Performance Evaluation of Business Processes through a Formal Transformation to SAN

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Agenda

1. **Business Processes**
   - Modeling and Analysis
   - Performance Evaluation: Challenges and Objectives
2. **Modeling Techniques Used in this Work**
   - Business Process Model and Notation
   - Stochastic Automata Networks
3. **Automated Conversion from Business Process Models to SAN**
   - Structure of BPMN and SAN Models and their Operations
   - Conversion Algorithm (Example)
4. **Conclusion**
   - Contributions and Discussion
   - Other Related Works

Business Process Management

Techniques, languages and tools to support process life cycle

- Design, Execution, Monitoring, **Analysis**

Why it is important to analyze business processes?

- They are everywhere (e-commerce, e-government, production)
- Thousands of people depend on their reliability

Qualitative Analysis $\times$ Quantitative Analysis

- Verification (syntactical correction)
- Validation (semantical correction)
- **Performance analysis**

Performance Analysis of Business Processes

Common performance indices

- Responsiveness – service and waiting times
- Productivity – throughput
- Utilization – utilization rate of resources
- Quality of service, reliability

Possible approaches for performance evaluation

- Measuring
- Simulation
- **Analytical modeling**

Business Process Modeling

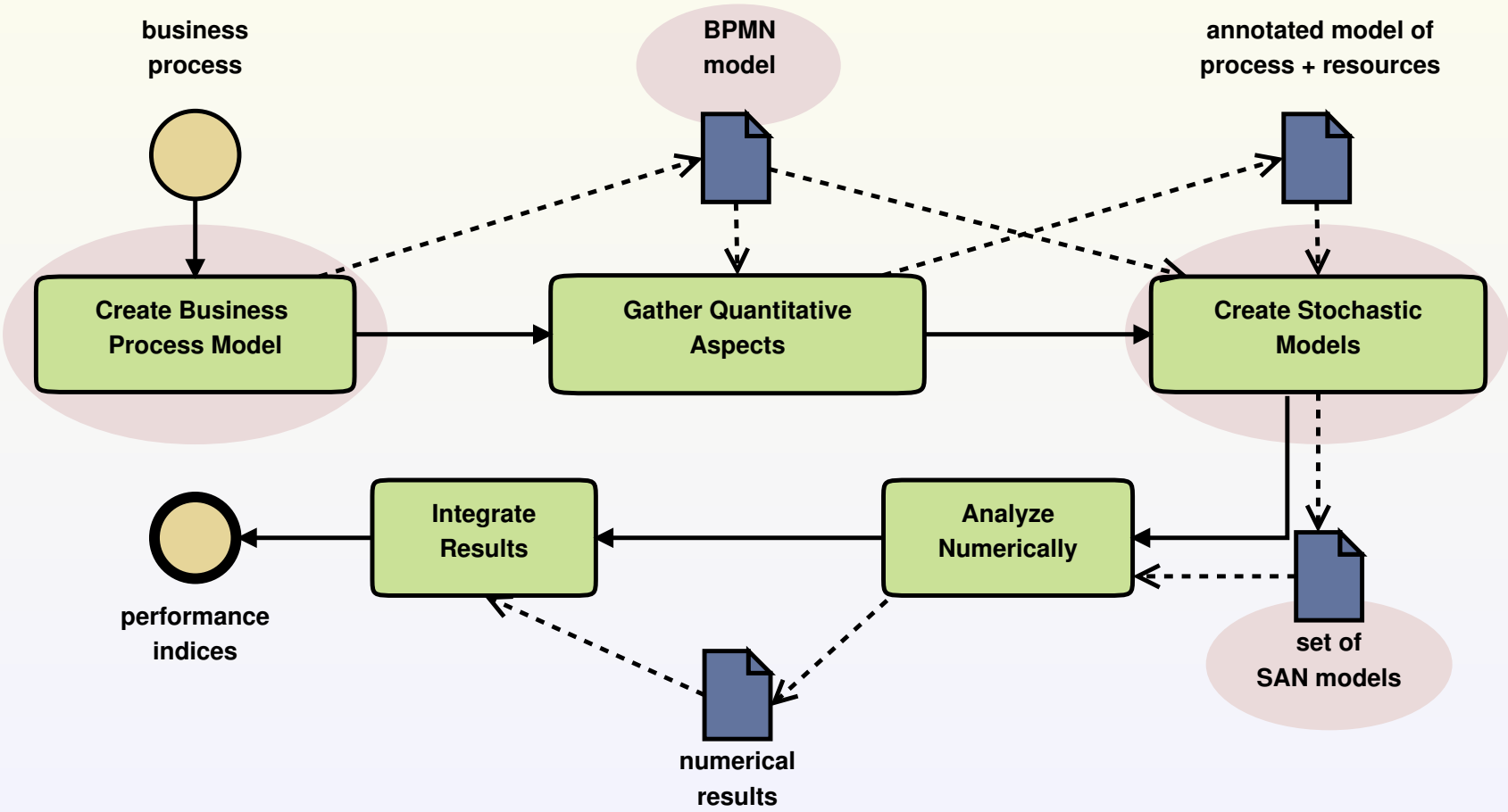
Domain-specific languages

- *Business Process Model and Notation* (BPMN), *Event-driven Process Chains* (EPC), *Unified Modeling Language* (UML)
- Do not have formal semantics and focus on control-flow
- Hard to model resources and quantify modeled behaviors

Our approach: automated conversion to stochastic models

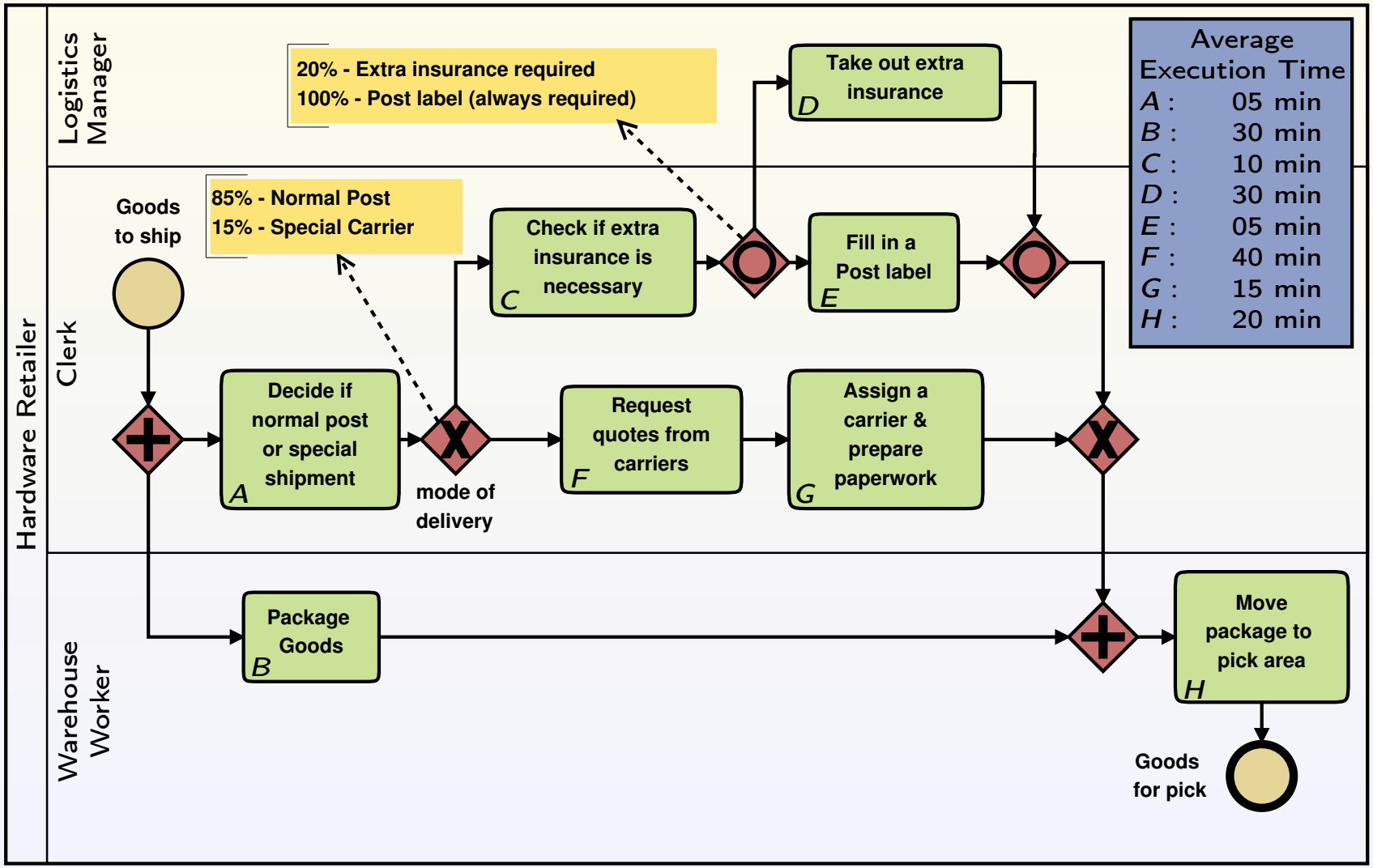
- BPMN $\Rightarrow$ SAN (*Stochastic Automata Networks*)
- Association of time with tasks
- Association of probabilities with alternative flows
- Characterization of resource usage

Performance Evaluation of Business Processes via Analytical Modeling



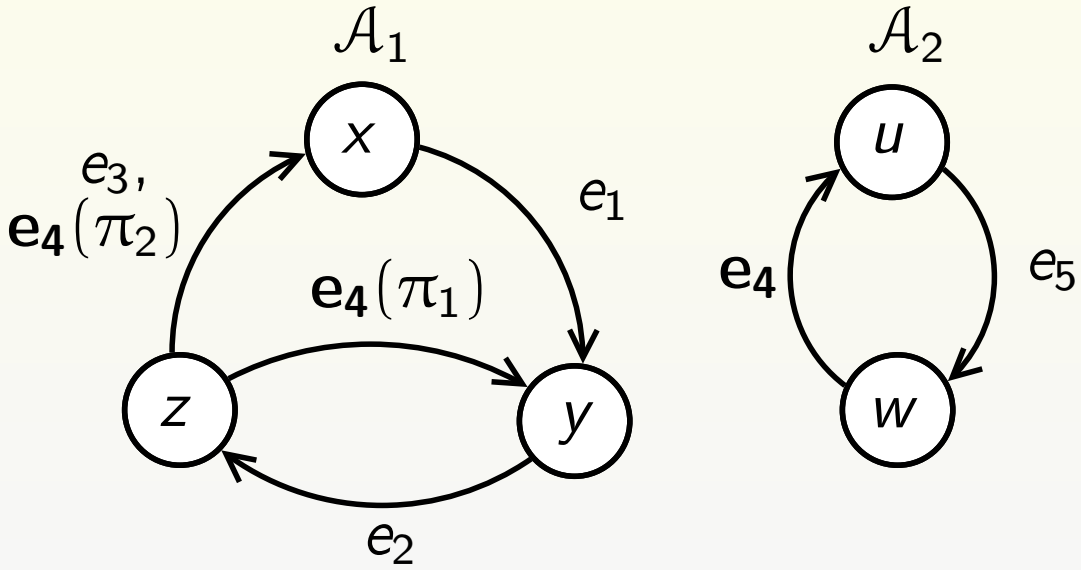
Business Process Model and Notation (BPMN)

Shipment Process of a Hardware Retailer



Stochastic Automata Networks (SAN)

