GRA4135
Decision Theory and System Dynamics

Exercises

Contents

Lecture 1: Introduction & the modeling process	
1.1	Some people can continue to influence the performance of a business even after they have stopped to be directly involved in that business, for example the alumni of a university, former customers or former employees. If this is the situation, should you include these people in the model when you are interested in simulating the performance of that business? A) No, you should only include them in the model when they are directly involved B) Yes, you should include them, but only when their influence is positive C) Yes, you should include them, but only when their influence is negative D) Yes, you should include them, regardless the direction of their influence (positive or negative)
1.2	In the "Beer game" we can observe some typical system dynamics phenomena. These are: A) Exponential growth B) Amplification, delays and oscillation C) Exponential decline D) Shifting the burden
1.3	Consider the following statement: "Road building programs designed to reduce congestion have increased traffic, delays, and pollution". This is a typical example of: A) Oscillation B) Loop polarity C) Mental models D) Policy resistance
1.4	Which of the following steps is NOT part of the modeling process? A) Problem articulation B) Oscillation C) Formulation of a dynamic hypothesis D) Policy design
1.5	Play the beer game (also used in the lecture) again, but now in Expert Mode https://forio.com/simulate/mbean/near-beer-game/run/
1.6	Watch the author of the book in action, explaining why you need this course: https://www.youtube.com/watch?v=AnTwZVviXyY
1.7	Find an example of something counterintuitive (from the newspapers, or from another course at BI, or from your personal life) → why did a solution not work out the way you planned? If you want, you can send me your idea (kim.v.oorschot@bi.no) to discuss further.

Lecture 2: Causal loop diagramming	
2.1	Consider the following two guidelines of drawing causal loop diagrams: (I) You should make the goals of negative loops explicit (II) You should distinguish between actual and perceived conditions A) Statement I is true, and statement II is true B) Statement I is true, and statement II is false C) Statement I is false, and statement II is true D) Statement I is false, and statement II is false
2.2	Which statement(s) is(are) true? Without changing the structure of a system: (I) A reinforcing loop can increase or decrease the state of a system (II) A balancing loop can evolve into a reinforcing loop A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
2.3	A bar is located close to BI in Nydalen. The owner of the bar gives a free drink to any customer in the bar that invites (via social media) at least two friends to come to bar. The free drink is given as soon as these two friends are in the bar, ordering a drink. These friends are then also allowed to invite two other friends, etc. This is a typical example of: A) Policy resistance B) Oscillation C) Balancing loop D) Reinforcing loop
2.4	Which statement(s) is(are) true? (I) A loop is reinforcing if it contains an even number of links that are positive (II) A loop is balancing if it contains an odd number of links that are negative A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
2.5	Which statement(s) is(are) true? Without changing the structure of a system: (I) A reinforcing loop can decrease or increase the state of the system (II) A balancing loop can evolve into a reinforcing loop A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false

2.6

Which statement(s) about drawing causal loop diagrams is(are) true?

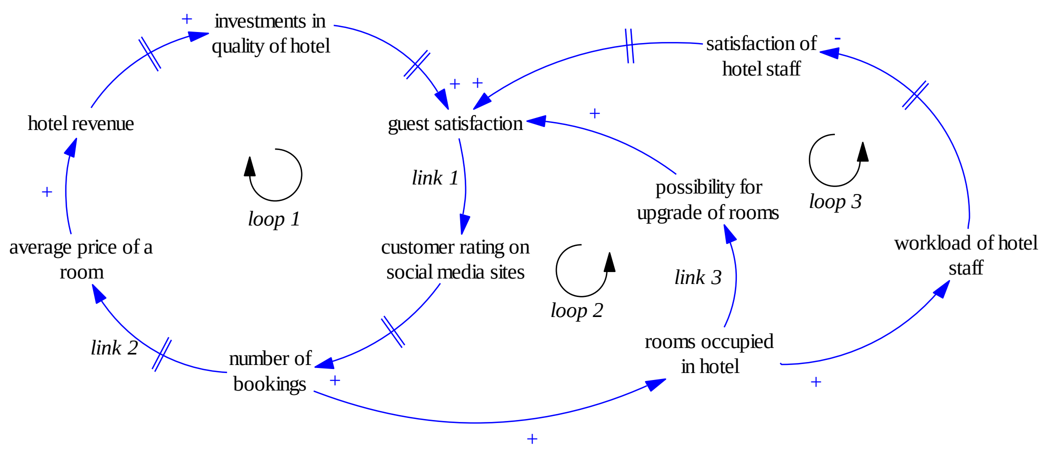
(I) You should make the goals of positive loops explicit

(II) You should choose variable names that have a clear sense of direction

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is true
D) Statement I is false, and Statement II is false

2.7a

The following causal loop diagram describes a situation in a hotel (before the pandemic occurred). The hotel started some years ago with investing in quality (redecorating the rooms, lobby, etc.). This positively influenced guest satisfaction which increased the ratings these guests gave the hotel on social media sites. This resulted in more bookings and accordingly a higher price per room (this is the price customers need to pay for the room). Hotel revenue increased and this gave the hotel more budget for investing in quality. Any negative side-effects of this "quality-loop" have not occurred yet, but the hotel manager fears the following effects in the future. Although guests appreciate quality, they also like to be offered a room upgrade (getting a better/bigger room for the same price or for a discount). But upgrades can only be given when rooms are available. Furthermore, guest satisfaction is positively influenced by the satisfaction of hotel staff, which is negatively influenced by the workload of hotel staff. Finally, workload of hotel staff is of course influenced by the number of rooms that is occupied. This story is summarized below.



What is the polarity of link 1 and link 2?
A) Link 1 is positive, link 2 is positive
B) Link 1 is positive, link 2 is negative
C) Link 1 is negative, link 2 is negative
D) Link 1 is negative, link 2 is positive

2.7b

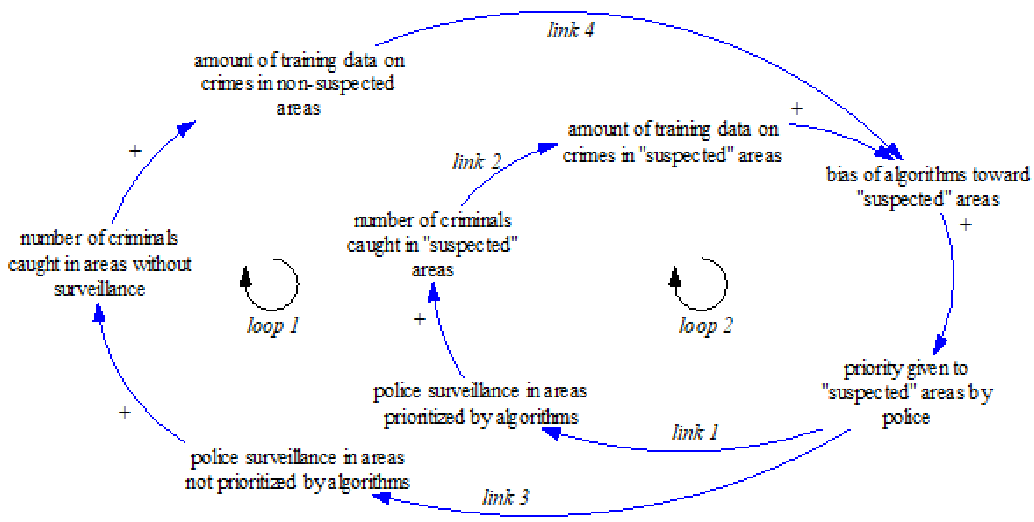
Continue with the causal loop diagram described in the previous question.
What is the polarity of loop 1 and loop 2? (You also have to find the polarity of link 3 when doing this.)

