Modernizing Agricultural Practice using Internet of Things

MAPIoT Summer School in Norway

24.07.2022 – 07.08.2022

Melsom High School, Sandefjord

organized by University of South-Eastern Norway

Digital design of food manufacturing processes – theory and applications

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ULBS

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Overview

Introduction to modeling and simulation using Petri Nets	• Basic elements: places, transitions , arcs • Simulation • Modeling concurrency • Timed nets • Determinism vs stochastic • Special arcs
Introduction to modelling and simulation of food manufacturing processes	• Modeling processing equipment • Modeling transport equipment • Modeling control • Modeling robots • Modeling human operators • Modeling a complete manufacturing line • Simulating a complete manufacturing line
Introduction to digital design manufacturing processes	• Designing the layout • Designing the operation of the line • Designing the command and control system

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MAPIoT

1. Introduction to modeling and simulation using Petri Nets

Modelling and simulation

- Model - simplified representation of reality
- Simulation – uses the model to predict how parts of/ real world evolve
- Mathematical models
  - Continous time models
    - Partial Differential Equation (PDE) from sciences (physics, chemistry, biology)
    - Change is continous in time
  - Discret event models
    - Change only at discret points in time (e.g Petri nets)

TINA (TIme petri Net Analyzer Toolbox

- Toolbox hompage with news, tutorials and software

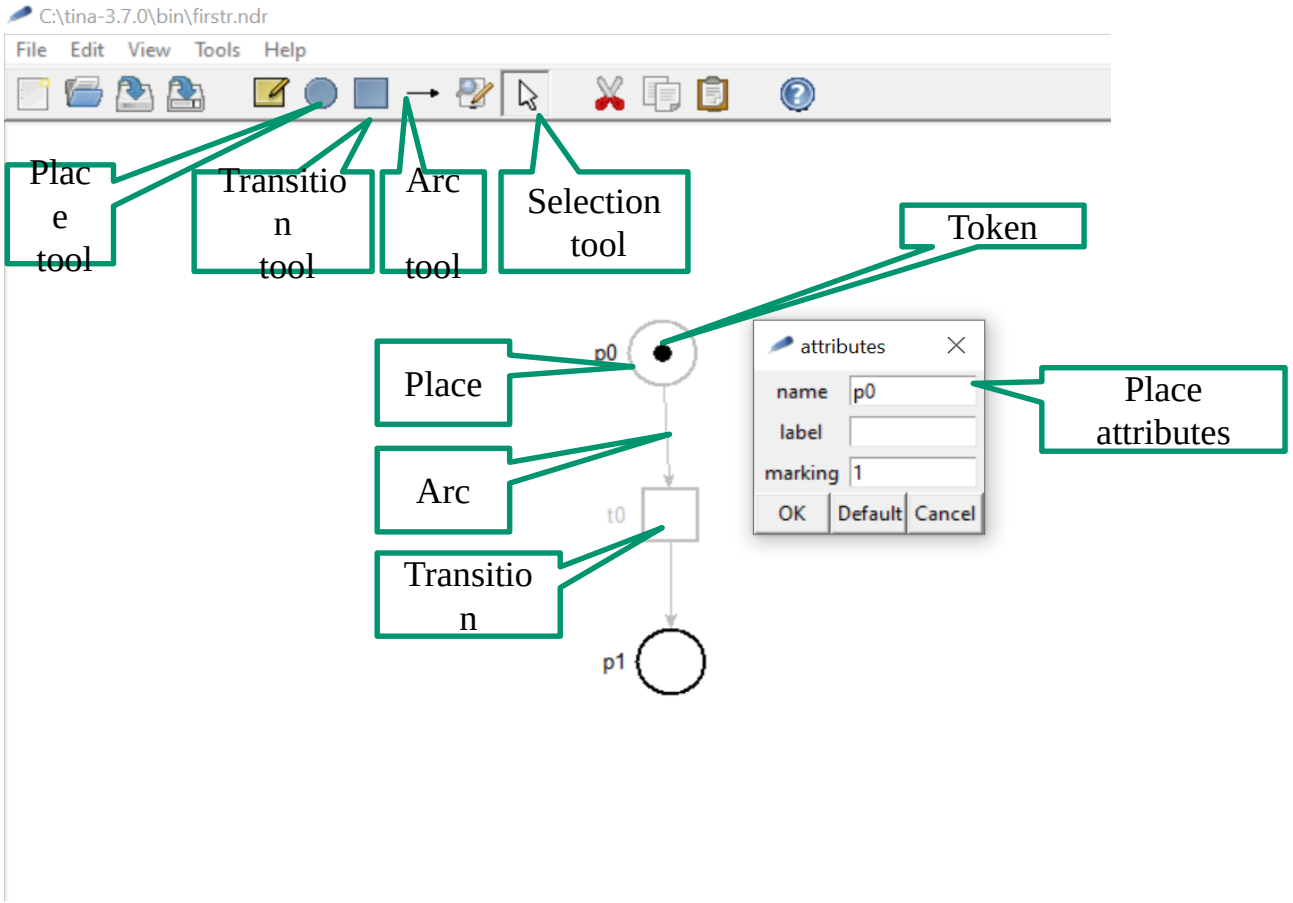
  https://projects.laas.fr/tina/papers.php

- Download software from

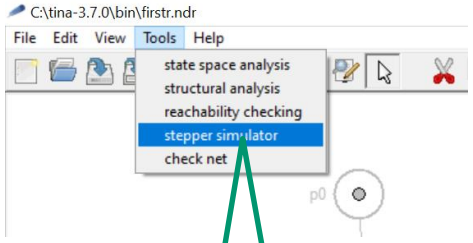
  https://projects.laas.fr/tina/binaries/tina-3.7.0-amd64-mswin.zip

- Unzip in an appropiate directory
- Start (with) the visual editor simulator **nd.exe** located in the bin subdirectory

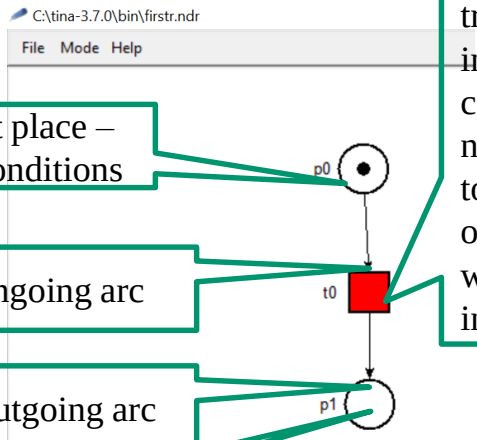
Basic elements: places, transitions , arcs



Simulation



Simulation tool



Input place – pre conditions

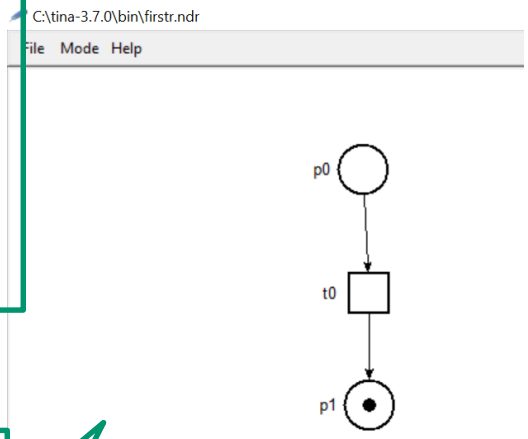
Ingoing arc

Outgoing arc

Output place -

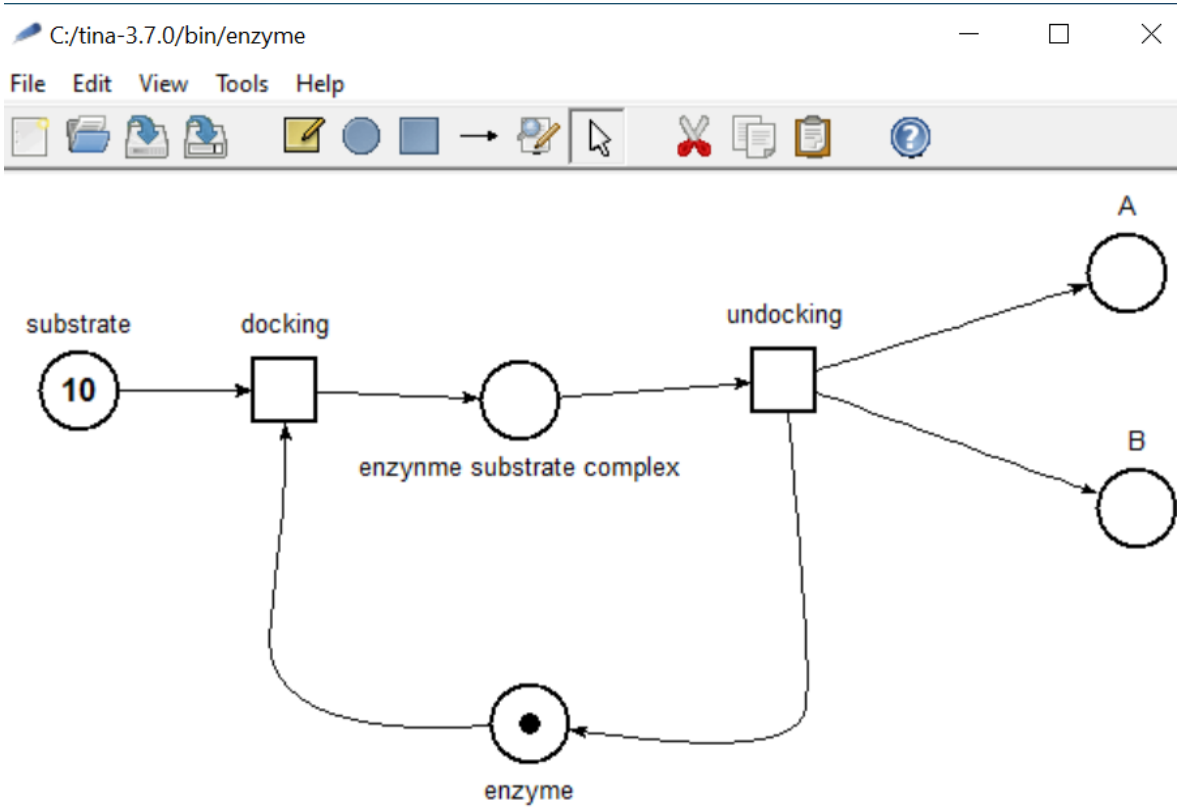
Active transition – the input places contain a number of token greater or equal to the weights of the ingoing arcs

By clicking on a active transition – the transition ***fires*** A number of token equal to the weight of the ingoing arc (1) is subtracted from the input places. A number of token equal to the weight of the outgoing arc (1) is added to the output places.

