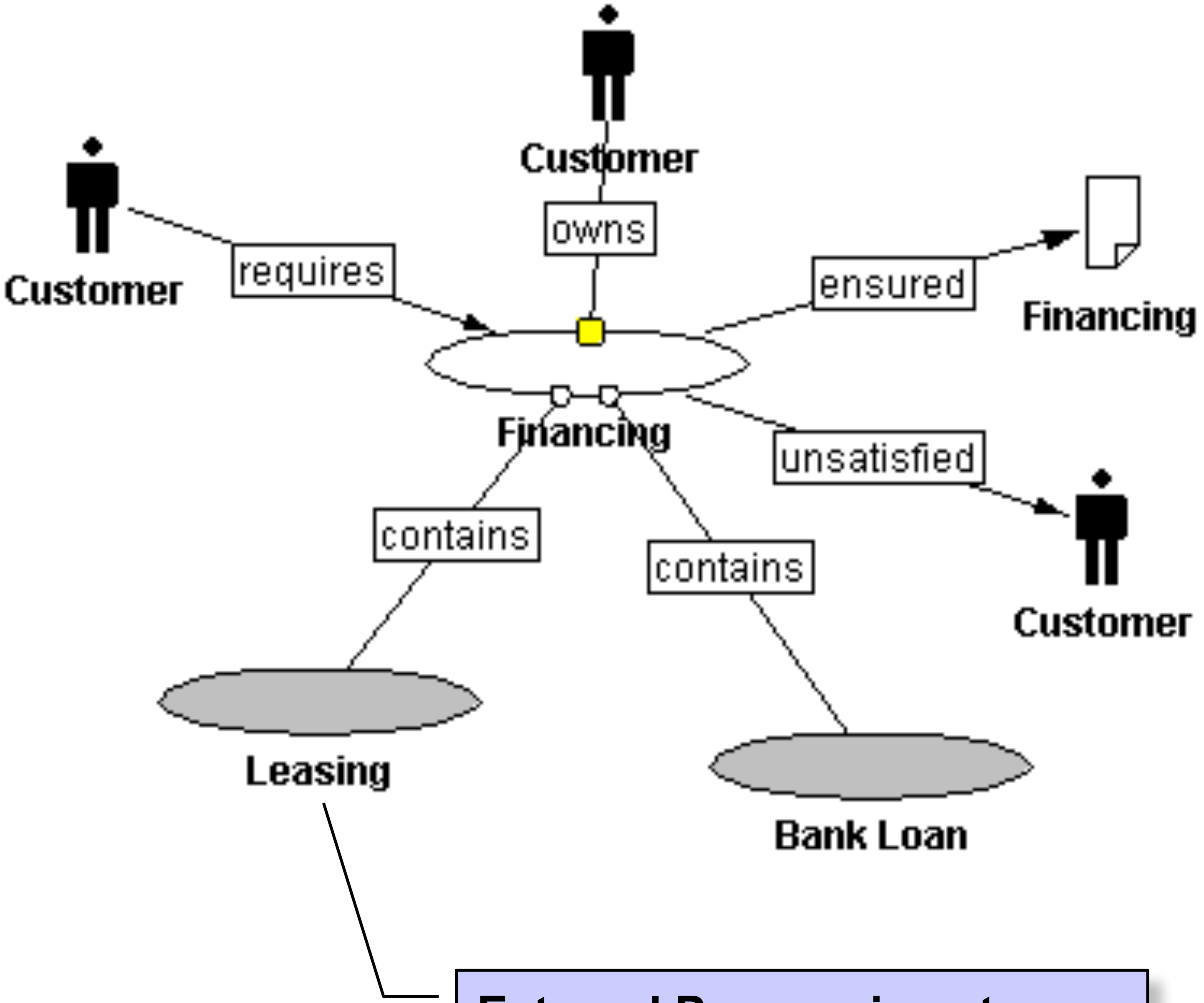
Process Product

Process

Contains relationship means that a process launches contained process and finishes it when required products are obtained

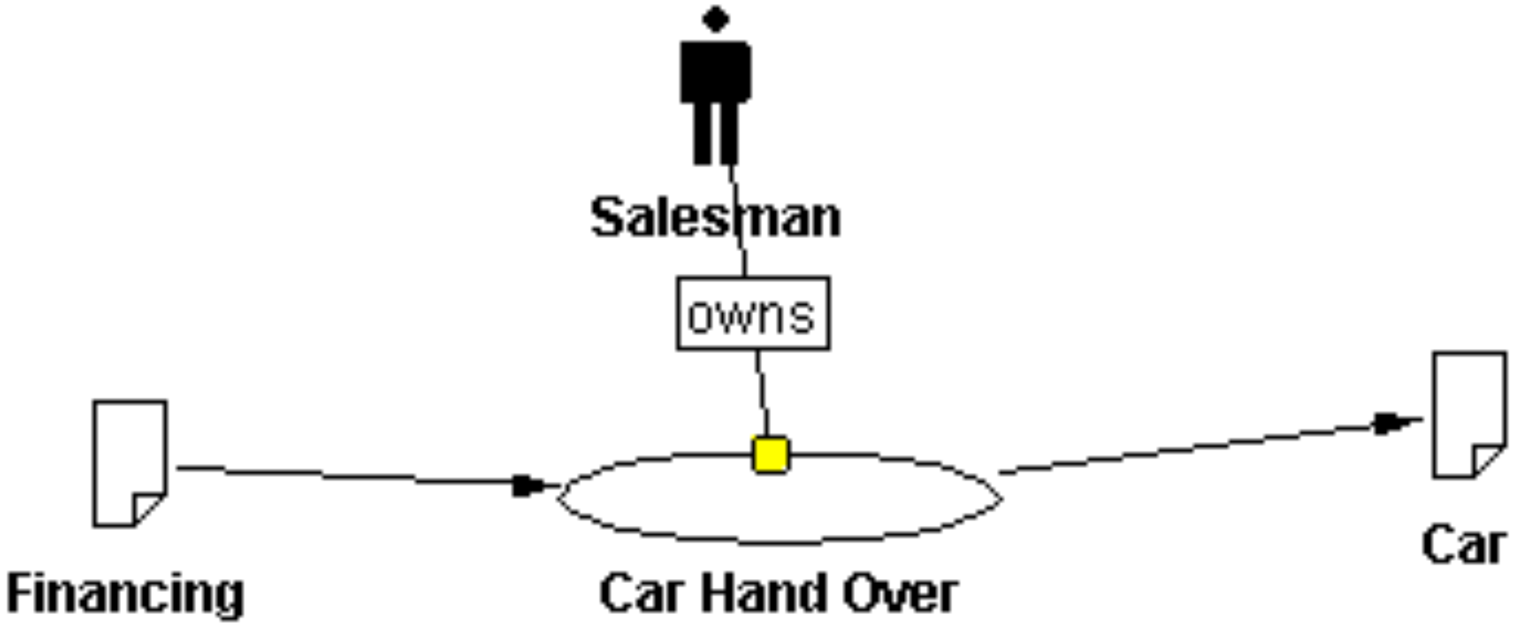
Collaboration relationship exhibits a possibility of concurrent existence of processes