A) Loop 1 is positive, loop 2 is positive
B) Loop 1 is positive, loop 2 is negative
C) Loop 1 is negative, loop 2 is negative
D) Loop 1 is negative, loop 2 is positive

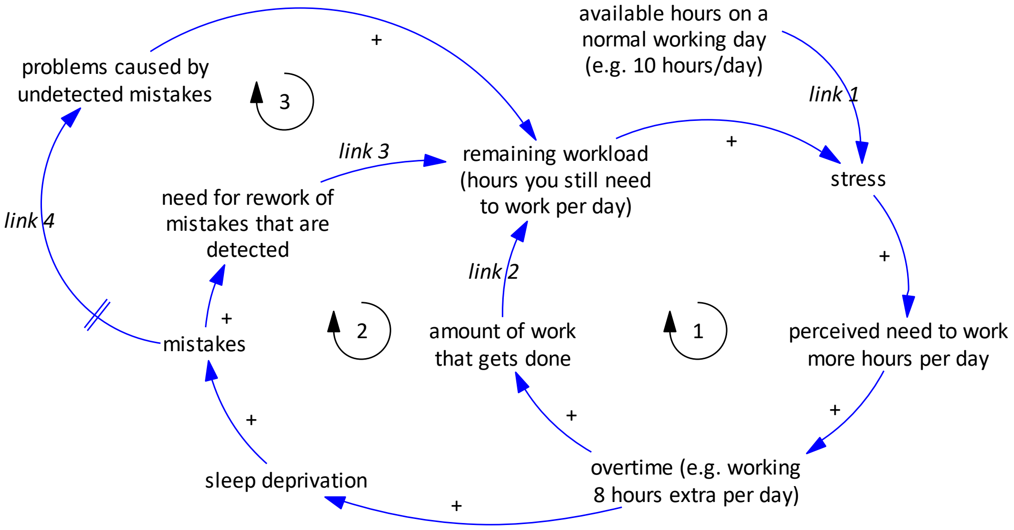
<table>
<tr><td>2.7c</td><td>Continue with the causal loop diagram described in the previous questions.
What is the polarity of link 3 and loop 3?

A) Link 3 is positive, loop 3 is positive
B) Link 3 is positive, loop 3 is negative
C) Link 3 is negative, loop 3 is negative
D) Link 3 is negative, loop 3 is positive</td></tr>
<tr><td></td><td></td></tr>
<tr><td>2.8a</td><td>Machine learning algorithms build a mathematical model based on sample data, known as "training data", to make predictions or decisions. Besides many advantages, machine learning algorithms can also lead to a self-fulfilling prophecy as the example below demonstrates.

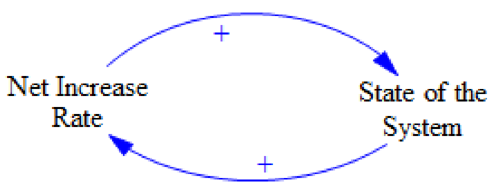
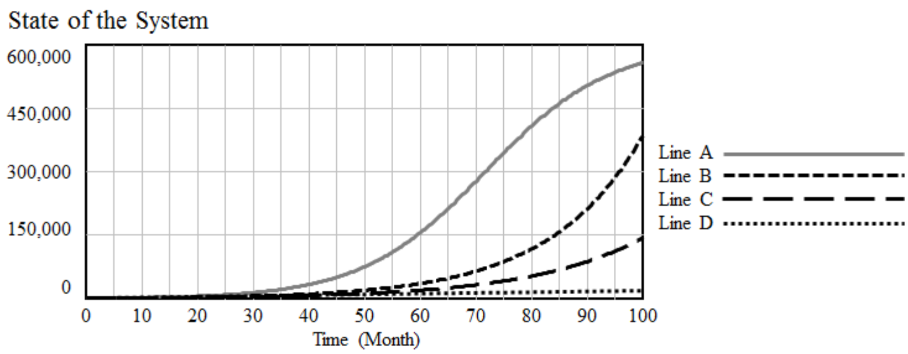
Predictive policing is a policy that uses machine learning to predict where (which cities or parts of cities) and when crimes are likely to happen. Police surveillance is then allocated to these “suspected” areas. Because of the high number of police officers in that area, the number of criminals that is caught will increase, which leads to more “training data” on crimes in these areas. This makes these areas even more suspect, leading to more police surveillance, whereas crimes committed in other areas that were not highlighted by the machine learning algorithms will remain undetected. The causal loop diagram below describes this “predictive policing”.

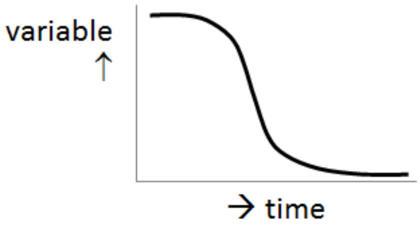


What is the polarity of link 1 and link 2?
A) Link 1 is positive, link 2 is positive
B) Link 1 is positive, link 2 is negative
C) Link 1 is negative, link 2 is negative
D) Link 1 is negative, link 2 is positive</td></tr>
<tr><td>2.8b</td><td>Continue with the predictive policing loops described in the previous question.
What is the polarity of link 3 and link 4?
A) Link 3 is positive, link 4 is positive
B) Link 3 is positive, link 4 is negative
C) Link 3 is negative, link 4 is negative
D) Link 3 is negative, link 4 is positive</td></tr>
</table>

2.8c	Continue with the predictive policing loops described in the previous questions. What is the polarity of loop 1 and loop 2? A) Loop 1 is positive, loop 2 is positive B) Loop 1 is positive, loop 2 is negative C) Loop 1 is negative, loop 2 is negative D) Loop 1 is negative, loop 2 is positive
2.9a	On August 27, 2018, an article about sleep was published online by the Harvard Business Review. Please read the following quote from this article: *"We all face a tradeoff between the quantity of work we do and the quality of that work. Increasing your work hours from 10 hours per day to 18 hours per day will surely increase the amount of work that you can get done. That's simple math. But it is also a mirage; you may be able to complete more tasks, at least in the short term. However, that 18-hour workday will destroy your effectiveness through the harmful effects of sleep deprivation. During those 18 hours, you will be like a boxer fighting with one hand tied behind his back. 18-hour-workday-you will make more mistakes. You will catch some of those mistakes, which means they will only waste your precious time. But some of those mistakes will go undetected until they create much bigger problems later on. 18-hour-workday-you will miss important opportunities for insight into difficult problems, so you will keep banging your head against a wall trying the same old solutions."* The causal loop diagram below summarizes this text.  You can assume that stress is defined as the ratio of remaining workload and available hours on a normal working day. So, if remaining workload is 15 hours for a particular day and you have 10 hours available to work on that day, your stress level is 1.5. What is the polarity of link 1? A) Positive B) Negative C) Impossible to say based on the information provided above D) Link 1 has no polarity because it is outside the loop

2.9b	Continue with the causal loop diagram described in the previous question. What is the polarity of link 2 and link 3? A) Link 2 is positive, Link 3 is positive B) Link 2 is positive, Link 3 is negative C) Link 2 is negative, Link 3 is positive D) Link 2 is negative, Link 3 is negative
2.9c	Continue with the causal loop diagram described in the previous questions. What is the polarity of loop 1 and loop 2? A) Loop 1 is positive, Loop 2 is positive B) Loop 1 is positive, Loop 2 is negative C) Loop 1 is negative, Loop 2 is positive D) Loop 1 is negative, Loop 2 is negative
2.9d	Continue with the causal loop diagram described in the previous questions. What is the polarity of link 4 and loop 3? A) Link 4 is positive, Loop 3 is positive B) Link 4 is positive, Loop 3 is negative C) Link 4 is negative, Loop 3 is positive D) Link 4 is negative, Loop 3 is negative
2.9e	Continue with the causal loop diagram described in the previous questions. What is the behavior of stress that will follow from these causal loops (most likely)? A) Stress is always the same, regardless of the remaining workload (stable) B) When remaining workload increases, stress decreases C) When remaining workload increases, stress first decreases because of working overtime, but increases again when the side-effects of overtime kick in D) None of the above
2.10	The Norwegian Public Roads Administration (Statens Vegvesen) wants to reduce the number of accidents involving cyclists. As a result, they have been building more separate bike lanes in the big cities which indeed seems to reduce the number of biking accidents. The extra bike lines make the use of a bike in the city much more attractive than the use of a car. Consequently, the number of people that start using the bike instead of the car to get to work increases. Sadly, the more cyclists on the bike lanes, the higher the number of biking accidents. Sketch a causal loop diagram that captures this story. Your diagram needs to include: the goal of this system, variables, two feedback loops, link and loop polarities.