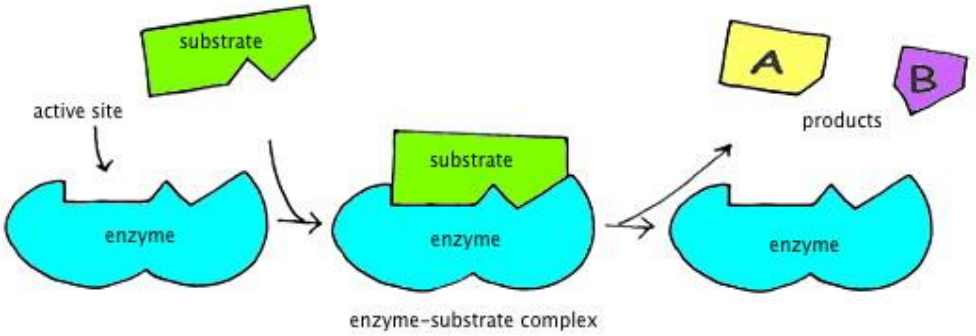


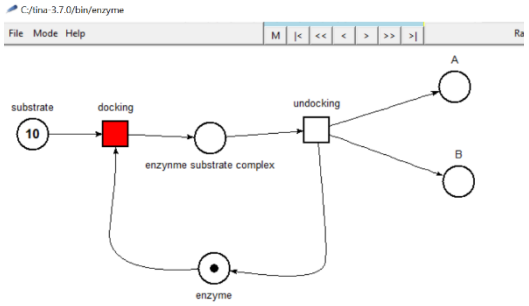
If no transition is active, the system has reached his final (dead) state

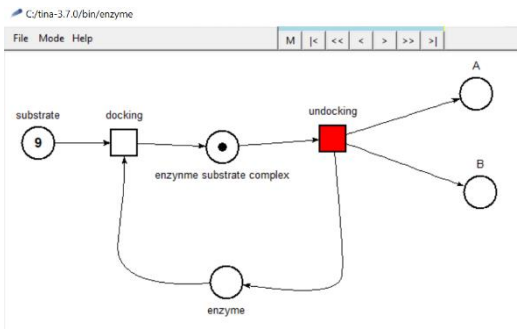
Simple model – enzymatic reaction

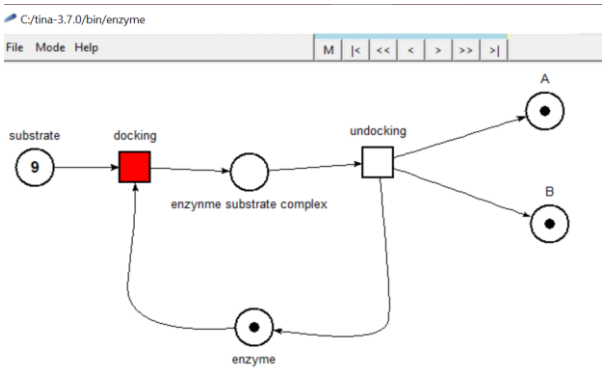


Simple model – simulation



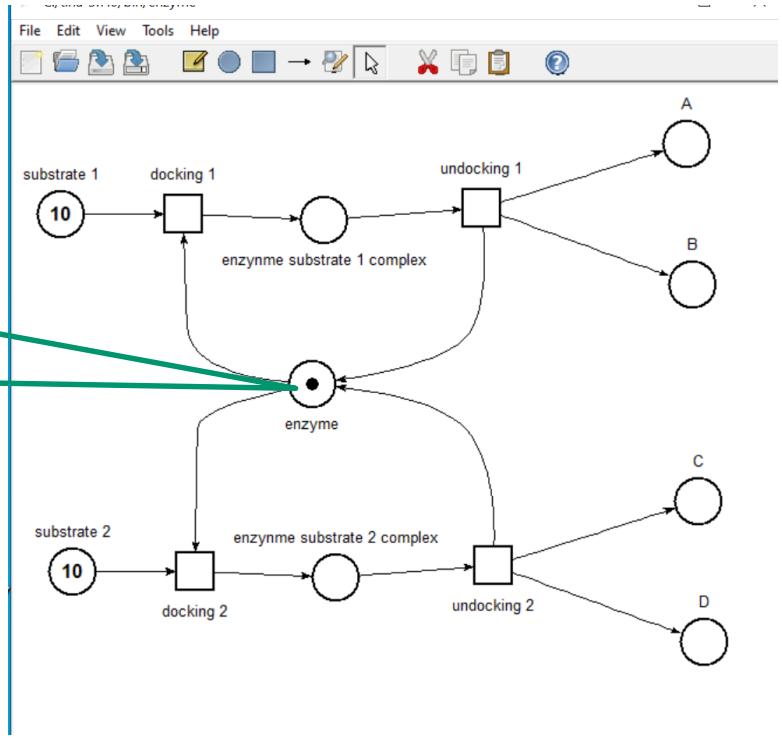




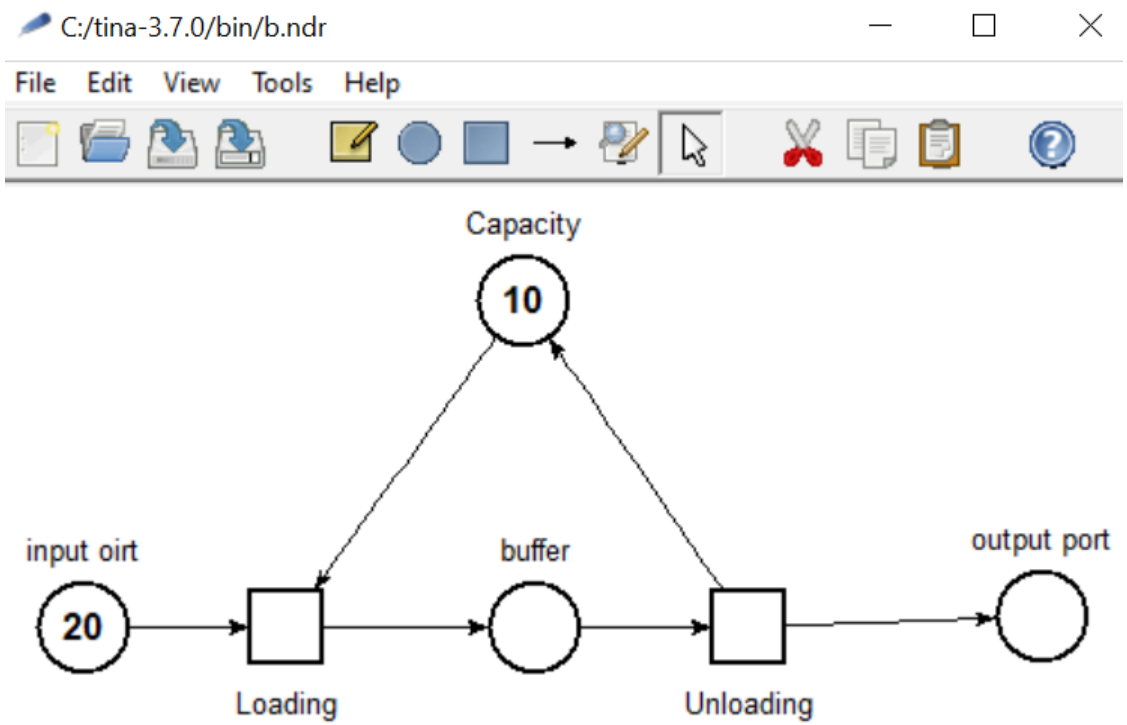


Modeling concurrency

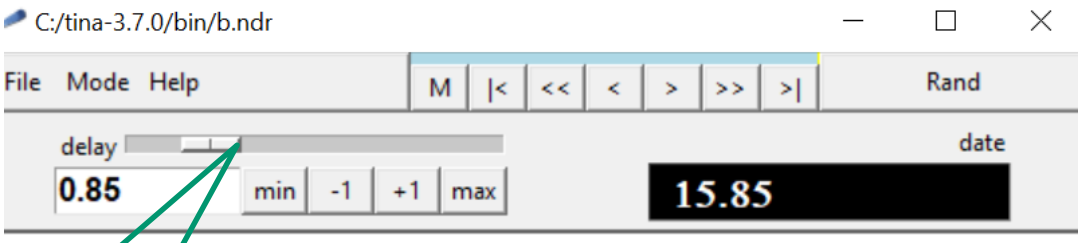
Two substrates can interact with the same enzyme – they compete for the active site



Buffer with limited capacity

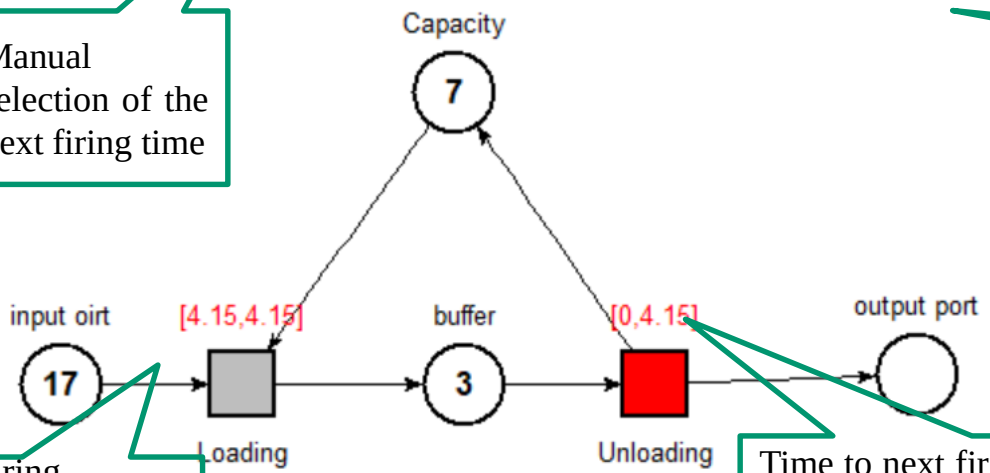


Timed nets



Manual selection of the next firing time

Current simulation time



Time to next firing – deterministic – if the transition remains active, it will fire in 4,15 time units

