Enriching Simheuristics with Petri Net Models: Potential Applications to Logistics and Supply Chain Management

2016 CYTED Madrid Workshop

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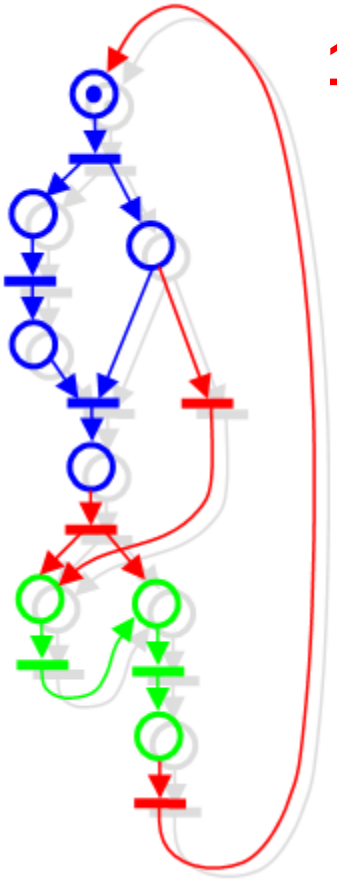

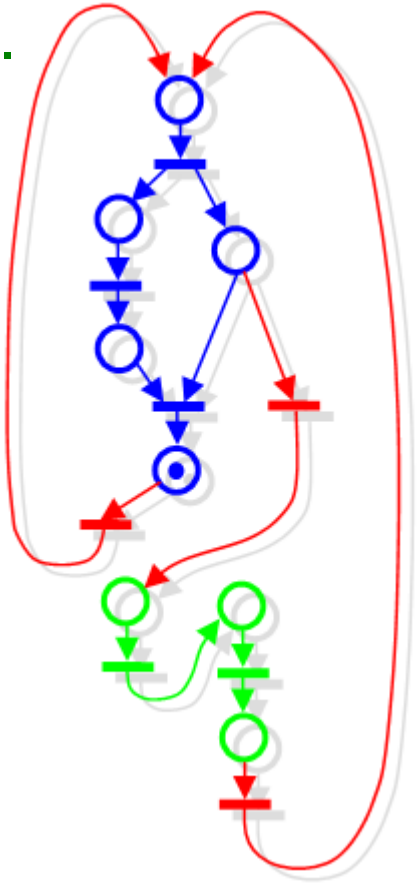

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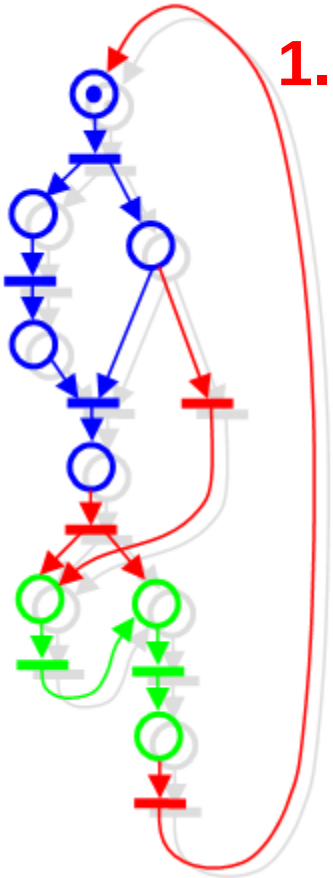
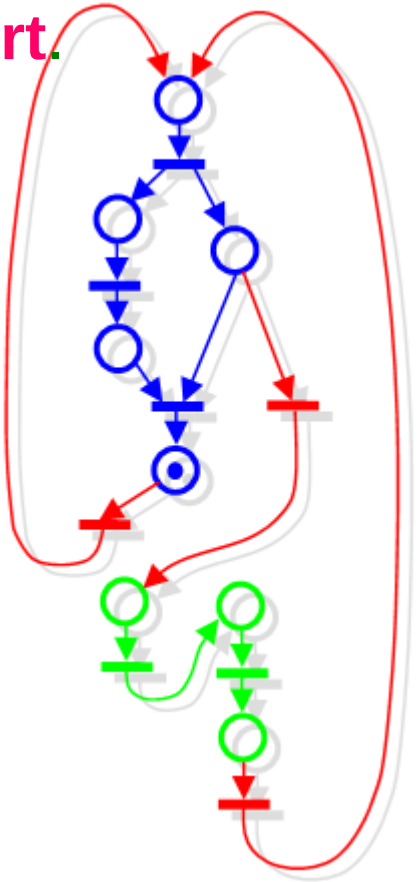




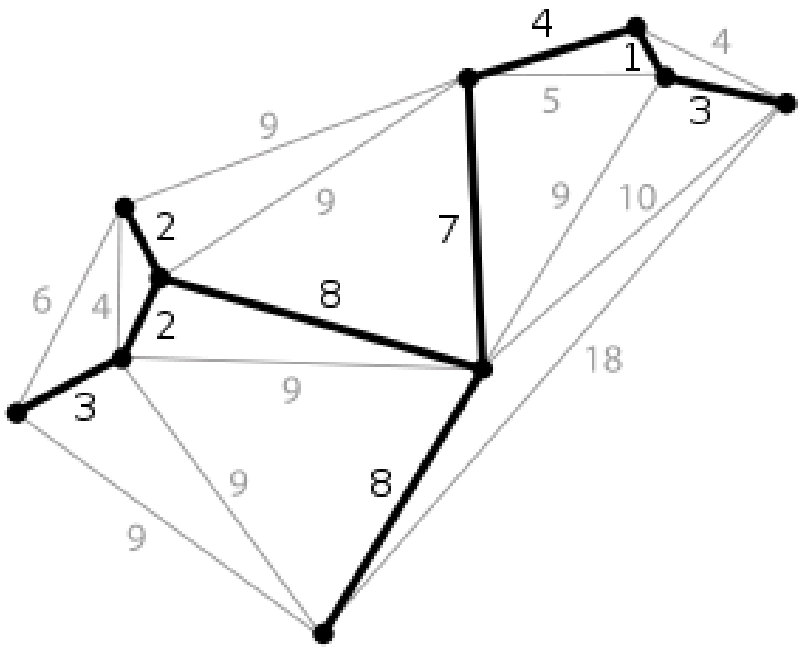
Decision making support

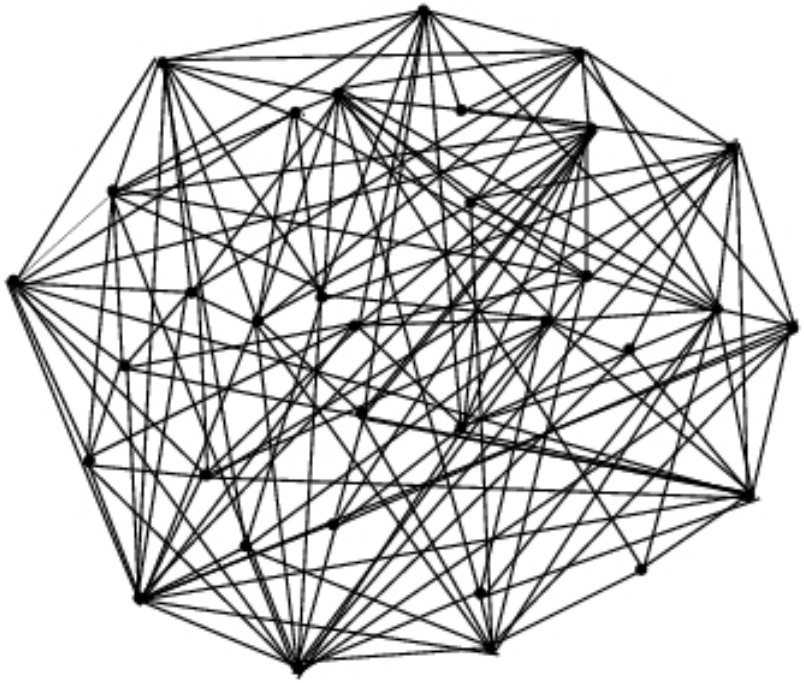
Complex and multimodal logistic systems and supply chains: difficult to consider all decisión variables, systems, possibilites and uncertainty to make efficient decisions.

Decision making support

Computer-based decision-making:

Representation as combinatorial optimization problems with uncertainty (NP-hard).

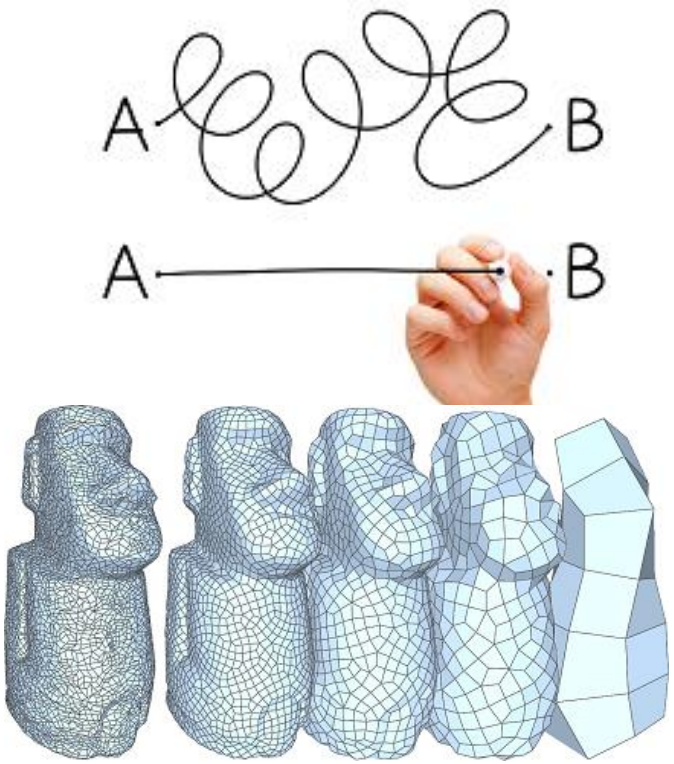


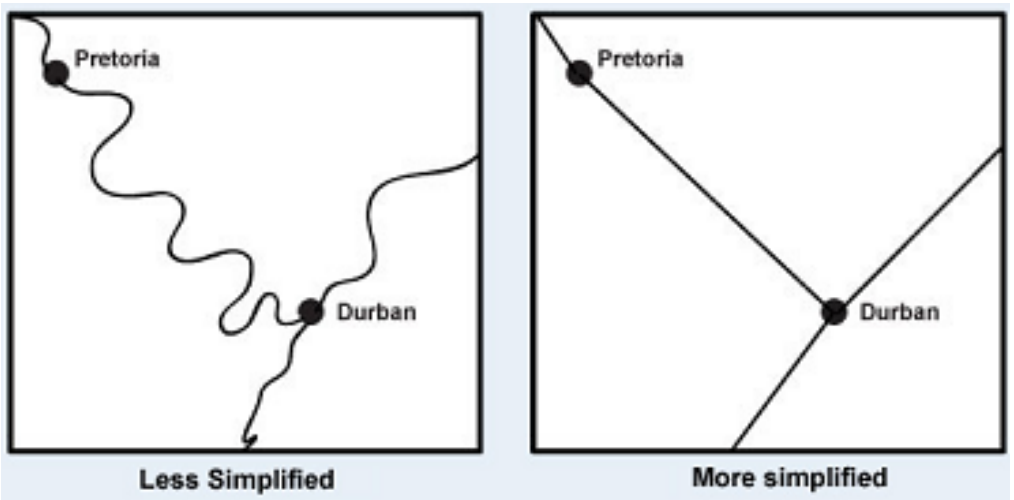


Decision making support

Usual approaches based on optimization:

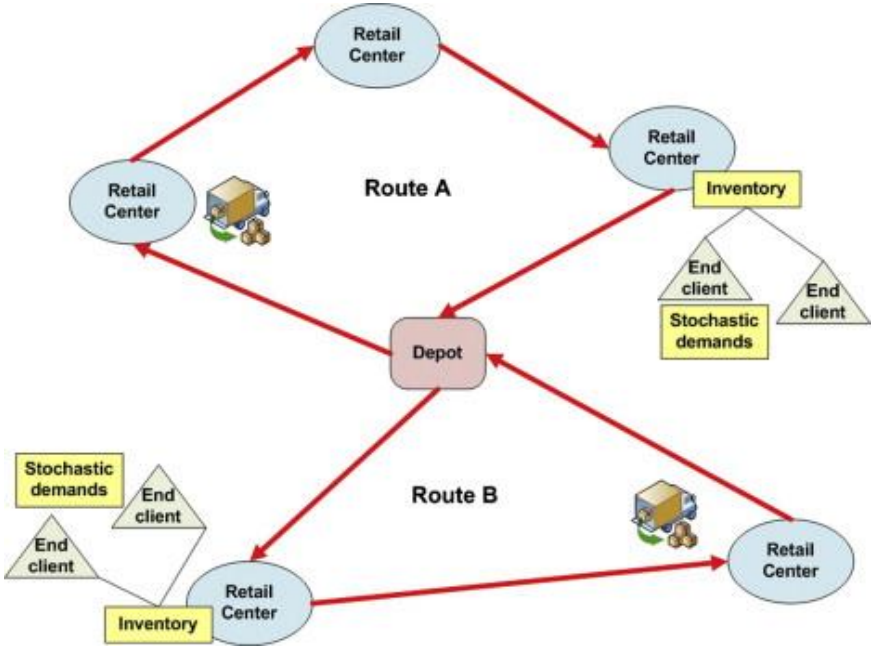
Simplified versions of real systems and processes based on deterministic parameters or (more recently) uncertainty.