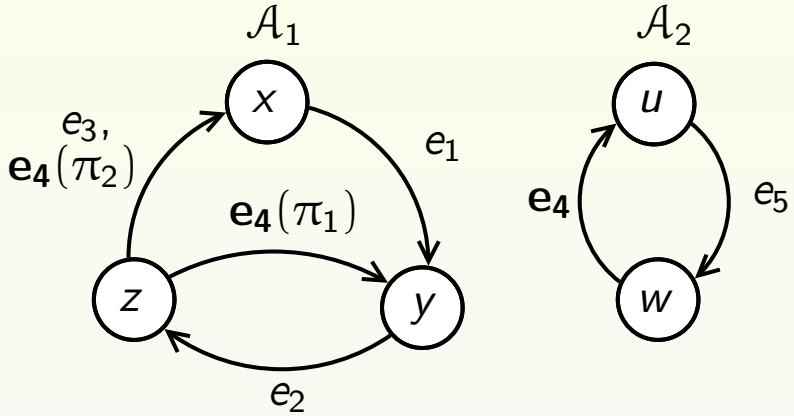
Example of a 2-Component System



Event	Rate
e_1	τ_1
e_2	τ_2
e_3	τ_3
$\mathbf{e_4}$	τ_4
e_5	f

$$f = \begin{cases} \lambda_1, & \text{if } \mathcal{A}_1 \text{ is in state } x \\ 0, & \text{if } \mathcal{A}_1 \text{ is in state } y \\ \lambda_2, & \text{if } \mathcal{A}_1 \text{ is in state } z \end{cases}$$

Underlying Continuous Time Markov Chain



Event	Rate
e_1	τ_1
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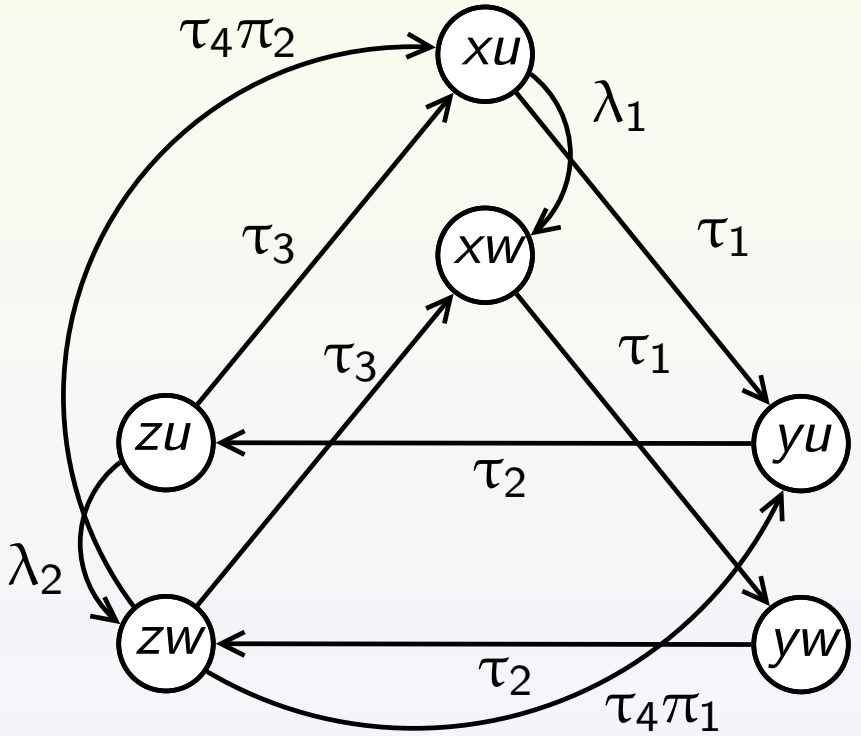
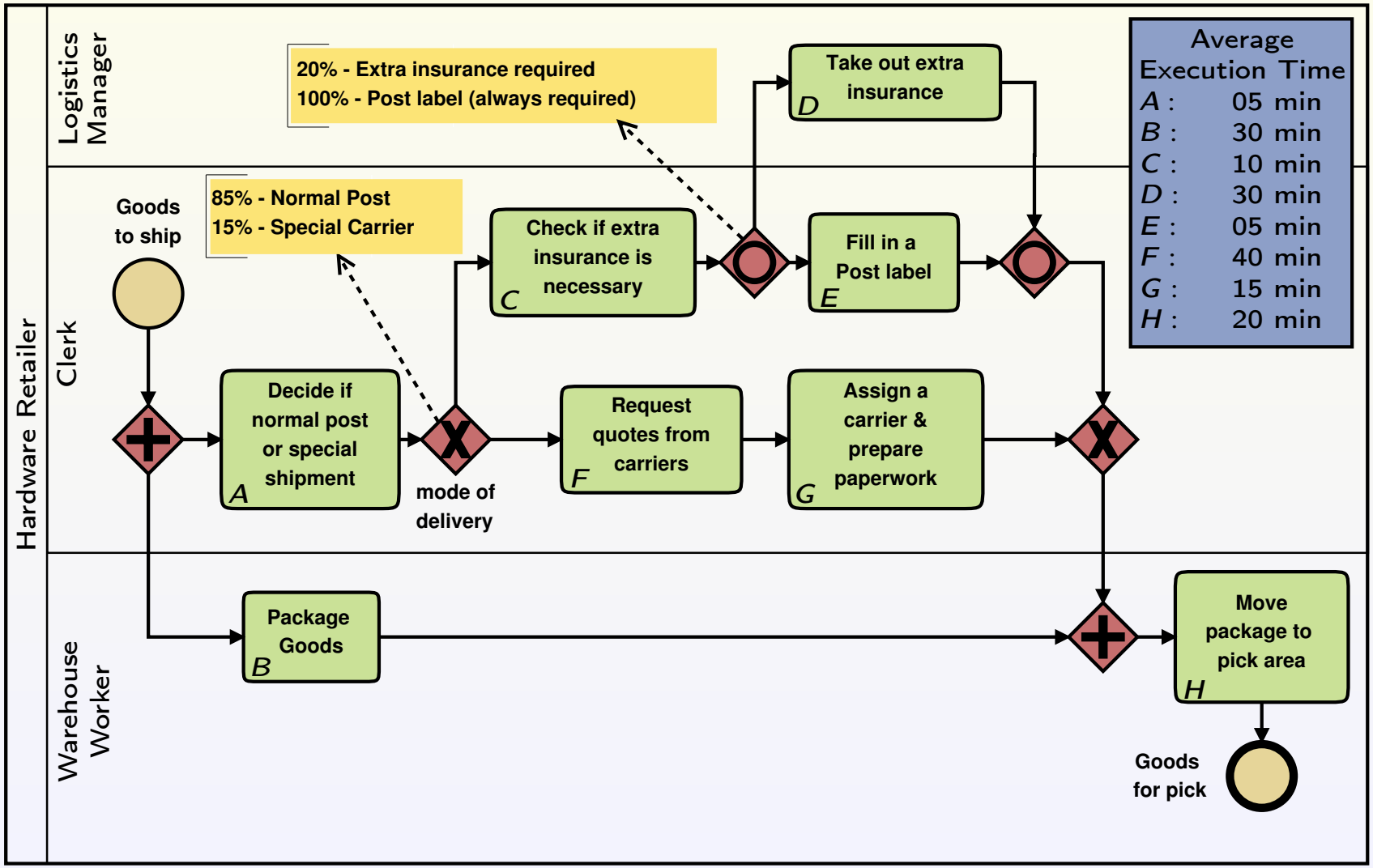


BPMN Process Graph

Shipment Process of a Hardware Retailer



BPMN Process Graph

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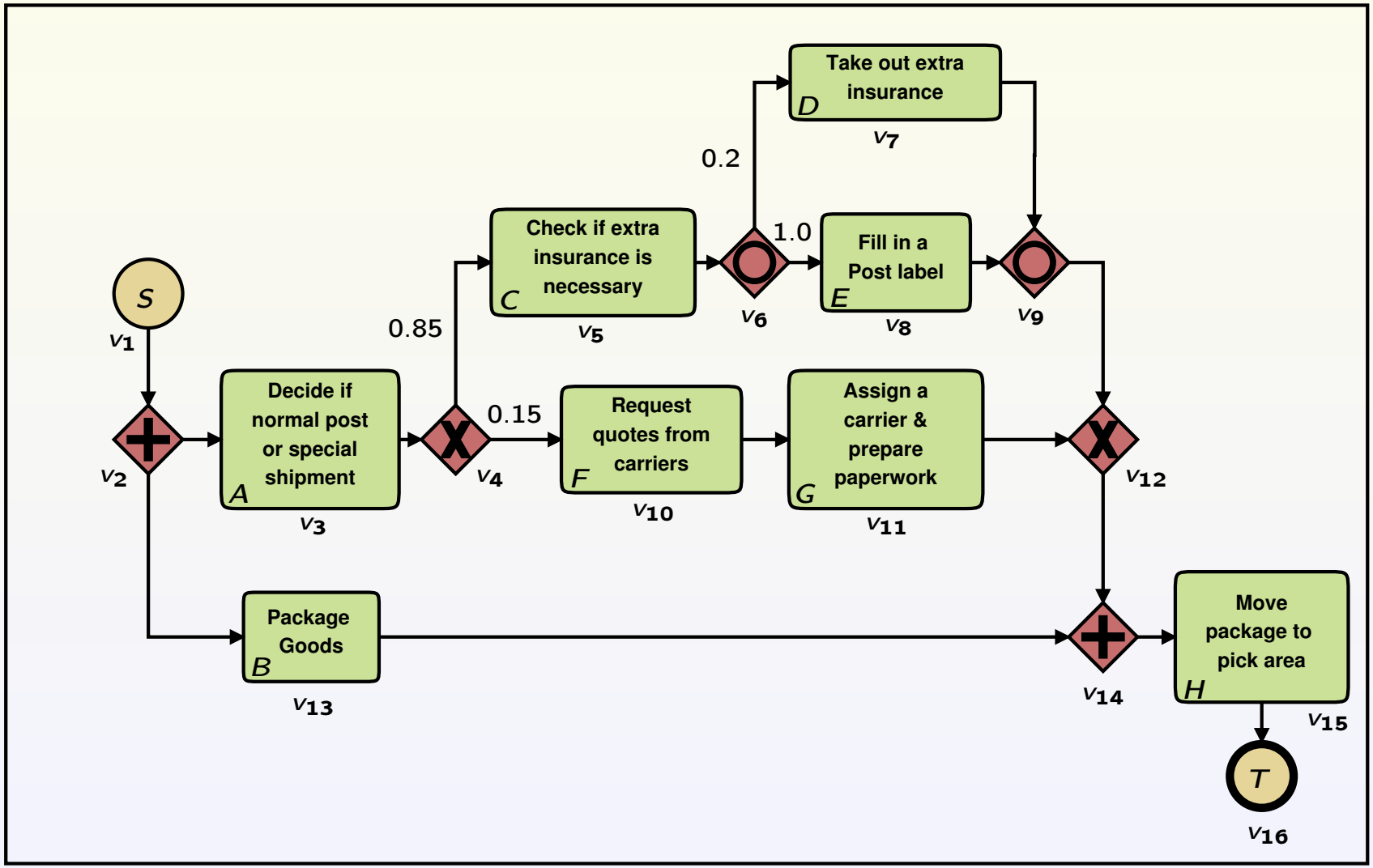
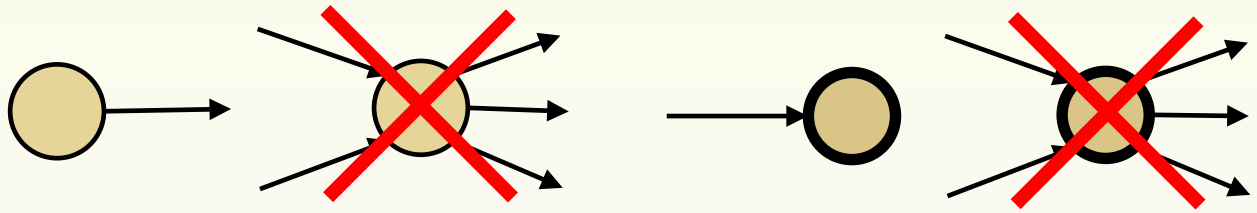
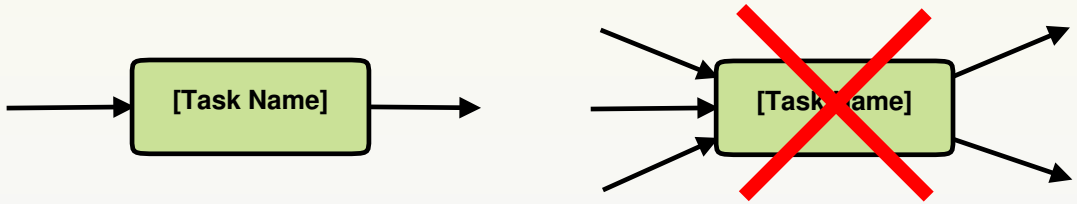