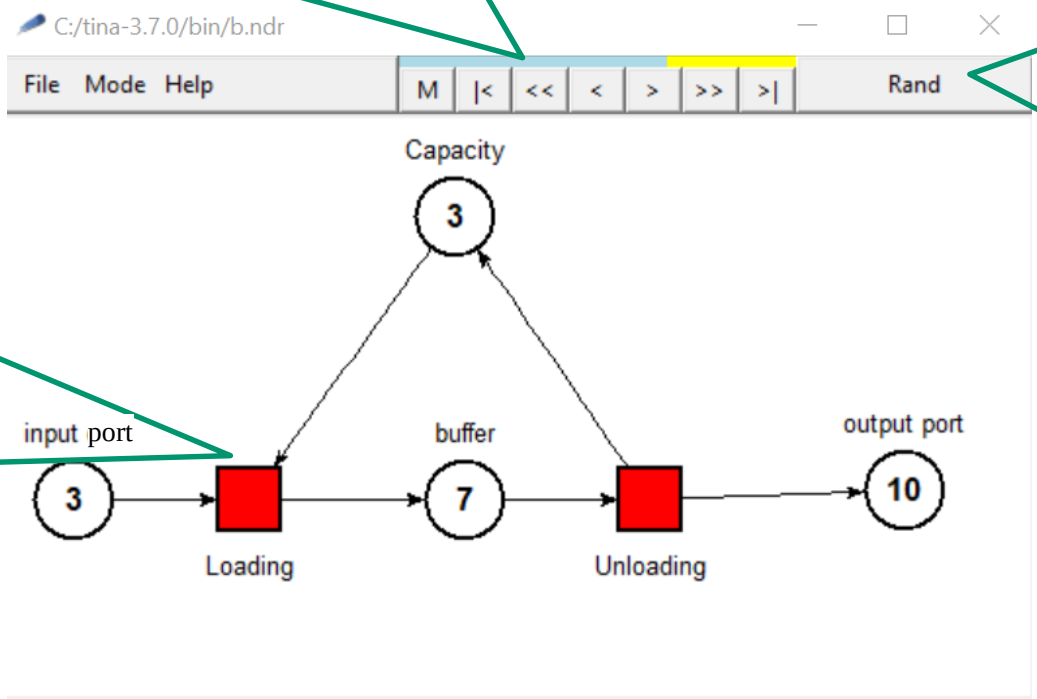
Time to next firing – stochastic – if the transition can fire now or at any time shorter then 4,15 time units

Determinism vs stochastic

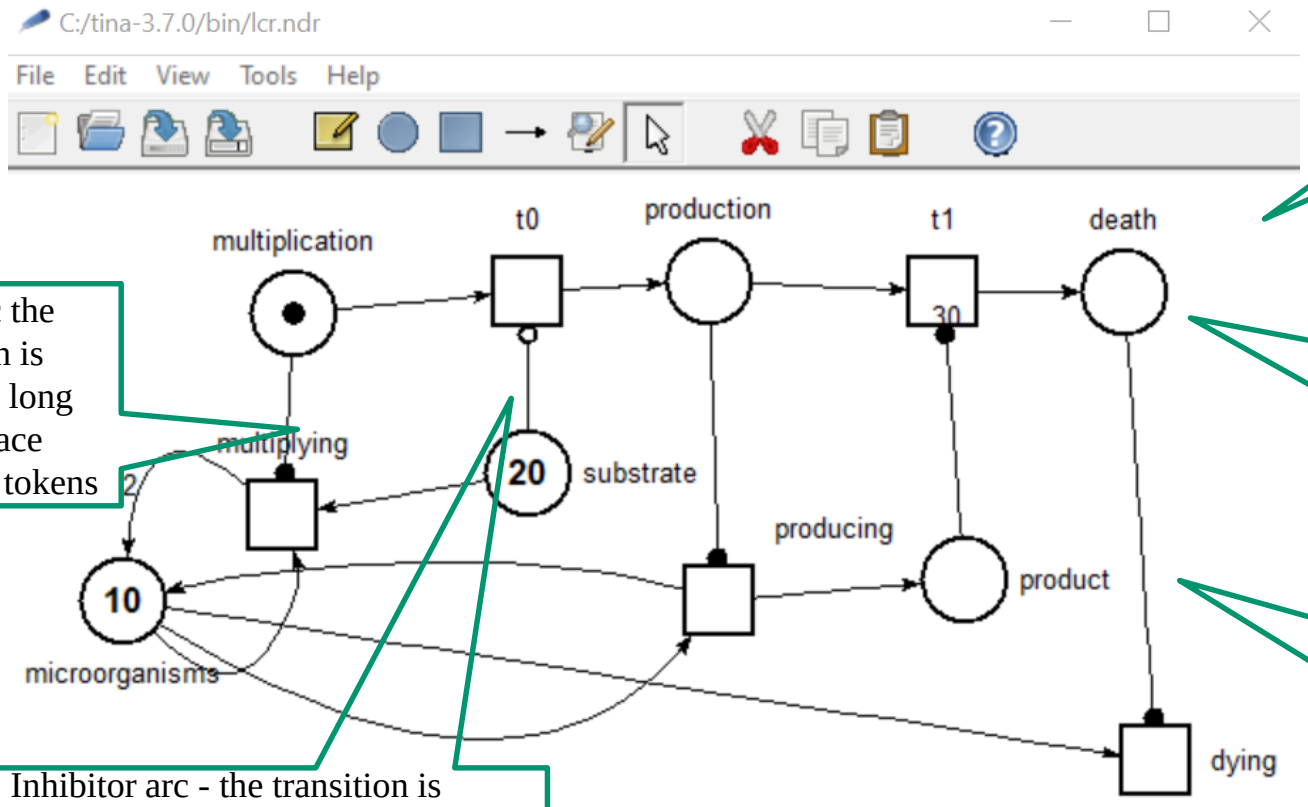
The player menu can be used to start, stop, rewind, replay step by step any current simulation

By runing the automatic simulation a non deterministic simulation can be performed – if two or more transition are active simultaneously the program selects randomly which is fired - the order of firing is not preserved

By manualy firing the transition, a deterministic simulation can be performed – maintaining the same order of firing each time



Special arcs - Life cycle example



The net models a microorganism population through its lifecycle

Read arc the transition is active as long as the place contains tokens

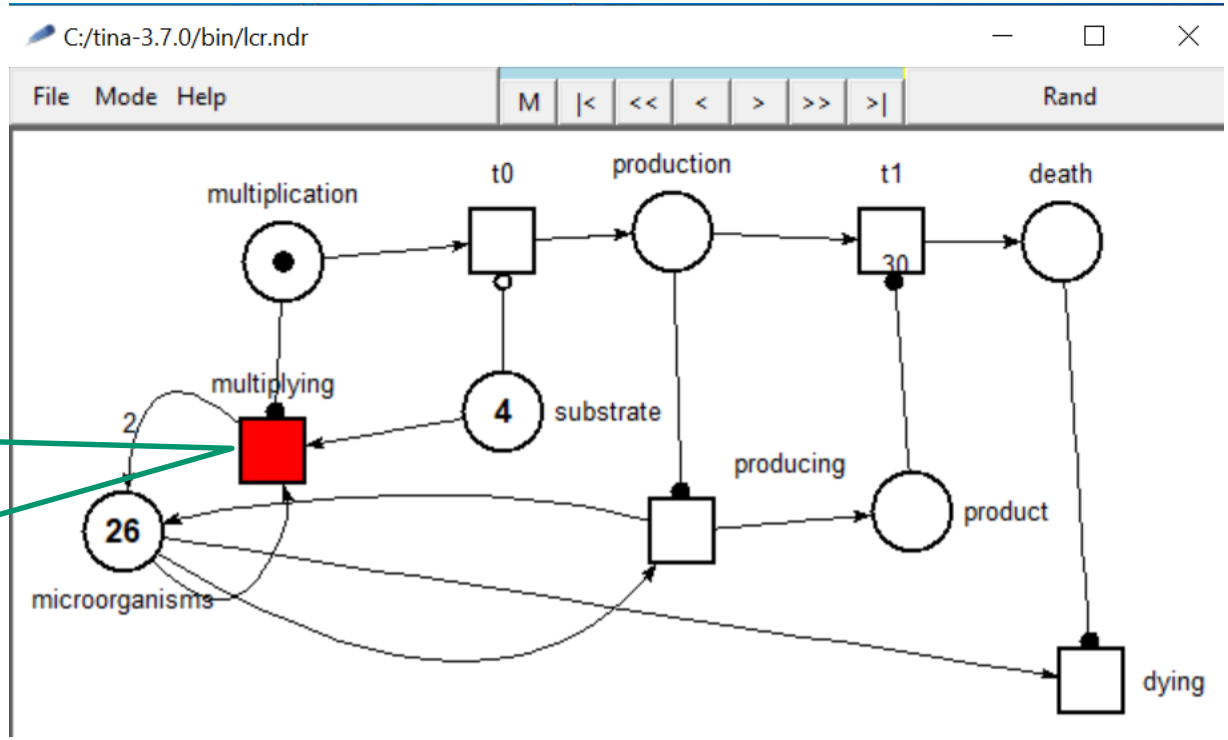
The upper part contains the phases of the lifecycle – each phase controls the processes that are specific

The lower part contains the model of real entities – microorganisms/ substrate/ products

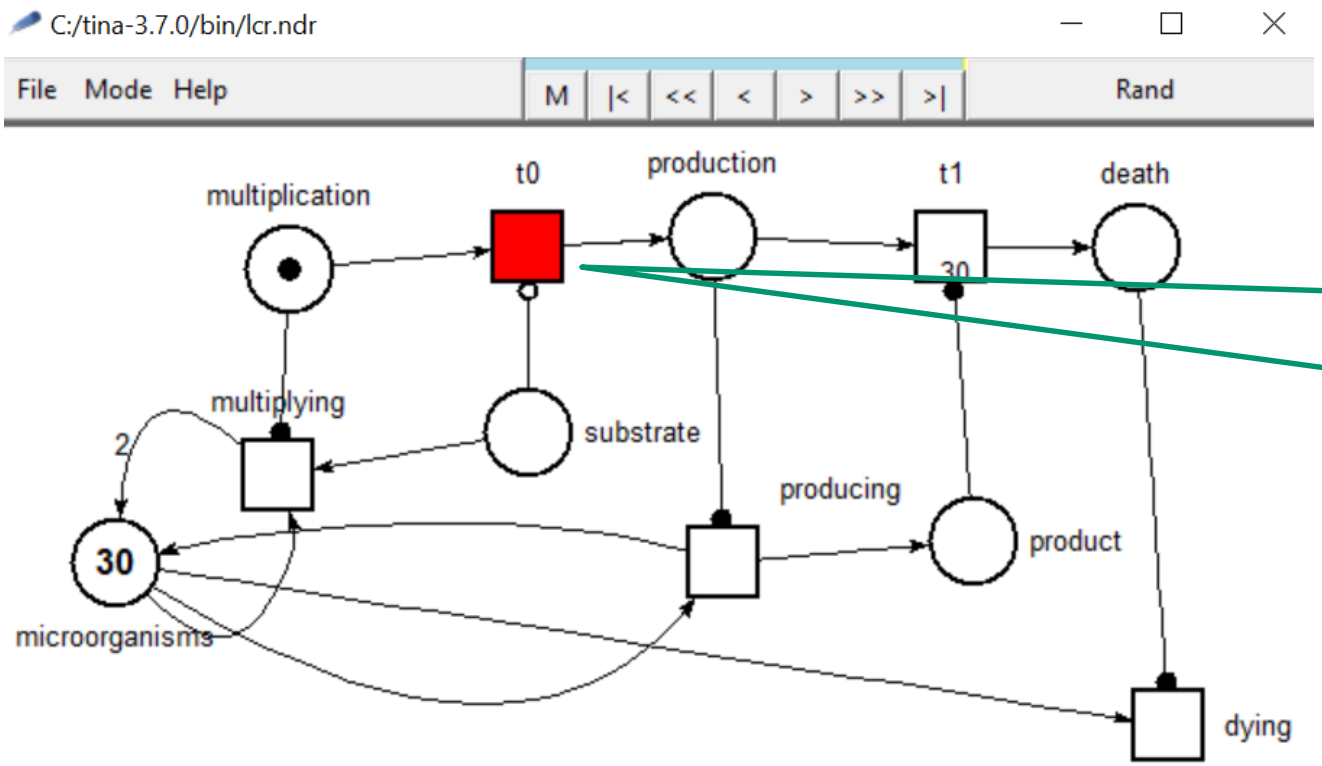
Inhibitor arc - the transition is inhibiated as long as the place contains tokens