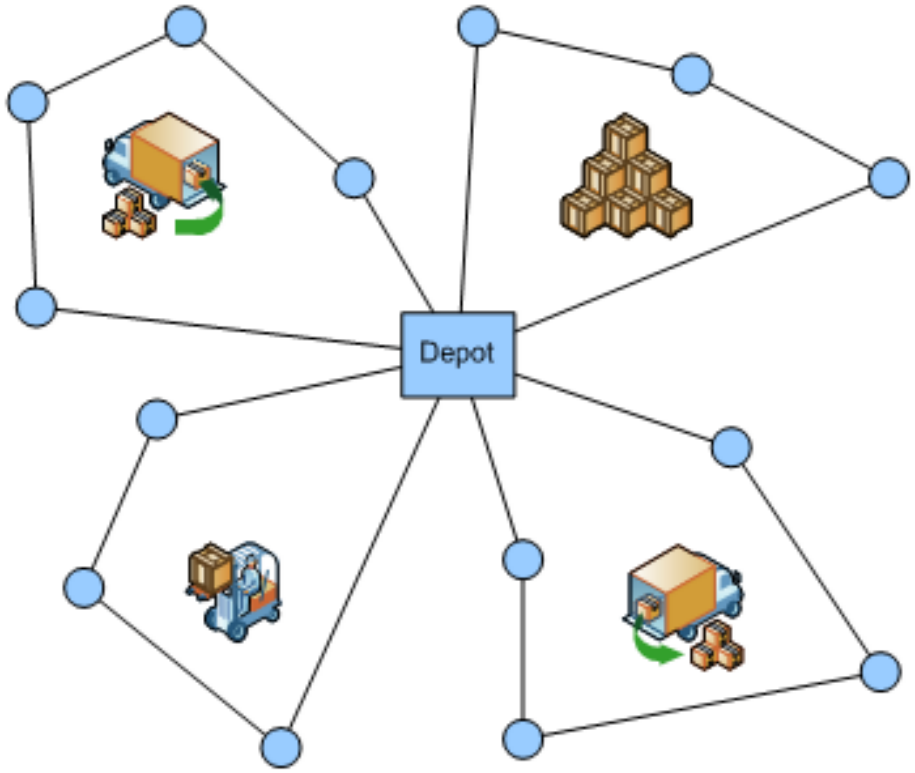
Simheuristics

Optimization methodology based on simulation: very succesful for providing quasi-optimal solutions to well-known logistic and supply chain benchmarks representing systems with stochastic behaviour.



Simheuristics

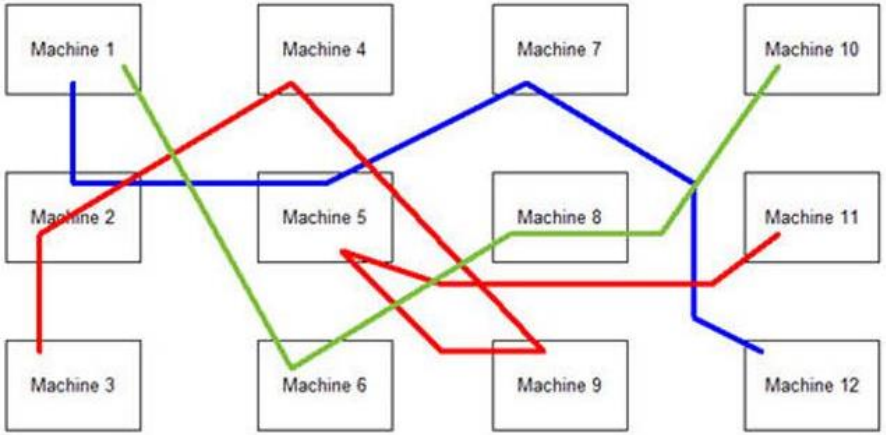
Examples of application:



Simheuristics

Examples of application:

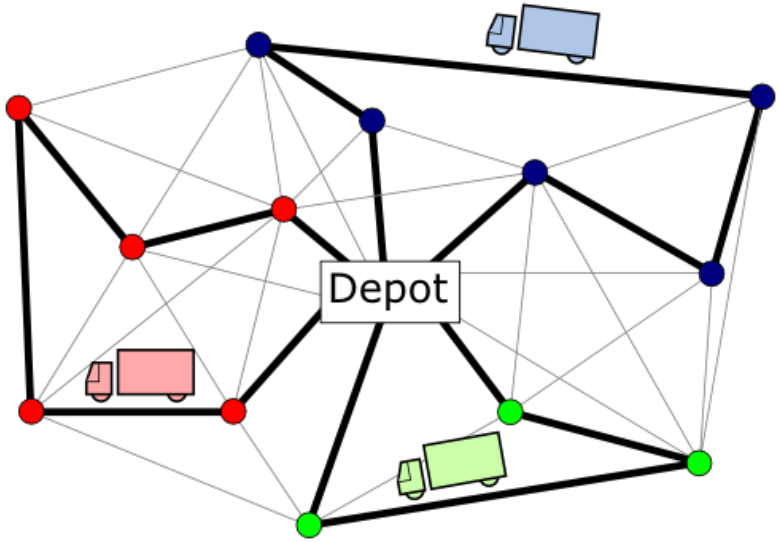
- Production planning and scheduling
  - ✓ Permutation flow-shop problem with stochastic times.



Simheuristics

Examples of application:

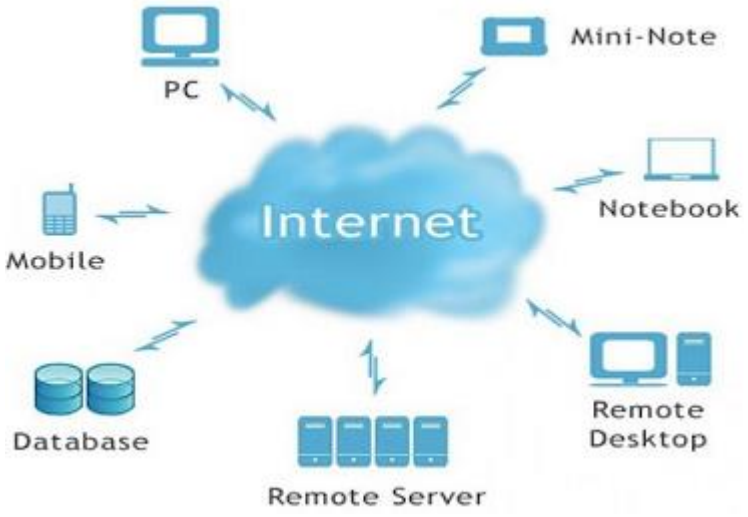
- Transportation and logistics
  - ✓ Vehicle routing problem with stochastic demands.
  - ✓ Inventory routing problem with stochastic demands.
  - ✓ Multi-vehicle routing problem with stochastic demand and duration limits.



Simheuristics

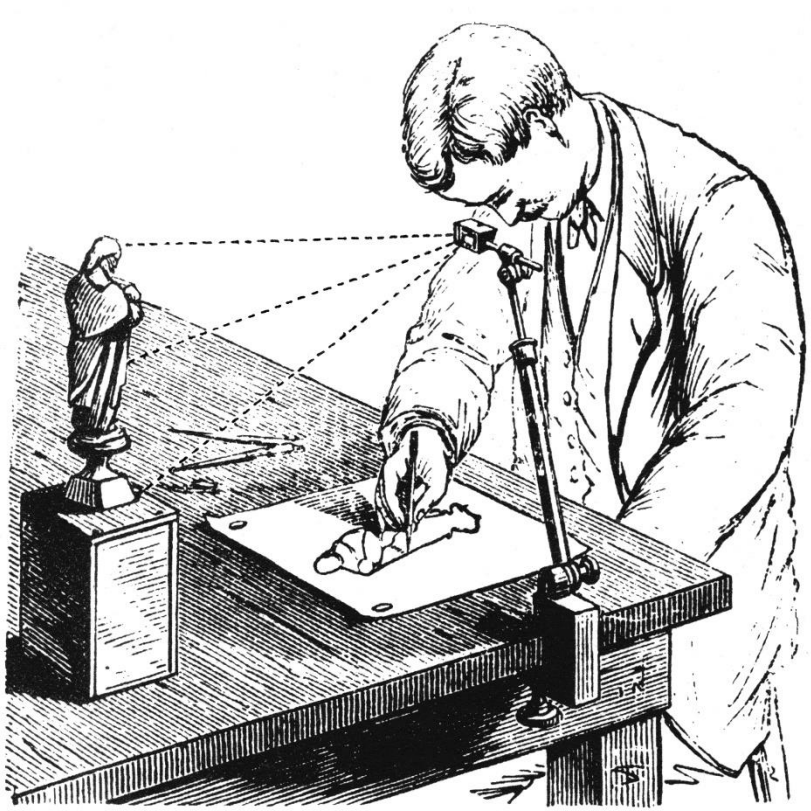
Examples of application:

- Internet computing
  - ✓ Stochastic COP of determining a minimum-cost configuration of non-dedicated resources able to support a service while maintaining the service availability level over a user-defined threshold



Simheuristics

How accuratelly **benchmarks** represent **real-life scenarios**?



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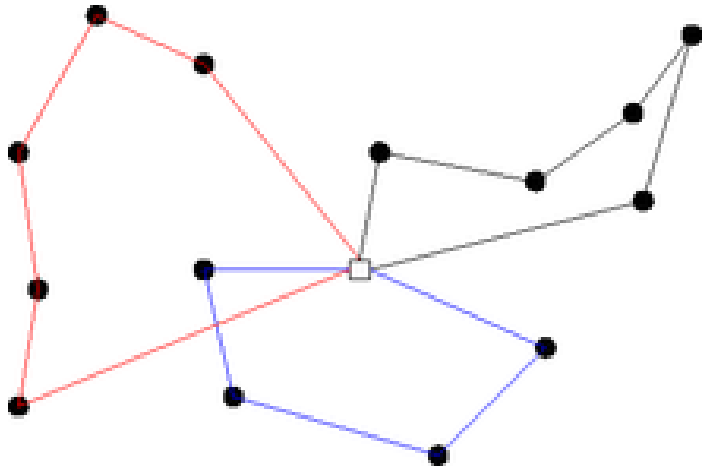
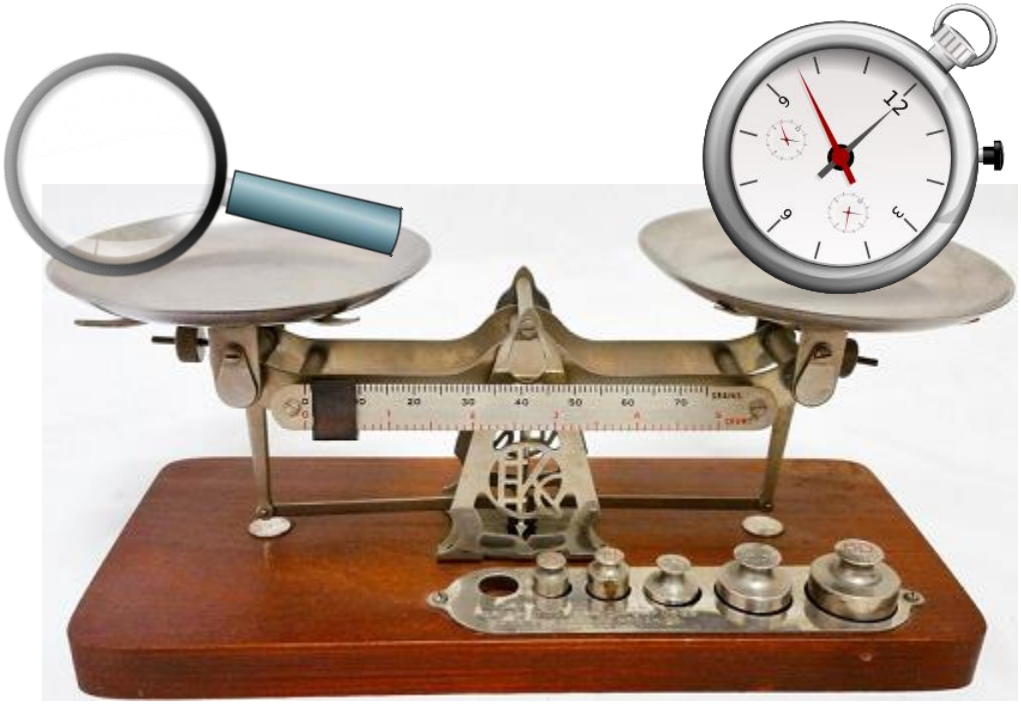


Simheuristics

How accuratelly **benchmarks** represent **real-life scenarios**?