Lecture 3: Structure & behavior	
3.1	A system that shows "S-Shaped Growth" has a structure that includes: A) Two positive loops B) Two negative loops C) At least one positive and one negative loop D) One positive loop
3.2	Which statement(s) is(are) true? (I) Exponential Growth, Goal Seeking and S-Shaped Growth are terms describing behavior in dynamic systems (II) Oscillations can arise if there are delays in the negative loop A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
3.3	Which statement(s) is(are) true? (I) If a system reaches the carrying capacity, it is better to remove the factors that limit the growth instead of finding new ways to increase growth (II) If the carrying capacity is increased, this has a direct effect on the reinforcing loop in a system characterized by "S-shaped growth" A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
3.4	Consider the following causal loop diagram:  Which of the graphs below cannot follow from the causal loop structure shown above?  A) Line A B) Line A and Line D C) Line B and Line C D) Line D

3.5	A system that shows “S-Shaped Decline” (see example) has a structure that includes: A) Two positive loops B) Two negative loops C) At least one positive and one negative loop D) One positive loop 
3.6	Which statement(s) is(are) true? (I) Goal Seeking behavior is behavior that you can expect when you have a system with a negative loop and a desired state (II) Oscillations can arise if there are delays in the positive loop A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
3.7	Which statement(s) is(are) true? Without changing the structure (like adding variables, changing causal links) of a system: (I) a reinforcing loop can increase or decrease the state of a system (II) the carrying capacity is always part of the reinforcing loop A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
3.8	Which statement(s) is(are) true? (I) If a system behaves like “S-shaped growth”, the system can be described by a reinforcing loop that is responsible for the growth and a balancing loop that reduces or limits this growth (II) If a system behaves like “S-shaped growth” and you want the system to grow beyond its carrying capacity, you should not push growth, but remove the factors that limit growth A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
3.9	Which of the following statement(s) is(are) true? (I) When a causal loop describes goal-seeking behavior, the loop is balancing (II) A loop can only be reinforcing when all links in the loop have a positive polarity A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false

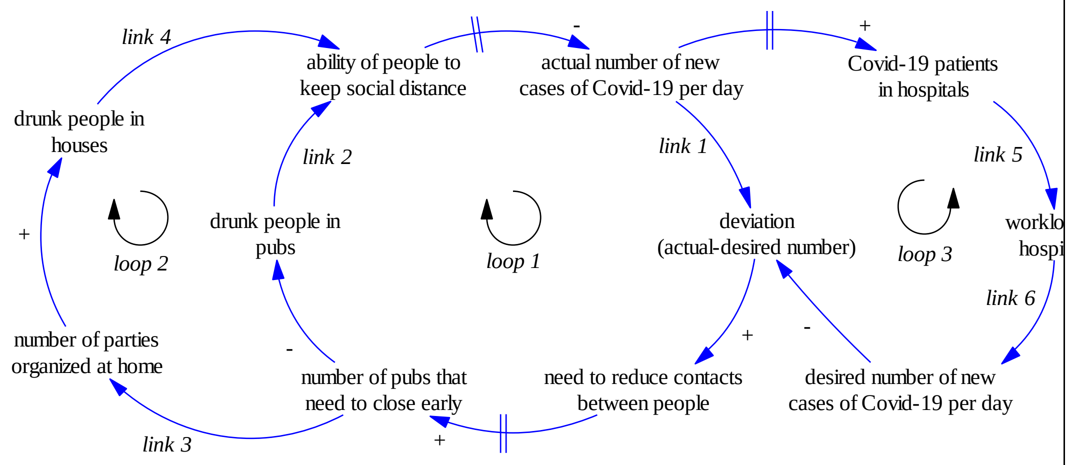
3.10 Which of the following statement(s) is(are) true?

(I) The state of a system that has only one reinforcing loop will be either increasing or decreasing over time

(II) The state of a system that has only one balancing loop can show exponential growth

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is true
D) Statement I is false, and Statement II is false

3.11a One of the interventions that many governments in Europe have implemented to reduce the number of new cases of Covid-19 is closing pubs early (or even completely). The rationale behind this idea is that when pubs close early, people will drink less alcohol and go home early. When people are less drunk, it will be easier for them to keep their social distance (of at least one meter) which reduces new infections. This intervention has side-effects. One of them is that people organize parties in their own house, where there is usually less space available then in pubs, which makes it even more difficult for people to keep their social distance (of at least one meter), especially when they are a bit drunk. Loops 1 and 2 below describe this situation. But there is another side-effect. When the actual number of new cases of Covid-19 per day decreases, fewer Covid-19 patients will go to the hospital and the workload in hospitals will decrease. This could influence the goal as the desired number of new cases of Covid-19 per day could go up if there is sufficient capacity (i.e., low workload) in hospitals. This is described by loop 3.



What is the polarity of link 1 and link 2?
A) Link 1 is positive, link 2 is positive
B) Link 1 is positive, link 2 is negative
C) Link 1 is negative, link 2 is negative
D) Link 1 is negative, link 2 is positive

3.11b Continue with the causal loop diagram described in the previous question.
What is the polarity of link 3 and link 4?

A) Link 3 is positive, link 4 is positive
B) Link 3 is positive, link 4 is negative
C) Link 3 is negative, link 4 is negative
D) Link 3 is negative, link 4 is positive

3.11c Continue with the causal loop diagram described in the previous questions.
What is the polarity of loop 1 and loop 2?

A) Loop 1 is positive, loop 2 is positive
B) Loop 1 is positive, loop 2 is negative
C) Loop 1 is negative, loop 2 is negative
D) Loop 1 is negative, loop 2 is positive

3.11d Continue with the causal loop diagram described in the previous questions.
What is the polarity of link 5 and link 6?