Well-Formed BPMN Process Graph

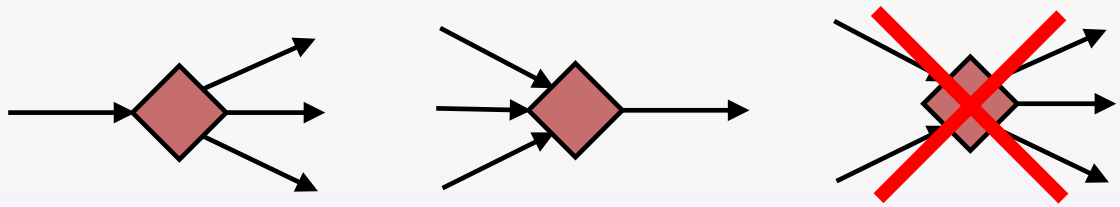
- Vertices accessible from start event / access end event
- Events



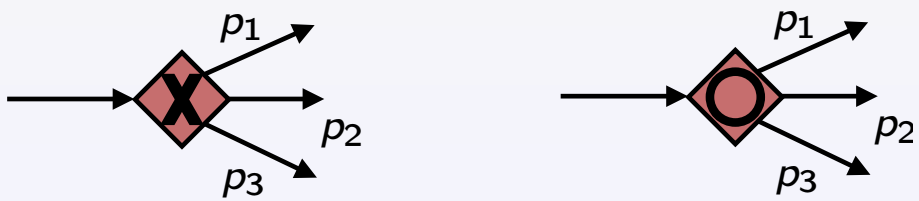
- Tasks



- Gateways



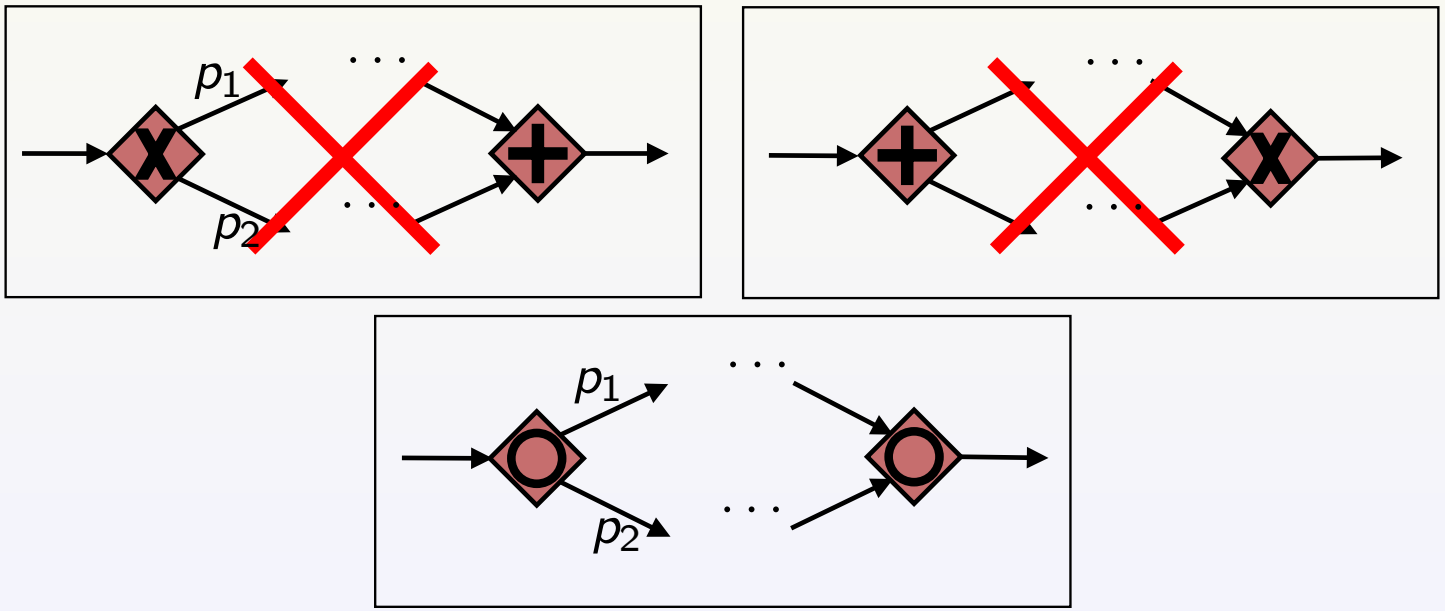
- Probabilities



$$p_1 + p_2 + p_3 = 1$$

Well-Defined BPMN Model

- An exclusive gateway does not join parallel sequence flows
- A parallel gateway does not join exclusive sequence flows
- An inclusive gateway only joins sequence flows originated by another inclusive gateway (one-to-one correspondence)



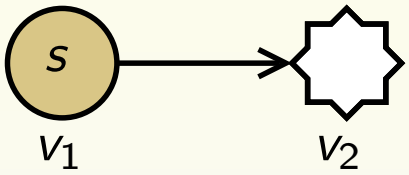
Conversion Algorithm

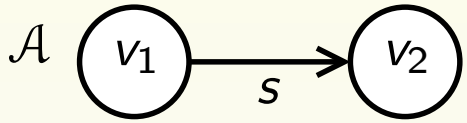
Main Steps

1. Conversion of vertices of the BPMN process graph into elementary SAN models
2. Operations of concatenation to join automata that model a same sequence flow
3. Operations of reduction, to eliminate redundant or unnecessary states

From BPMN Objects to SAN Elementary Models

Start Event





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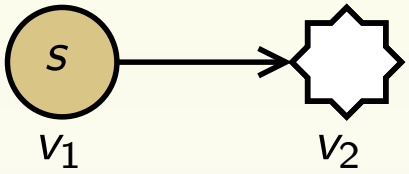
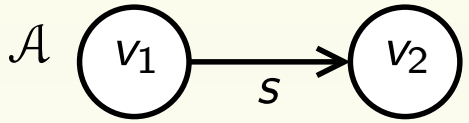
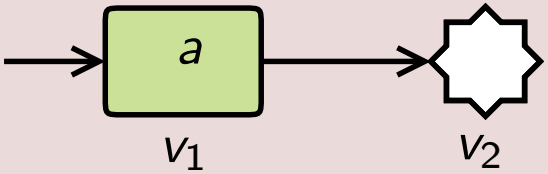
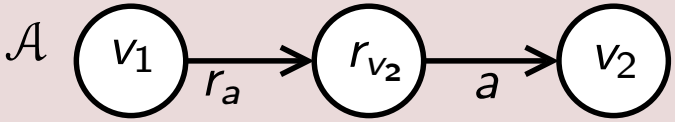




Atomic Task





From BPMN Objects to SAN Elementary Models

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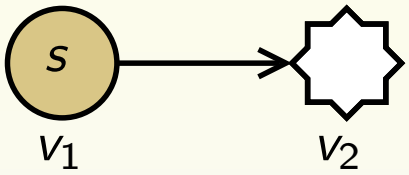

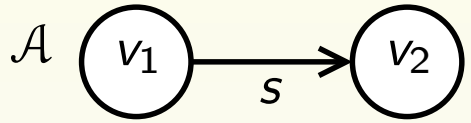

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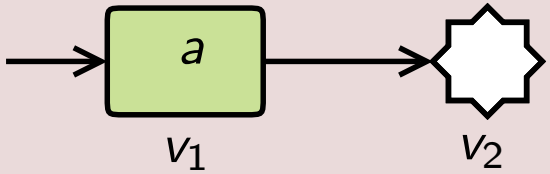
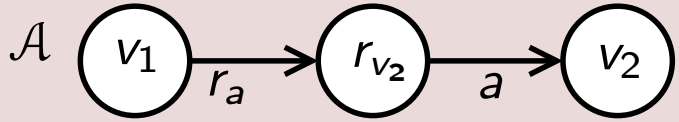
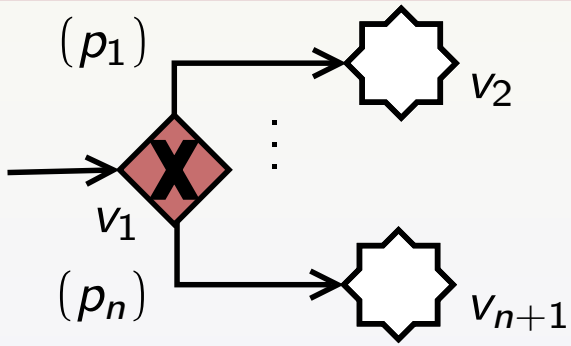
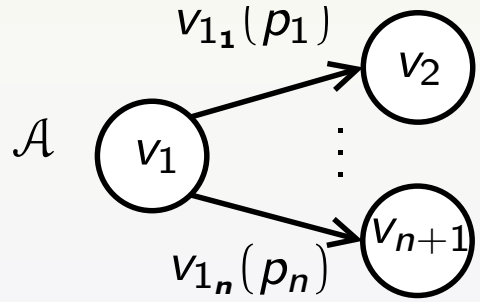




Exc. Gateway 1





From BPMN Objects to SAN Elementary Models

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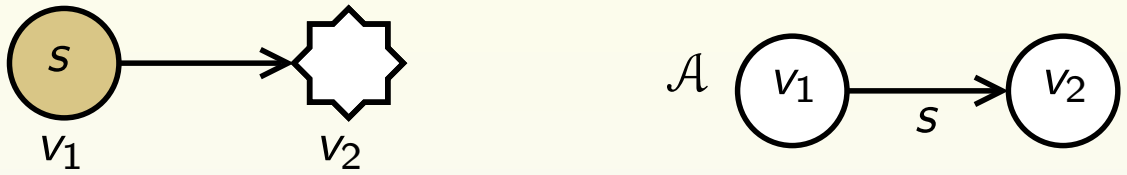
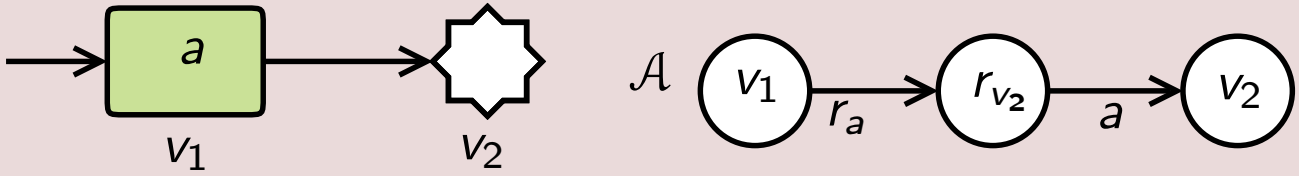