Functional Model: Financing

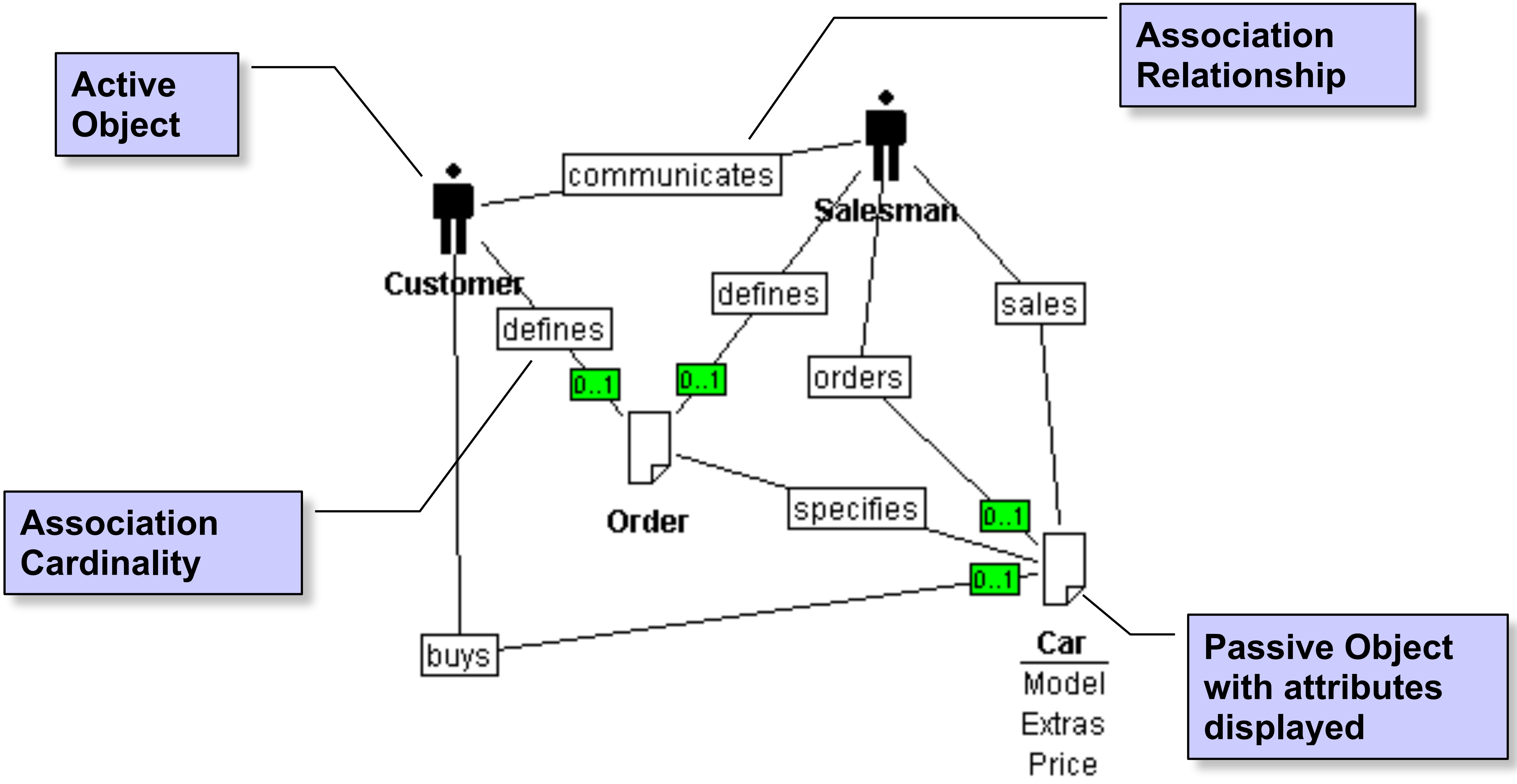


External Process is not elaborated in a given “Car Sale” process model

Functional Model: Car Hand Over



Object Model: Car Sale



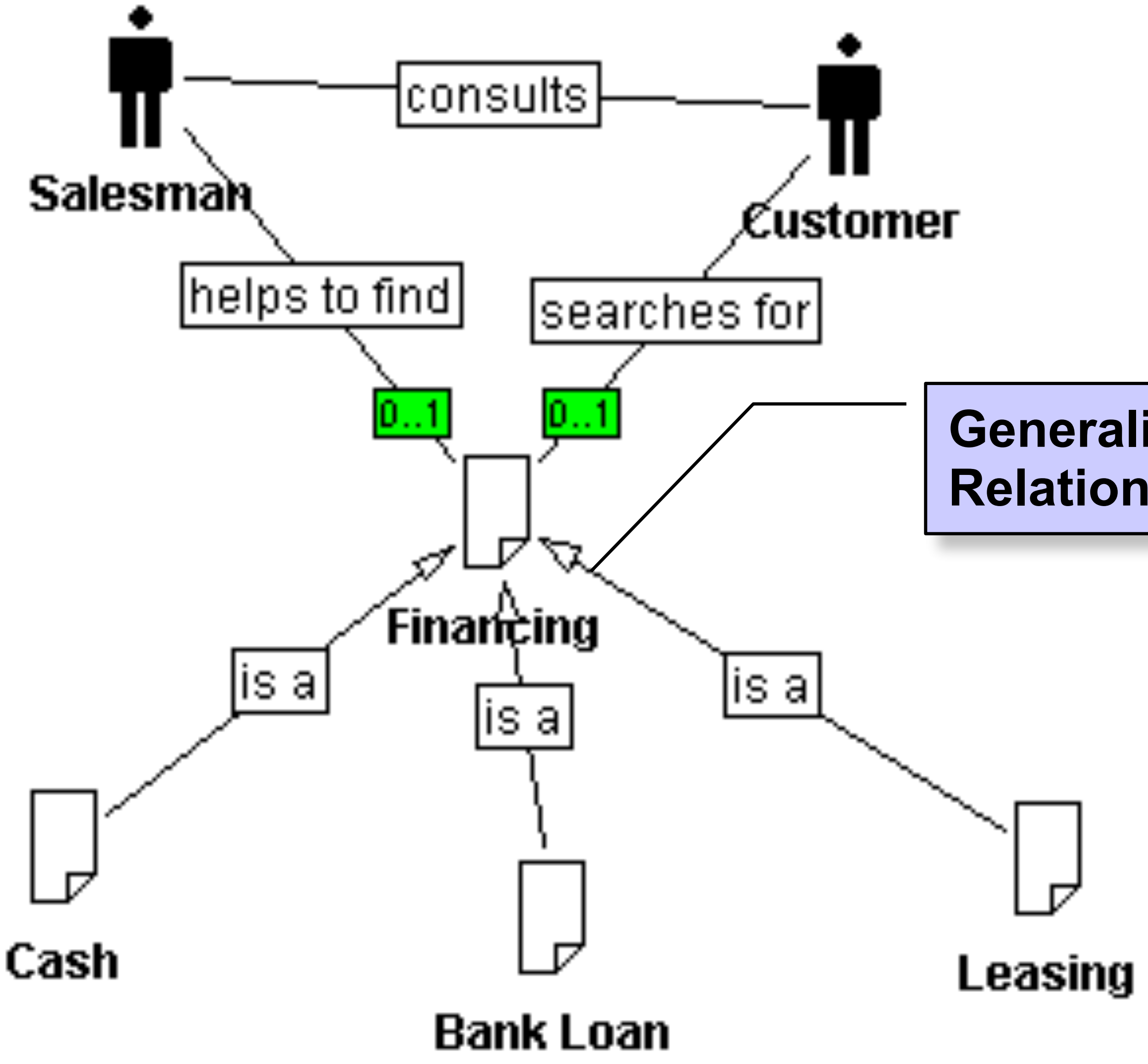
Active Object

Association Relationship

Association Cardinality

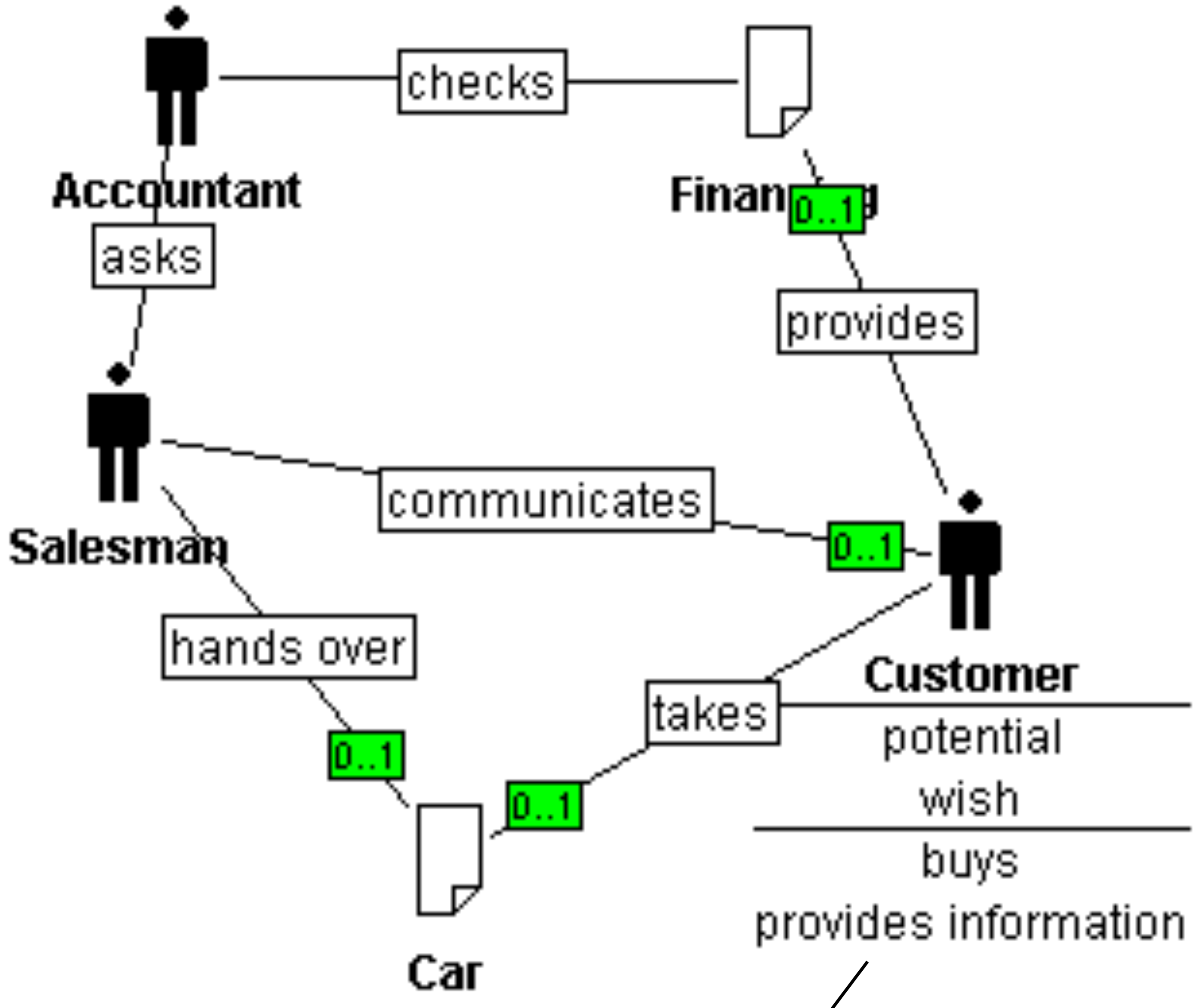
Passive Object with attributes displayed