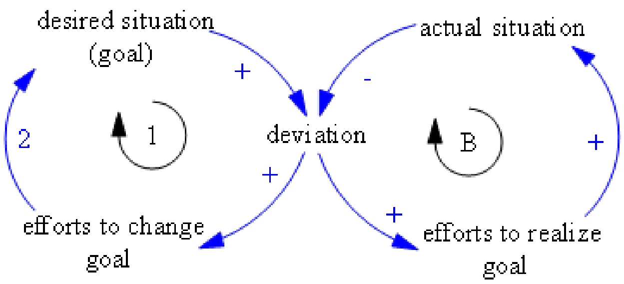
A) Link 5 is positive, link 6 is positive
B) Link 5 is positive, link 6 is negative
C) Link 5 is negative, link 6 is negative
D) Link 5 is negative, link 6 is positive

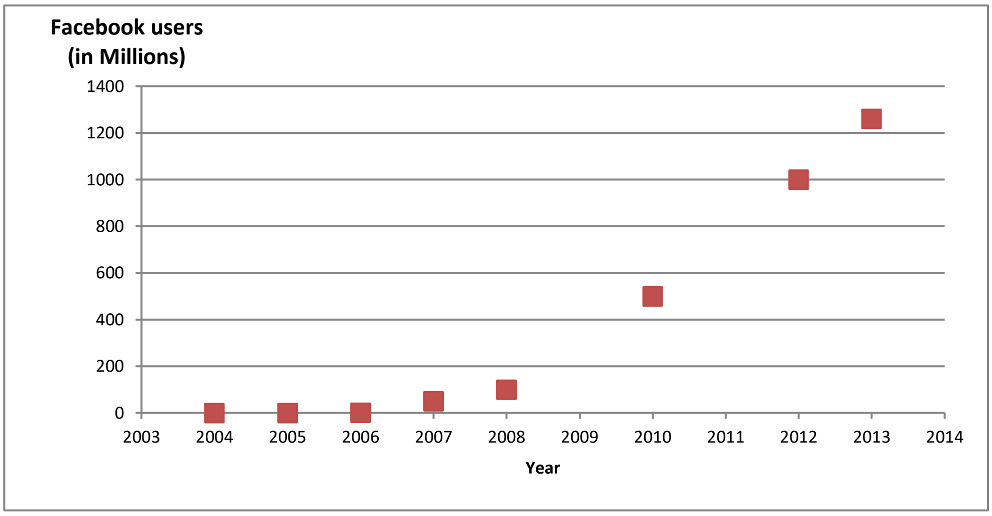
3.11e Continue with the causal loop diagram described in the previous questions.
If there are no other variables to consider, could this system show oscillating behavior and why (not)?

A) No, because there is an odd number of loops in the system (3 is an odd number)
B) Yes, because there is an odd number of loops in the system
C) Yes, because there is a balancing loop in the system with two delays
D) Yes, because there is a reinforcing loop in the system with two delays

3.12a The graph below shows the average price of houses in Oslo (in 1000 Norwegian kroners per m2) from 2003 until 2017. What is the best description of the behavior of these prices over time until 2017?

A) Growth and overshoot
B) Limits to growth
C) S-shaped growth
D) Exponential growth

3.12b	Recently, the prices for 2017 have been published. The new graph now looks like this:  It is too soon to tell, but if you assume that the prices start oscillating around 68000 Norwegian kroner per m2 from 2018 until 2028, how would you describe the behavior of these prices then? A) Growth and overshoot B) Limits to growth C) S-shaped growth D) Exponential growth
3.13a	Consider the following causal loop diagram:  This system describes a situation in which the goal is decreased if it is too difficult to realize it and increased when it is easy to realize it. How would you characterize loop 1 and link 2? A) Loop 1 is balancing, link 2 is negative B) Loop 1 is balancing, link 2 is positive C) Loop 1 is reinforcing, link 2 is negative D) Loop 1 is reinforcing, link 2 is positive
3.13b	Continue with the model described in the previous question. How would you characterize the behavior of this system? A) This system describes “oscillation” B) This system describes “S-shaped growth” C) This system describes “growth and overshoot” D) None of the above.

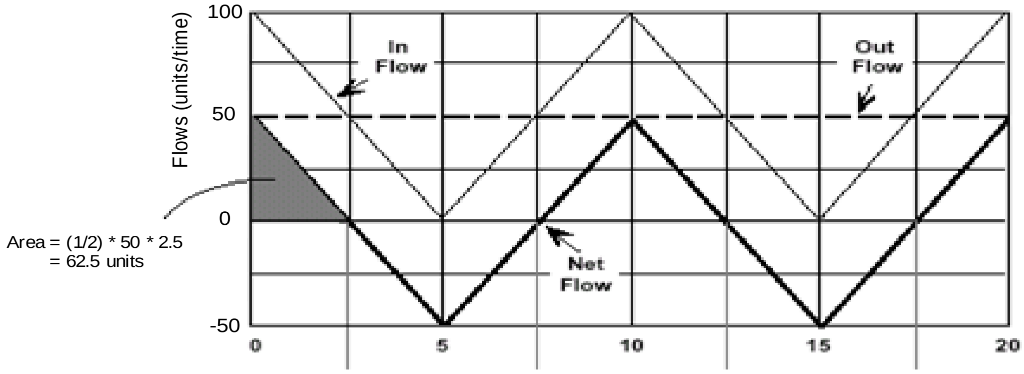
3.14a	The graph below shows the number of Facebook users over the years.  How would you describe this behavior (from 2004-2013)? A) Goal-seeking behavior B) Exponential growth C) Oscillation D) Growth and overshoot
3.14b	Continue with the Facebook-graph described in the previous question. What kind of causal structure is most likely responsible for this behavior (from 2004-2013)? A) Balancing loop B) Balancing loop with delays C) Balancing and a reinforcing loop D) Reinforcing loop
3.14c	Continue with the Facebook-graph described in the previous question. Assuming there is a limit to the number of Facebook users (both current users and potential users) of 2000 million users, how would you describe the behavior of Facebook users over time from 2004 - 2100? A) Goal-seeking behavior B) Exponential growth C) S-shaped growth D) Growth and overshoot
3.14d	Continue with the Facebook-graph described in the previous question. What kind of loop would you need to add (on top of the loop you already used in a previous question) to the causal structure to model the influence of this limit on the number of Facebook users? A) Balancing loop B) Reinforcing loop C) Both a balancing and a reinforcing loop D) No extra loop is necessary to model this

3.14e	Continue with the Facebook-graph described in the previous question. Assume that a competitive product is introduced to all Facebook users in 2020 which leads all users (including potential users) to abandon Facebook, how would you describe the behavior over time from 2004 – 2100? A) Exponential growth B) S-shaped growth C) Overshoot and collapse D) Exponential decline
3.14f	Sketch a causal loop diagram that represents the situation described in the previous question and that can explain the behavior (your answer to the previous question). Your diagram needs to include (among other things): the number of Facebook users, some kind of limit to the growth of the number of Facebook users, and the users of a competitive social media product. Make sure to indicate link and loop polarities.

Lecture 4: Stocks & flows

4.1

Consider the following graph, describing the flow and stock of a first order system with an initial state of 500 units (graph is copied from Sterman (2000), Chapter 7, p. 239).



What is the value of the stock at t = 5?

A) 250
B) 437.5
C) 500
D) 750

4.2

A bar is located close to BI in Nydalen. The model below depicts the most important stock and flows required to model customers of this bar. The departure rate is the outflow of the system and defines the number of customers that leaves the bar.

Which of the following equations is correct?

A) Customers in the Bar = arrival rate – departure rate
B) d/dt (Customers in the Bar) = arrival rate – departure rate
C) INTEGRAL(Customers in the Bar) = arrival rate - departure rate
D) Customer in the Bar = INTEGRAL(arrival rate + departure rate)

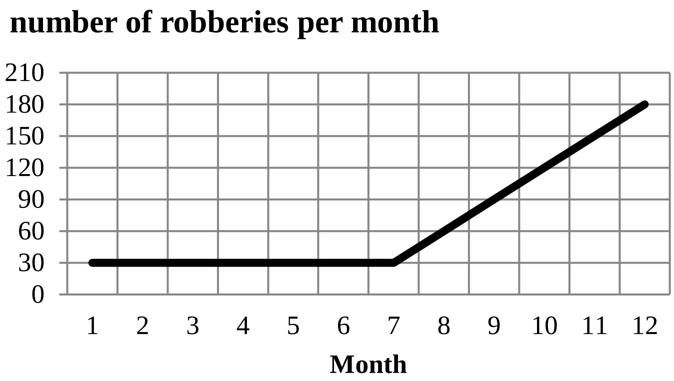
4.3

Which statement(s) is(are) true?