- Benchmarks use to be a **trade-off** between **accuracy** and **time** constrains for decision making.



Simheuristics

How accurately **benchmarks** represent **real-life scenarios**?

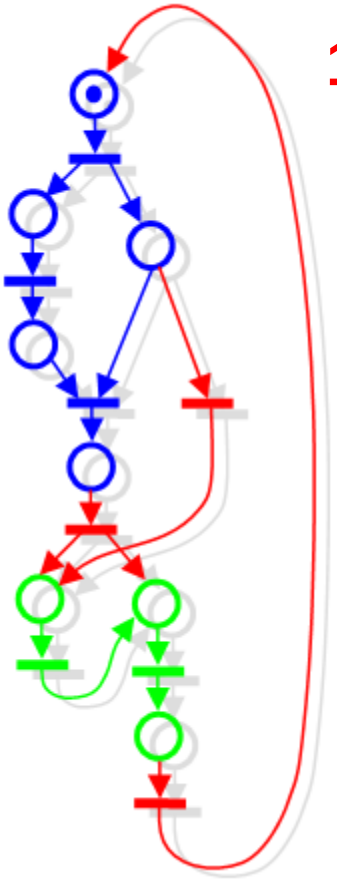
- Benchmarks use to be a trade-off between accuracy and time constrains for decision making.
- Usually focussed on a **single stage** of the **whole picture** (i.e. supply chain):
  - The modelled system might be **decontextualized**.
  - Some **uncontrolable parameters** are modelled by **stochastic variables** in absence of a better model.

Simheuristics

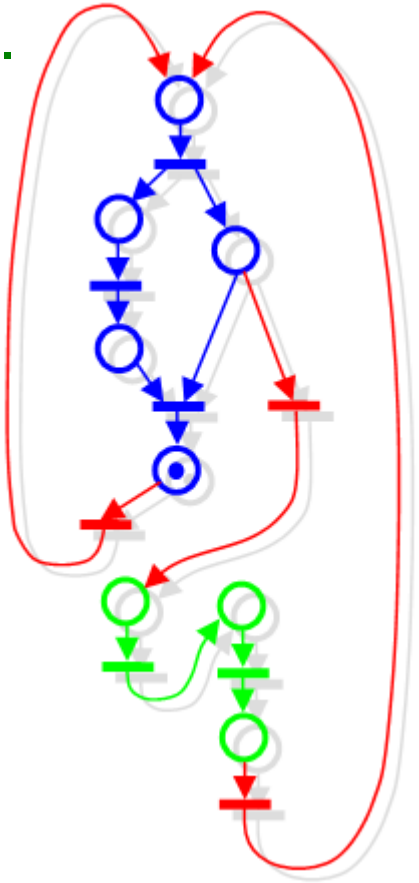
How accurately **benchmarks** represent **real-life scenarios**?

- Benchmarks use to be a trade-off between accuracy and time constrains for decision making.
- Usually focussed on a single stage of the whole picture (i.e. supply chain):
  - The modelled system might be decontextualized.
  - Some uncontrolable parameters are modelled by stochastic variables in absence of a better model.
- Usually **skip details** in the structure and behaviour of the **elements** composing the system of interest (i.e. nodes).

Contents

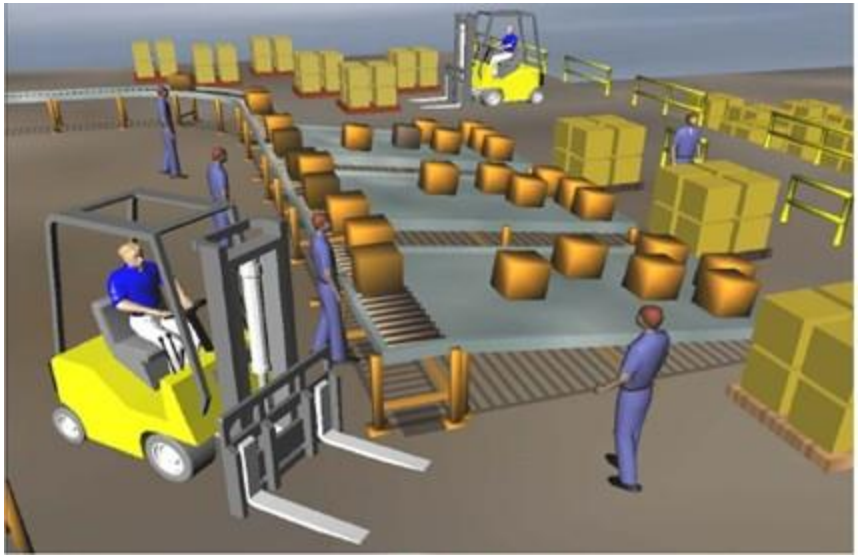


1. Motivation: decision making support.
2. **Proposed methodology.**
3. Conclusions.
4. Open research lines.



Simheuristics & PN

How is it posible to **improve** the **modelling scope** applied to **Simheuristics**?

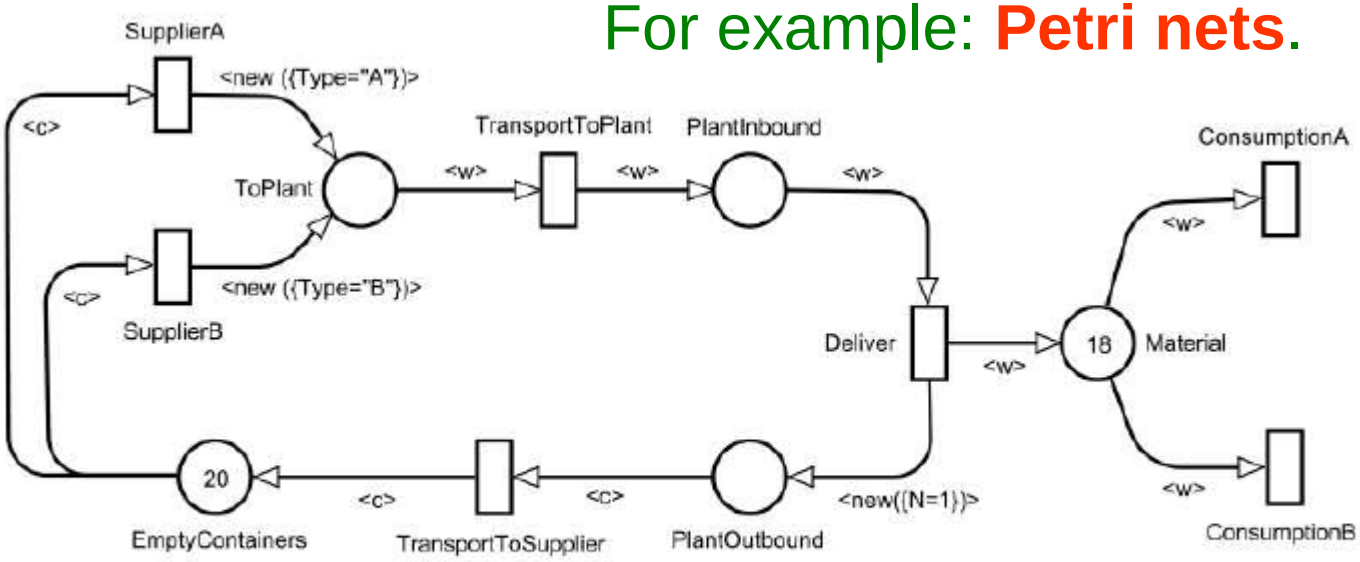


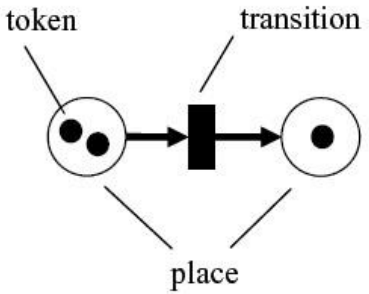
Simheuristics & PN

How is it posible to **improve** the **modelling scope** applied to **Simheuristics**?

Combining Simheuristics with a **modelling formalism**.

For example: **Petri nets**.





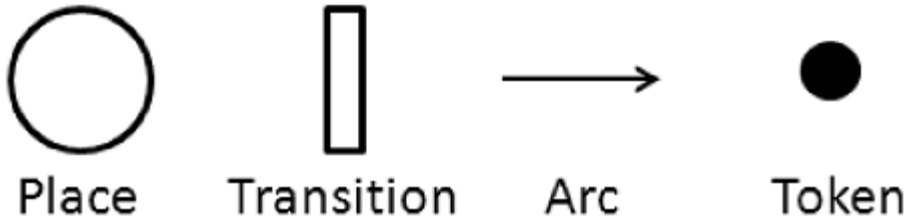
Simheuristics & PN

How is it posible to **improve** the **modelling scope** applied to **Simheuristics**?

Combining Simheuristics with a **modelling formalism**.

For example: **Petri nets**.

•Its main application consists of modelling **discrete event systems** with **parallel processes**, **competition for shared resources**, and **synchronizations**. However, they can also represent **hybrid and continuous systems**.



Simheuristics & PN

How is it posible to **improve** the **modelling scope** applied to **Simheuristics**?

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For example: **Petri nets**.

- Its main application consists of modelling **discrete event systems** with **parallel processes**, **competition for shared resources**, and **synchronizations**. However, they can also represent **hybrid and continuous systems**.
- Many **logistic systems** and **supply chains** can be interpreted as **discrete event systems**.

Simheuristics & PN

Outcome of **Combining Simheuristics with Petri nets**.

Simheuristics provides:

- A representation of the **elements of the benchmark** (nodes, routes).
- A representation of the **optimization problem** itself (objective function, constraints).
- A **methodology for solving the stochastic problem**.

Simheuristics & PN

Outcome of **Combining Simheuristics with Petri nets**.

Petri nets can provide models for:

- Detailing **elements of the grid**
- Detailing **elements of the environment** of the system itself.
- **Linking** different **benchmarks**.
- Update of **objective function**, **constraints**, and structure of a **solution** of the optimization problem with **decision variables** and parameters provided by the Petri net.

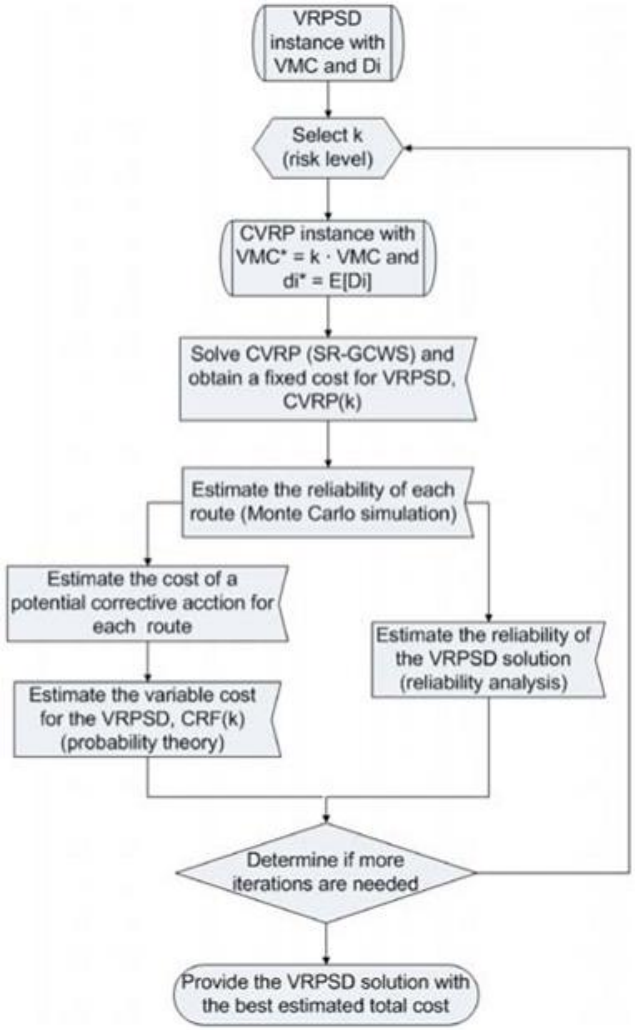
Simheuristics & PN

Outcome of **Combining Simheuristics with Petri nets**:

- More **computer resources** required to complete an optimization process. ☹
- More **accurate description** and quantification of the behaviour of the system. ☺
- More **useful decision support**, since the system is more detailed and/or represents a broader system. ☺
- It is posible to model **complete supply chains**, including several benchmarks for different logistic systems and different Petri nets to glue and synchronize them. ☺

Example

Integrating Petri nets in Simheuristics applied to solve the CVRPSD.