Object Model: Financing



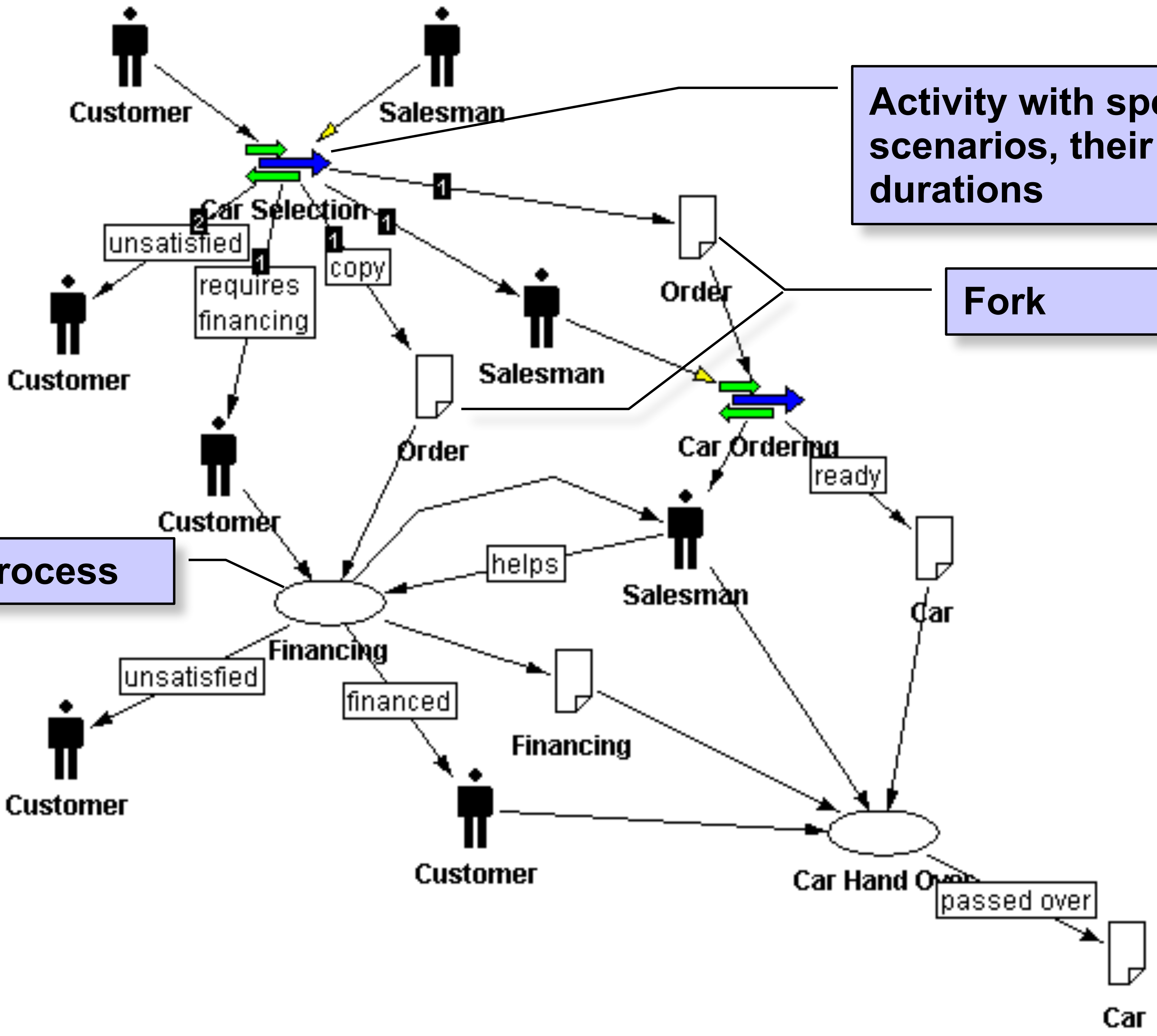
Generalization/Specialization Relationship