(I) Stocks (stages) in a chain must be mutually exclusive
(II) Each unit that flows through a series of stocks can only be in one stock at a time

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is true
D) Statement I is false, and Statement II is false

<table>
<tr>
<td>4.4</td>
<td>
The graph below describes the number of robberies per month in Oslo in the year 2013.



What can you say about the total number of robberies during in the entire year 2013?

A) The total number of robberies is around 810 and this should be modeled as a stock
B) The total number of robberies is around 810 and this should be modeled as a flow
C) The total number of robberies is around 180 and this should be modeled as a stock
D) The total number of robberies is around 180 and this should be modeled as a flow
</td>
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<tr>
<td>4.5</td>
<td>
Suppose you have made a simulation model in Vensim about a certain business process. The simulation runs from week 1 until week 52. However, you want to simulate what will happen on the long term (3 years, so let's say until week 156). What do you need to change in your model to make this work?

A) Change the time units from weeks to years
B) Change the time step into 156 weeks
C) Change the final time into 156 weeks
D) Multiply the value of all variables in the model by 3
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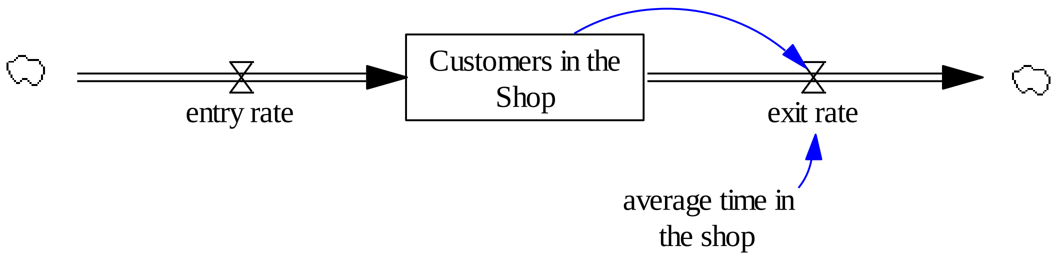
<td>4.6a</td>
<td>
The following system represents a small shop selling designer clothes in a city in Norway. The shop is open for about 10 hours a day (from 900 to 1900, but it can stay open a bit longer if there are still customers in the shop at 1900 hours). Customers stay on average 30 minutes in the shop. Initially, there are no customers in the shop.



The graph below shows the entry (in blue) and exit (in red) rate in customers/hour for one day.
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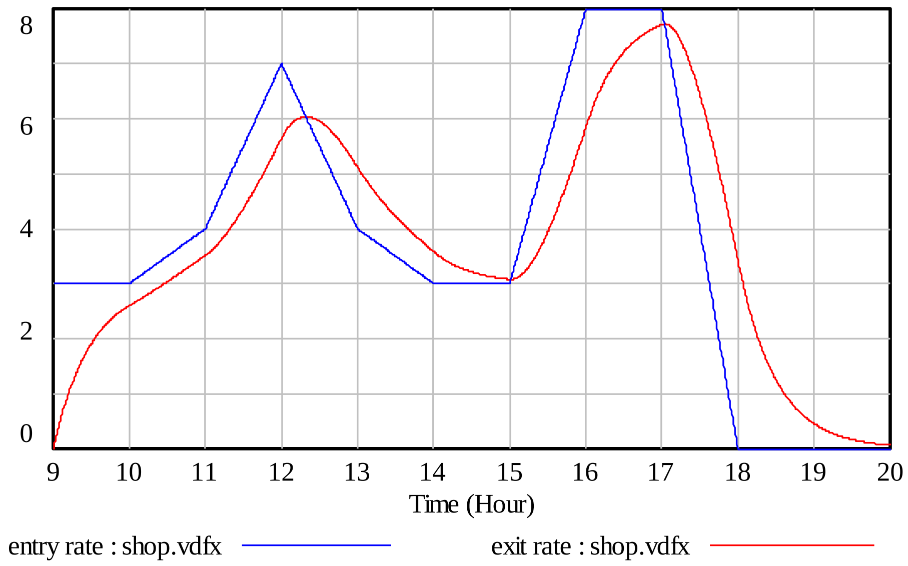
	 At what time did the stock “Customers in the Shop” increase the most? A) At around 0900 hours B) At around 1200 hours C) At around 1600 hours D) At around 1800 hours
4.6b	Continue with the model described in the previous question and the graphs of entry and exit rate. At what time did the stock “Customers in the Shop” decrease the most? A) At around 1300 hours B) At around 1600 hours C) At around 1800 hours D) At around 2000 hours
4.6c	Continue with the model described in the previous questions and the graphs of entry and exit rate. Which of the following statements about the stock “Customers in the Shop” is true? (I) The stock is stable (not changing) between 1400 and 1500 hours (II) The stock is at its maximum around 1700 hours A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is false D) Statement I is false, and Statement II is true
4.6d	Continue with the model described in the previous questions and the graphs of entry and exit rate. How many customers were in the shop at 1000 hours (what is the stock at 1000 hours)? A) About 0.5 customers B) About 1.5 customers C) About 3.1 customers D) About 5.5 customers

4.6e

Continue with the model described in the previous questions and the graphs of entry and exit rate.
As you can see from the entry rate, there are not so many customers arriving from 1300 to 1500 hours. To attract more customers, the owner will offer free coffee between 1300 and 1500 hours. This increases the entry rate during these hours. This also has a side-effect of keeping customers in the shop for a longer time.

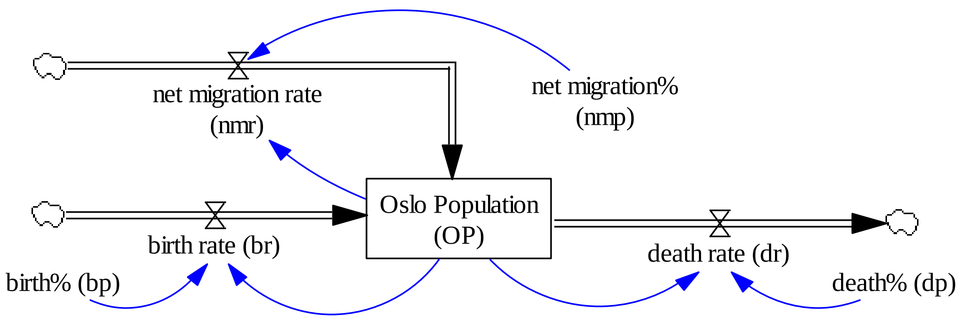
Which of the following statement(s) about the stock "Customers in the Shop" after 1300 hours is(are) true?

- I) The stock increases because of the combination of a higher entry rate and a longer average time in the shop
- II) The stock is hardly influenced because the higher entry rate increases the stock, but the longer average time in the shop decreases the stock again

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is false
D) Statement I is false, and Statement II is true

4.7a

The population of Oslo was 678182 people in 2018. The population is influenced by a birth percentage (bp = 1.40%) and a death percentage (dp = 0.6%). Furthermore, there is a net migration percentage (nmp = 0.33%) which is the difference between the percentage of people moving to Oslo and the percentage of people moving from Oslo.
The model below describes this situation. The equations for the flows are:
nmr = nmp*OP
br = bp*OP
dr = dp*OP