Multiplication phase

As long as the token is marking the multiplication phase, the multiplying transition is active and the nicroorganism consumes substrate and divide

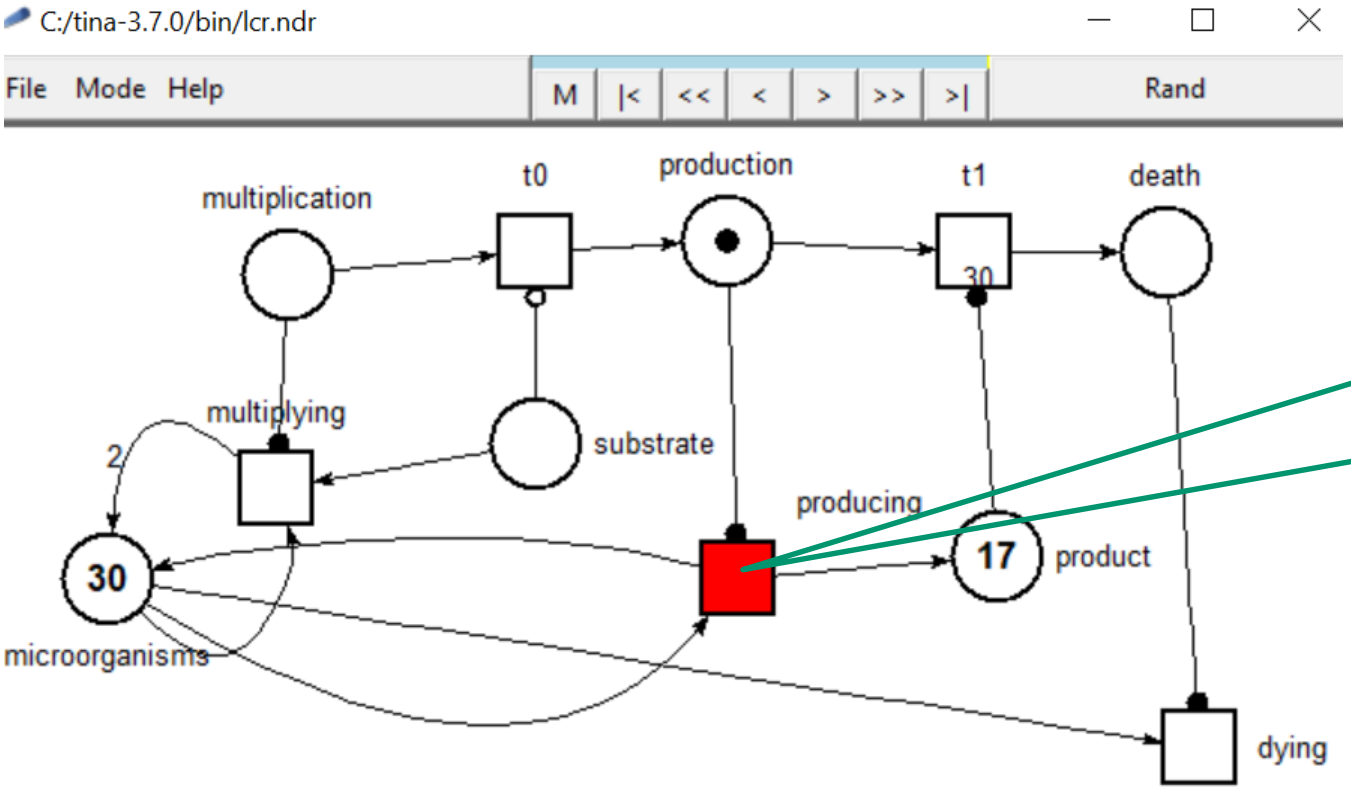


Transition to production phase



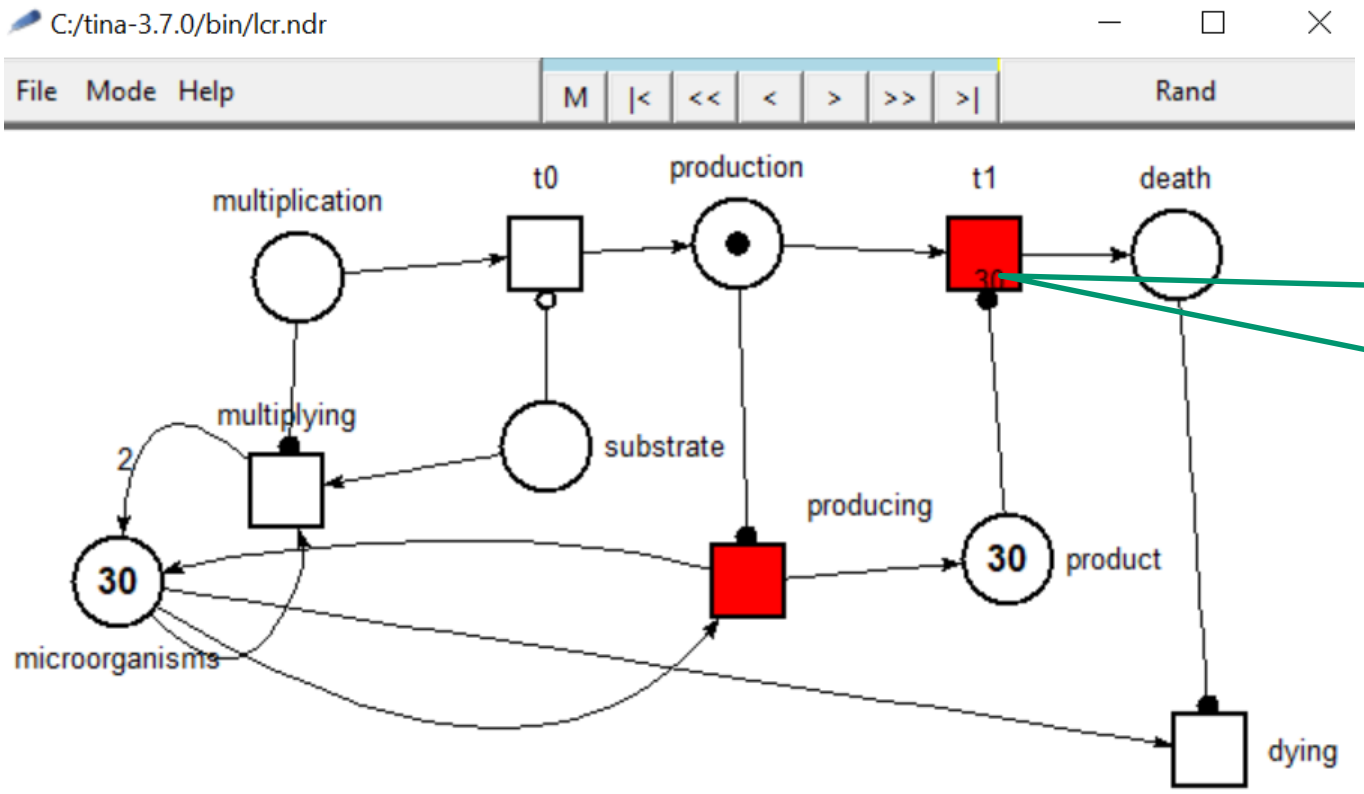
When no substrate token are available, the transition t0 to the production phases is activated

Production phase



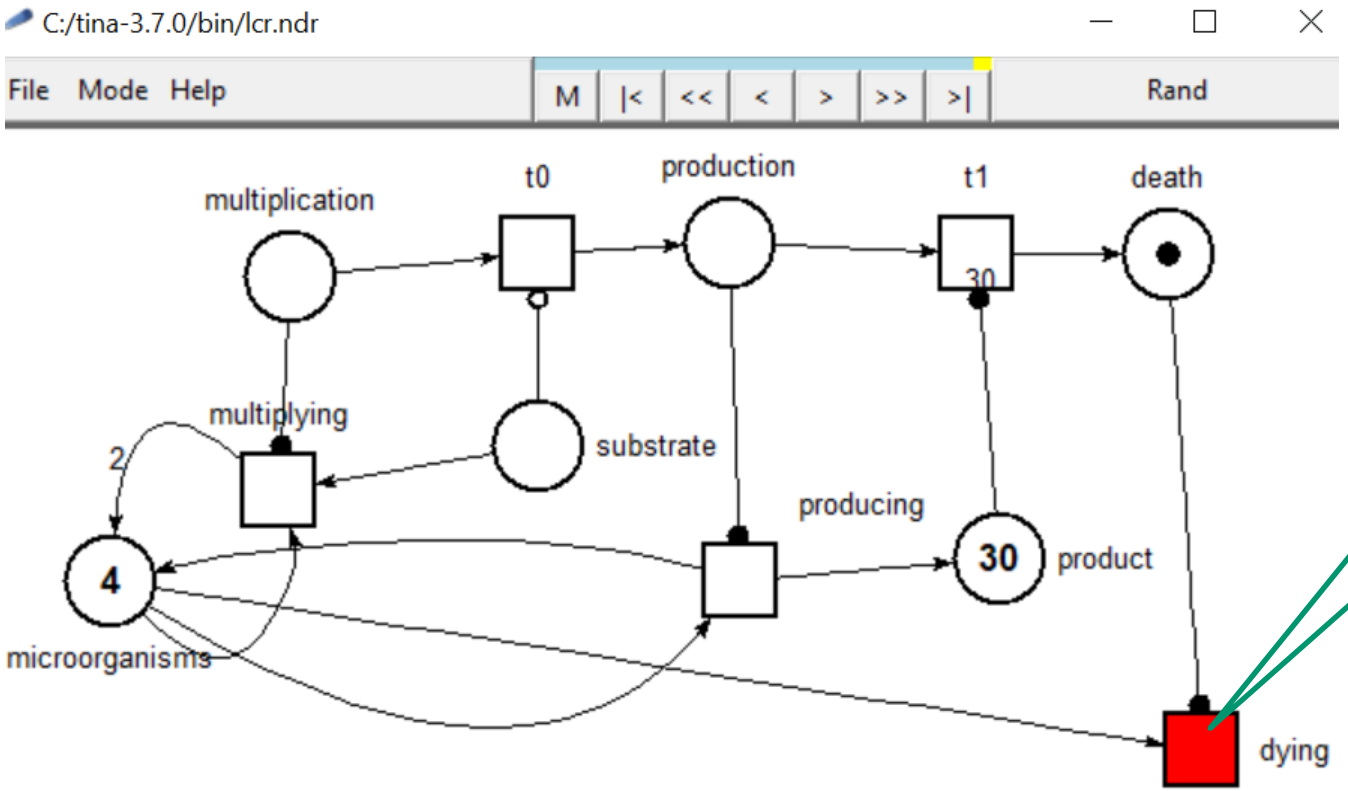
In the production phase, the producing transition is activated and product tokens are generated