Atomic Task



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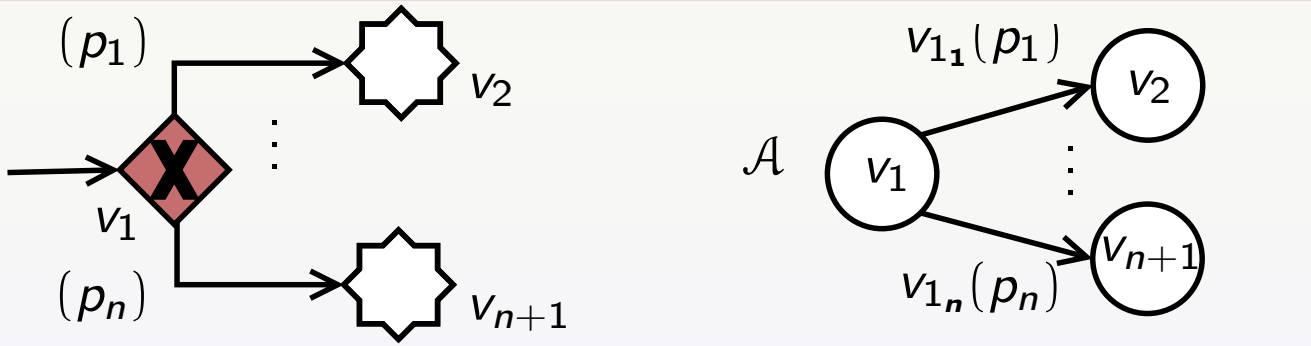
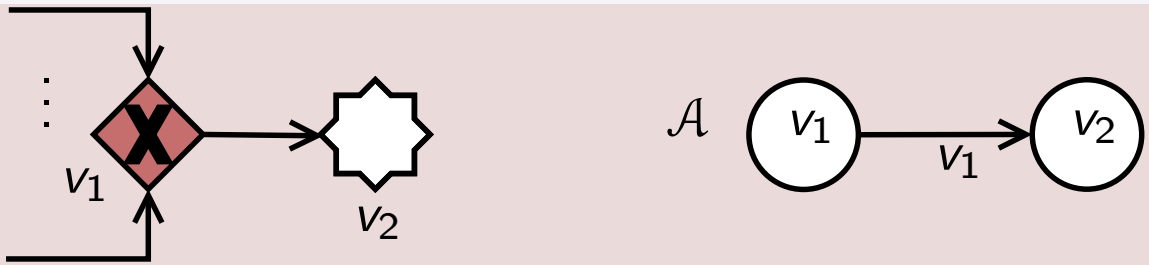
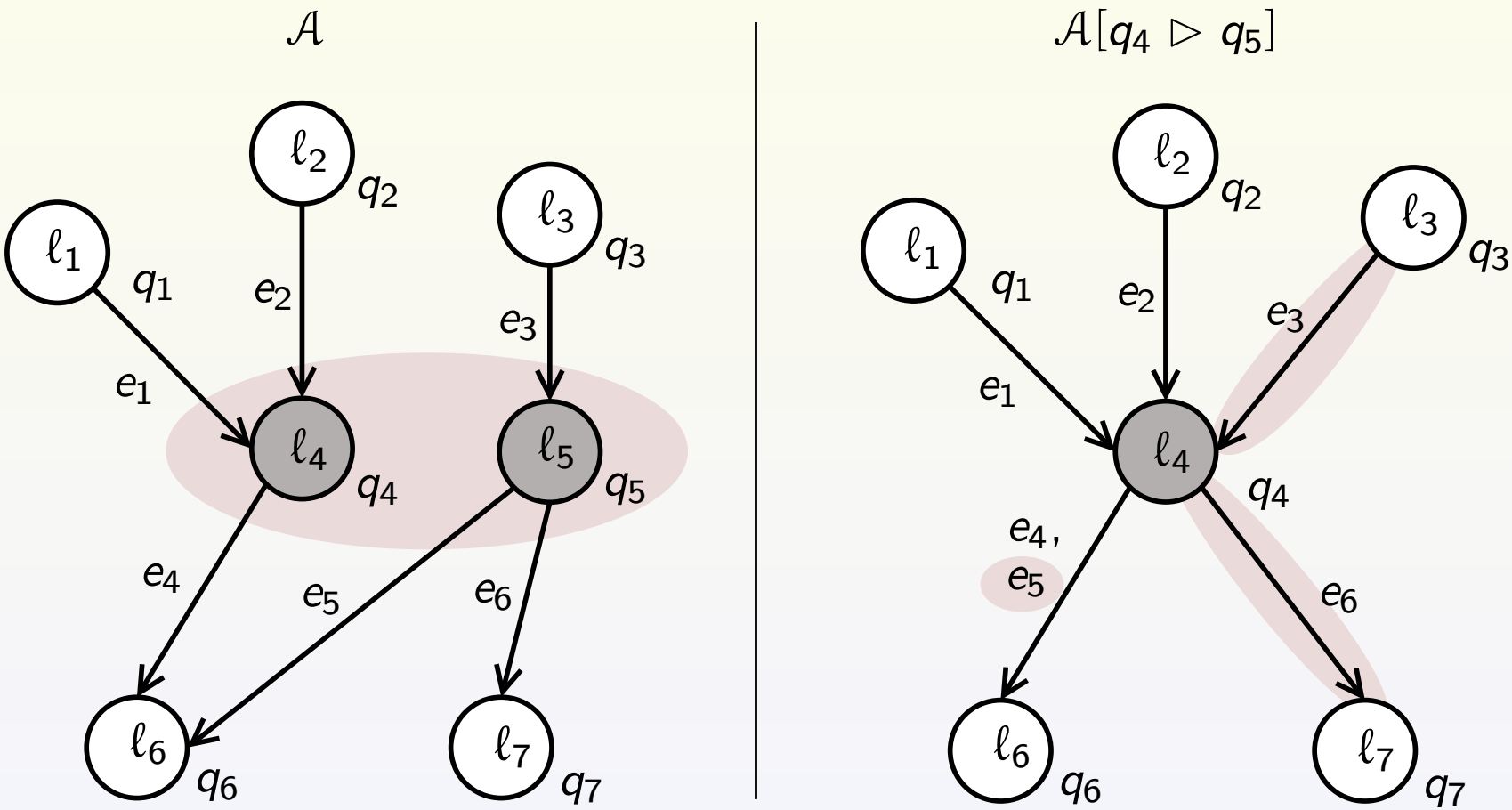


Exc. Gateway 2

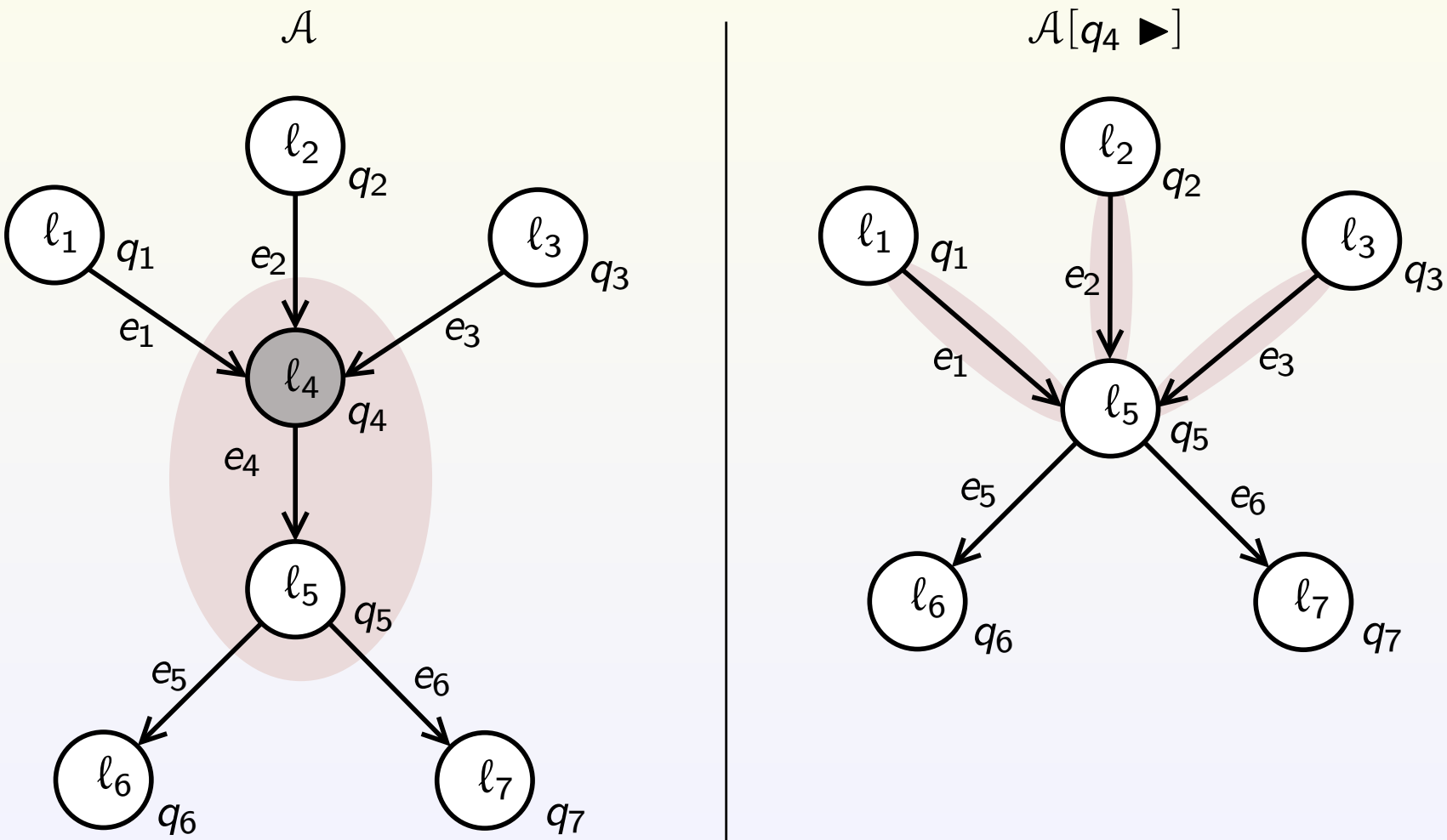


Operation 1 – State Merge ($\triangleright$)

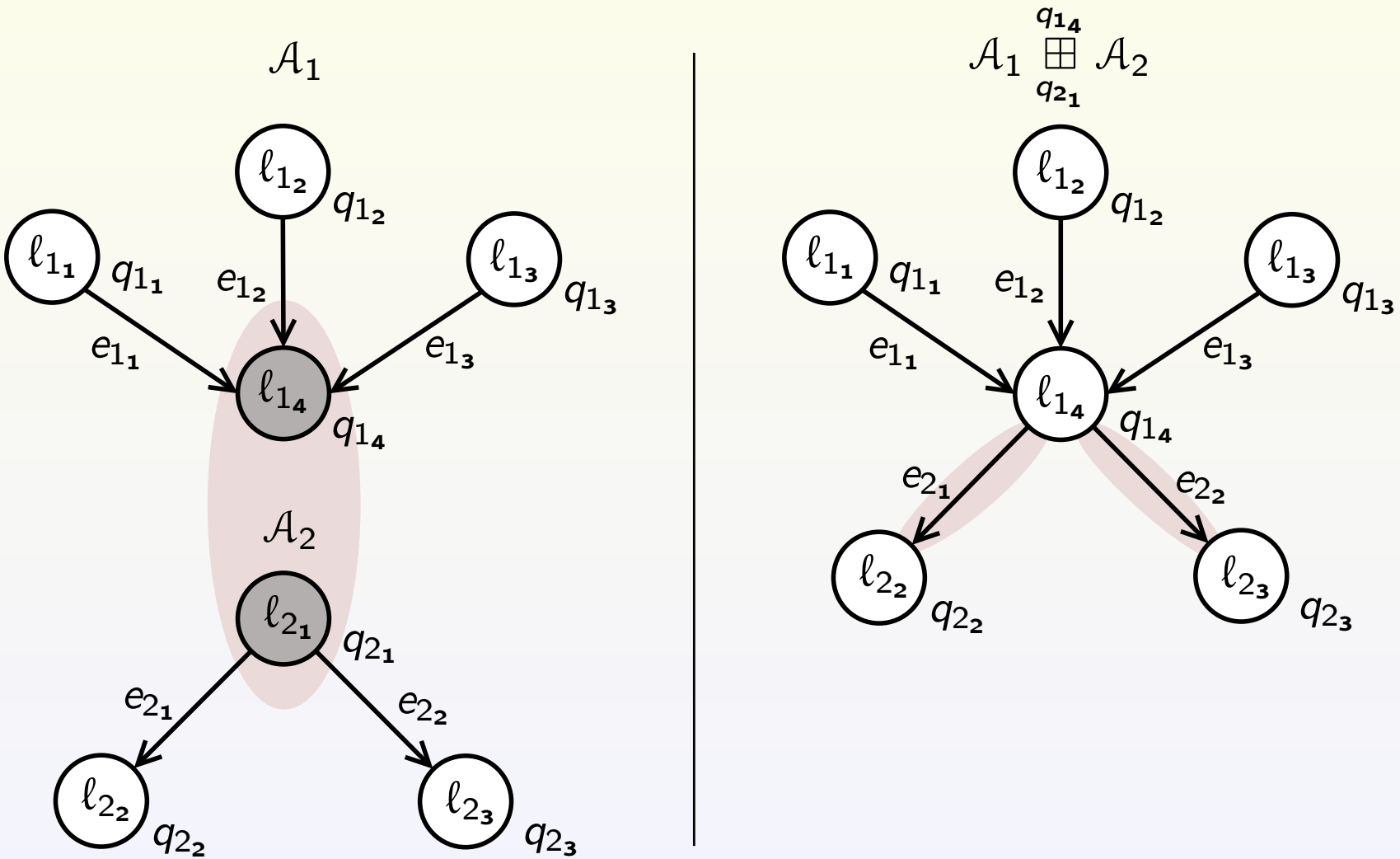


Operation 2 – State Suppression (▶)