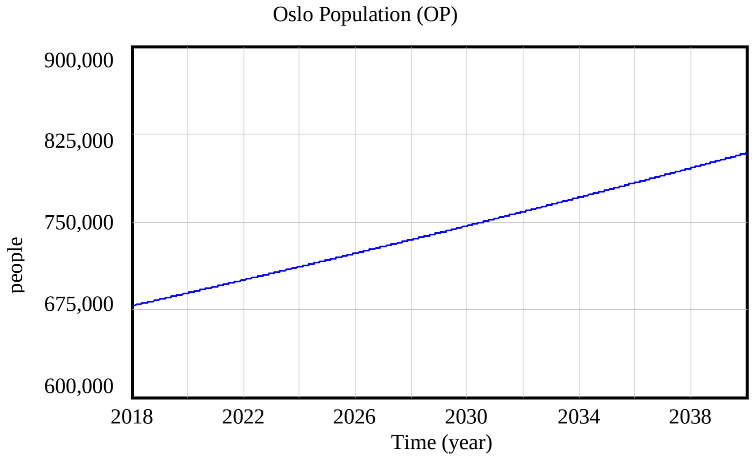
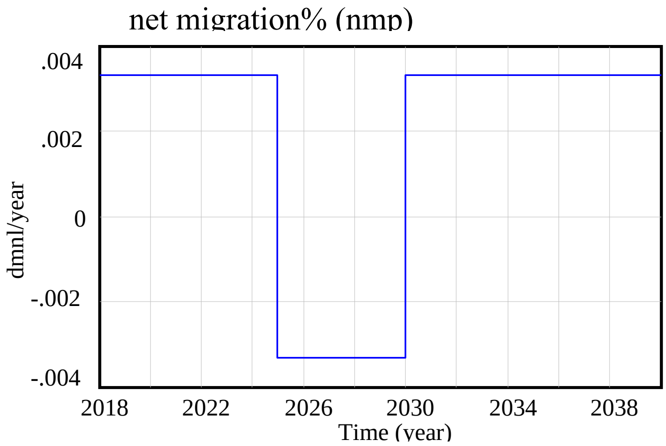


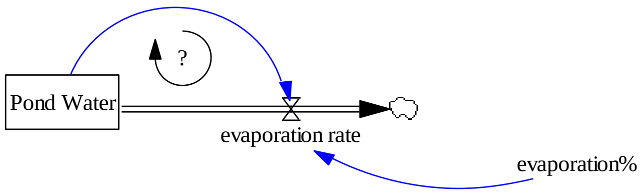
What is the equation for the stock Oslo Population (OP)?

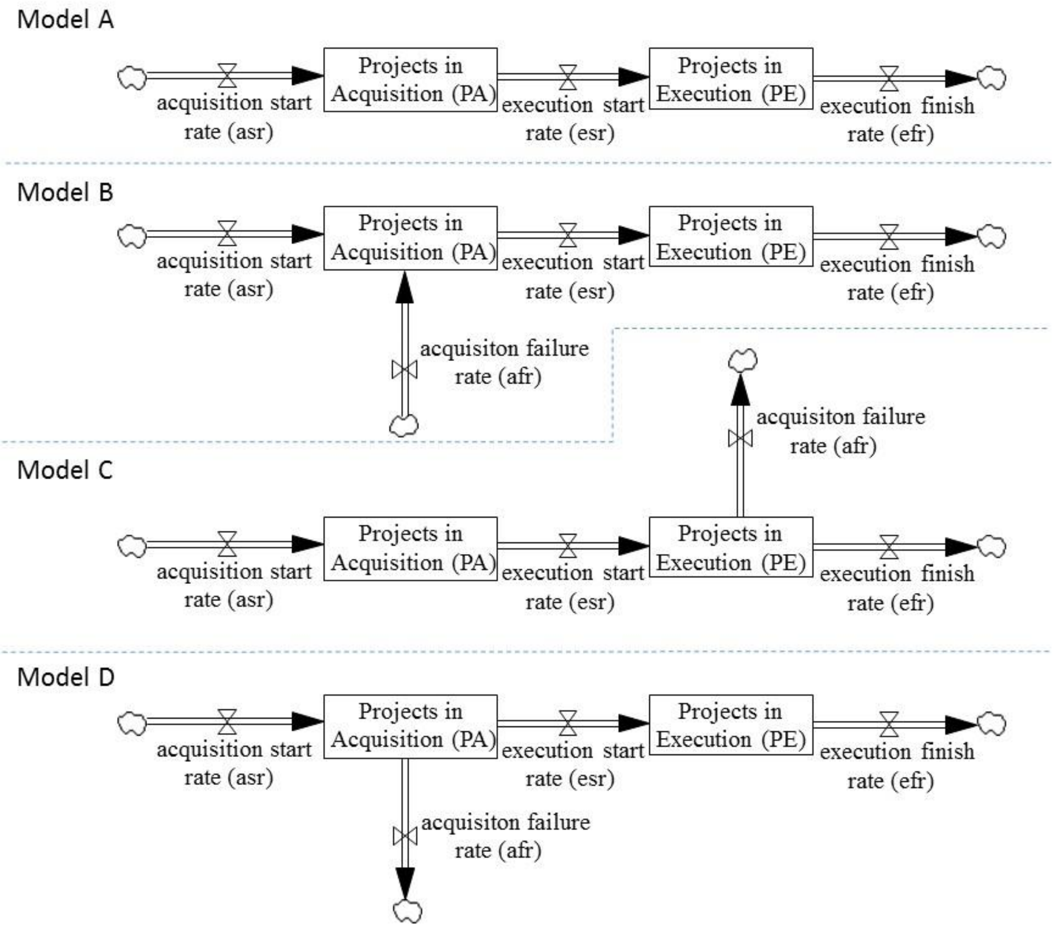
A) OP = INTEGRAL (br - nmr – dr) + OP(0)
B) OP = INTEGRAL (br + nmr – dr) + OP(0)
C) OP = INTEGRAL (br-dr) + OP(0) + nmr
D) OP = INTEGRAL (br + nmr – dr)