Transition to death phase



As the number of product token reaches an fixed threshold (30) the transition t1 to death phase is activated

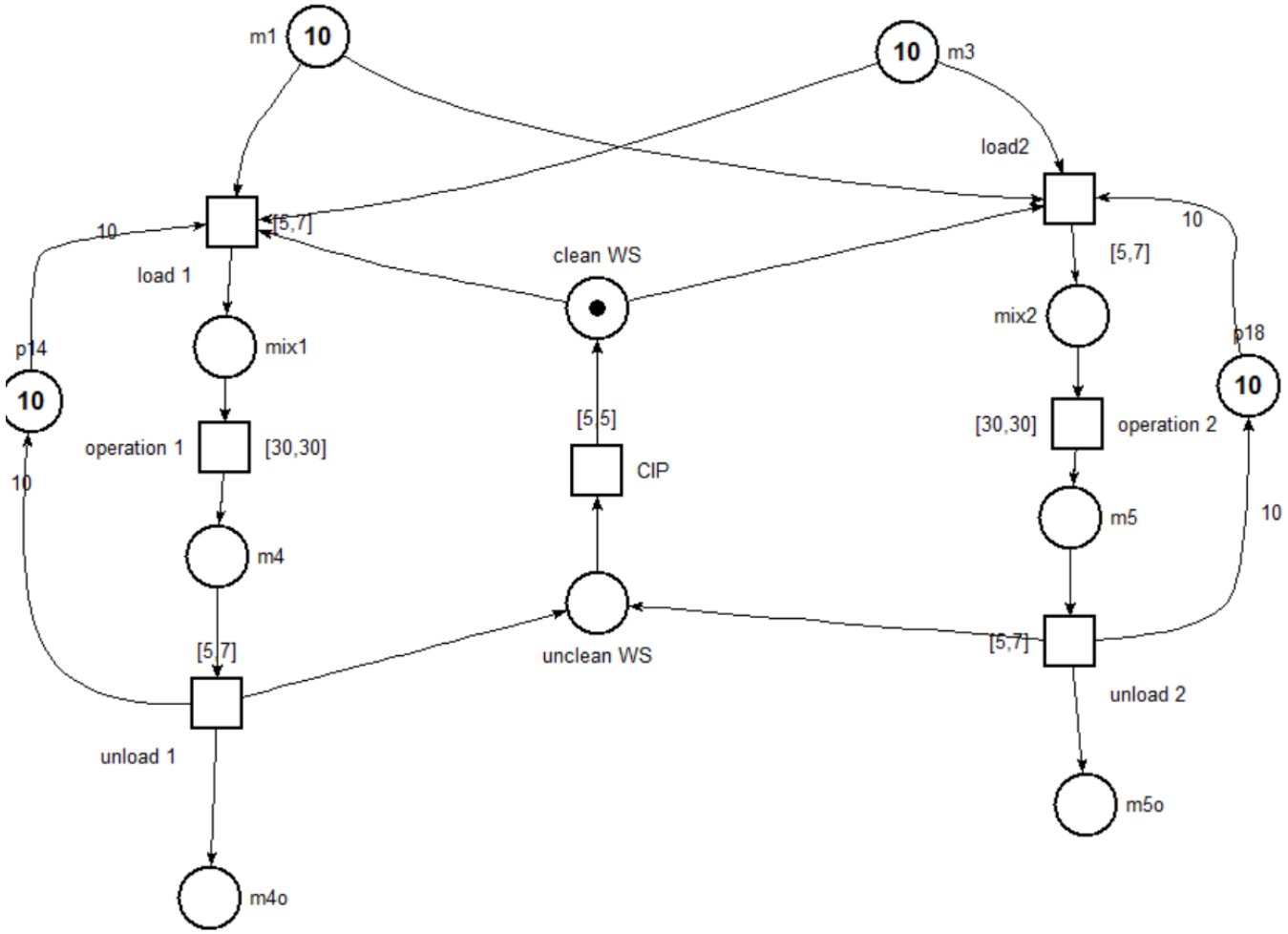
Death phase



In the death phase, the tokens from the microorganism place are removed by the dying transition

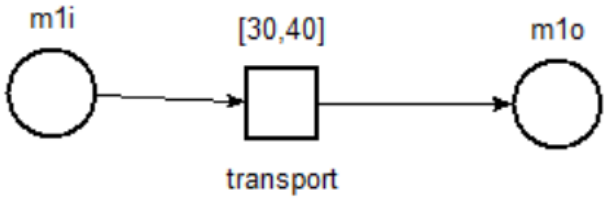
2. Introduction to modelling and simulation of food manufacturing processes

Modeling processing equipment

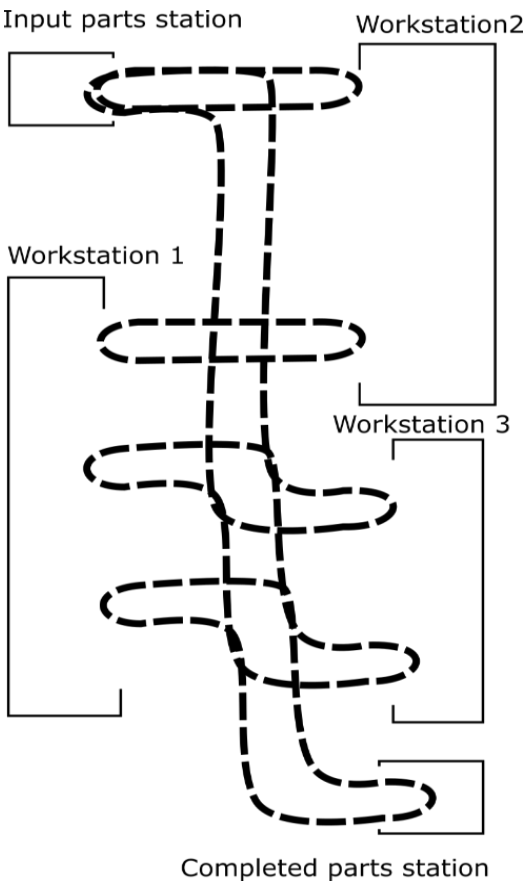


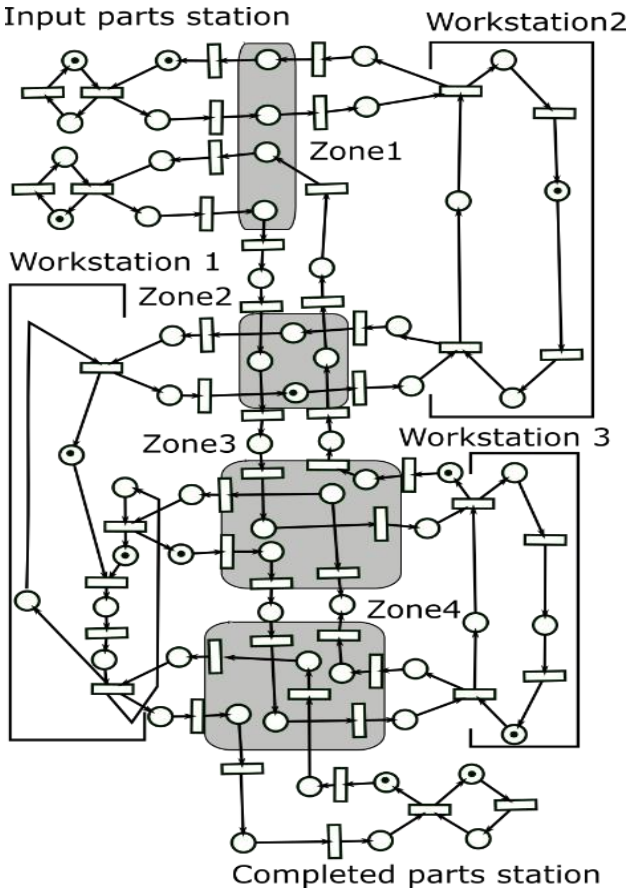
Modeling transport equipment

- Belts, pipes, conveyors
- Manipulator arms
- AVG



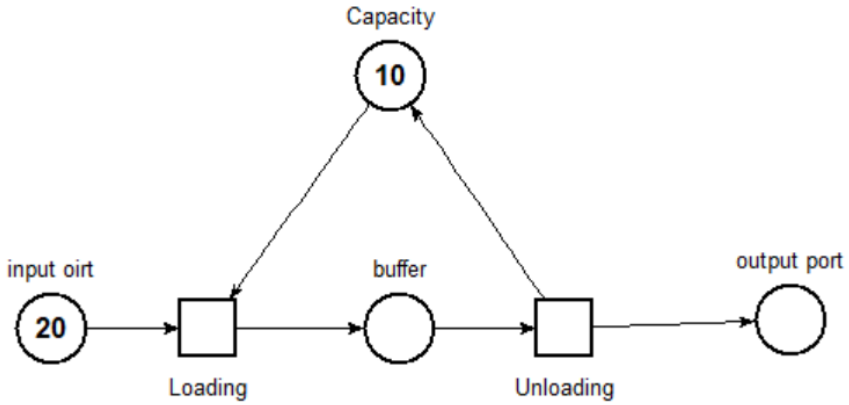
AVG

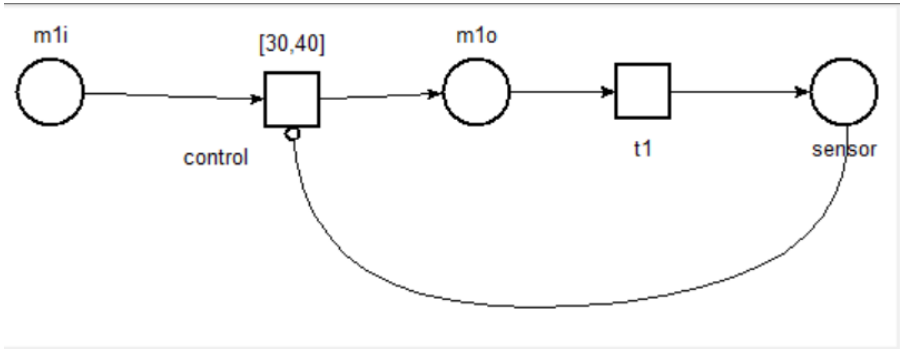

Input parts station
Workstation2
Workstation 1
Workstation 3
Completed parts station


Input parts station
Workstation2
Zone1
Workstation 1
Zone2
Zone3
Workstation 3
Zone4
Completed parts station