Object Model: Car Hand Over



Active Object with attributes and services displayed

Coordination Model: Car Sale

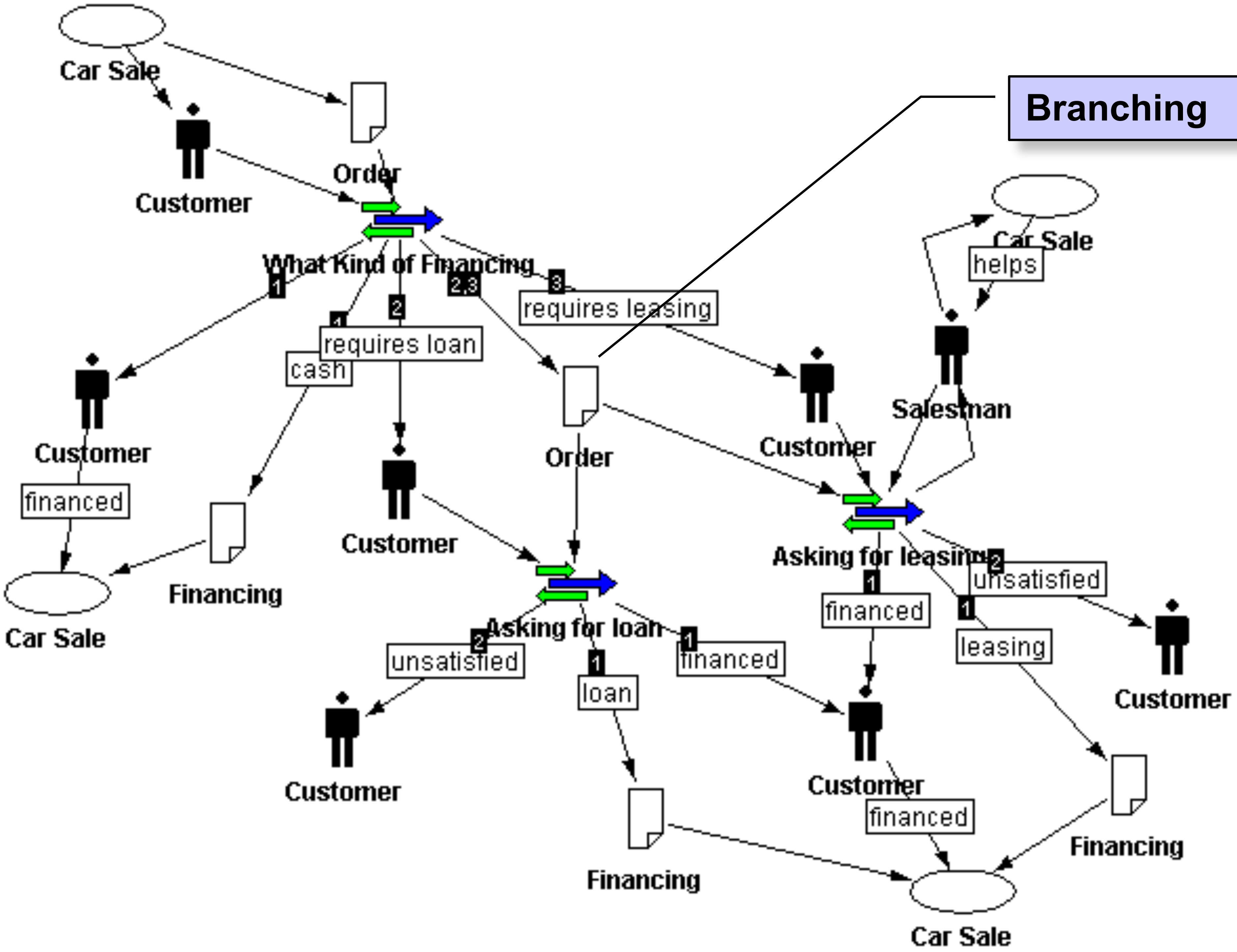


Activity with specified scenarios, their costs and durations

Fork

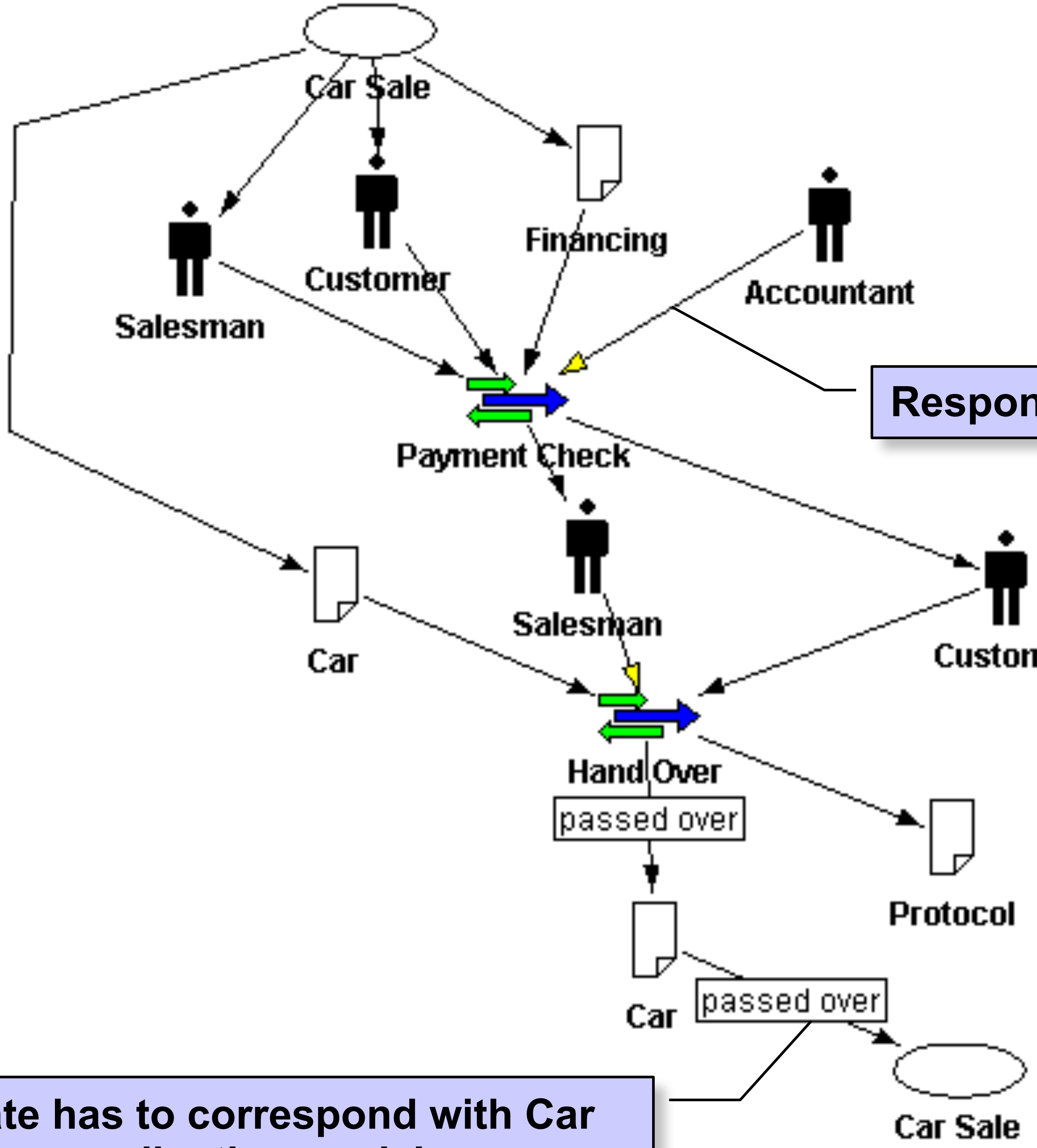
Contained process

Coordination Model: Financing



Branching

Coordination Model: Car Hand Over



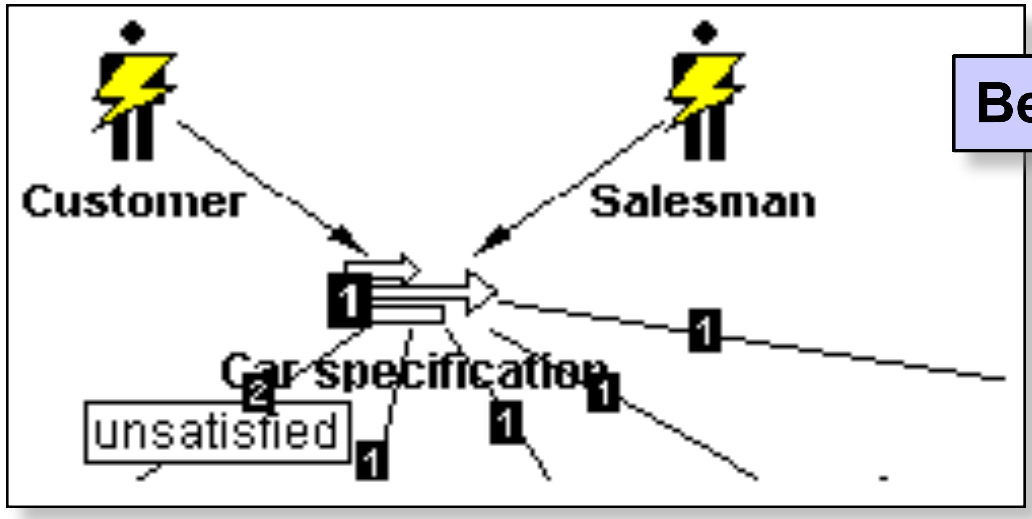
Responsibility

State has to correspond with Car Sale coordination model

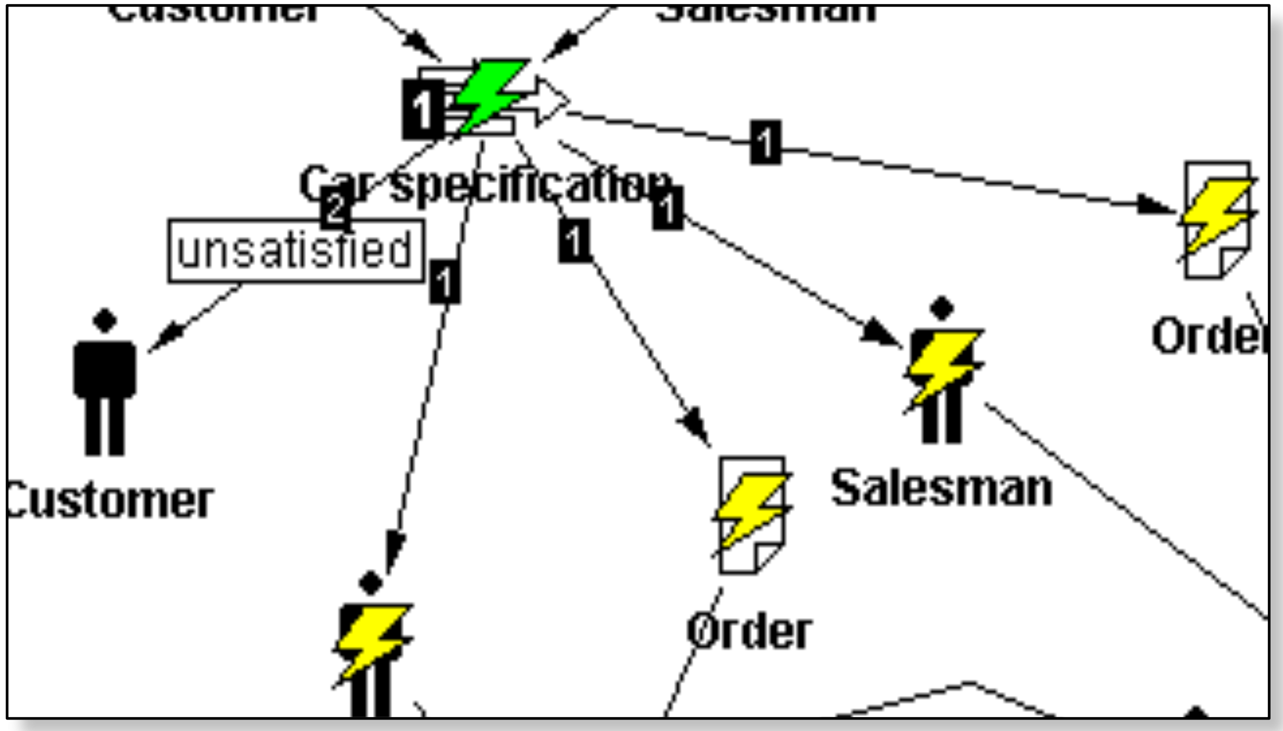
Structural Analysis

- What activities define the process
- What activities and processes the active object participates in
- What activities and processes the active object is responsible for
- What activities and processes manipulate, consume or produce the passive object