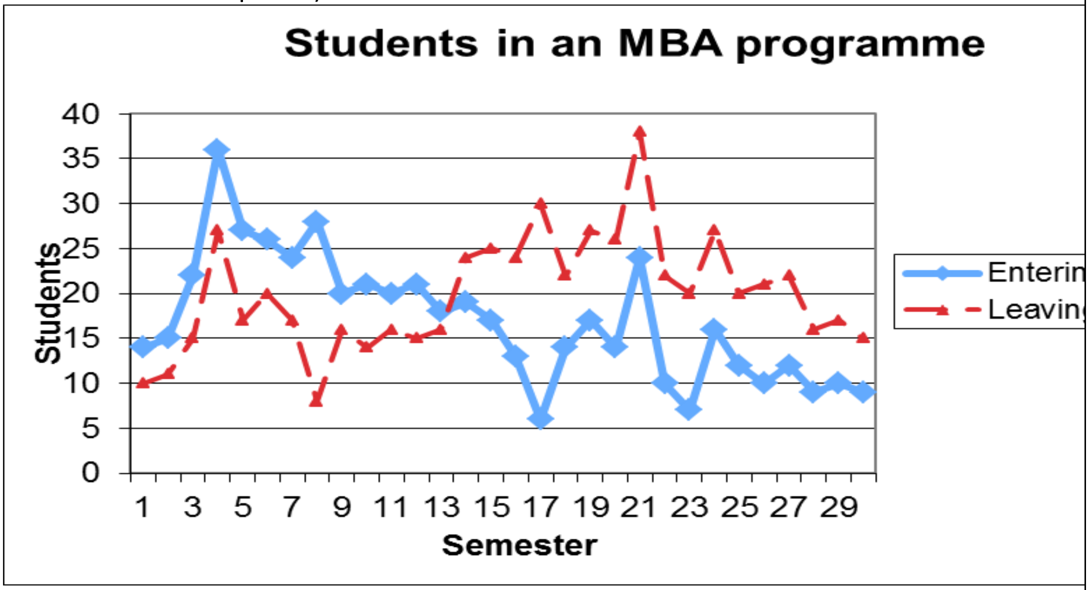
4.7b

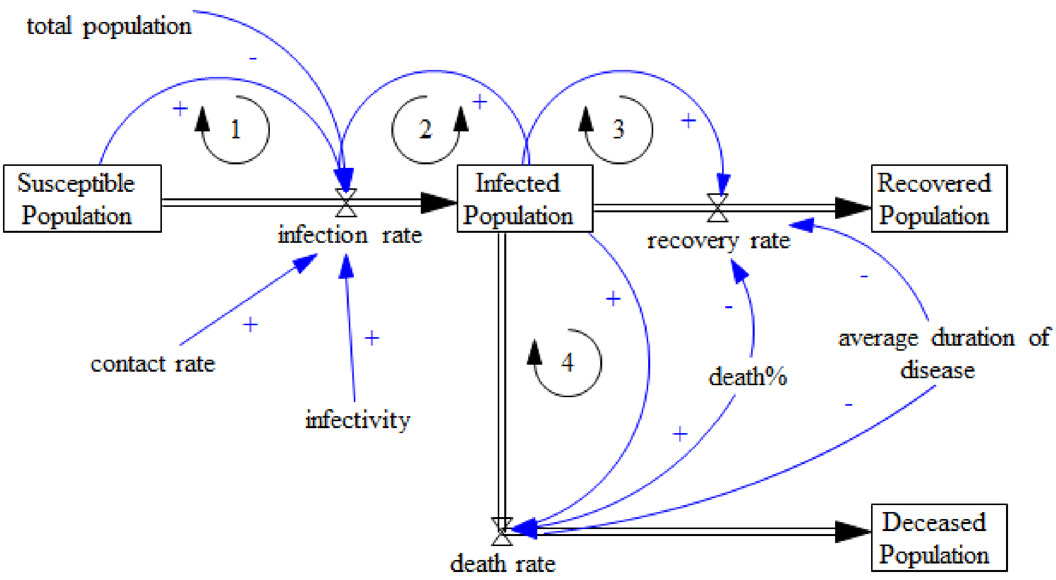
Continue with the model described in the previous question.
When we run the simulation from the year 2018 to 2040, we get the following graph for the population of Oslo. What can you say about the behavior of this population, assuming all percentages remain constant, and you do not have to consider any other variables than the ones shown in the model?

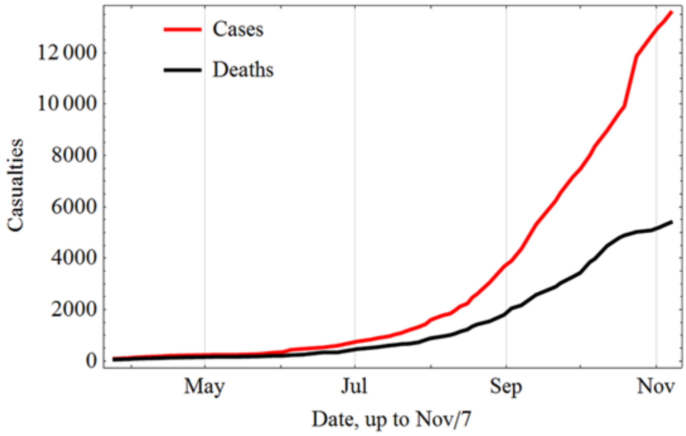
	 A) Oslo Population is stable B) Oslo Population will start to oscillate after 2040 C) Oslo Population shows linear growth, also after 2040 D) Oslo Population shows exponential growth, although it looks like linear growth until 2040
4.7c	Continue with the model described in the previous questions. Suppose that from 2025 to 2030 the net migration% (nmp) suddenly drops from 0.0033 to -0.0033 (note that 0.33% = 0.0033). After 2030 it jumps back to 0.0033. The graph below shows this drop. You can assume that the birth- and death percentages remain the same (1.4% and 0.6% per year).  What will happen to the Oslo Population (OP) between 2025 and 2030? A) OP will decrease between 2025 and 2030 B) OP will stabilize between 2025 and 2030 (OP will not change between 2025 and 2030) C) OP will increase between 2025 and 2030 D) OP will oscillate between 2025 and 2030
4.7d	Continue with the model described in the previous questions, but you can assume that the net migration% is always 0.0033 (0.33%) again. As the previous graph shows, the Oslo Population is expected to grow to over 750 000 people after around 2030. Even though new houses are constantly being built, there is a limit to the number of new houses that can be built because the area of Oslo is limited by the sea in the south and the forest in the north. This housing limitation (you can call this the carrying capacity, which is 750

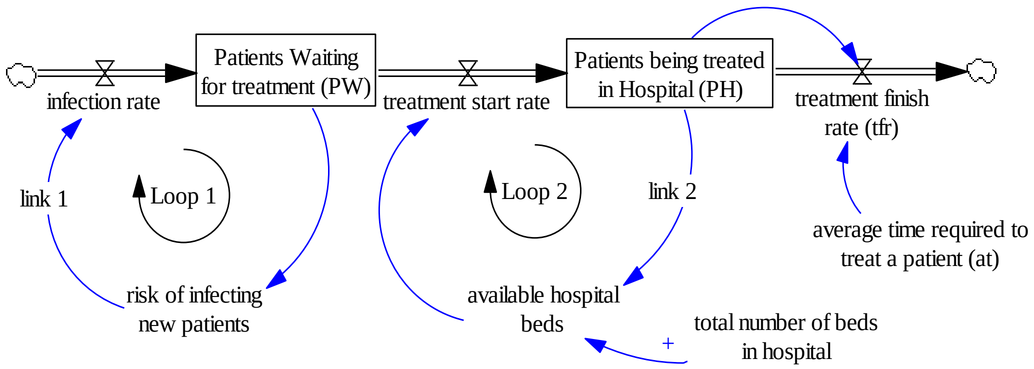
	000 people) is not yet modeled. If you would include this carrying capacity in the model, what will happen to the Oslo Population? A) OP will decrease after 2030 B) OP will start decreasing already some years before 2030 C) OP will not be influenced by the lack of houses (same behavior as shown in a previous graph) D) OP will grow toward the carrying capacity (like S-shaped growth)
4.7e	Continue with the situation described in the previous question (carrying capacity is now included in the model). Which of the following statement(s) is(are) true? I) dOP/dt is positive after 2030 II) dOP/dt is decreasing after 2030 A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is false D) Statement I is false, and Statement II is true
4.7f	To practice your modeling skills in Vensim, build this model in Vensim and run the simulation to check your answers to the previous questions. You can assume that the net migration% is always 0.0033 (0.33%).
4.8a	A retired teacher has bought a 1000 liter pond to keep his goldfish. He fills the pond completely with water. It is summertime and it has been warm for a long time, so on average 1% of the content evaporates per day. This model below describes this system:  What is the polarity of the loop? A) The loop is positive B) The loop is negative C) I need more information to answer this question D) This is not a loop, so there is no polarity
4.8b	Continue with the model described in the previous question. Our teacher notices the evaporation and decides to add 50 liters of water on day 10 (one time, only on day 10). What does this mean for the loop polarity after day 10? A) The loop is positive after day 10 B) The loop is negative after day 10 C) I need more information to answer this question D) This is not a loop, so there is no polarity

