# Manufacturing Systems and Supply Chain Dynamics
# Project Work

EPFL, Master's Program in Microengineering

January 6, 2025

## Preliminaries

This project work is composed of four workflows:

**(1)** The output of the first workflow is theoretical, and we expect from each group a commented calculation based on the presented theory together with a conclusion.

**(2)** The output of the second workflow is practical, and is based on simulation results performed with the `AnyLogic` software. Each group is required to build specific simulation models, and to comment the obtained output.

**(3)** The output of the third workflow is both theoretical and practical, and is based both on calculations and on simulation results performed with the `AnyLogic` software. Each group is required to build specific simulation models, and to comment the obtained output.

**(4)** The output of the fourth workflow is both theoretical and practical, and is based both on calculations and on simulation results performed with the `AnyLogic` software. Each group is required to build specific simulation models, and to comment the obtained output.

## Deliverables

The output of the above workflows has to be presented in a concise report of maximum $10$ pages, including:

- An executive summary of Workflows $1$ to $4$ ($1$ page maximum).
- Detailed calculations for theoretical Workflows $1$, $3$ and $4$, as well as comments and conclusion.
- Simulation outputs for practical Workflows $2$, $3$, and $4$, and associated discussion.

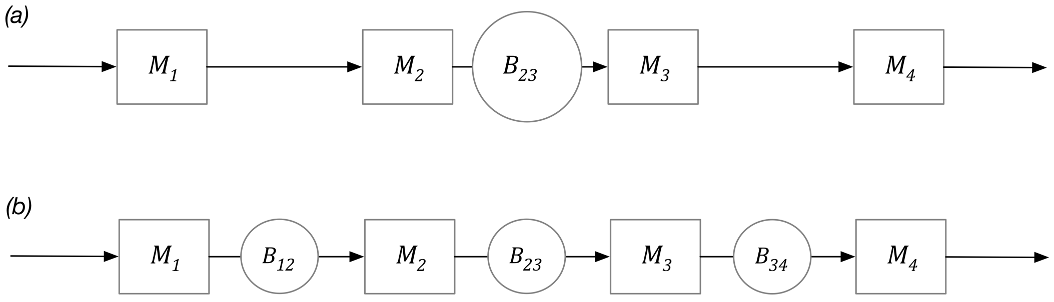
This concise report has to be handed in latest on June 2$^{\text{nd}}$, 2025 (`roger.filliger@bfh.ch` and `olivier.gallay@unil.ch`).

## Workflow 1 - Situation

A product is assembled in four consecutive working steps. These steps are accomplished by $4$ prone-to-failure machines (let us call them $M_1$,...,$M_4$) with approximately identical flow characteristics (same production rates $U$ [pce/min], and exponential failure and repair characteristics with respective mean values $1/p$ and $1/r$). To enhance the production flow, we have at disposal a total buffer space given by $3h$ (quantity measured in workpieces).

Machine $M_1$ is always fed with the required spare parts (no stock-outs), and Machine $M_4$ can always deliver the finished products in an upstream inventory.

For practical reasons, the production engineer has the following two possibilities, as shown in the figure below: $(a)$ all the buffer space is located in the middle of the line between $M_2$ and $M_3$; $(b)$ the buffer space is equally distributed between the machines.

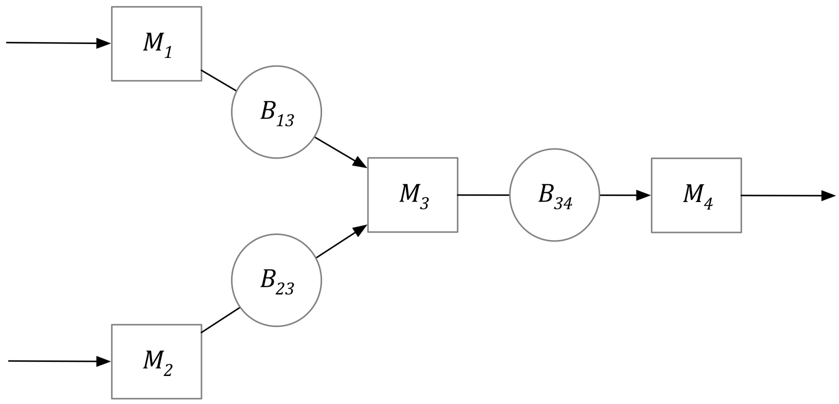



## Workflow 1 - Task

Using the aggregation method outlined in the course, calculate the mean production rate for both cases $(a)$ and $(b)$. Then, consider the particular case where $p = 0.001$ [1/sec], $r = 0.005$ [1/sec], $U = 8000$ [pce/min], and draw the behavior for the mean production rate as a function of $h$.