Simulation



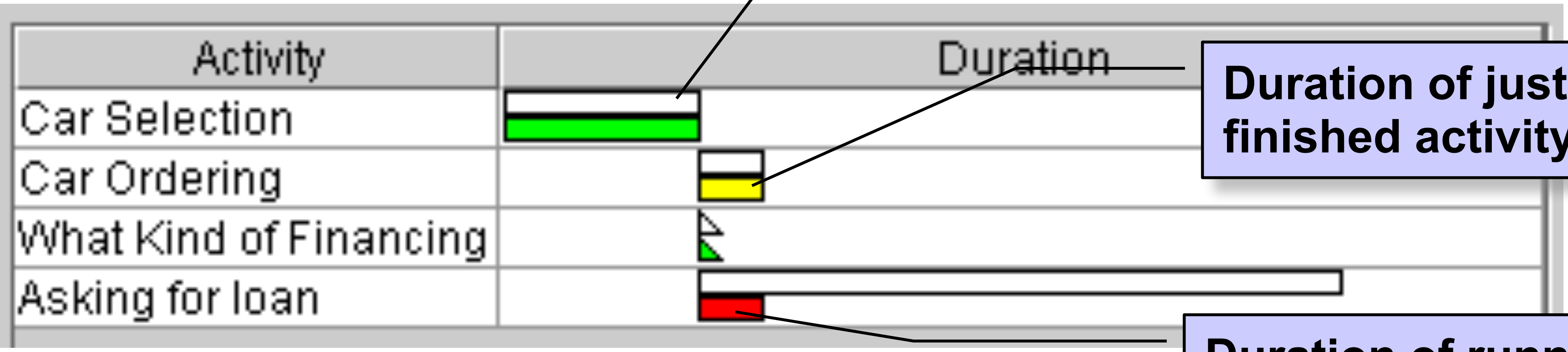
Before activity execution



After activity execution

- Verification
- Validation
- Costs analysis
- Time analysis

Simulation Result

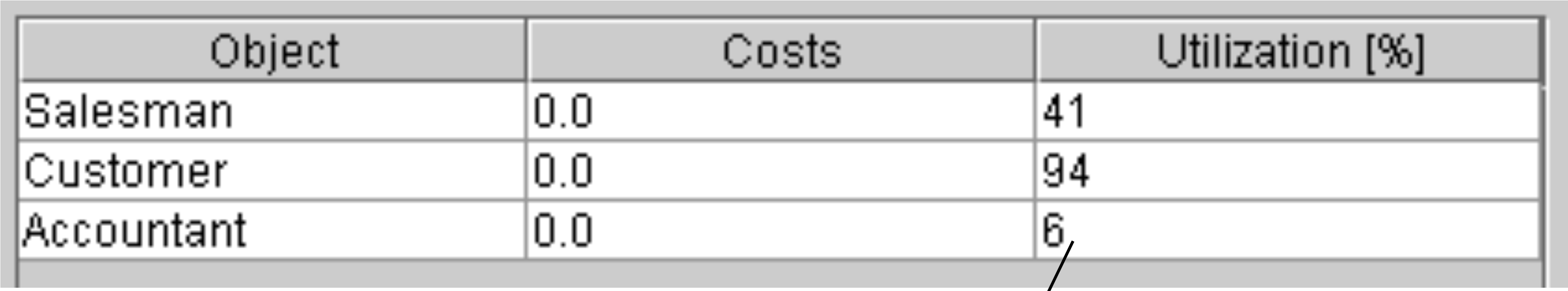


Activity	Duration
Car Selection	🟩
Car Ordering	🟨
What Kind of Financing	
Asking for loan	🟥

Predicted duration

Duration of just finished activity

Duration of running activity

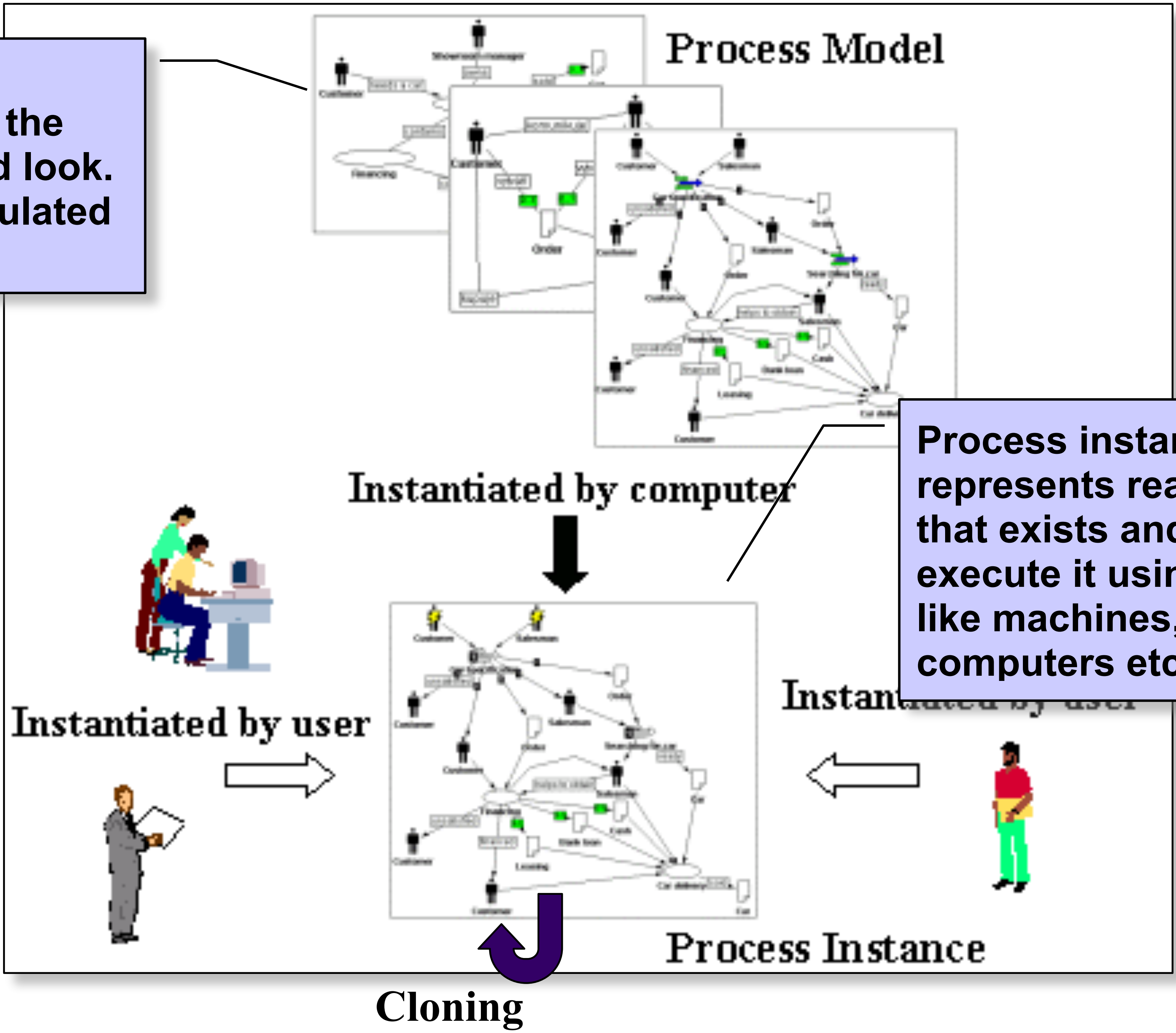


Object	Costs	Utilization [%]
Salesman	0.0	41
Customer	0.0	94
Accountant	0.0	6

Utilization means how much time object spent in a process compared to the process total time.

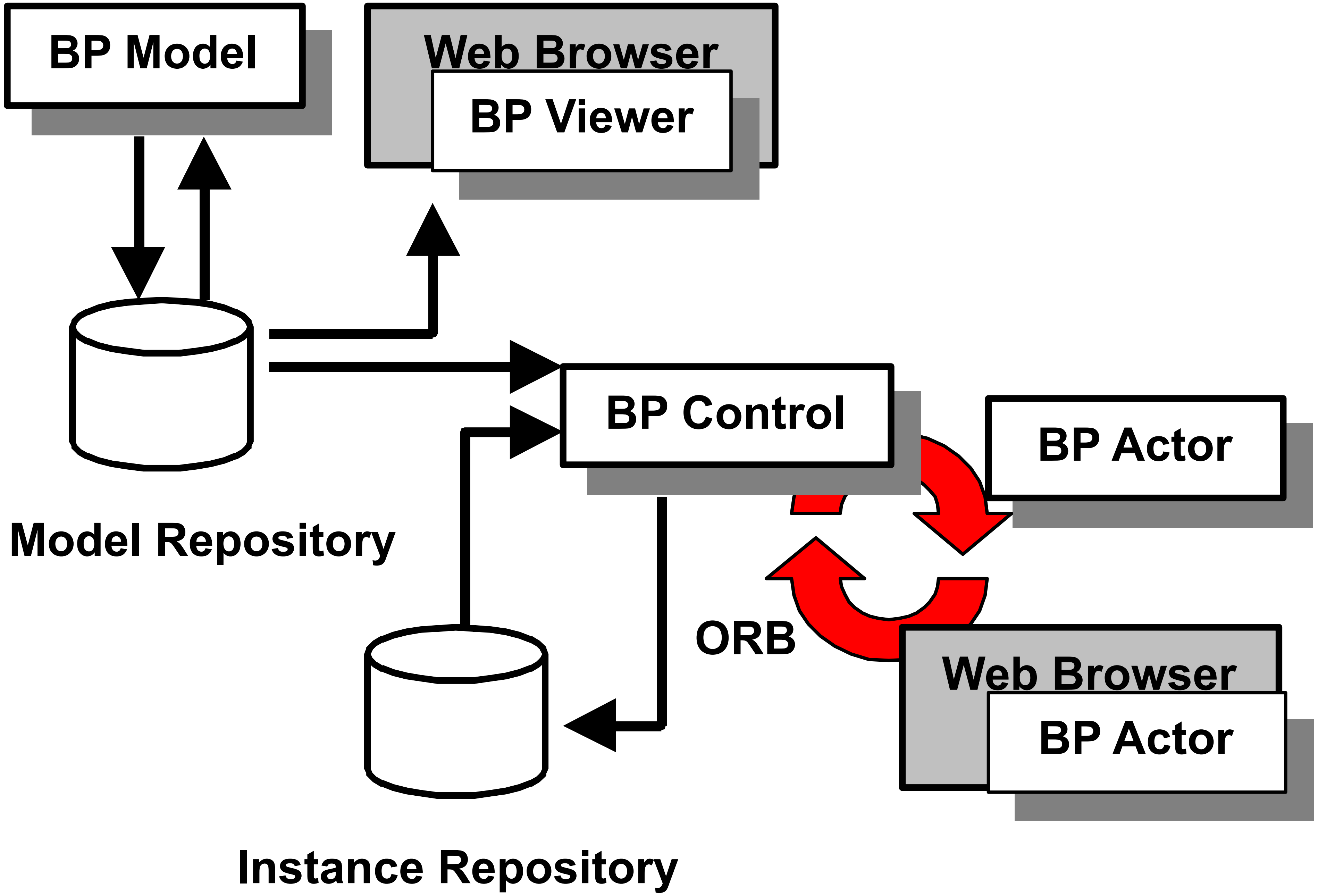
Process Enactment

Process model describes how the process should look. Process is simulated by a computer.