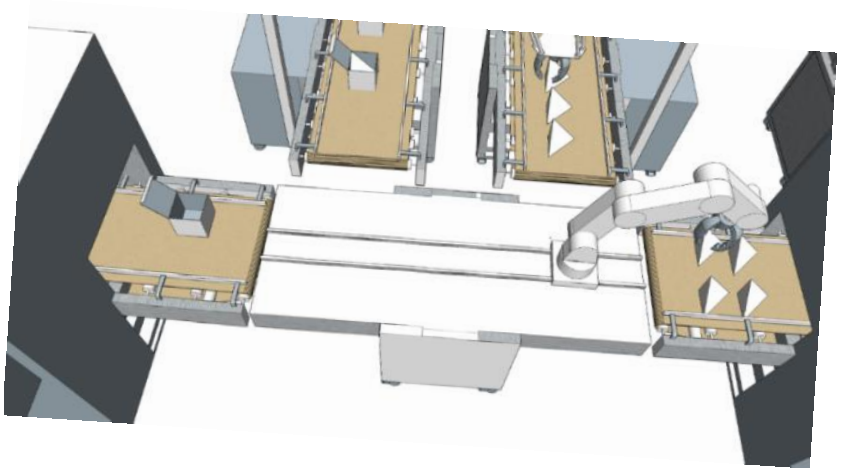
Modeling control

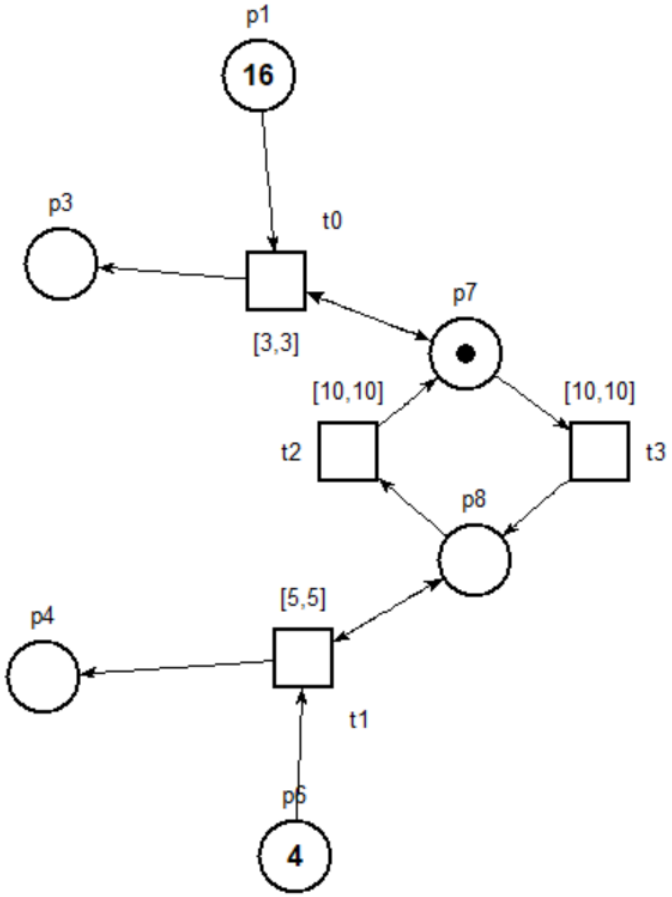
- Control loop
  - sensors – observable outputs - sensor places
  - control unit
  - efectors/enablers – controlable inputs – control places or control transitions