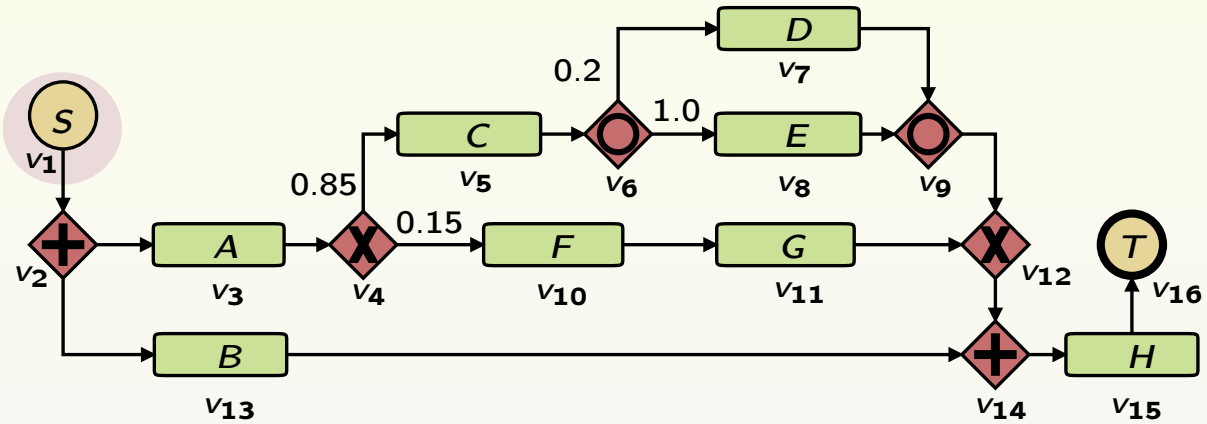
Condition: $|outputs(q_4)| = 1$



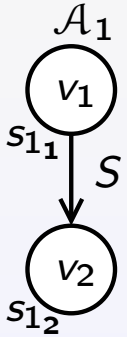
Operation 3 – Automata Concatenation (⊞)



Vertex Mappings – Shipment Process



v_1



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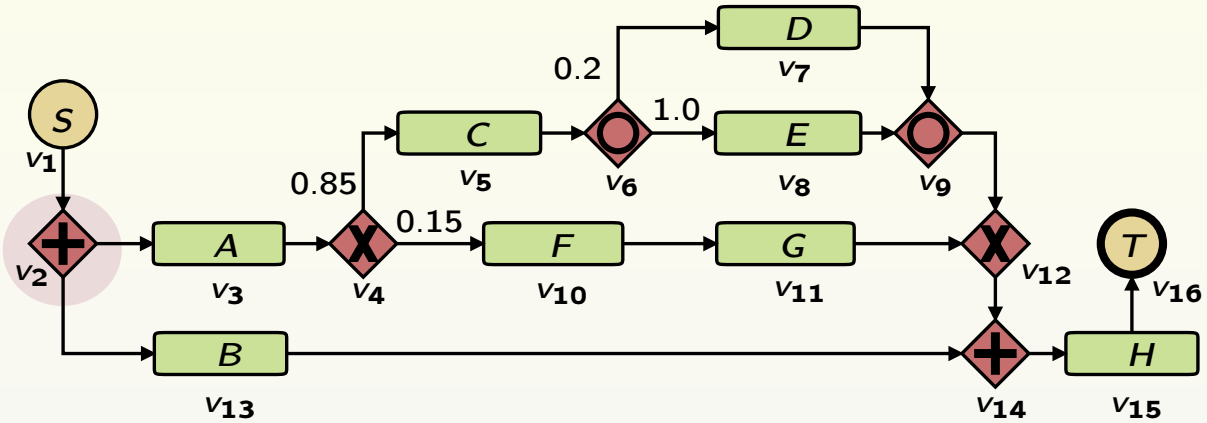

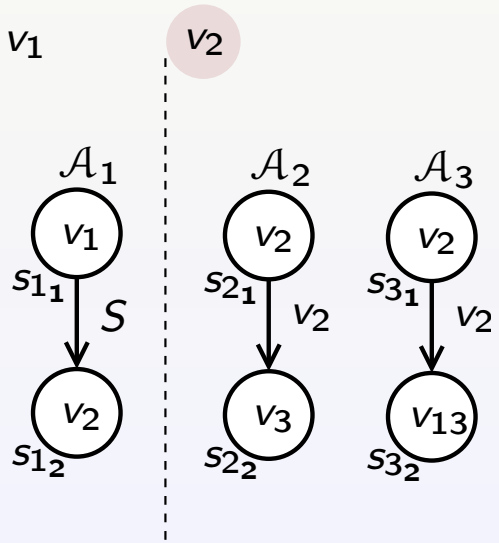

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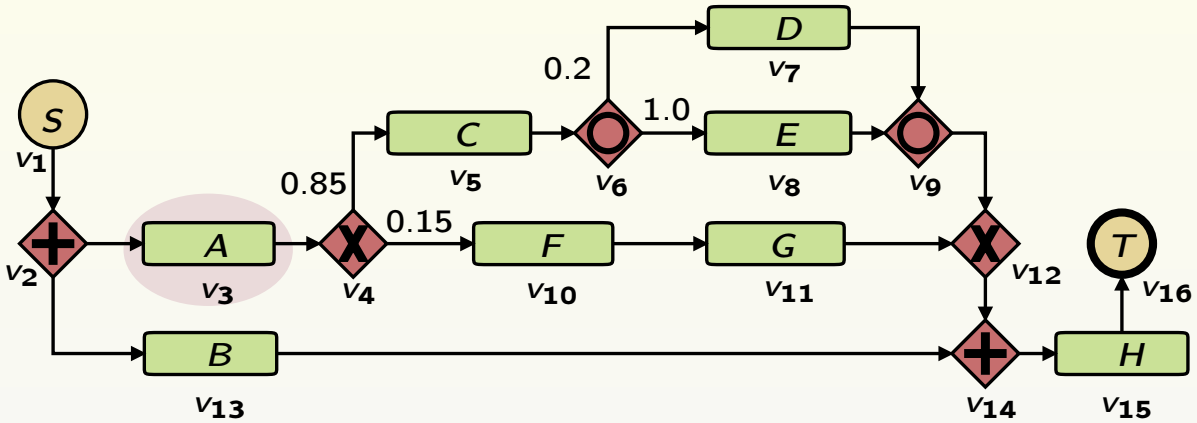

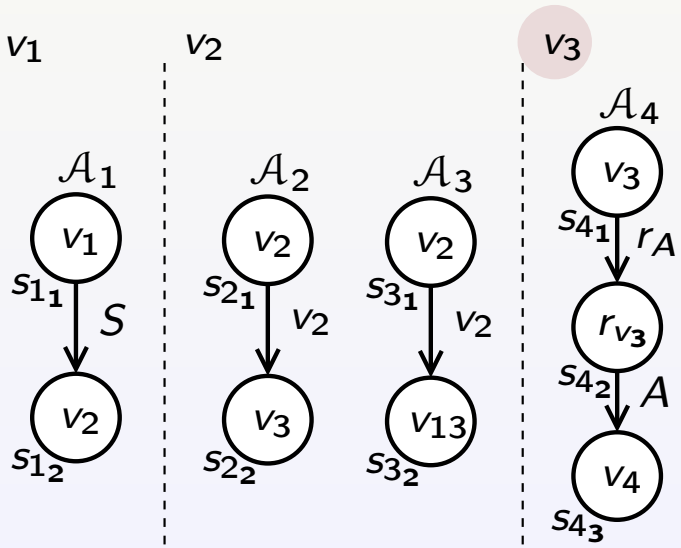

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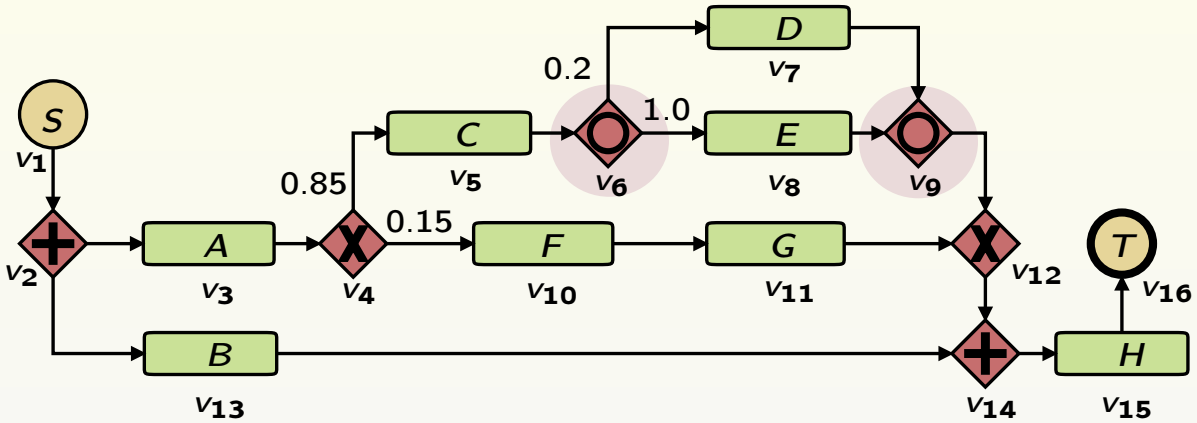