Process instance represents real process that exists and humans execute it using tools like machines, computers etc.

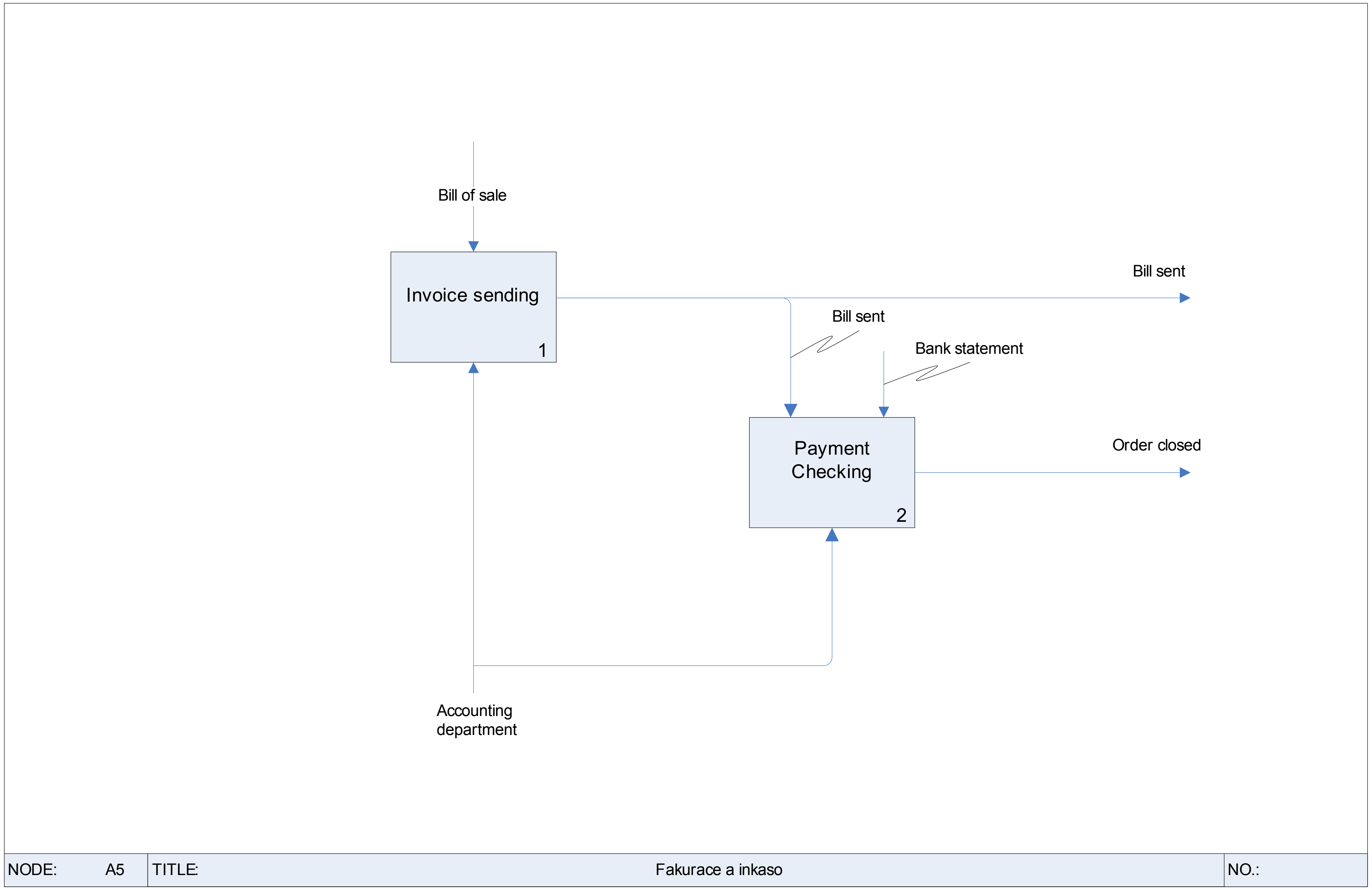
BPStudio Architecture



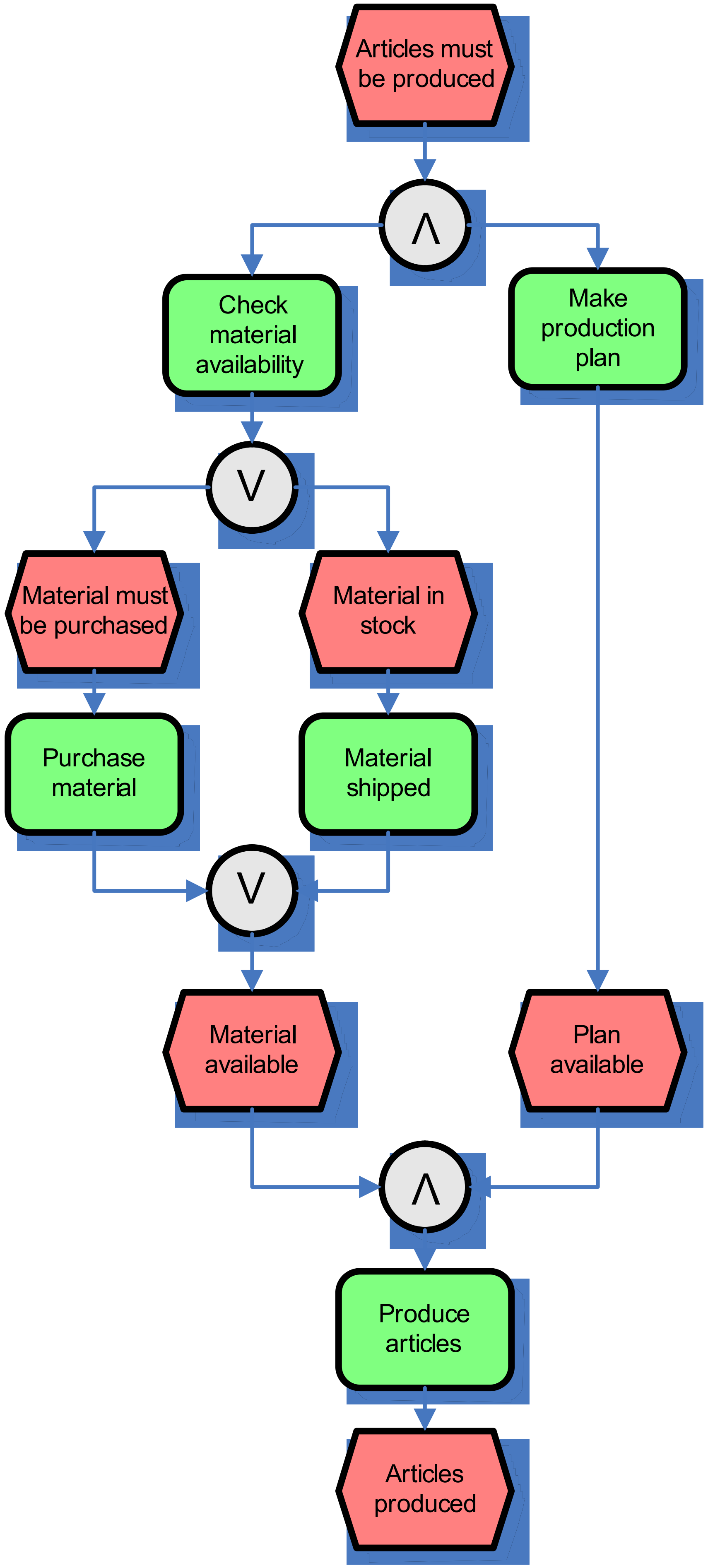
Conclusions

- Common methods for business modeling were introduced: IDEF, EPC and UML.
- Importance of formal methods and their contribution to business process modeling were demonstrated.
- Software tools ARIS and BPStudio were introduced to show how eEPC and Petri Nets can be used in practice.