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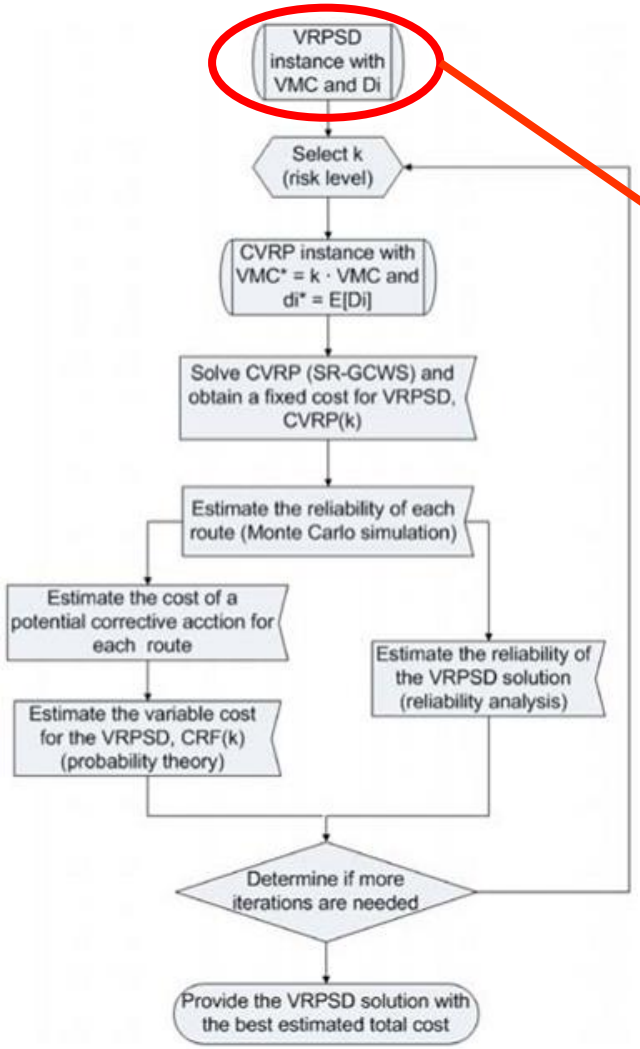
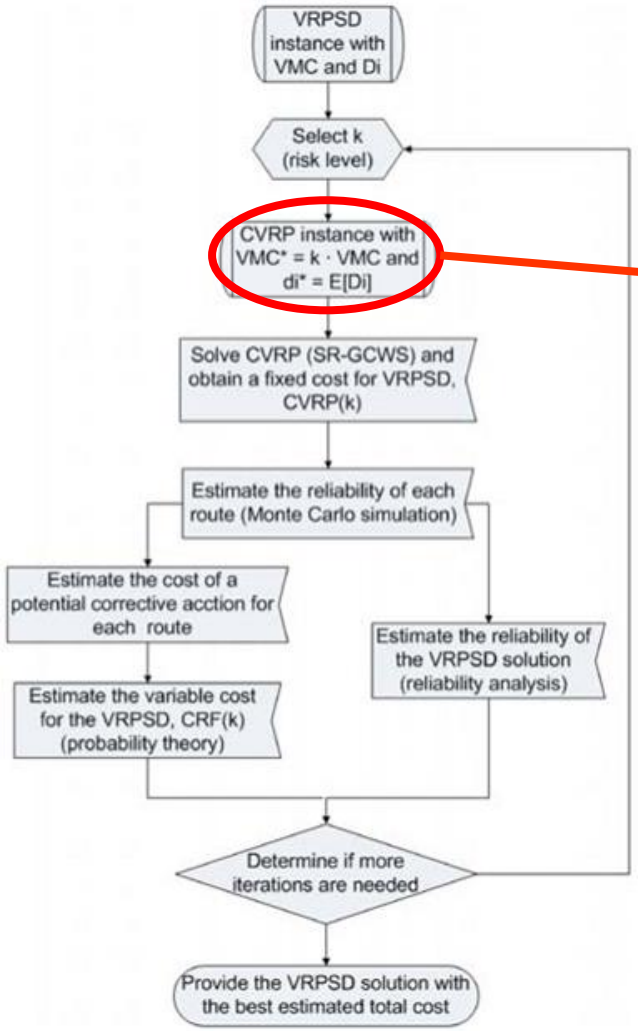


Completing the objective function and the necessary constrains with the additional decision variables and parameters provided by the Petri net

Example

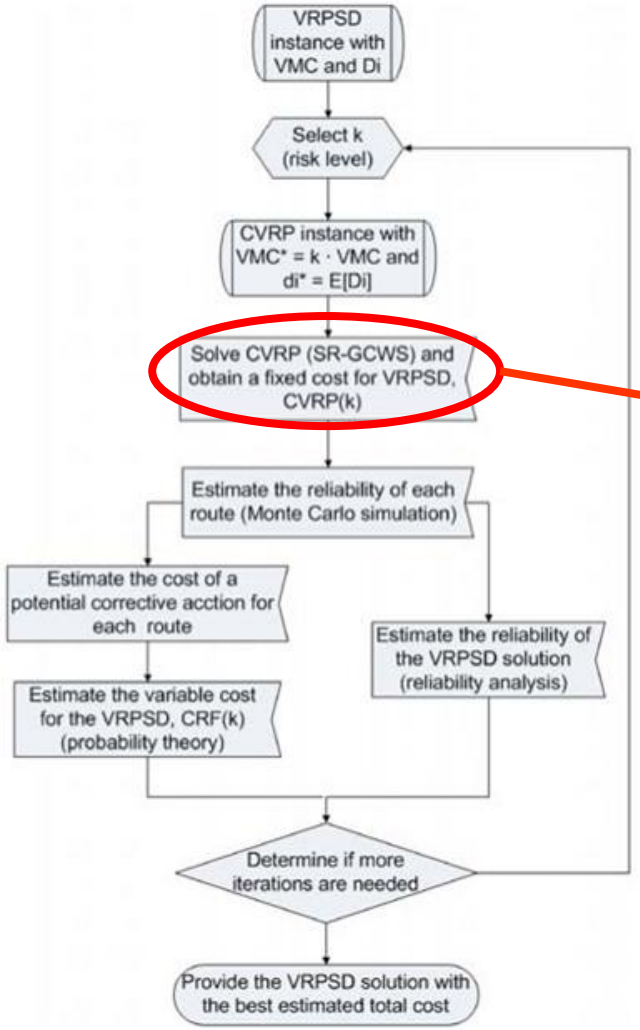
Integrating Petri nets in Simheuristics applied to solve the CVRPSD.



Initial simulation of the Petri net model of the nodes, leading to 'deterministic' demands

Example

Integrating Petri nets in Simheuristics applied to solve the CVRPSD.



Calculate the cost for the CVRP by simulating the Petri net with the chosen solution, since its application may be interferred by the behaviour of the nets.

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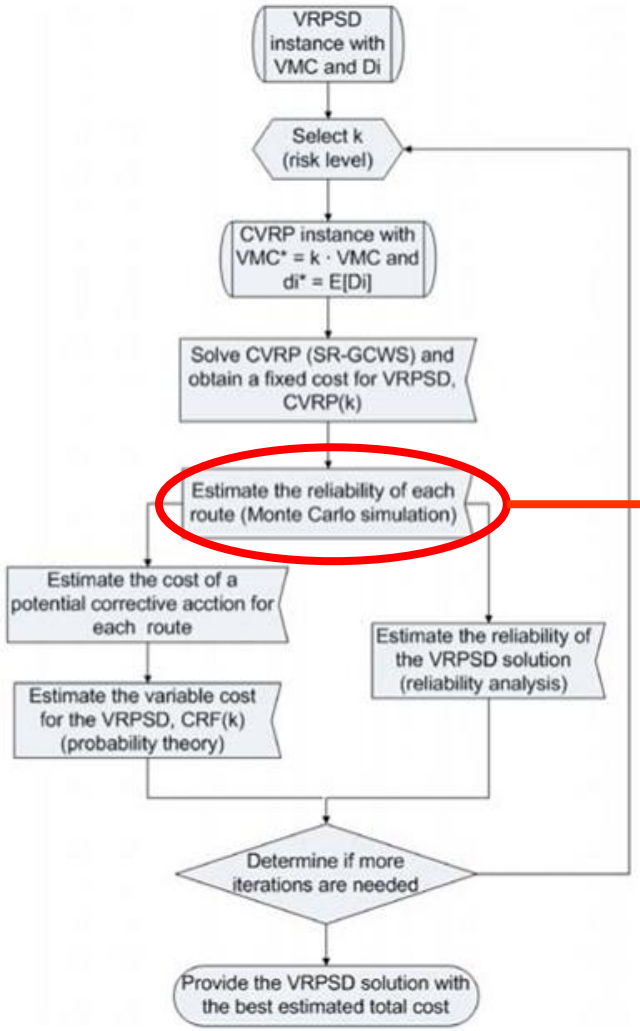
Integrating Petri nets in Simheuristics applied to solve the CVRPSD.



Apply Montecarlo simulation for the stochastic parameters of the PN and simulate the behaviour of the net in conjunction with the solution of the problem to calculate reliability (**high computational cost**).

Example

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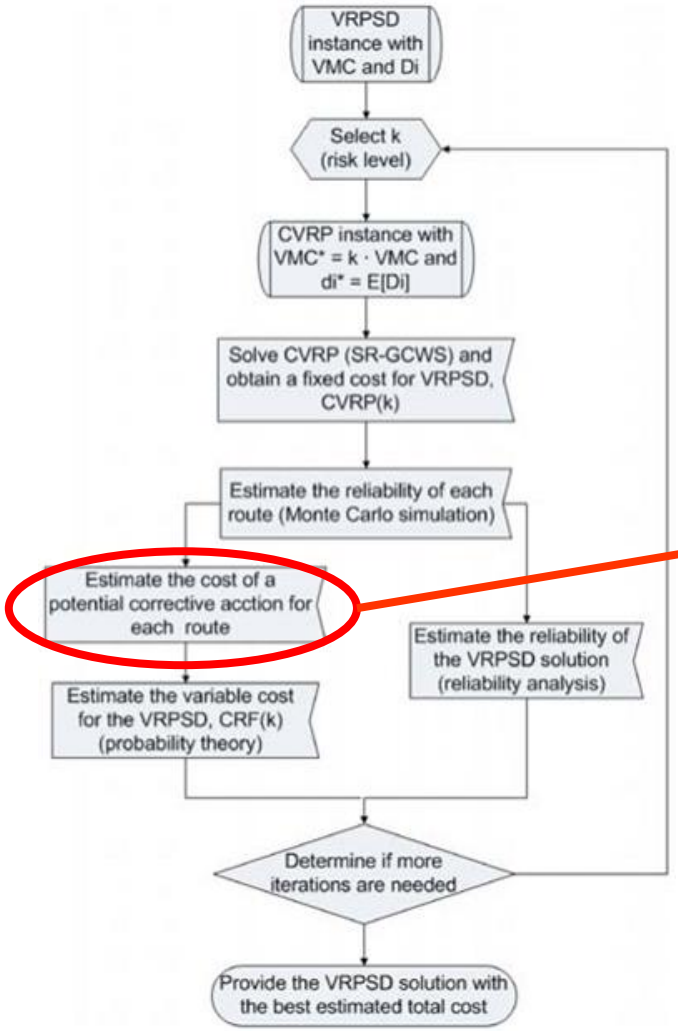