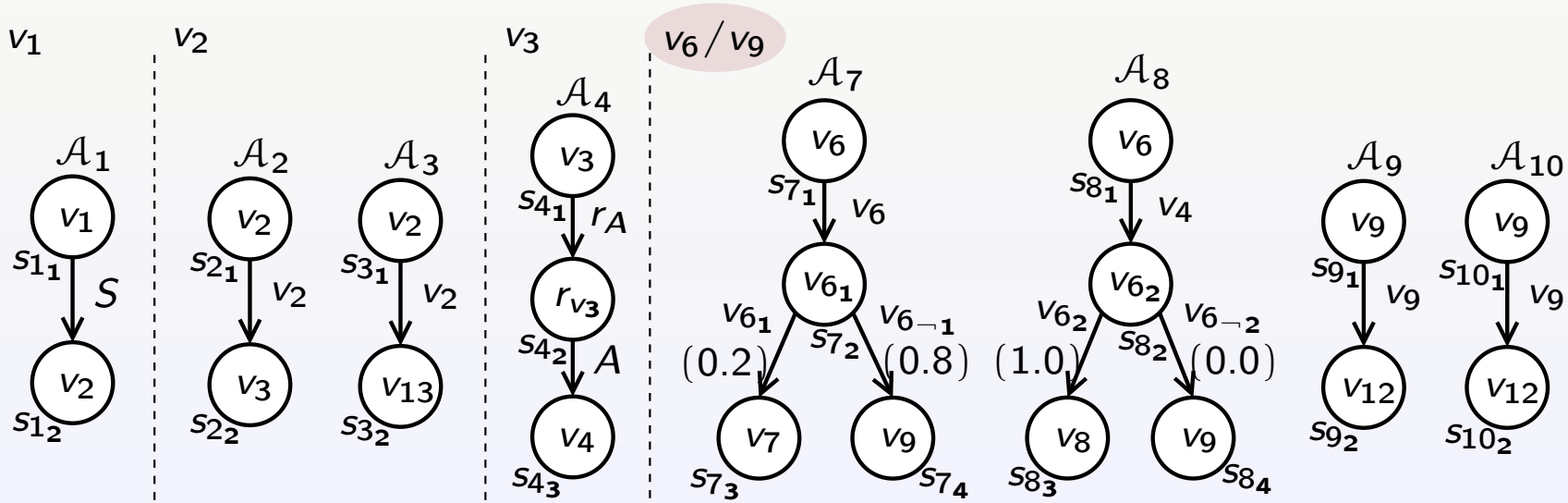

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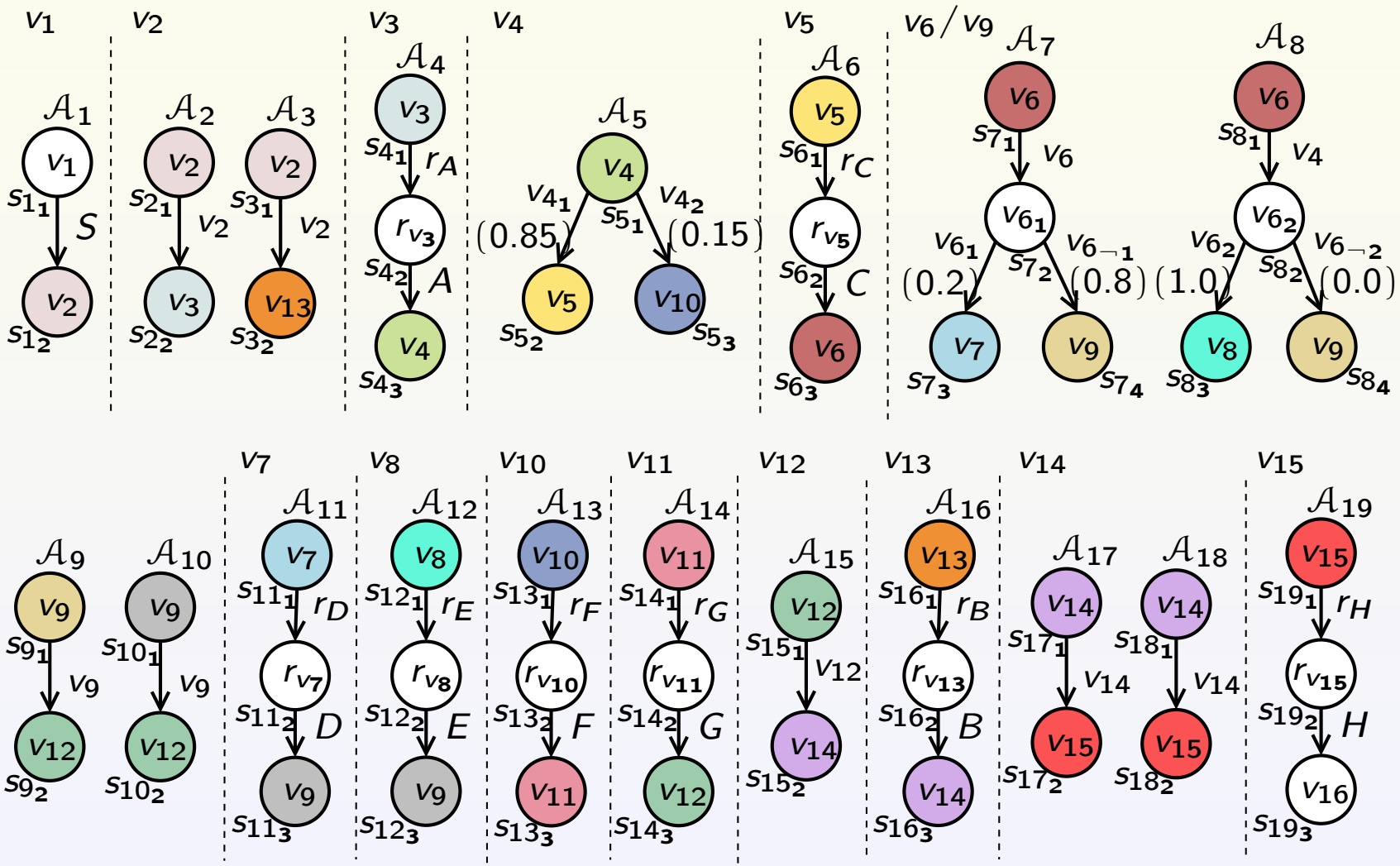
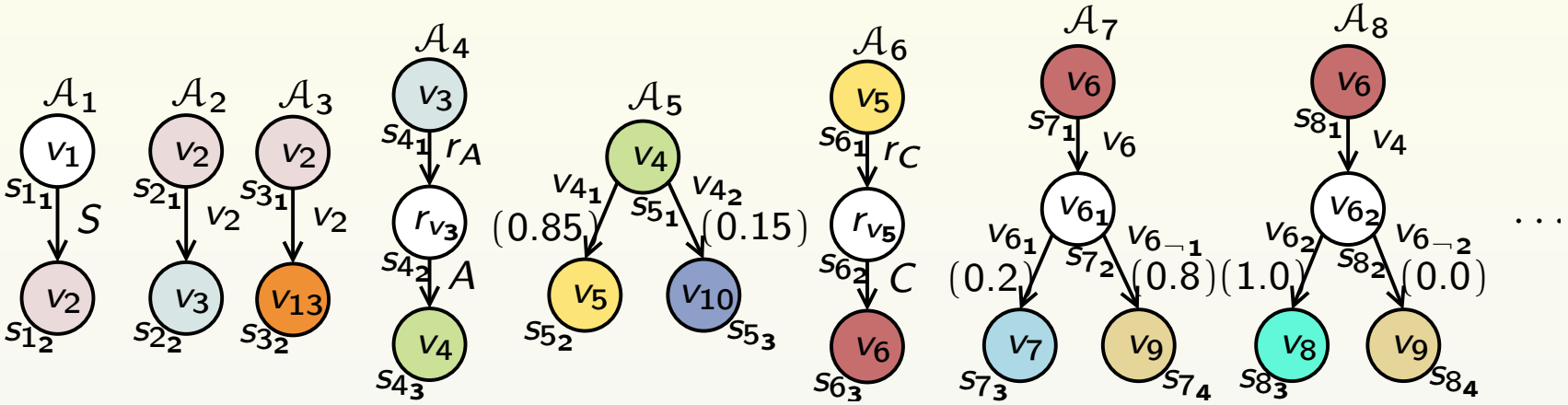
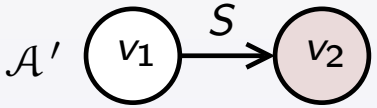


Automata Concatenations/State Merges – Shipment Process



$$\boxed{\mathcal{A}' = \mathcal{A}_1}$$



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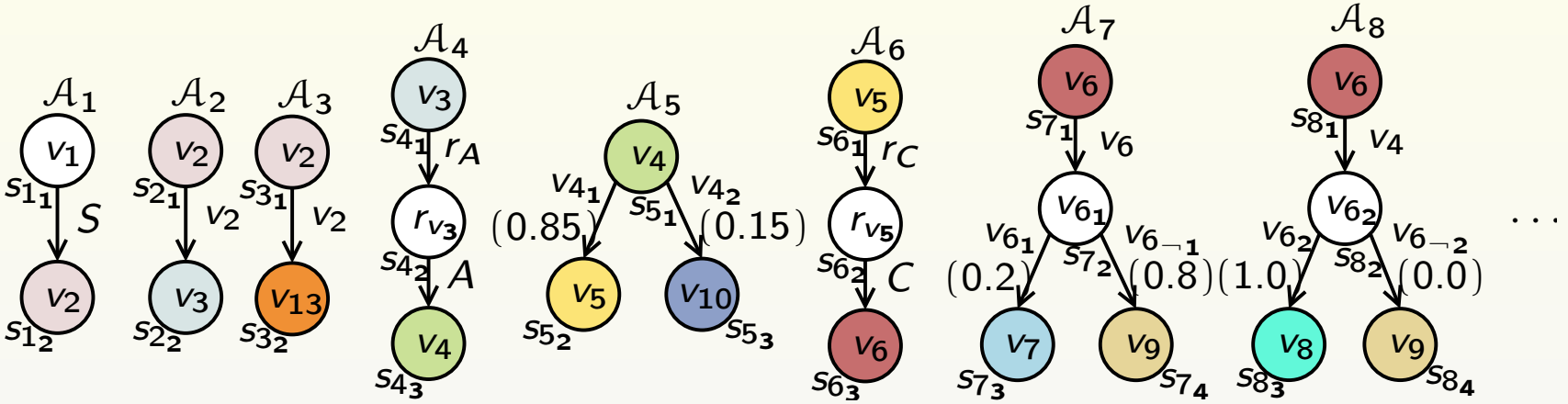
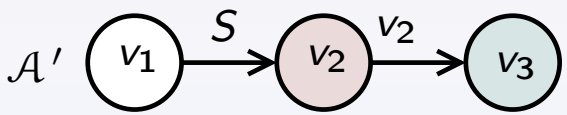


$$\mathcal{A}' = \mathcal{A}_1 \overset{s_{1_2}}{\underset{s_{2_1}}{\boxplus}} \mathcal{A}_2$$



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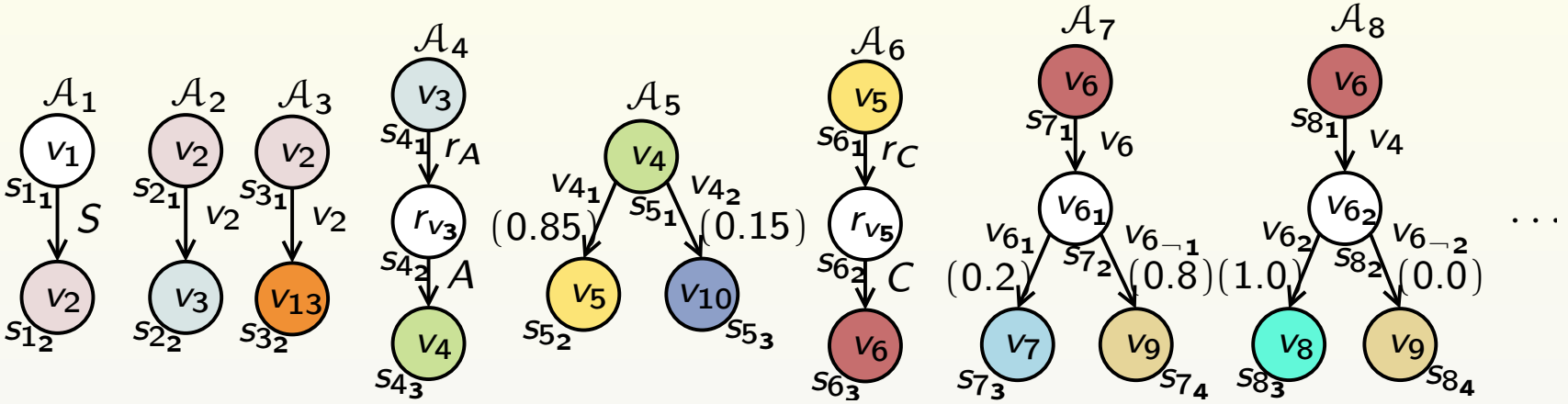
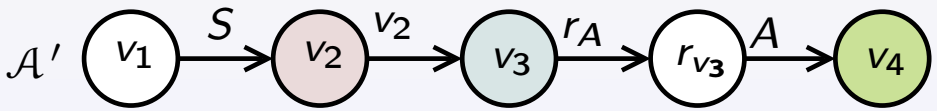


$$\mathcal{A}' = \mathcal{A}_1 \underset{s_{2_1}}{\overset{s_{1_2}}{\boxplus}} \mathcal{A}_2 \underset{s_{4_1}}{\overset{s_{2_2}}{\boxplus}} \mathcal{A}_4$$