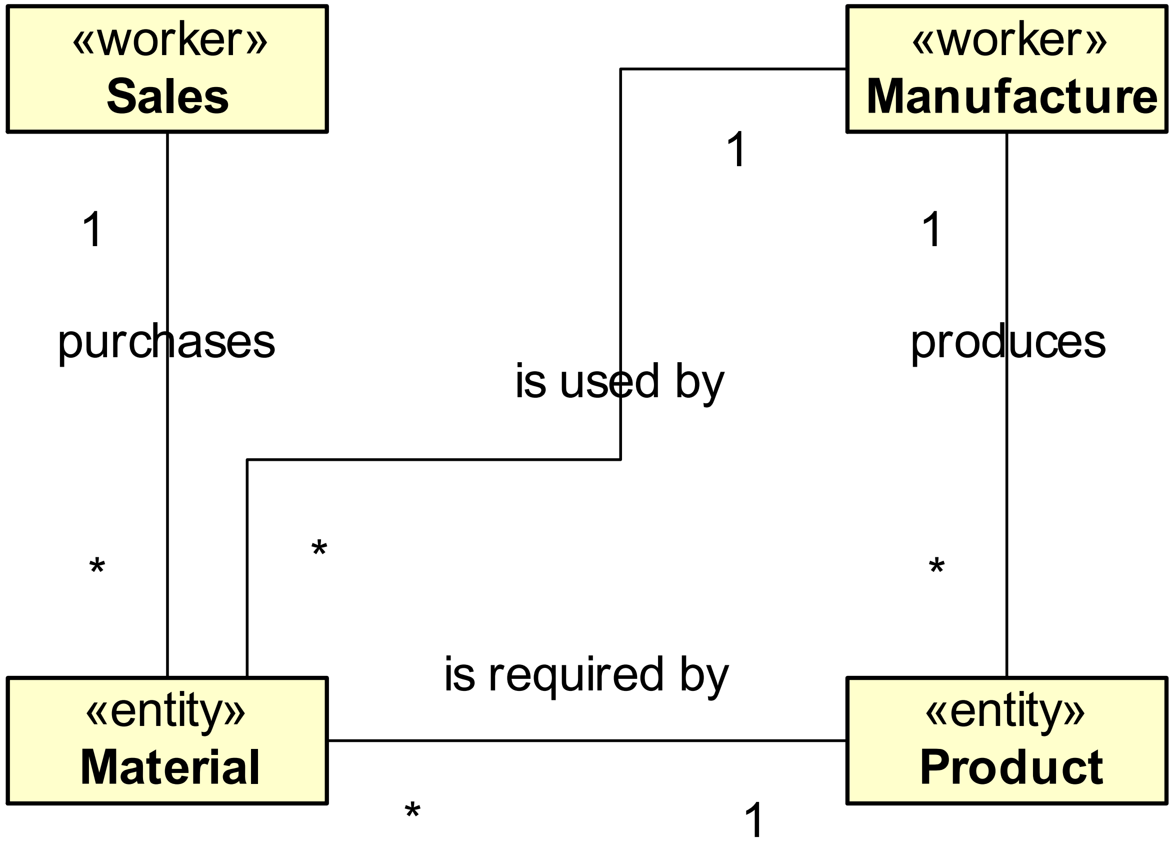
Solution to Exercise 1



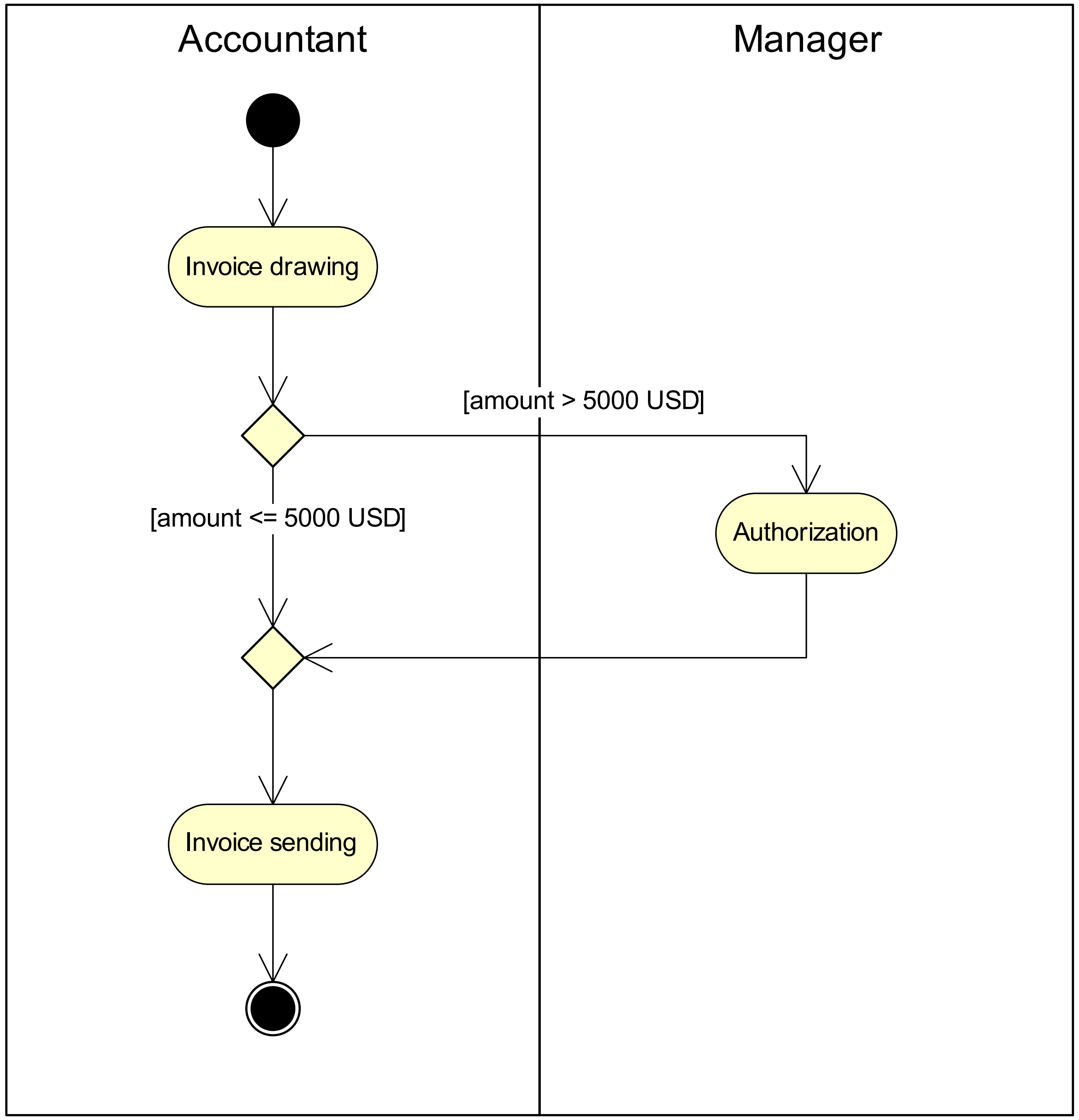
Solution to Exercise 2



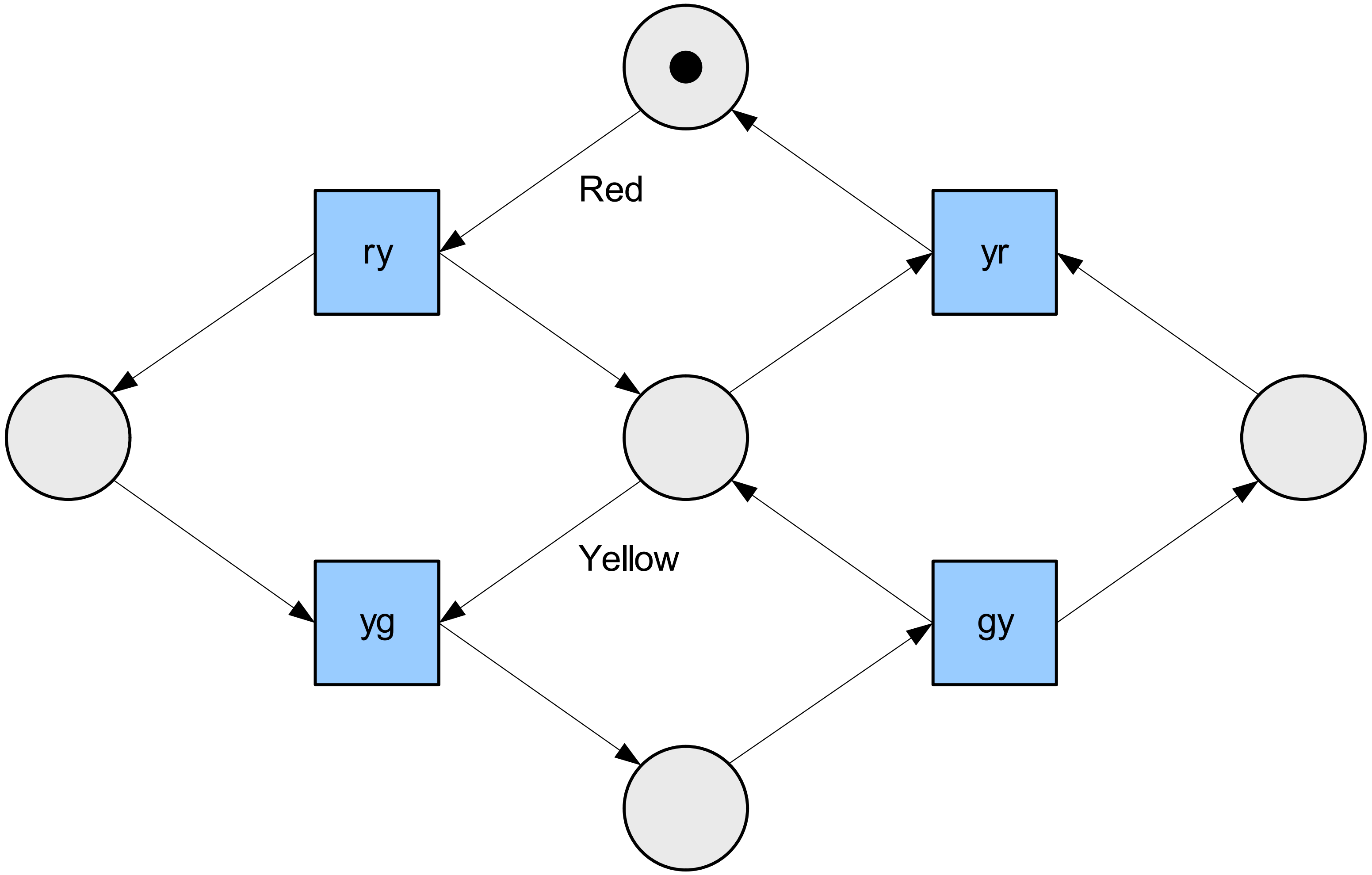
Solution to Exercise 3