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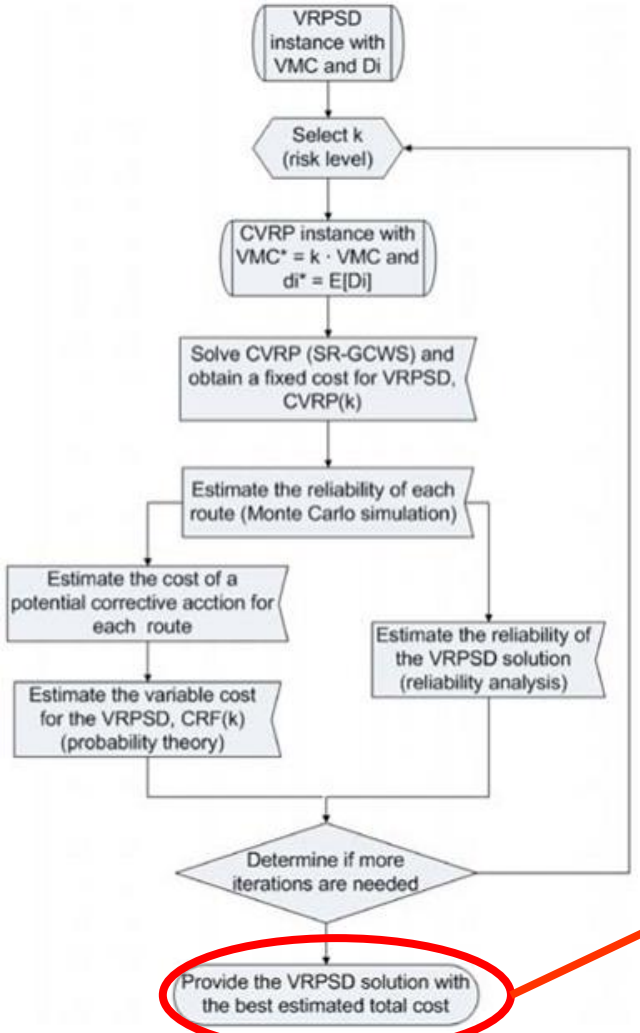
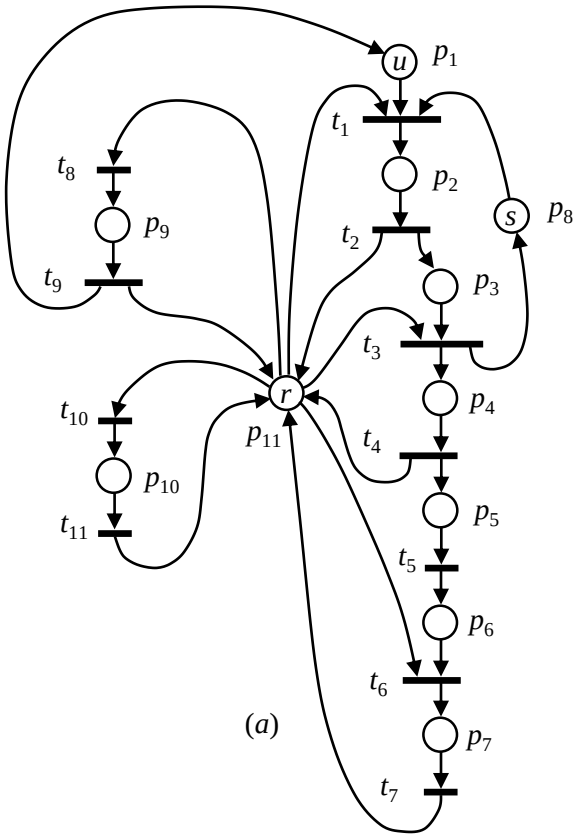


Provide also selected values for the decisión variables added by the Petri net to the original system.

Example (CVRPSD)

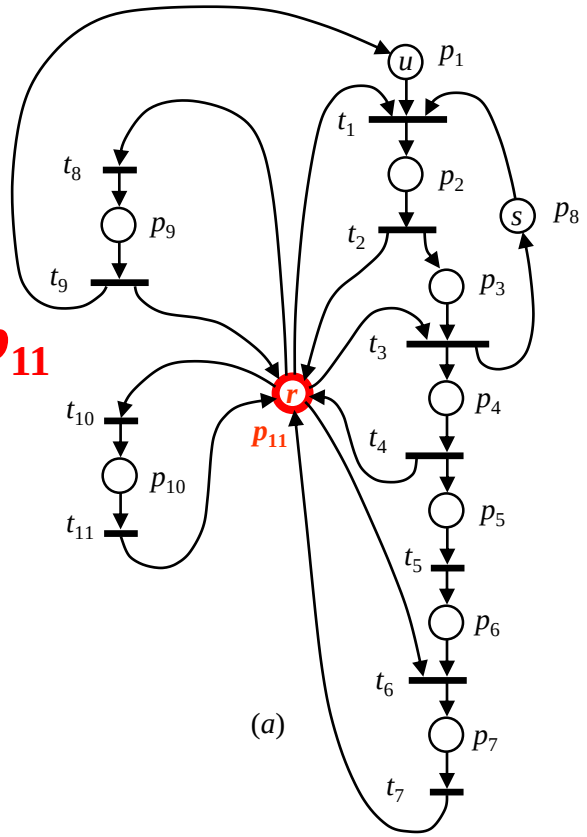
Node: manufacturing facility



Example (CVRPSD)

Node: manufacturing facility

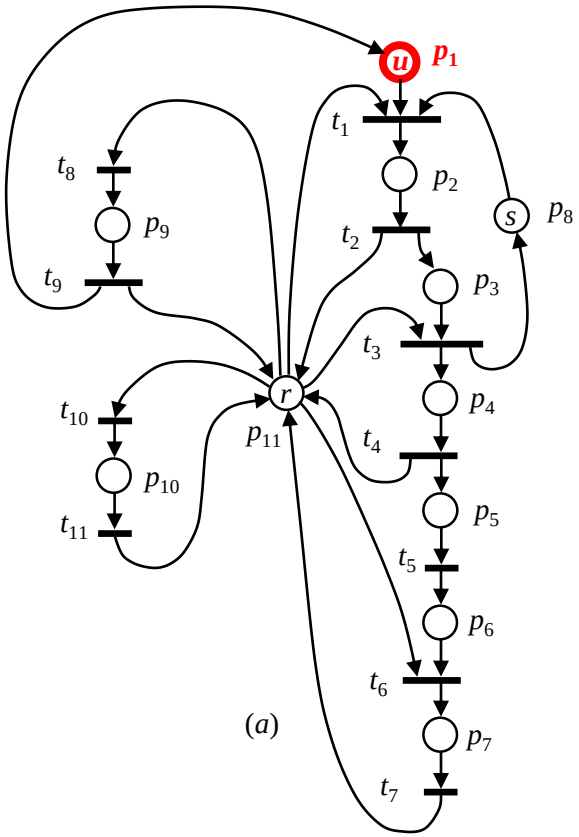
shared resources – p_{11}



operators,
forklifts,
AGVs,
etc.

Example (CVRPSD)

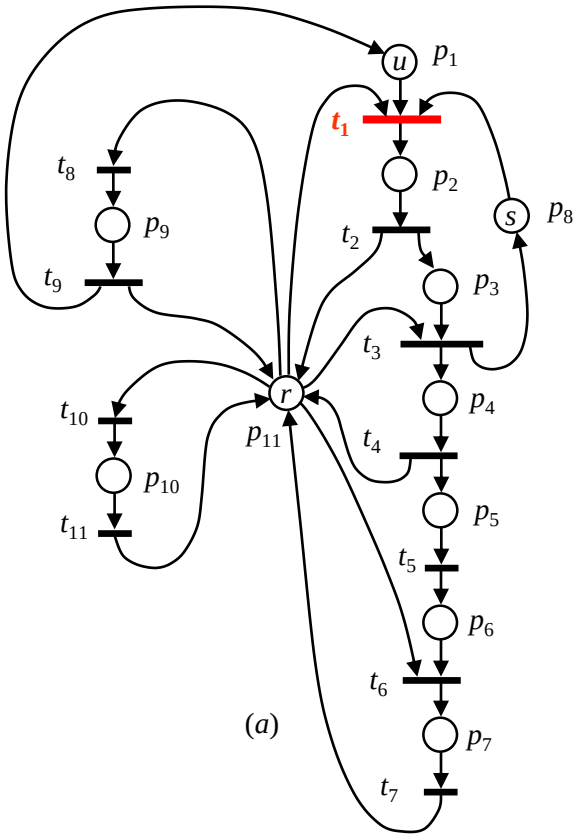
Node: manufacturing facility



p_1 - stock of raw materials

Example (CVRPSD)

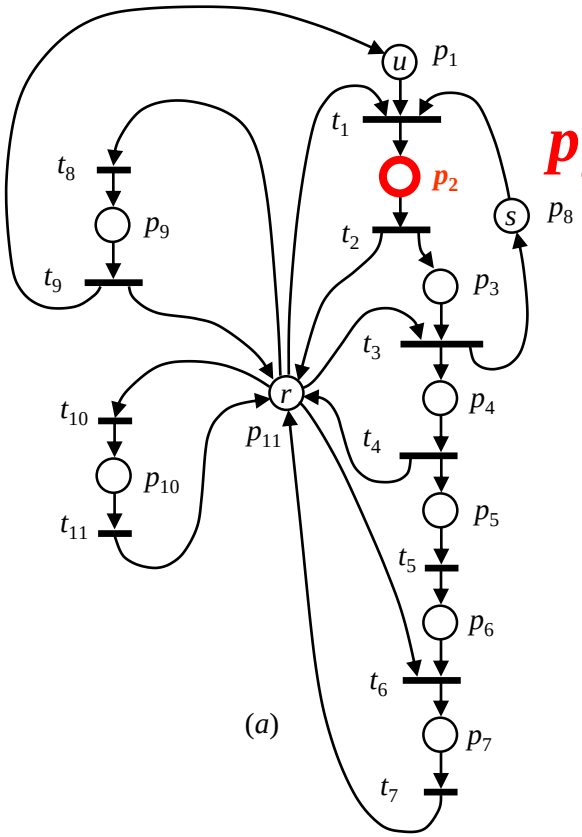
Node: manufacturing facility



t_1 – loading of raw materials in the manufacturing line

Example (CVRPSD)

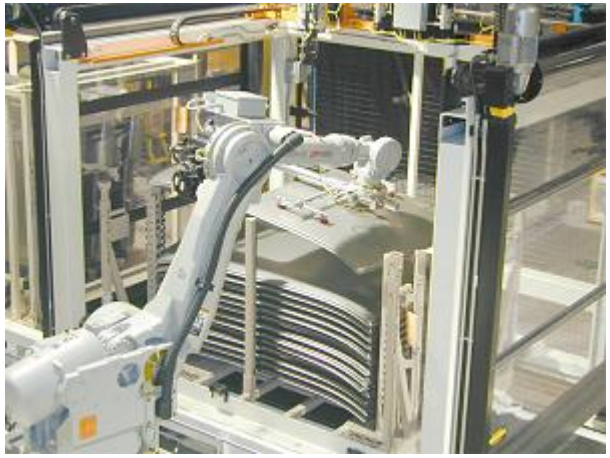
Node: manufacturing facility

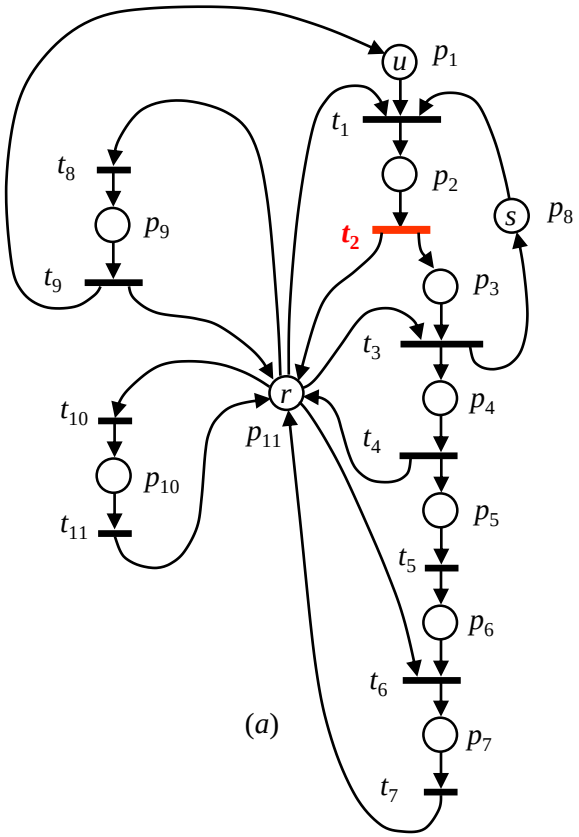


p_2 – manufacturing line

Example (CVRPSD)