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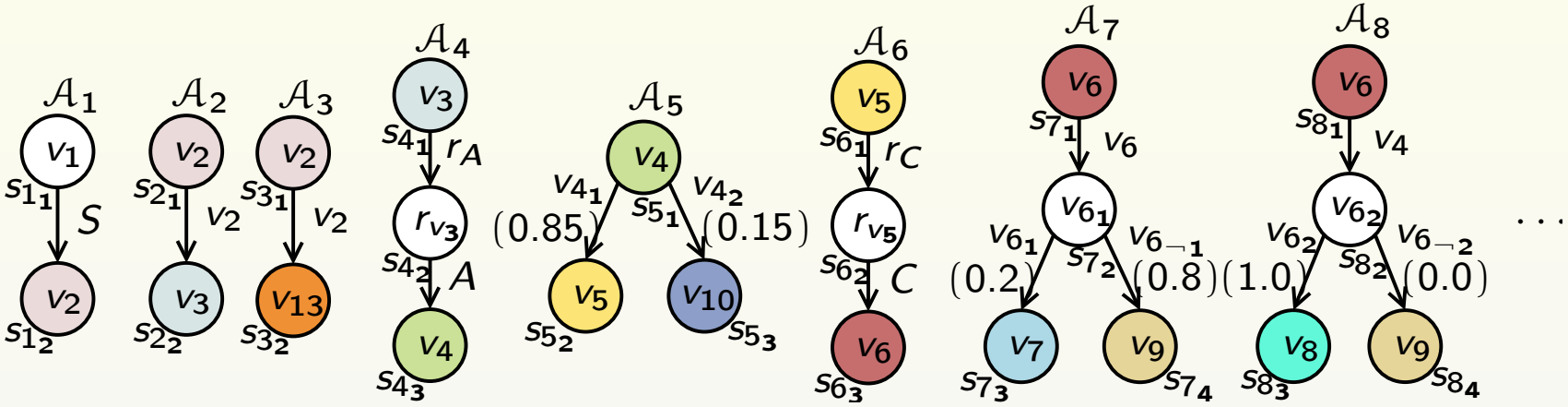
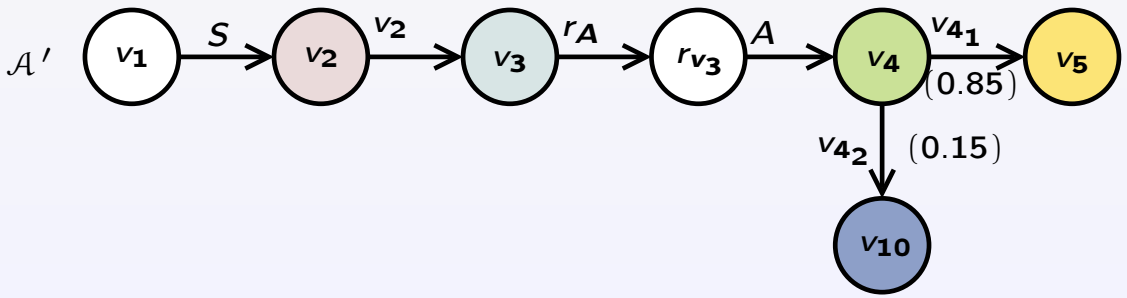
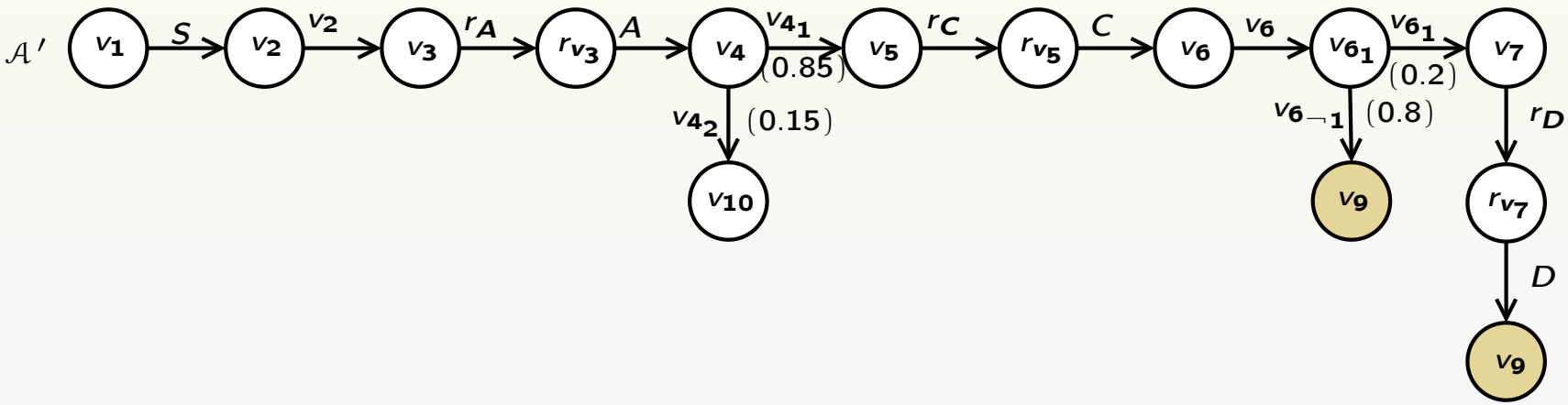


$$\mathcal{A}' = \mathcal{A}_1 \underset{s_{2_1}}{\overset{s_{1_2}}{\boxplus}} \mathcal{A}_2 \underset{s_{4_1}}{\overset{s_{2_2}}{\boxplus}} \mathcal{A}_4 \underset{s_{5_1}}{\overset{s_{4_3}}{\boxplus}} \mathcal{A}_5$$



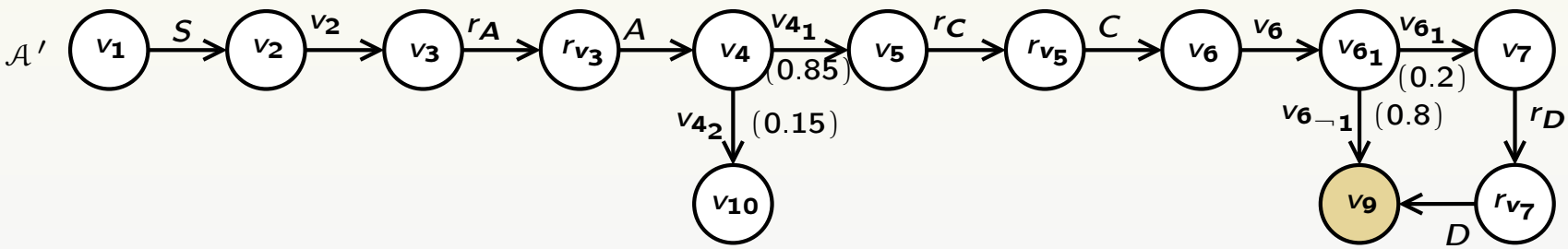
Automata Concatenations/State Merges – Shipment Process

$$\mathcal{A}' = \mathcal{A}_1 \underset{s_{2_1}}{\overset{s_{1_2}}{\boxplus}} \mathcal{A}_2 \underset{s_{4_1}}{\overset{s_{2_2}}{\boxplus}} \mathcal{A}_4 \underset{s_{5_1}}{\overset{s_{4_3}}{\boxplus}} \mathcal{A}_5 \underset{s_{6_1}}{\overset{s_{5_2}}{\boxplus}} \mathcal{A}_6 \underset{s_{7_1}}{\overset{s_{6_3}}{\boxplus}} \mathcal{A}_7 \underset{s_{9_1}}{\overset{s_{7_4}}{\boxplus}} \mathcal{A}_9 \underset{s_{11_1}}{\overset{s_{7_3}}{\boxplus}} \mathcal{A}_{11}$$



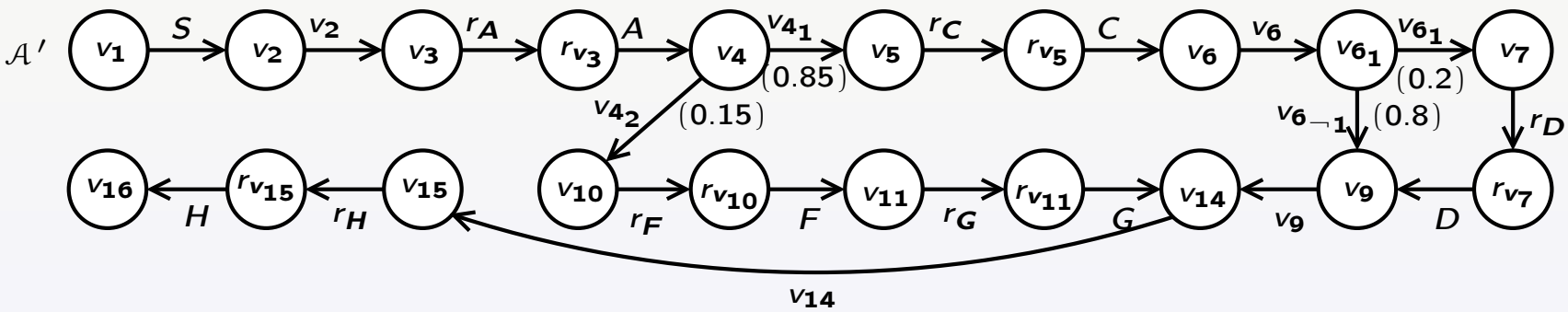
Automata Concatenations/State Merges – Shipment Process

$$\mathcal{A}' = (\mathcal{A}_1 \overset{s_{1_2}}{\underset{s_{2_1}}{\boxplus}} \mathcal{A}_2 \overset{s_{2_2}}{\underset{s_{4_1}}{\boxplus}} \mathcal{A}_4 \overset{s_{4_3}}{\underset{s_{5_1}}{\boxplus}} \mathcal{A}_5 \overset{s_{5_2}}{\underset{s_{6_1}}{\boxplus}} \mathcal{A}_6 \overset{s_{6_3}}{\underset{s_{7_1}}{\boxplus}} \mathcal{A}_7 \overset{s_{7_4}}{\underset{s_{9_1}}{\boxplus}} \mathcal{A}_9 \overset{s_{7_3}}{\underset{s_{11_1}}{\boxplus}} \mathcal{A}_{11}) \; [s_{7_4} \rhd s_{11_3}]$$



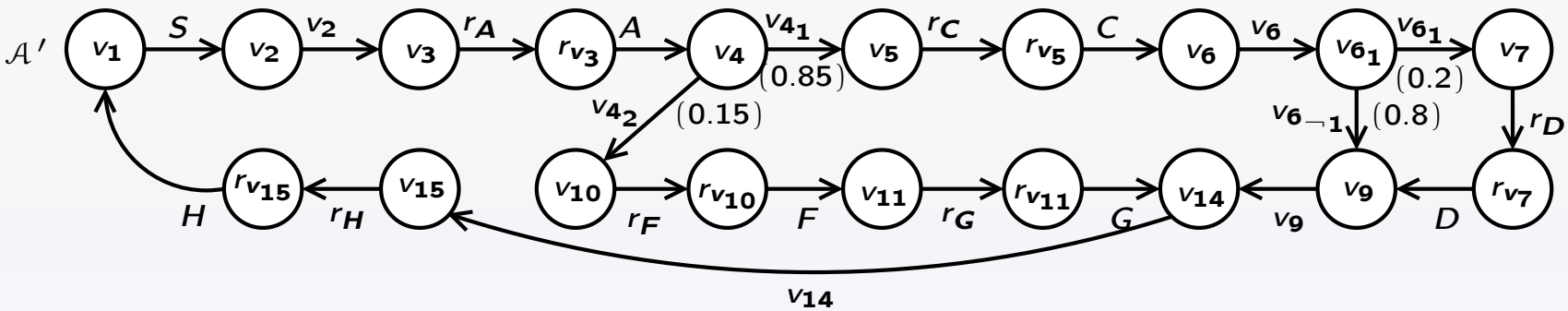
Automata Concatenations/State Merges – Shipment Process

$$\begin{aligned}\mathcal{A}' = (((&(\mathcal{A}_1 \underset{s_{2_1}}{\overset{s_{1_2}}{\boxplus}} \mathcal{A}_2 \underset{s_{4_1}}{\overset{s_{2_2}}{\boxplus}} \mathcal{A}_4 \underset{s_{5_1}}{\overset{s_{4_3}}{\boxplus}} \mathcal{A}_5 \underset{s_{6_1}}{\overset{s_{5_2}}{\boxplus}} \mathcal{A}_6 \underset{s_{7_1}}{\overset{s_{6_3}}{\boxplus}} \mathcal{A}_7 \underset{s_{9_1}}{\overset{s_{7_4}}{\boxplus}} \mathcal{A}_9 \underset{s_{11_1}}{\overset{s_{7_3}}{\boxplus}} \mathcal{A}_{11}) \\ &[s_{7_4} \rhd s_{11_3}] \underset{s_{13_1}}{\overset{s_{5_3}}{\boxplus}} \mathcal{A}_{13} \underset{s_{14_1}}{\overset{s_{13_3}}{\boxplus}} \mathcal{A}_{14})[s_{9_2} \rhd s_{14_3}] \underset{s_{15_1}}{\overset{s_{9_2}}{\boxplus}} \mathcal{A}_{15} \\ &\underset{s_{17_1}}{\overset{s_{15_2}}{\boxplus}} \mathcal{A}_{17} \underset{s_{19_1}}{\overset{s_{17_2}}{\boxplus}} \mathcal{A}_{19})[s_{9_2} \blacktriangleright]\end{aligned}$$