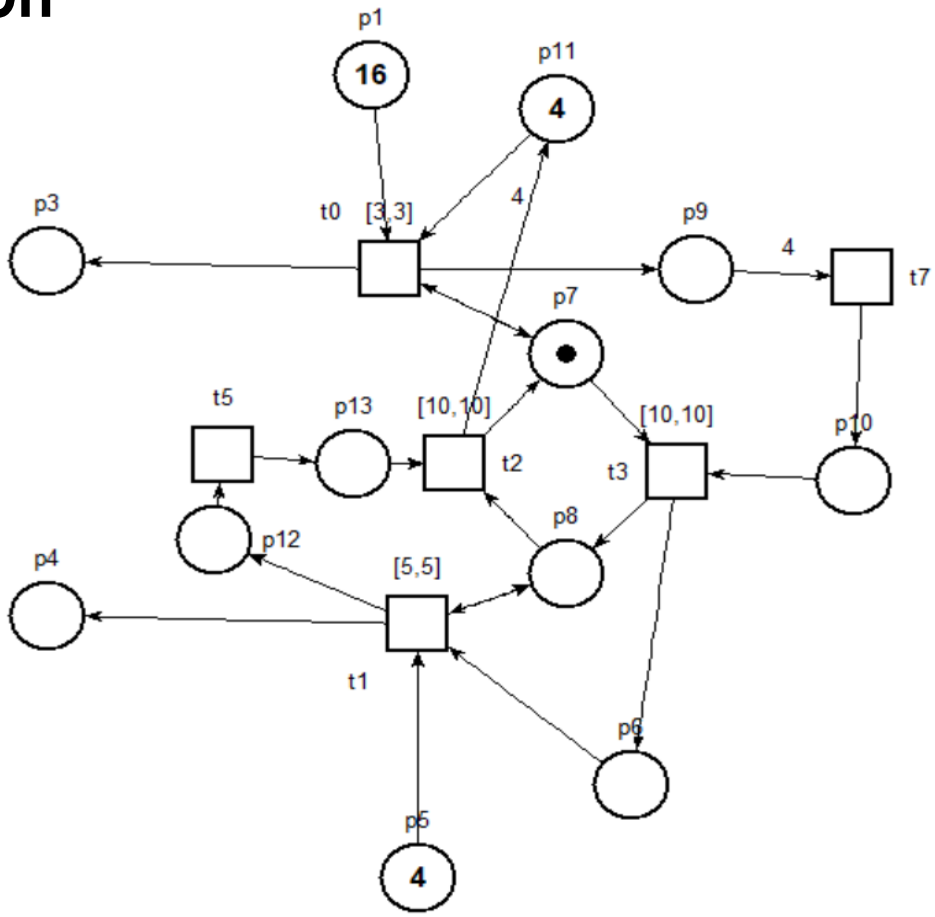


Modeling robots

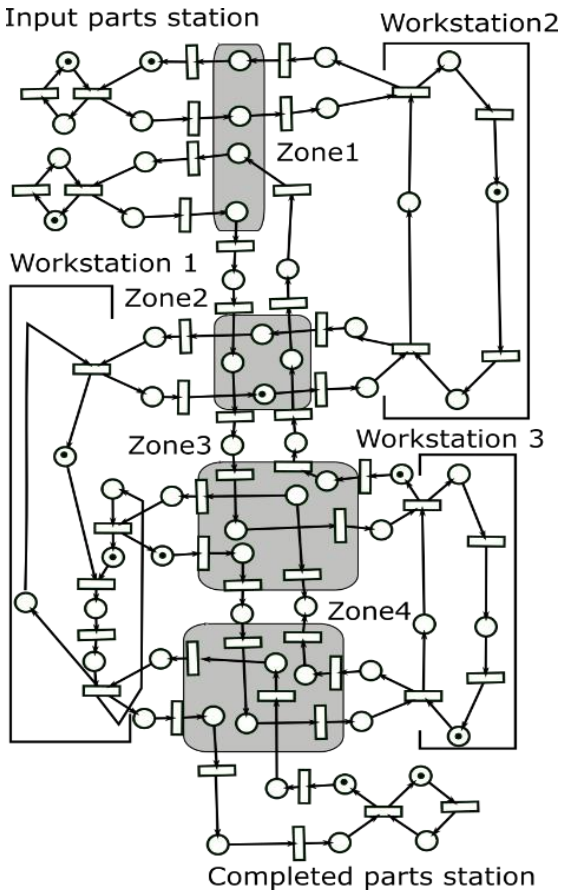


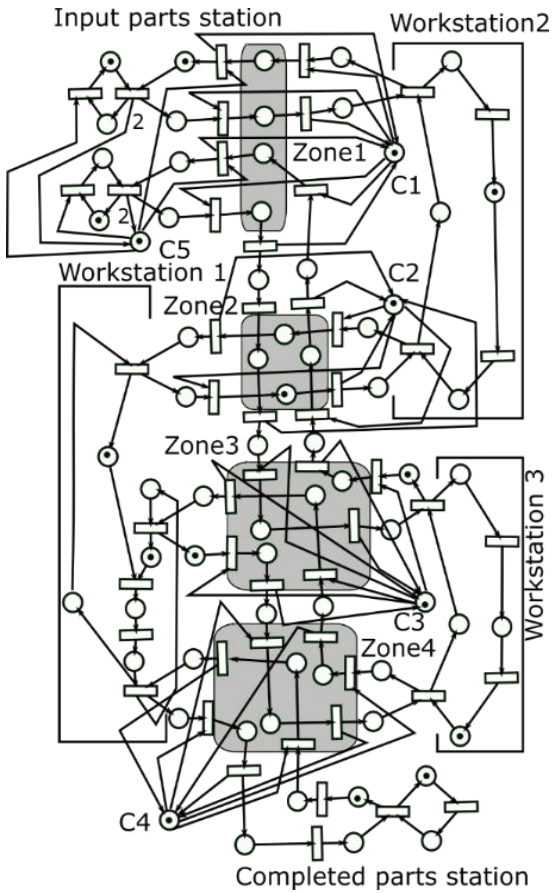


Robotic arm automation

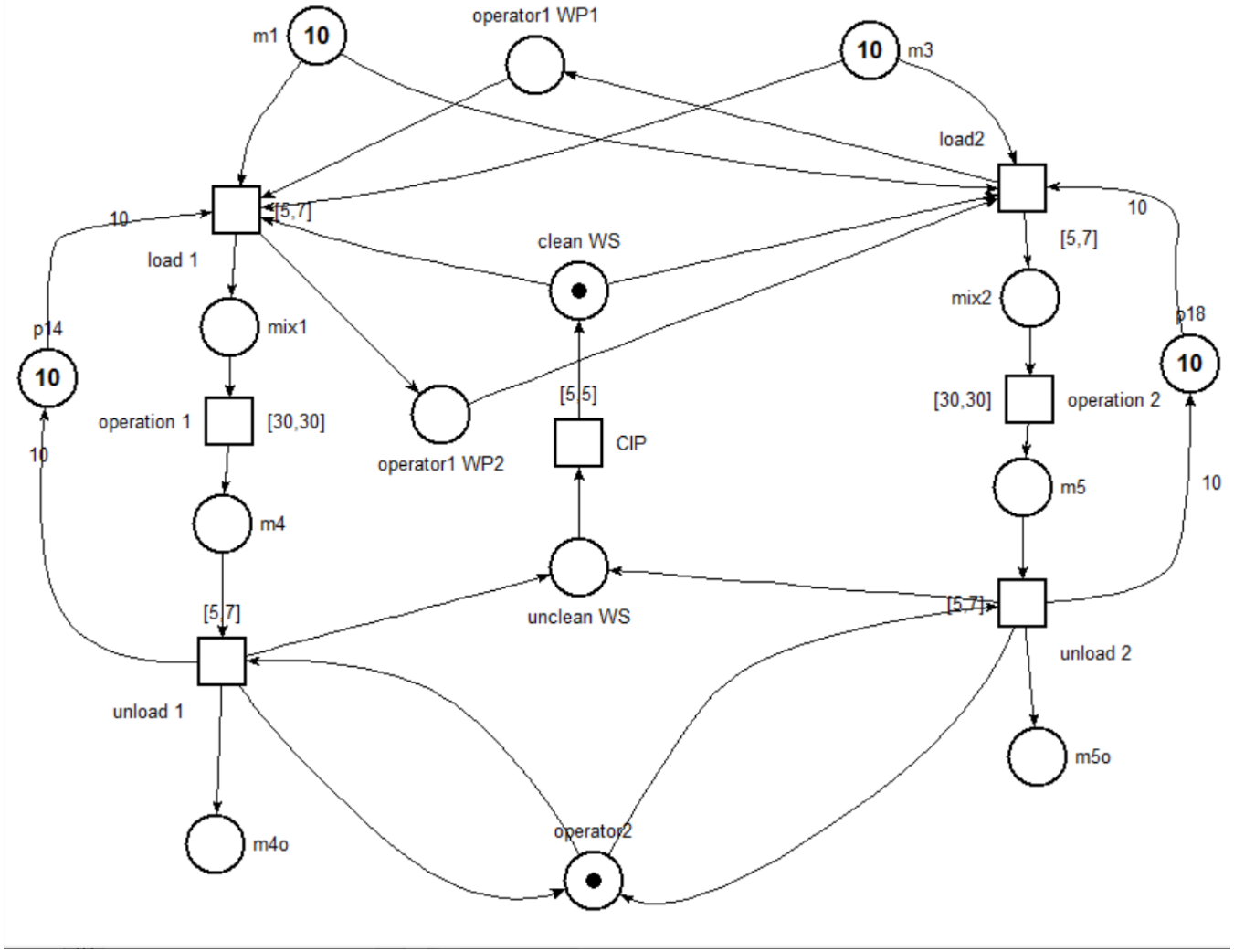


AVG automatisation

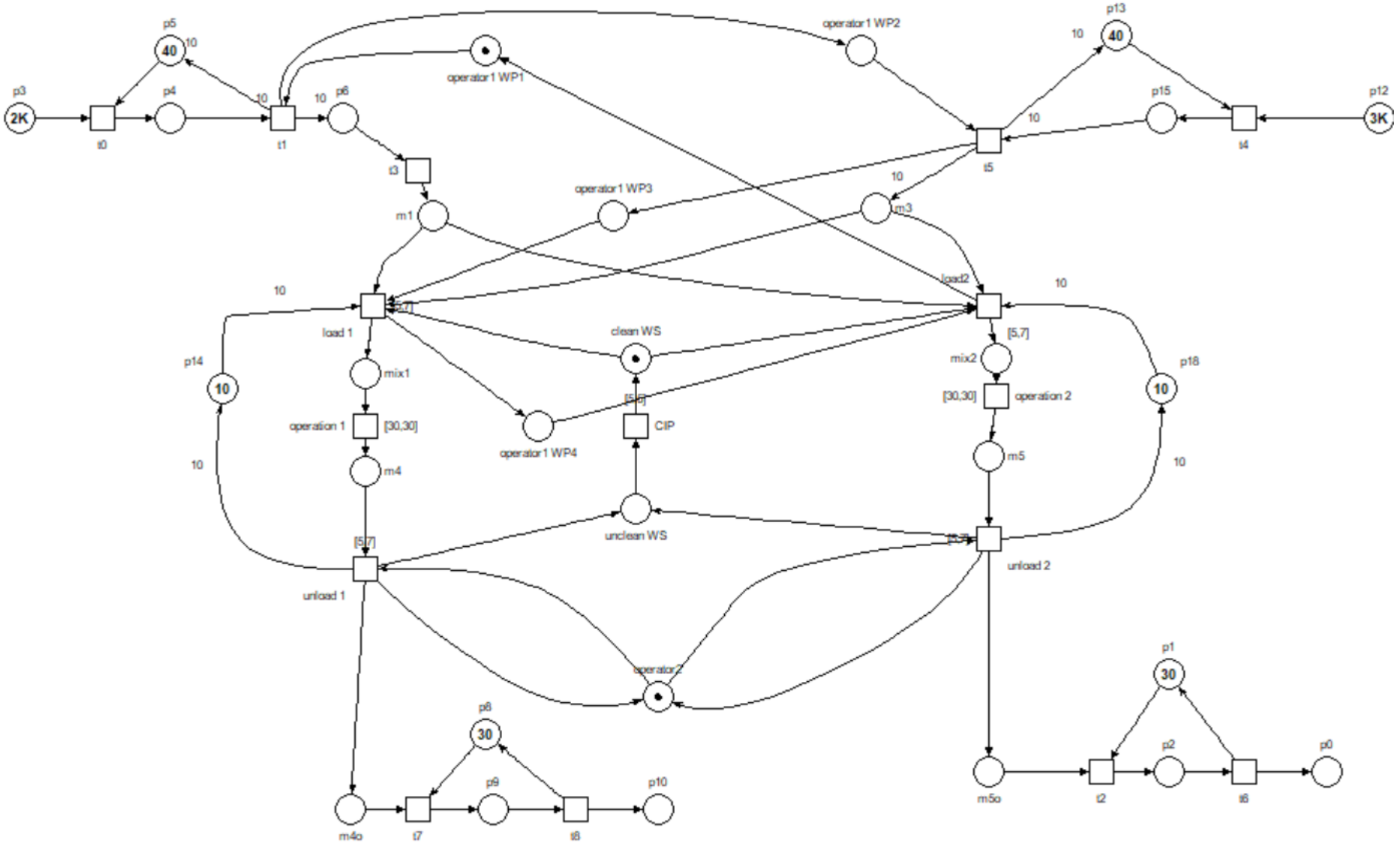




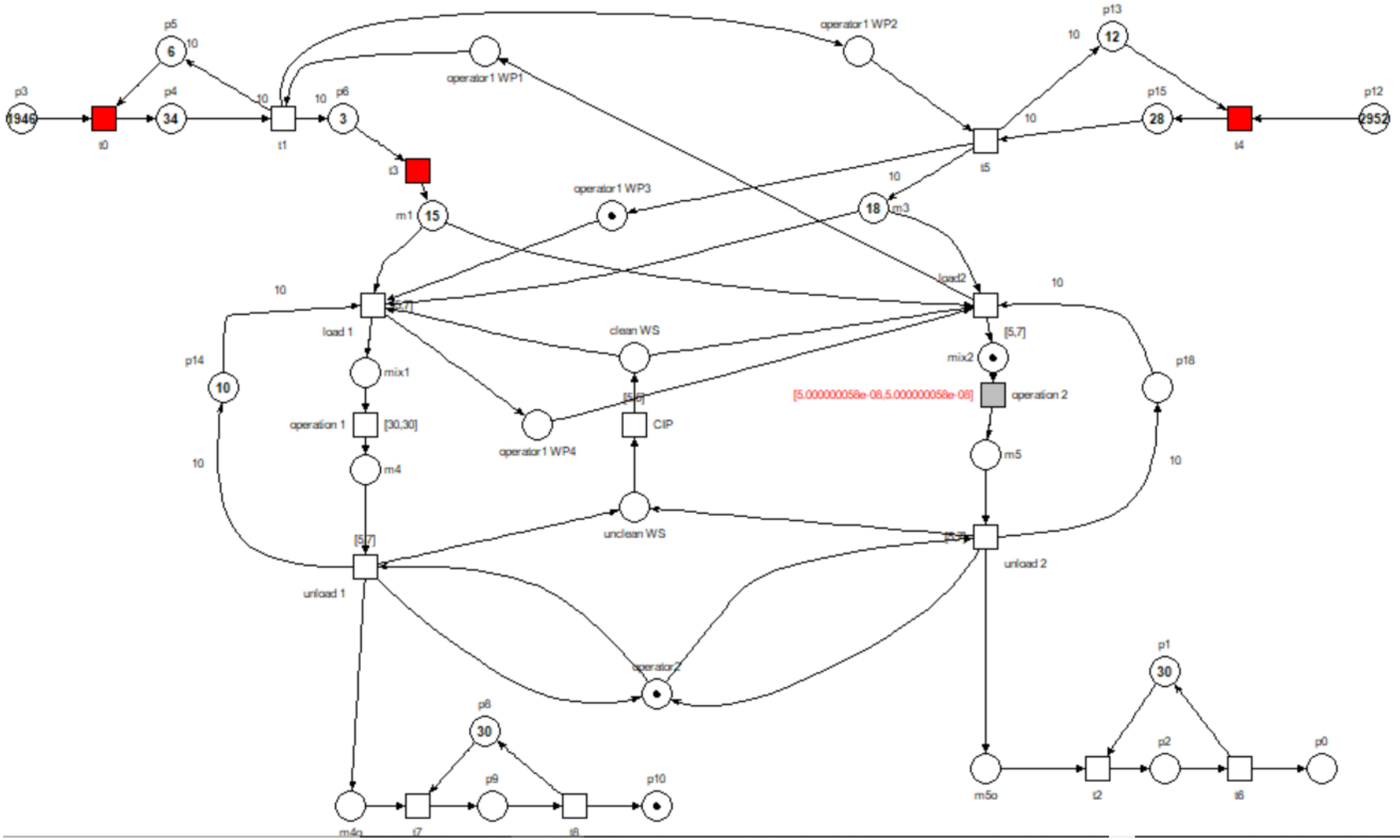
Modeling human operators



Modeling a complete manufacturing line

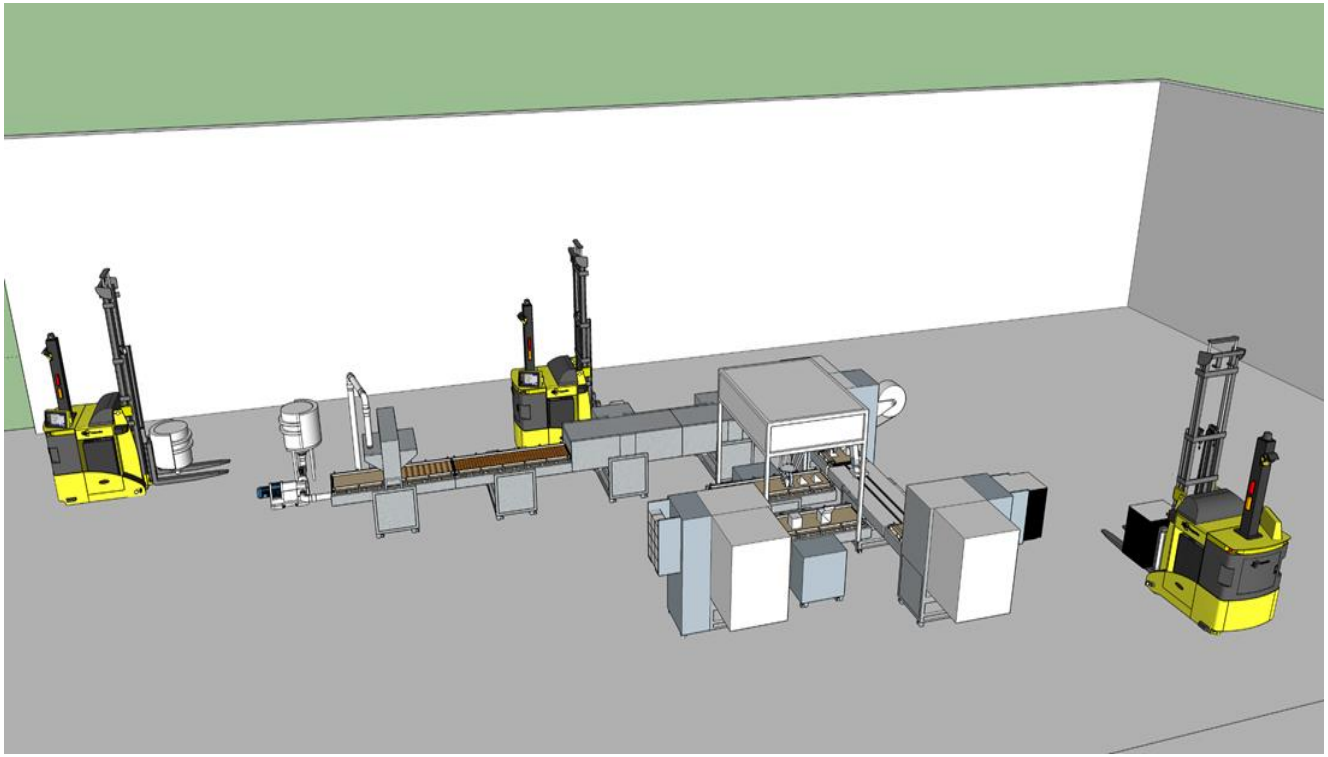


Simulating a complete manufacturing line

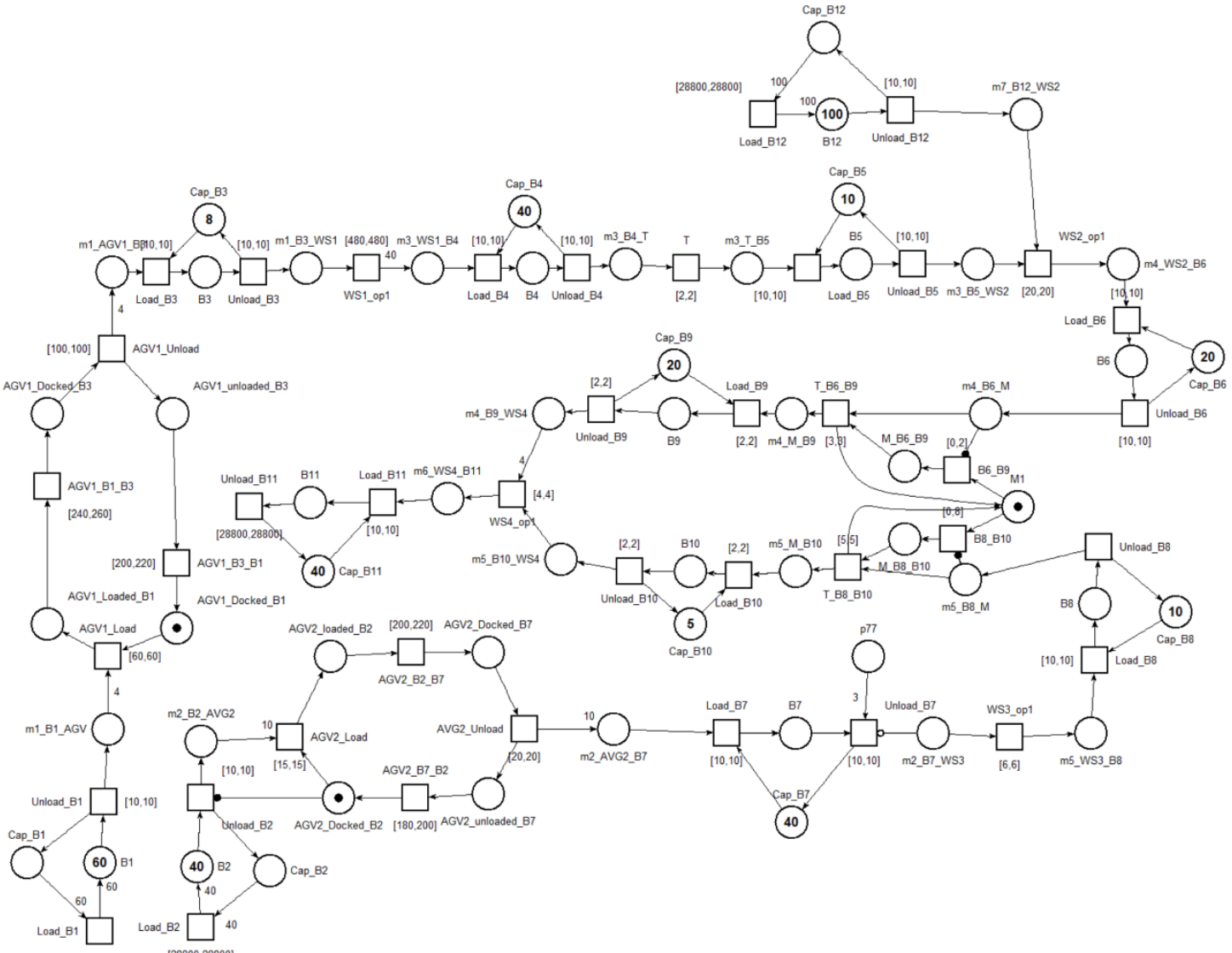


3. Introduction to digital design manufacturing processes

Line layout



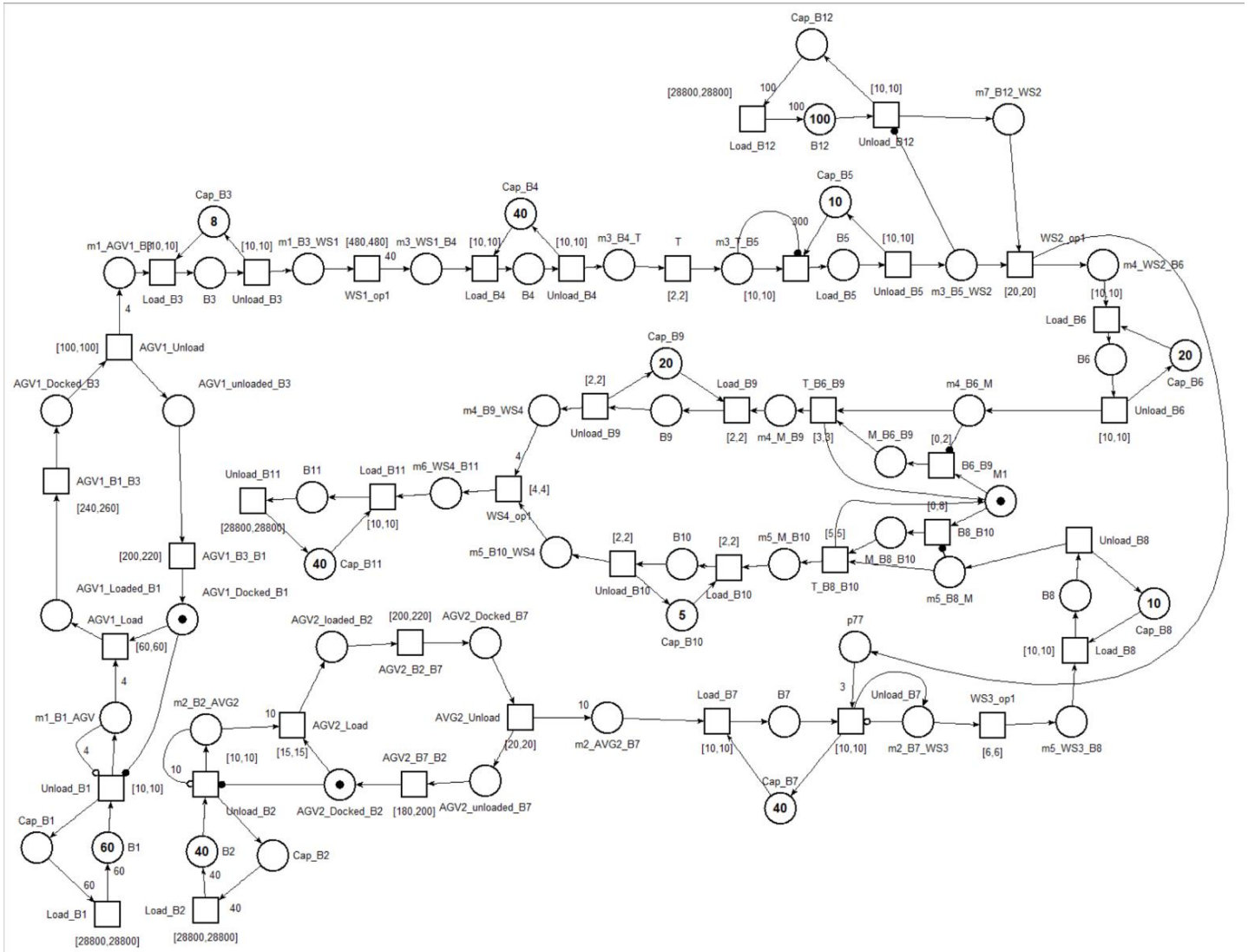
Petri net model of the line



Designing the operation of the line - Scheduling

- Optimization problem represented by a triple $\alpha \mid \beta \mid \gamma$
  - α The design of the resources
  - β The running properties and constraints
  - γ The target function to be maximised or minimised - a combination (weighted sum) of completion time C_j, flow time F_j, Lateness L_j Throughput U_j, Tardiness T_j, Earlisness E_j
- is an NP problem for $m>2$
- Intensive researched domain
- need intensive mathematical support for solving
- But
- - modeling can qualitatively help understand and classify the scheduling problem ($\alpha \mid \beta \mid \gamma$)
- - simulation can qualitatively and quantitatively validates the results and algorithms

Designing the command and control system



Recap

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Introduction to modelling and simulation of food manufacturing processes	• Modeling processing equipment • Modeling transport equipment • Modeling control • Modeling robots • Modeling human perators • Modeling a complete manufacturing line • Simulating a complete manufacturing line
Introduction to digital design manufacturing processes	• Designing the layout • Designing the operation of the line • Designing the command and control system