Node: manufacturing facility

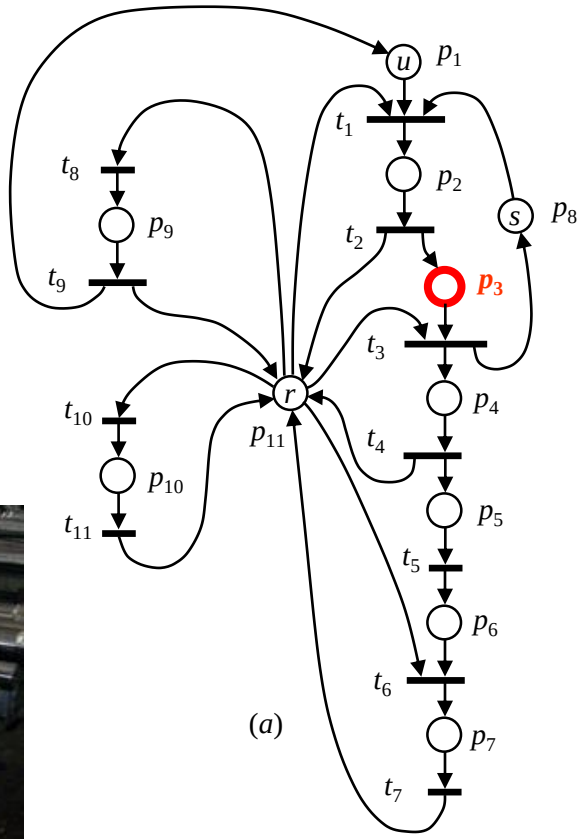




t_2 – placing a finished product in the manufacturing buffer

Example (CVRPSD)

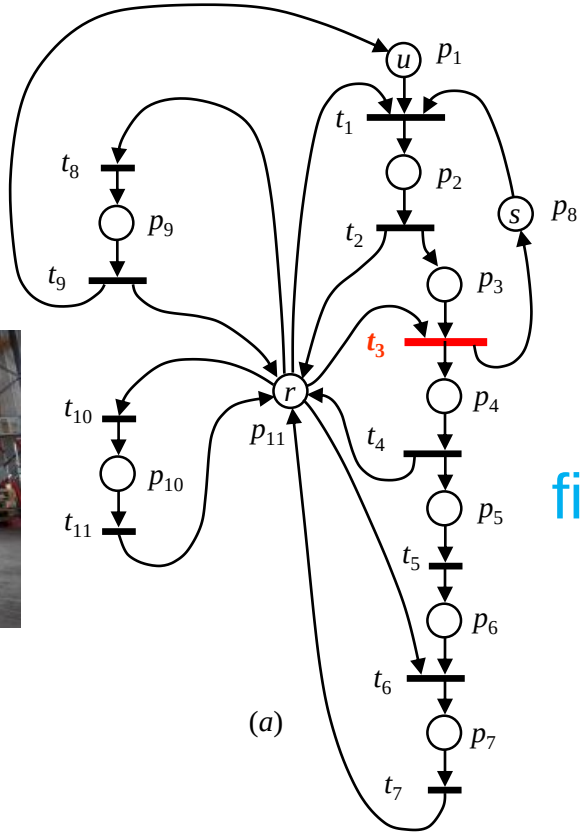
Node: manufacturing facility



p_3 – buffer of finished products

Example (CVRPSD)

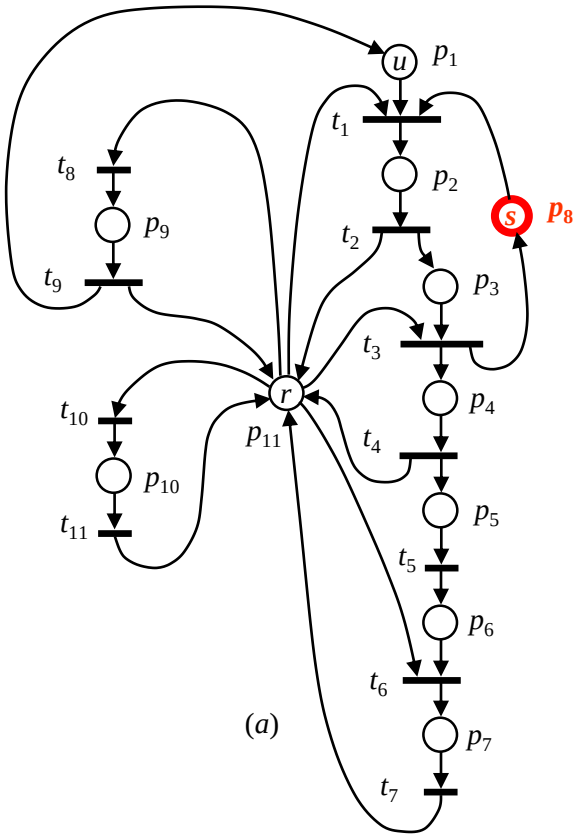
Node: manufacturing facility



t_3 – starting the transportation of finished products to the warehouse

Example (CVRPSD)

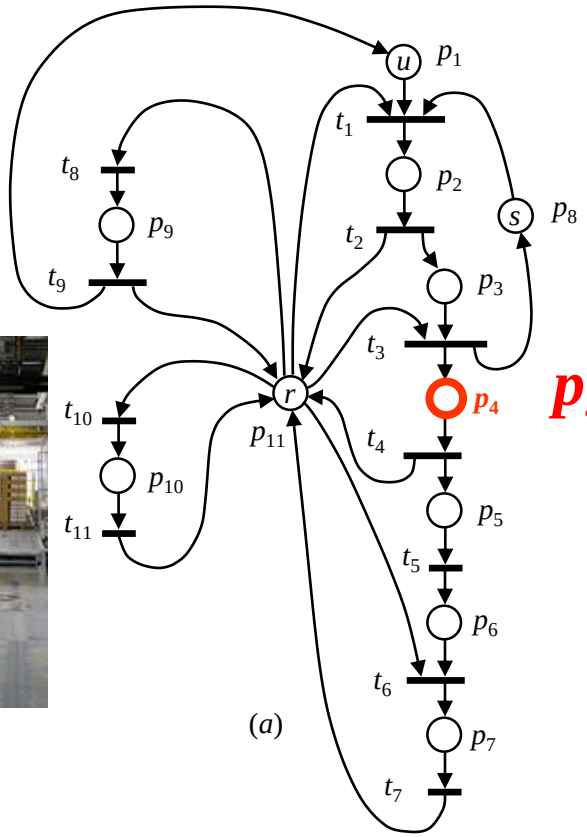
Node: manufacturing facility



p_8 – capacity of the manufacturing line and its output buffer

Example (CVRPSD)

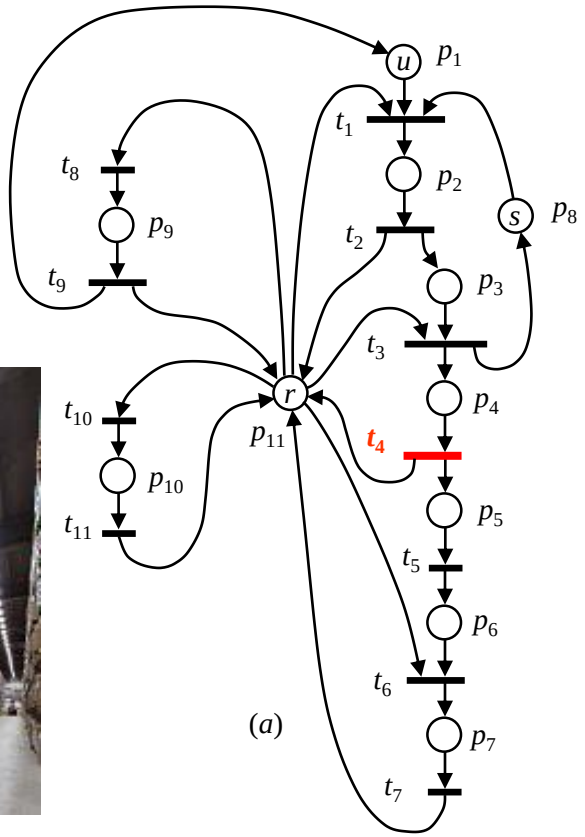
Node: manufacturing facility



p_4 – transportation to warehouse

Example (CVRPSD)

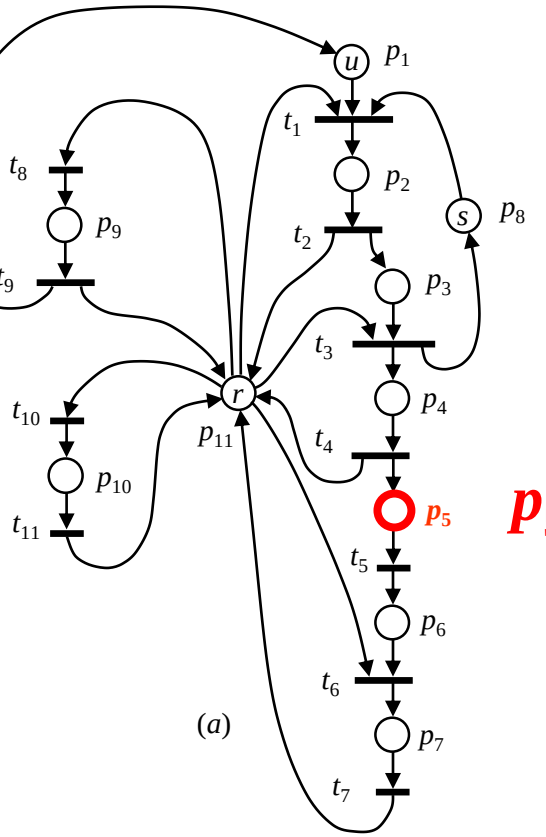
Node: manufacturing facility



t_4 – storing finished products in the warehouse

Example (CVRPSD)

Node: manufacturing facility

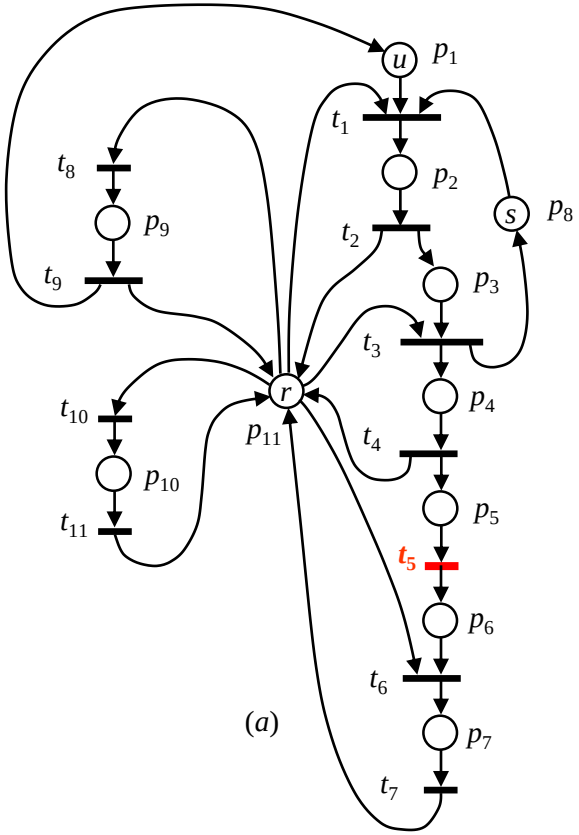


p_5 – warehouse

Example (CVRPSD)

Node: manufacturing facility

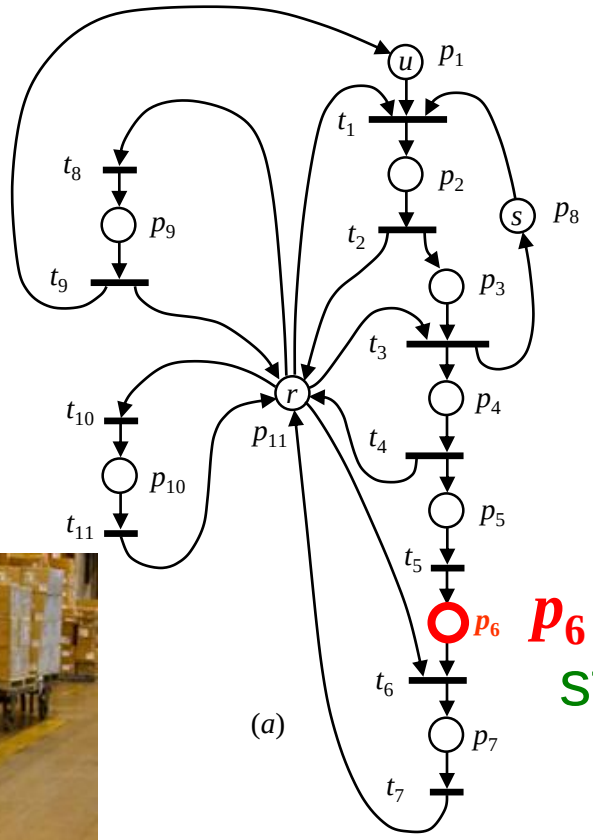
Stochastic firing (selling and shipping goods)



t_5 – Selection of products to be delivered.