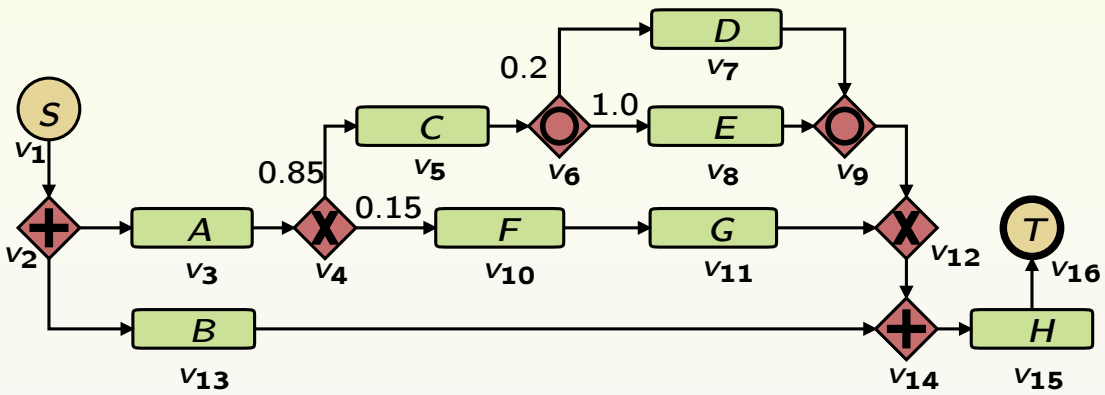


Automata Concatenations/State Merges – Shipment Process

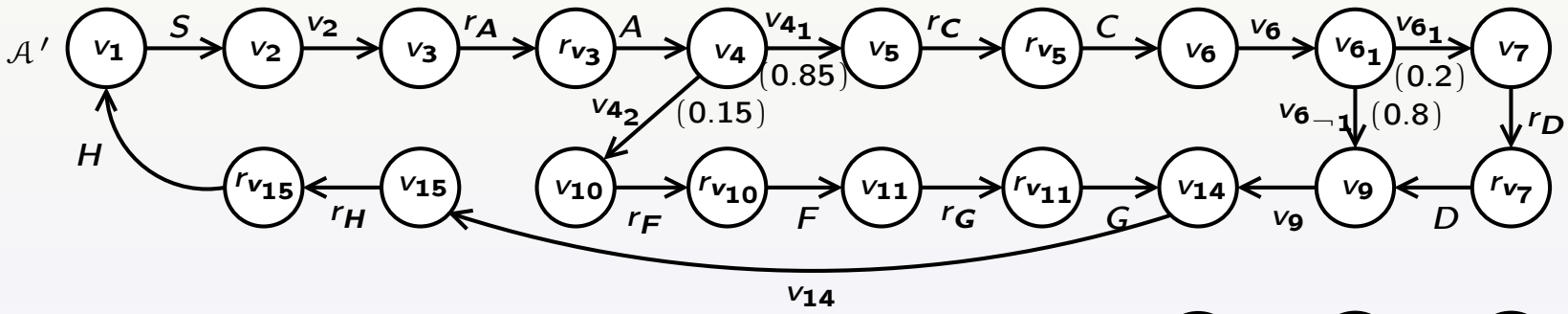
$$\begin{aligned}\mathcal{A}' = (((&(\mathcal{A}_1 \underset{s_{2_1}}{\overset{s_{1_2}}{\boxplus}} \mathcal{A}_2 \underset{s_{4_1}}{\overset{s_{2_2}}{\boxplus}} \mathcal{A}_4 \underset{s_{5_1}}{\overset{s_{4_3}}{\boxplus}} \mathcal{A}_5 \underset{s_{6_1}}{\overset{s_{5_2}}{\boxplus}} \mathcal{A}_6 \underset{s_{7_1}}{\overset{s_{6_3}}{\boxplus}} \mathcal{A}_7 \underset{s_{9_1}}{\overset{s_{7_4}}{\boxplus}} \mathcal{A}_9 \underset{s_{11_1}}{\overset{s_{7_3}}{\boxplus}} \mathcal{A}_{11}) \\ &[s_{7_4} \rhd s_{11_3}] \underset{s_{13_1}}{\overset{s_{5_3}}{\boxplus}} \mathcal{A}_{13} \underset{s_{14_1}}{\overset{s_{13_3}}{\boxplus}} \mathcal{A}_{14})[s_{9_2} \rhd s_{14_3}] \underset{s_{15_1}}{\overset{s_{9_2}}{\boxplus}} \mathcal{A}_{15} \\ &\underset{s_{17_1}}{\overset{s_{15_2}}{\boxplus}} \mathcal{A}_{17} \underset{s_{19_1}}{\overset{s_{17_2}}{\boxplus}} \mathcal{A}_{19})[s_{9_2} \blacktriangleright][s_{1_1} \rhd s_{19_3}]\end{aligned}$$

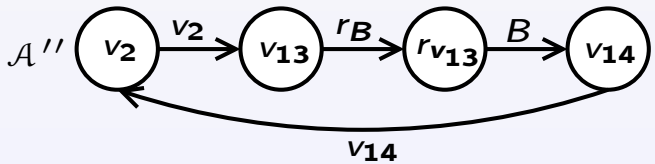


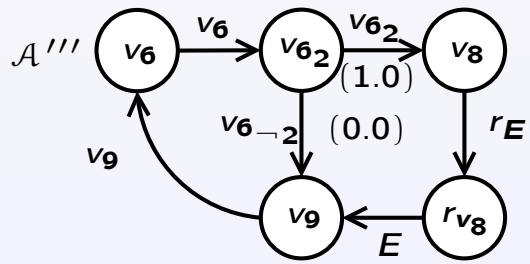
Automata Concatenations/State Merges – Shipment Process



	Average Time	Rate
A	05 min	0.200
B	30 min	0.033
C	10 min	0.100
D	30 min	0.033
E	05 min	0.200
F	40 min	0.025
G	15 min	0.066
H	20 min	0.050







Analysis of the SAN Model of the Shipment Process

- Solving tool: **PEPS** [1]
- Parallel process instances $\Rightarrow$ **automata replicas**
- Disabling of tasks in the case of unavailability of resources $\Rightarrow$ **functional rates**

Parallel Instanc.	State Space	Reachable Space	Response Time (h)	Utiliz. Manager	Utiliz. Clerk	Utiliz. Worker
1	380	85	1.106	0.052	0.269	0.518
2	144,400	5,809	1.599	0.080	0.412	0.793
3	54,872,000	349,013	2.228	0.093	0.476	0.916

[1] http://www-id.imag.fr/Logiciels/peps/

Automated conversion of BP models to SAN models

- Abstraction of the complexity involved in stochastic modeling
- Ability to deal with large scale models
- Software tool: **BP2SAN**
  (`http://www.ime.usp.br/~kellyrb/bp2san`)

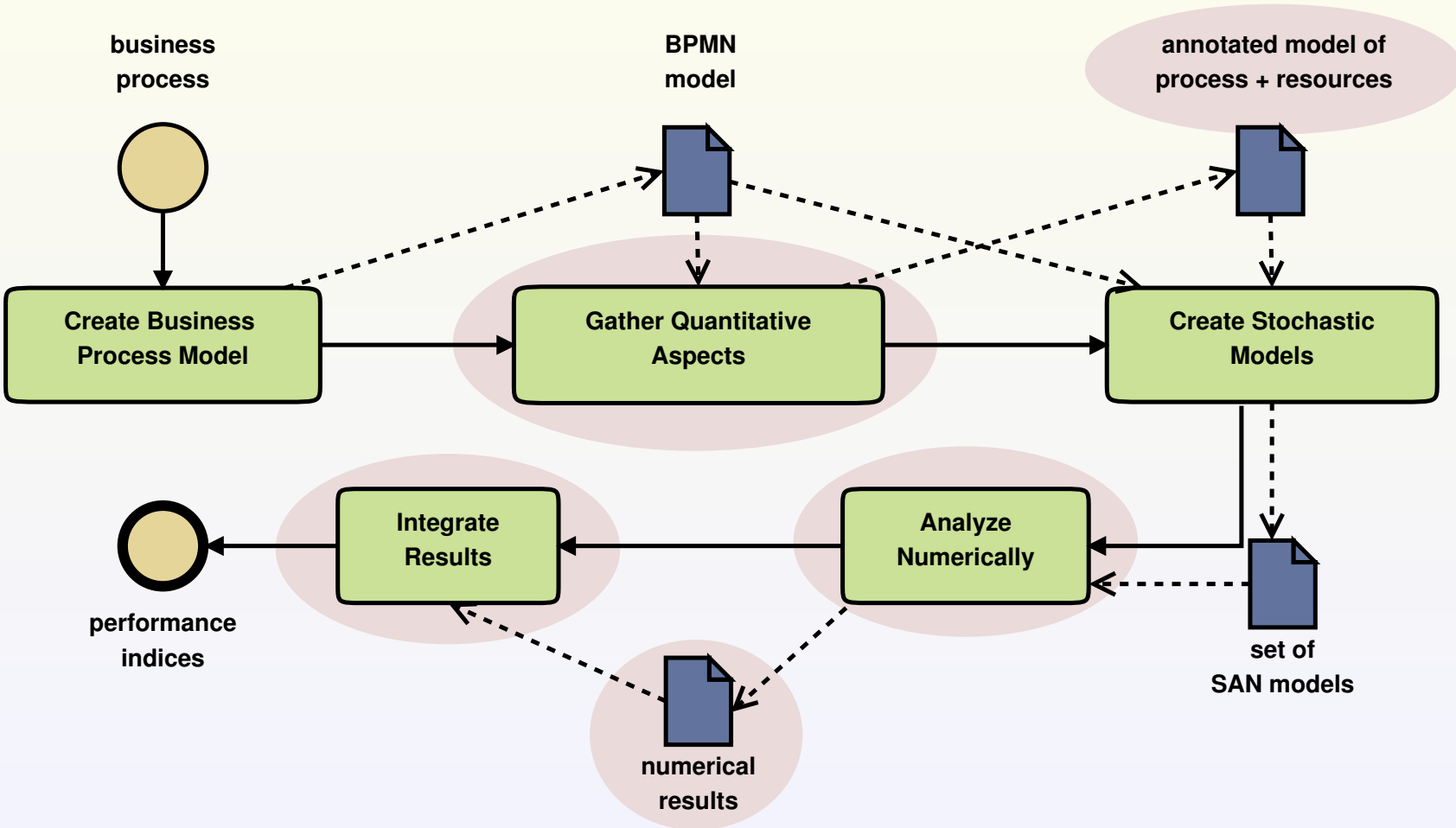
Missing: Resource Management Info

BP models lack information about resources:

- What are the resources required in the business process?
- How many are available?
- What is their work capacity?
- How are they accessed?

Extensions of the Work

Modeling Resource Management of Business Processes



Related Publications

K. R. Braghetto, J. E. Ferreira, J.-M. Vincent
"Performance Evaluation of Resource-Aware Business Processes Using Stochastic Automata Networks"
International Journal of Innovative Computing, Information and Control (IJICIC), special issue on Intelligent and Innovative Computing in Business Process Management (IICBPM), 2011.

K. R. Braghetto, J. E. Ferreira, J.-M. Vincent
"Performance Analysis Modeling Applied to Business Processes"
Symposium on Theory of Modeling & Simulation – DEVS Integrative M & S Symposium (DEVS'10)

I thank you for your attention