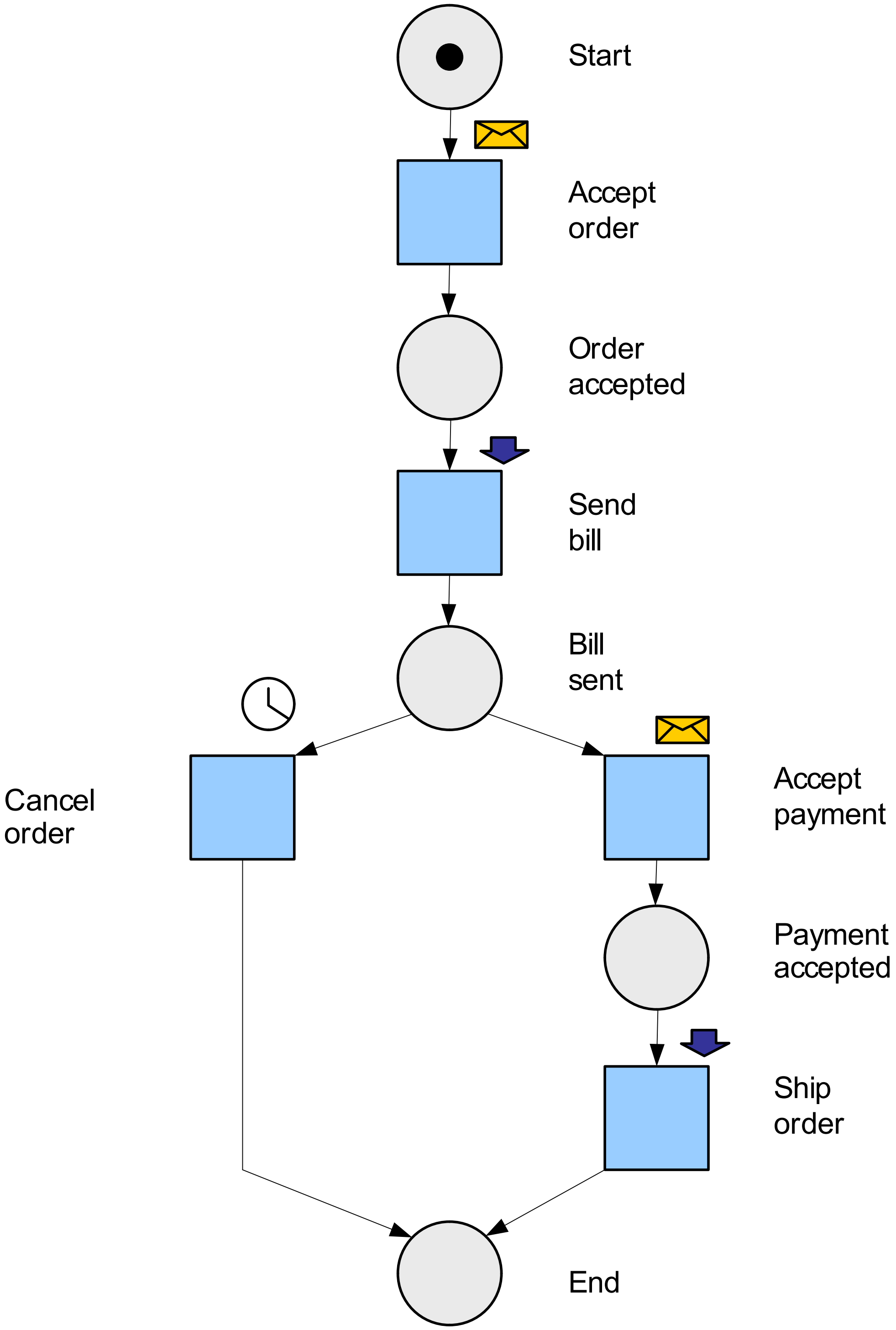
Solution to Exercise 4



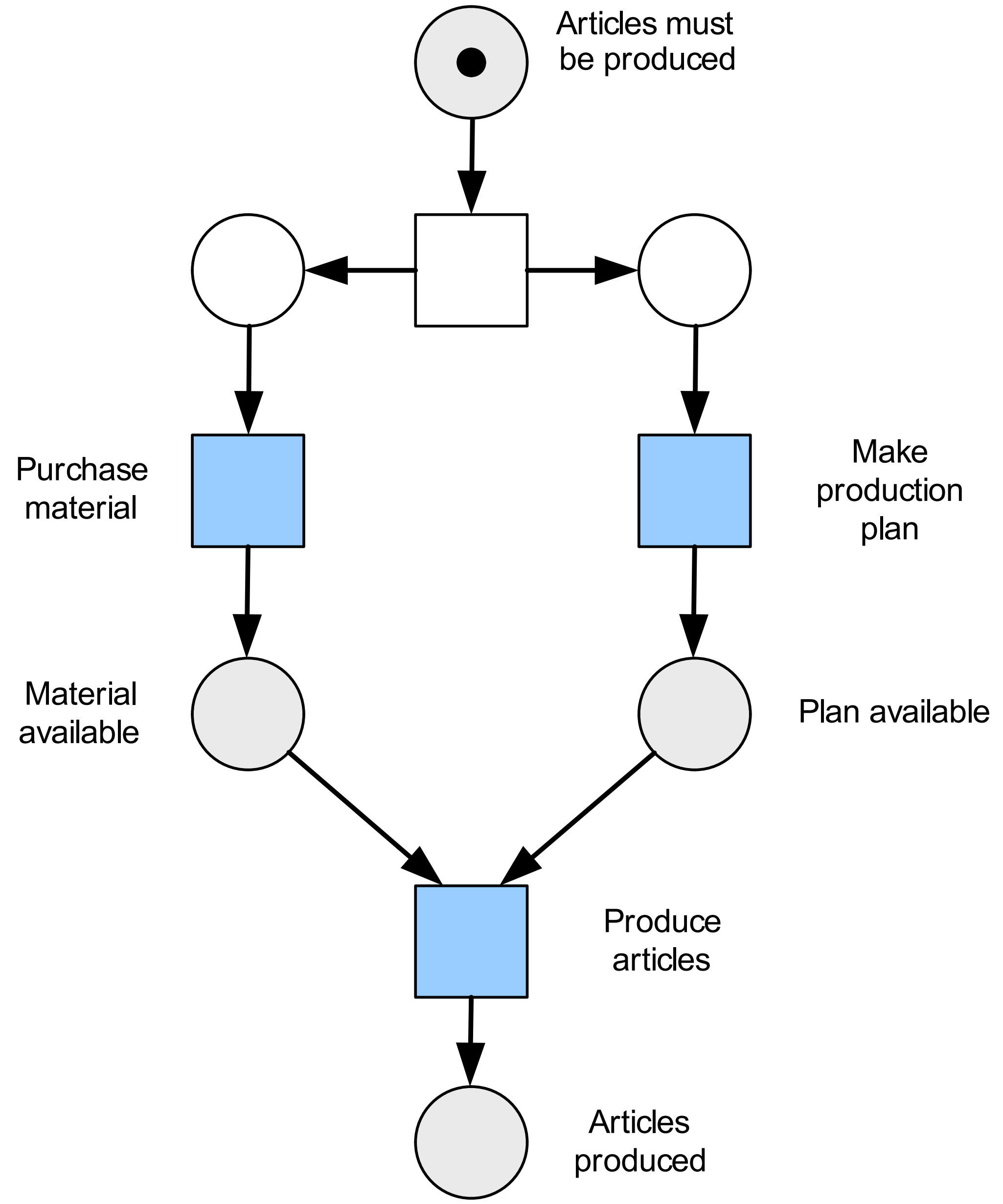
Solution to Exercise 5



Solution to Exercise 6



Solution to Exercise 7



The WF-Net is sound.