Example (CVRPSD)

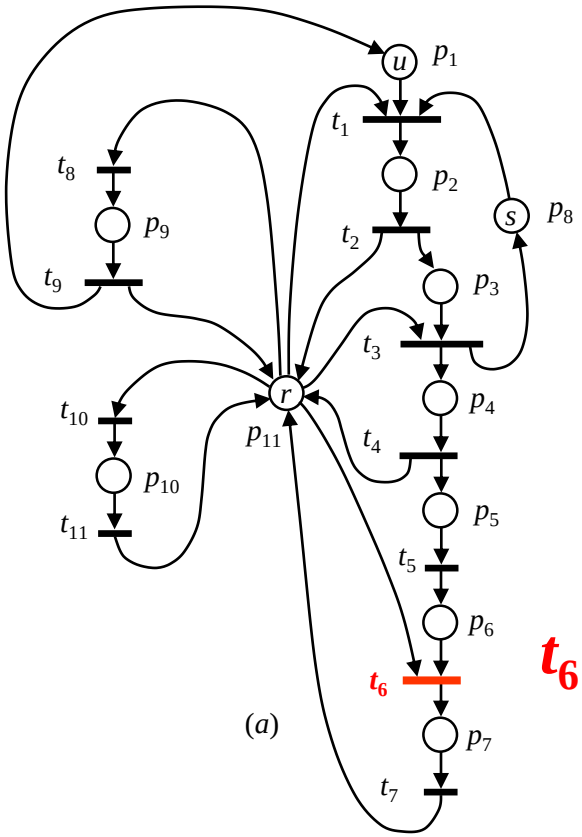
Node: manufacturing facility



p_6 – transportation of stored products for shipping

Example (CVRPSD)

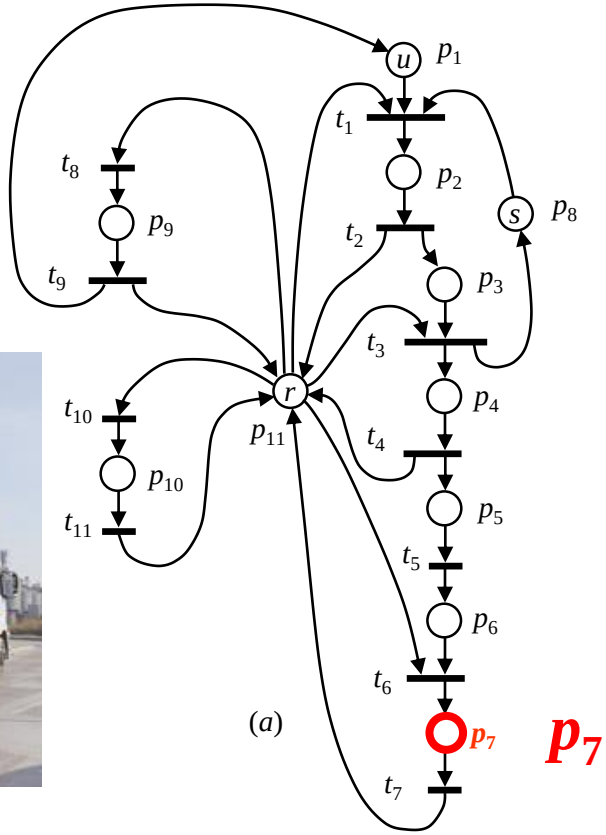
Node: manufacturing facility



t_6 – starting freight preparation

Example (CVRPSD)

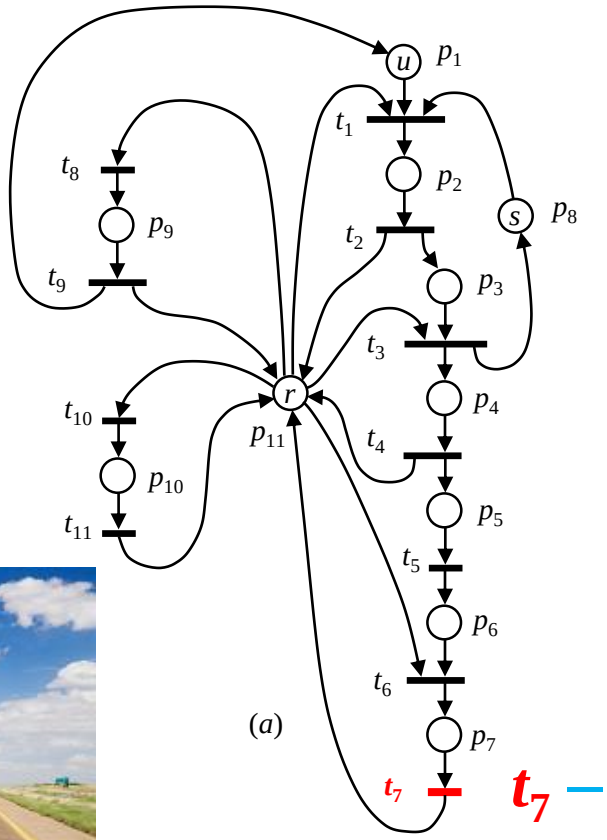
Node: manufacturing facility



p_7 – freight preparation

Example (CVRPSD)

Node: manufacturing facility

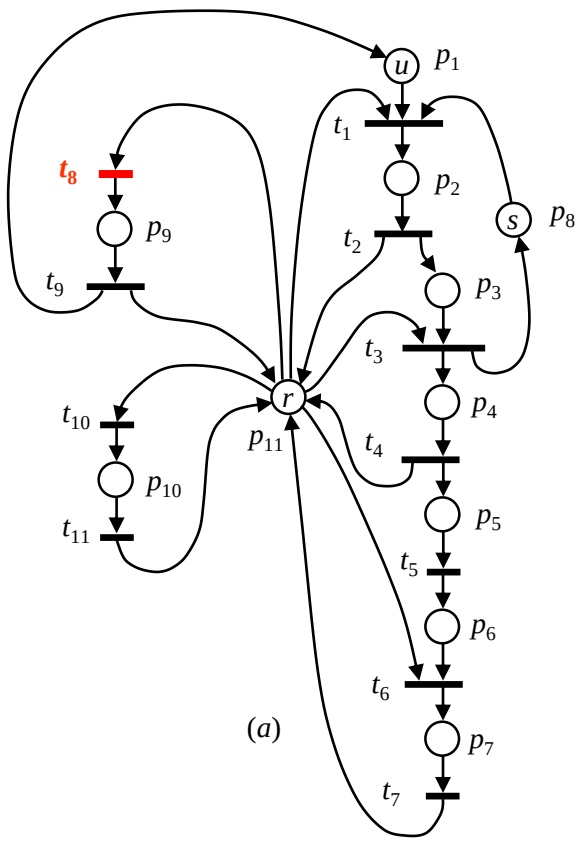


t_7 – shipping of sold products

Example (CVRPSD)

Node: manufacturing facility

Arriving of a vehicle with raw materials from the depot – t_8

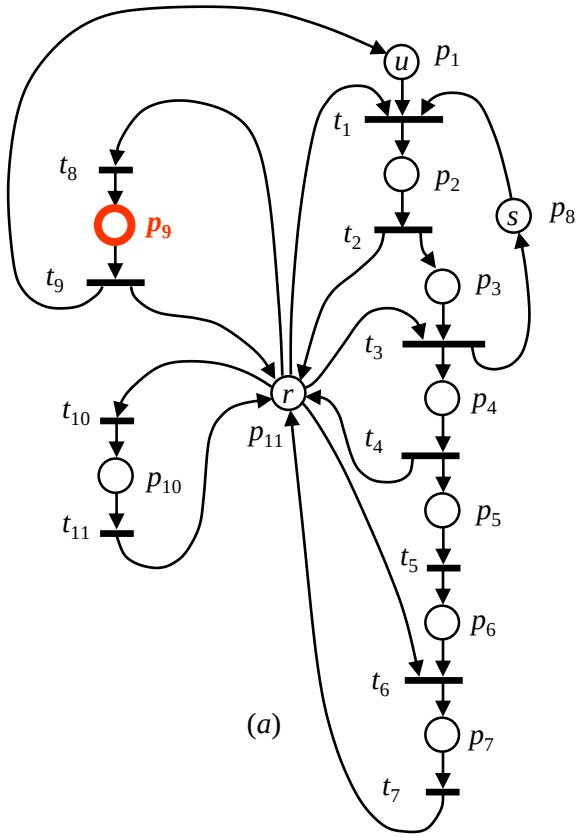


1st. sinchronization with Simheuristics

Example (CVRPSD)

Node: manufacturing facility

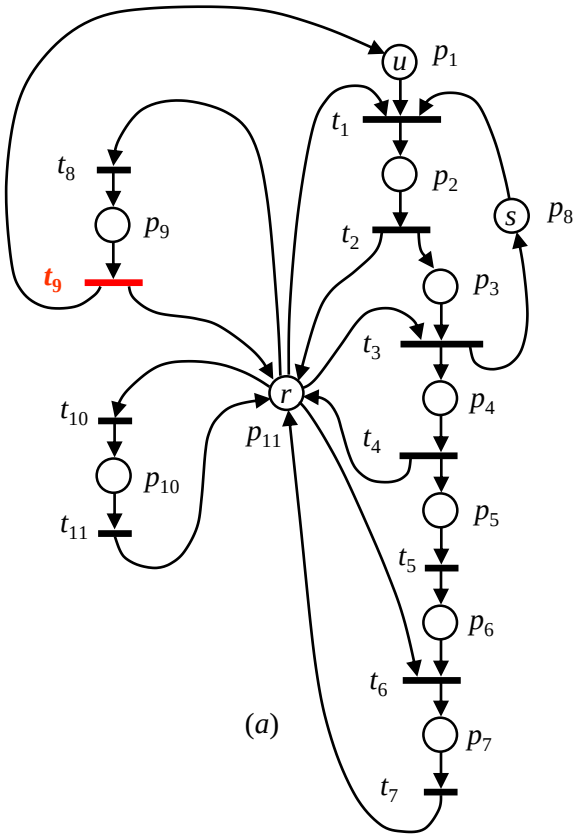
Unloading of a vehicle – p_9



Example (CVRPSD)

Node: manufacturing facility

Departing of an unloaded vehicle – t_9

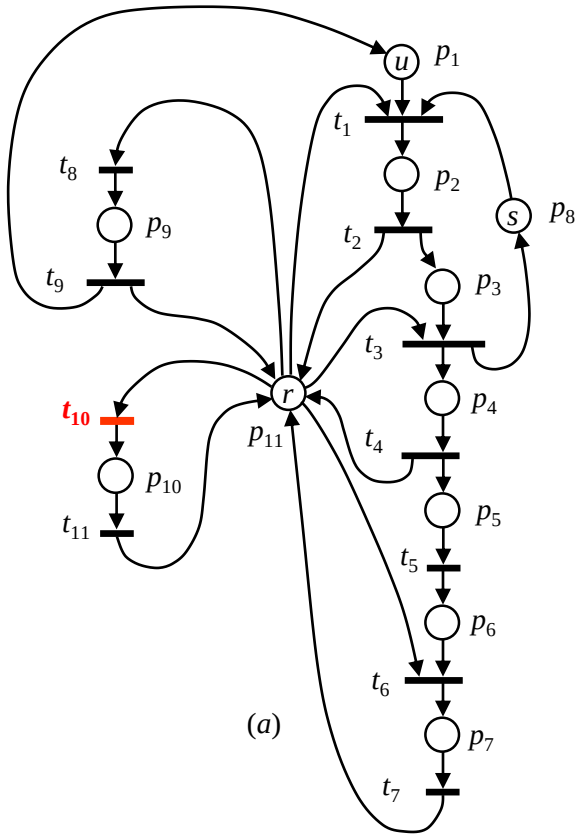


2nd. sinchronization with Simheuristics

Example (CVRPSD)