## Workflow 2 - Situation

The building of a product requires four working steps to be accomplished by $4$ different machines, denoted as $M_1$,...,$M_4$. The assembly step performed by $M_3$ needs one output of $M_1$ and one output of $M_2$ to start, as represented in the figure below.




Machines $M_1$ and $M_2$ are always fed with the required spare parts (no stock-outs), and Machine $M_4$ can always deliver the finished products in an upstream inventory.

The processing times of machines $M_1$,...,$M_4$ are random (*e.g.*, because they depend on a human operator), and all four of them follow an exponential distribution with parameter $\frac{1}{4}$.

To enhance the production flow, we have at disposal a total buffer space of size $10$ (quantity measured in workpieces), which has to be distributed between stocks $B_{13}$, $B_{23}$, and $B_{34}$.

*n.b.,* In this situation, we are not in presence of prone-to-failure machines. However, the operations of the machines are affected by randomness, as their processing time is random.

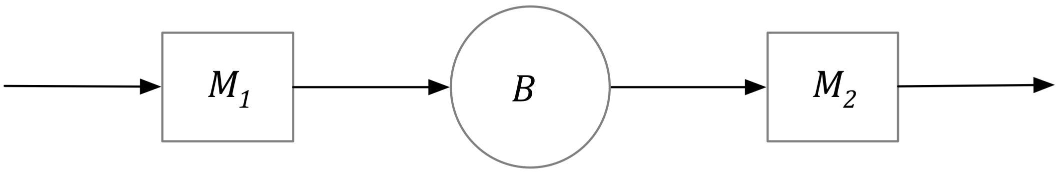
*hint :* You will need to use the `combine` object in `AnyLogic`.

## Workflow 2 - Task

Distribute the available buffer space between stocks $B_{13}$, $B_{23}$, and $B_{34}$, in order to maximize the throughput of the line (*i.e.,* the mean production rate, computed here in number of pieces per hour). For the selected configuration, give an estimation of the throughput variation.

## Workflow 3 - Situation

A product is assembled in two steps accomplished by $2$ different machines, denoted as $M_1$ and $M_2$, and separated by a buffer $B$ of size $h$ (quantity measured in workpieces), as illustrated in the figure below:




Machine $M_1$ is always fed with the required spare parts (no stock-outs), and Machine $M_2$ can always deliver the finished products in an upstream inventory.

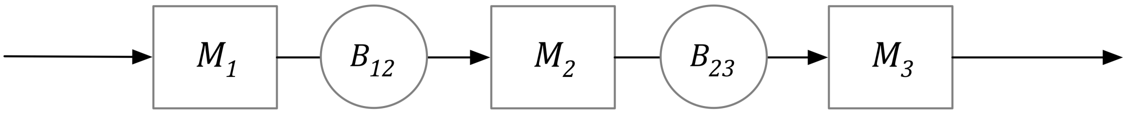
The processing time of machine $M_1$ (resp. $M_2$) is equal to $U_1 = 2.64$ [pce/sec] (resp. $U_2 = 3$ [pce/sec]). Both $M_1$ (resp. $M_2$) are prone-to-failure machines with exponential failure and repair characteristics with respective mean values $1/p_1 = 1000$ [sec] (resp. $1/p_2 = 100$ [sec]) and $1/r_1 = 100$ [sec] (resp. $1/r_2 = 25$ [sec]). Note that $\frac{U_1}{1+I_1} = \frac{U_2}{1+I_2}$ (i.e., the two machines have the same mean production rate).

## Workflow 3 - Task

The formula for the mean production rate of a production dipole, as given in Chapter 6, assumes two machines with same production rate ($U_1 = U_2$). To approximate the mean production rate of the considered production dipole, use the formula of Chapter 6 when (a) the two machines have the characteristics of machine $M_1$, and when (b) the two machines have the characteristics of machine $M_2$. Simulate the effective mean production rate of the considered production dipole (with the real characteristics of machines $M_1$ and $M_2$), and discuss the obtained results in function of $h$.

## Workflow 4 - Situation

A product is assembled in three consecutive working steps. These steps are accomplished by $3$ different prone-to-failure machines (let us call them $M_1$,...,$M_3$) with approximately identical flow characteristics (same production rates $U = 1$ [pce/min], and exponential failure and repair characteristics with respective mean values $1/p = 100$ [min] and $1/r = 15$ [min]). The machines are separated by two buffers $B_{12}$ (of size $h_{12} = 15$) and $B_{23}$ (of size $h_{23} = 20$) (quantity measured in workpieces), as illustrated in the figure below.




Machines $M_1$ is always fed with the required spare parts (no stock-outs), and Machine $M_3$ can always deliver the finished product in an upstream inventory.

## Workflow 4 - Task

Using both the downstream and upstream aggregation methods outlined in the course, calculate the mean production rate of the considered production line. Simulate the effective mean production rate of the considered production line, and draw conclusions about the observed behavior.