Node: manufacturing facility

Starting 'other activity' – t_{10}

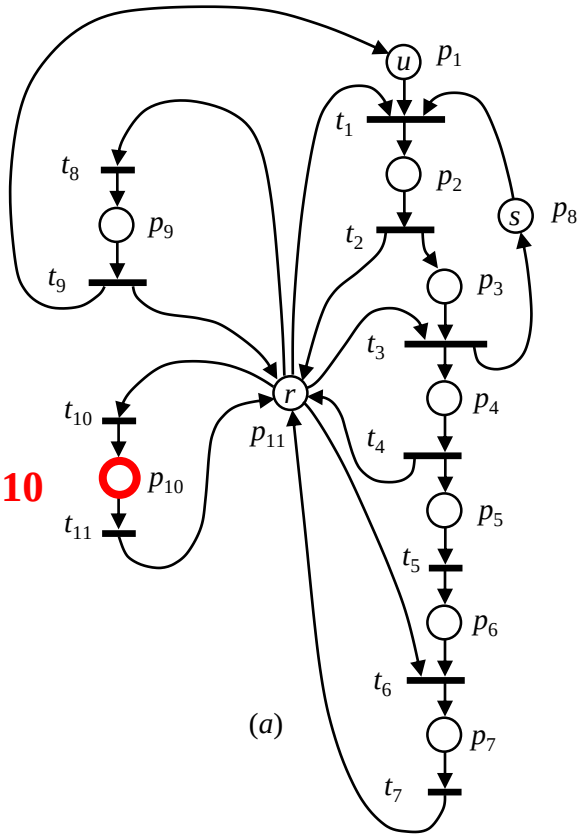


'Other activities' prevent the use of shared resources for different tasks

Example (CVRPSD)

Node: manufacturing facility

Other activities – p_{10}

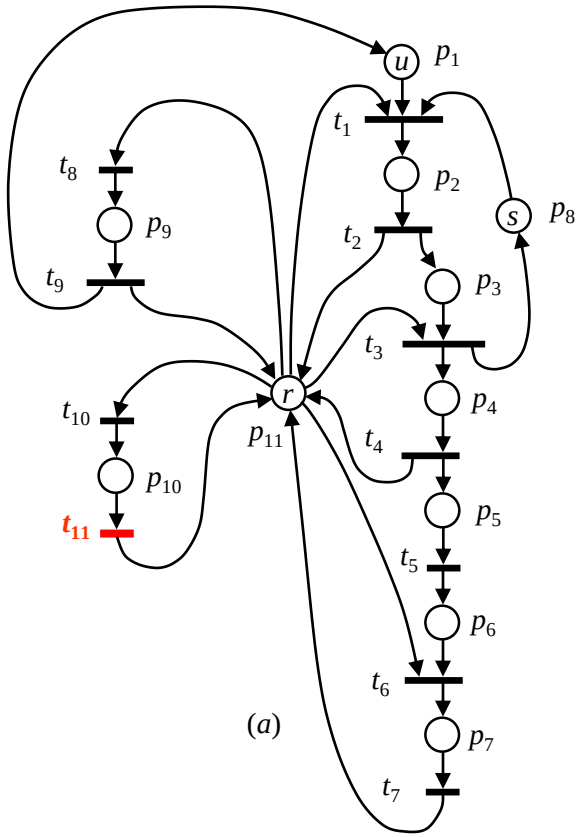


‘Other activities’ prevent the use of shared resources for different tasks

Example (CVRPSD)

Node: manufacturing facility

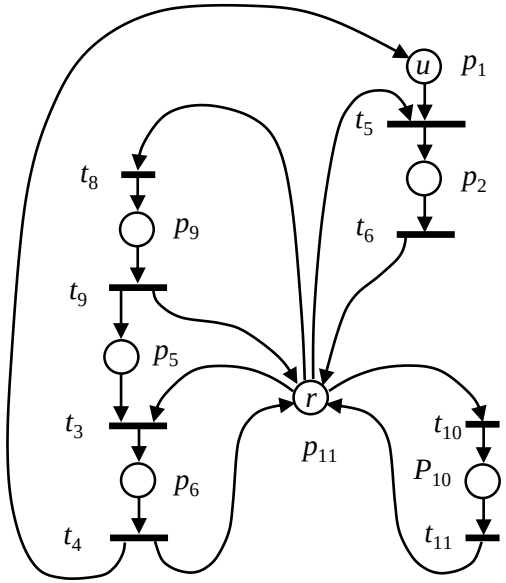
Finishing ‘other activity’ – t_{11}



‘Other activities’ prevent the use of shared resources for different tasks

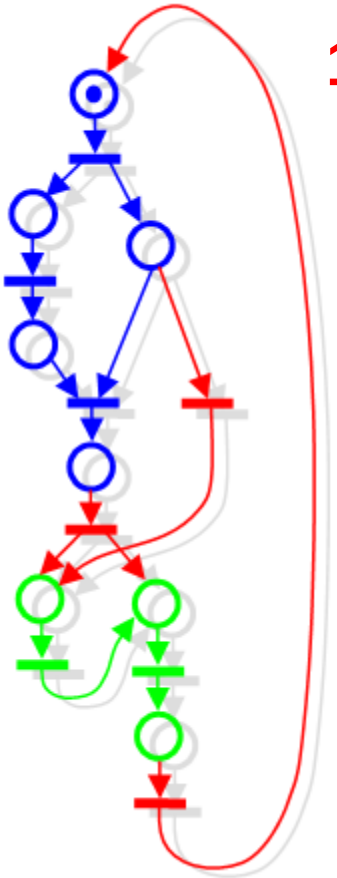
Example (CVRPSD)

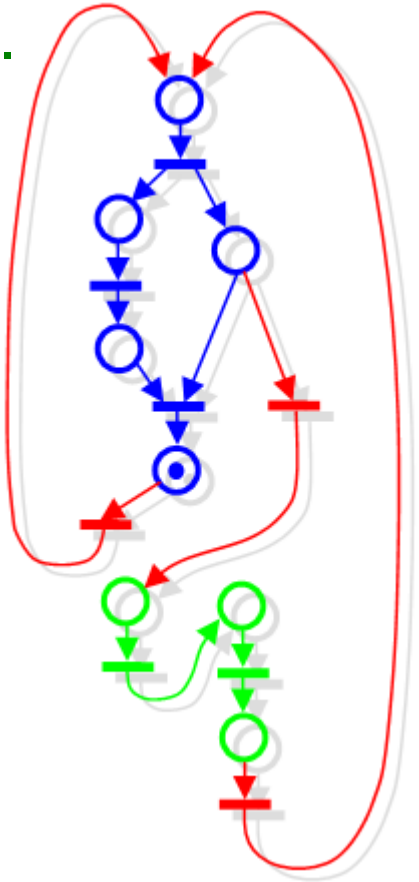
Node: retailer



(*b*)

Contents





Conclusions

Combining Simheuristics and Petri nets is a **promising methodology** allowing to **expand** the modeling potential of **Simheuristics**.

Advantages:

a) More **detailed representation** of the **behaviour** of the system and its environment.

b) Wider range of decision variables, as components of the solution of the problem and of the objective function.

c) Substitution of **uncontrollable stochastic parameters** in the original system by **deterministic** outcomes of the **Petri net** models (these models may also present stochastic parameters).

Conclusions

Advantages of **combining Simheuristics** and **Petri nets**:

d) Expanding the scope of the original **Simheuristic** problem in **time** and **space**:

d.1) Considering a **time span** of the optimization problem a **bit longer** than the original one (better setting of initial conditions & assesing the effects of the decisions made).

d.2) Considering a **time span** of the optimization problem including **several times the original one**; hence, a solution of a combined problem would include several (sequential) solutions of the original one. This would mitigate the **'transient'** effects of a single solution and assess **tactical decisions** and not only operational ones.

Conclusions

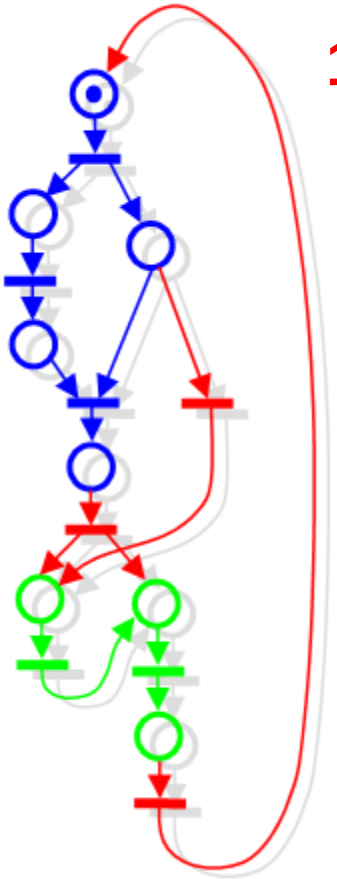
Advantages of **combining Simheuristics** and **Petri nets**:

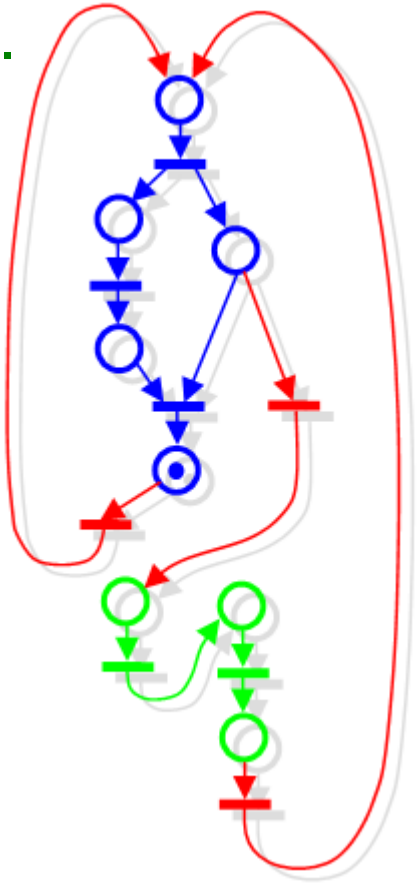
d) Expanding the scope of the original **Simheuristic** problem in **time and space**:

d.3) Considering a **scope** of the **modelled system** a bit **longer** or **more detailed** than the original one (more **accurate description** of the behaviour of the system).

d.4) Considering a **scope** of the **modelled system several times** the original one; hence, a solution of a combined problem would include **several** (perhaps simultaneous) **solutions of the original one**. This would include an **accurate description** of the influence of every solution to the others and of a **larger system**.

Contents





Open research lines

Apply and **test the** proposed **methodology** to different cases.

Explore different approaches for **integrating Petri net** models in logistic, industrial, or computer systems to state combinatorial **optimization problems** with stochastic parameters to be solved by **Simheuristics**, for instance:

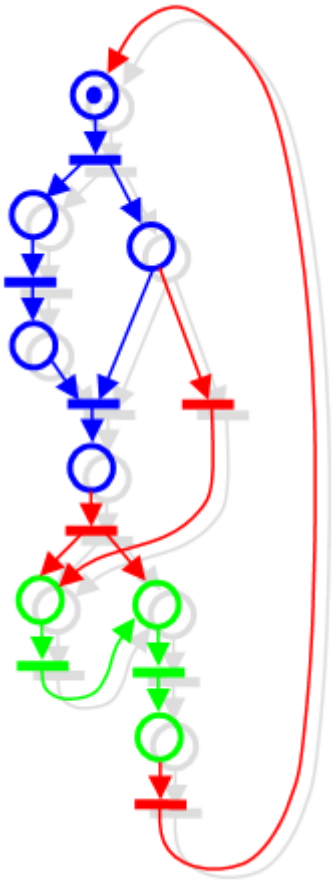
a) Model with a **Petri net** the **complete system** itself for example for avoiding collisions/conflicts/ deadlocks or for considering failures in a vehicle, traffic jams, etc. This approach might present as **practical limit** the number of potential routes as they may lead to too large models to be efficient.

Open research lines

Explore different approaches for **integrating Petri net** models and **Simheuristics**:

b) **Complement the system** of interest with its **environment**, modeled by the paradigm of Petri nets.

c) Develop **stochastic models of Petri nets** in diverse fields and apply **Simheuristics** as **solving methodology** for optimization problems with stochastic parameters.



Thank you very much for your attention!