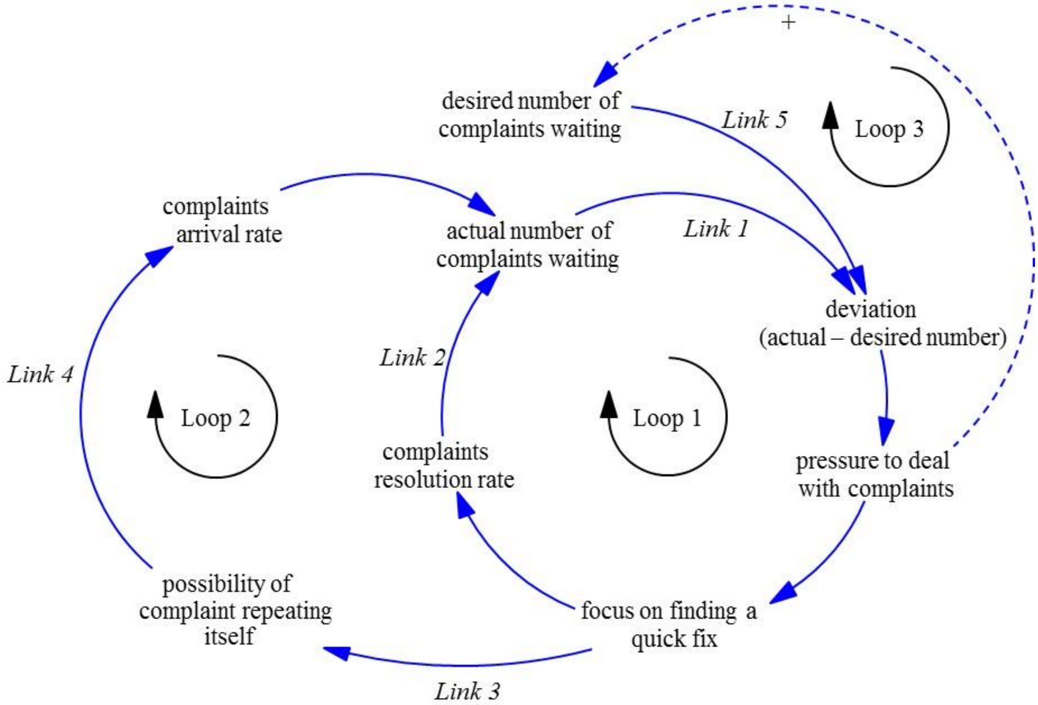
4.9a	Consultancy companies basically have two kinds of jobs. First, new projects need to be acquired (this is called: acquisition). Second, these new projects need to be executed (this is called: execution). So, projects go through two stages or stocks: first they are in the stock “Projects in Acquisition”, and when the customer says “yes” after the acquisition process, these projects flow to the second stage “Projects in Execution”. Customers can also say “no” during the acquisition process, which means that the specific project will not be executed. This is called the “acquisition failure rate”. Below you will find 4 Stocks & flows diagrams. Which one depicts this consultancy company correctly (including the possibility that customers say “no”)? A) Model A B) Model B C) Model C D) Model D 
4.9b	Continue with the consultancy company described in the previous questions. The CEO of the company wants to keep track of the total number of projects that have been finished since the start of the company (year 0) until now (suppose we are in year 10 now). How can the CEO use the model for this? A) The CEO needs to run the model and then find the value of efr in year 10 B) The CEO needs to run the model and then find the value of PE in year 10 C) The CEO needs to run the model and then find the value of PA + PE in year 10 D) The CEO needs to add a new stock (NS) that accumulates the efr, and after running the model, the CEO needs to find the value of this new stock in year 10

4.10a	A small-sized European business school has kept track of how many students enter and leave its MBA-program for the past 30 semesters. The figure below summarizes the results over this period: one graph describes the inflow of students (the number of students entering the university per semester) and other graph describes the development of the outflow (the number of students leaving university every semester, with or without a diploma).  During which semester did the most people leave the program (biggest outflow)? A) semester 4 B) semester 8 C) semester 17 D) semester 21
4.10b	Continue with the model described in the previous question. During which semester was the biggest net increase in people in the program? A) semester 4 B) semester 8 C) semester 17 D) semester 21
4.10c	Continue with the model described in the previous questions. During which semester were the most people IN the program (highest value of the stock)? A) semester 4 B) semester 13 C) semester 21 D) semester 31
4.10d	Continue with the model described in the previous questions. During which semester were the fewest people IN the program (lowest value of the stock)? A) semester 4 B) semester 13 C) semester 21 D) semester 31

Lecture 5: S-shaped growth	
5.1	Which statement(s) is(are) true? A system generates S-Shaped Growth, when two critical conditions are met: (I) The negative loops must not include any significant time delays (II) The carrying capacity cannot be fixed A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
5.2a	The stocks & flows diagram below shows a model of the Ebola outbreak.  What is the polarity of loops 1 and 2? A) Loop 1 is negative, Loop 2 is negative B) Loop 1 is negative, Loop 2 is positive C) Loop 1 is positive, Loop 2 is negative D) Loop 1 is positive, Loop 2 is positive
5.2b	Continue with the Ebola-model described in the previous question. What is the polarity of loops 3 and 4? A) Loop 3 is negative, Loop 4 is negative B) Loop 3 is negative, Loop 4 is positive C) Loop 3 is positive, Loop 4 is negative D) Loop 3 is positive, Loop 4 is positive

5.2c	Continue with the Ebola-model described in the previous questions. The graph below, taken from Wikipedia, shows the behavior over time of the number of people infected by Ebola, and the number of people that died because of this disease. (Note that “Cases” is the same as the stock Infected Population, and “Deaths” is the same as the stock Deceased Population.) This same Wikipedia page reports that in September the actual average death percentage (or case fatality rate) was 70%.  Assuming that all other variables and equations in the model are not changed, what appears to be happening to the death percentage in November? A) Death percentage seems to be stable (70%) B) Death percentage seems to be increasing because more people are dying C) Death percentage seems to be decreasing because the graph of “deaths” is not increasing as fast as the graph of “cases” D) Death percentage seems to be zero (no one dies from Ebola anymore)
5.2d	Continue with the model described in the previous questions. If the death percentage behaves the way you predicted in the previous question, and all other variables and equations are not changed, how will this influence the Infected Population (or the number of “cases” in the graph above) after November? A) It will not influence the behavior of the Infected Population at all B) The Infected Population will increase faster from November onward C) The Infected Population will increase slower from November onward D) The Infected Population will decrease after November
5.2e	Continue with the model described in the previous questions. What is the correct equation for death rate in the model? A) Death rate = death% * Infected Population B) Death rate = death% * Infected Population / average duration of disease C) Death rate = death% * average duration of disease / Infected Population D) Death rate = death% * Deceased Population / average duration of disease
5.2f	Continue with the model described in the previous questions. What are the units for infection rate in the model? A) People B) People * month C) People / month D) Months

5.3a	The model below describes the behavior of patients getting a certain infection that requires treatment in a hospital. When there are no beds available, patients are waiting at home for treatment. This increases the risk that these patients infect other, still healthy people. When patients get admitted in the hospital, they occupy hospital beds. An occupied bed cannot be given to a new patient. Only when the patient finishes the treatment and leaves the hospital, the bed can be given to a new patient.  What is the polarity of Link 1 and Link 2? A) Link 1 is positive, Link 2 is negative B) Link 1 is positive, Link 2 is positive C) Link 1 is negative, Link 2 is negative D) Link 1 is negative, Link 2 is positive
5.3b	Continue with the model described in the previous question. What is the polarity of Loop 1 & 2? A) Loop 1 is positive, Loop 2 is negative B) Loop 1 is positive, Loop 2 is positive C) Loop 1 is negative, Loop 2 is negative D) Loop 1 is negative, Loop 2 is positive
5.3c	Suppose the total number of beds in the hospital could be doubled in case of an epidemic. How would this influence the risk of infecting new patients? A) There is no influence because there is no causal link between these two variables B) There is no influence because hospital beds only influence the patients being treated in the hospital C) The risk will be increased D) The risk will be decreased
5.3d	Continue with the model described in the previous question. How would you model the treatment finish rate (tfr)? Note that: PH = Patients being treated in Hospital at = average time required to treat a patient A) tfr = PH*at B) dPH/dt = -tfr C) tfr = PH/at D) dPH/dt = tfr/at

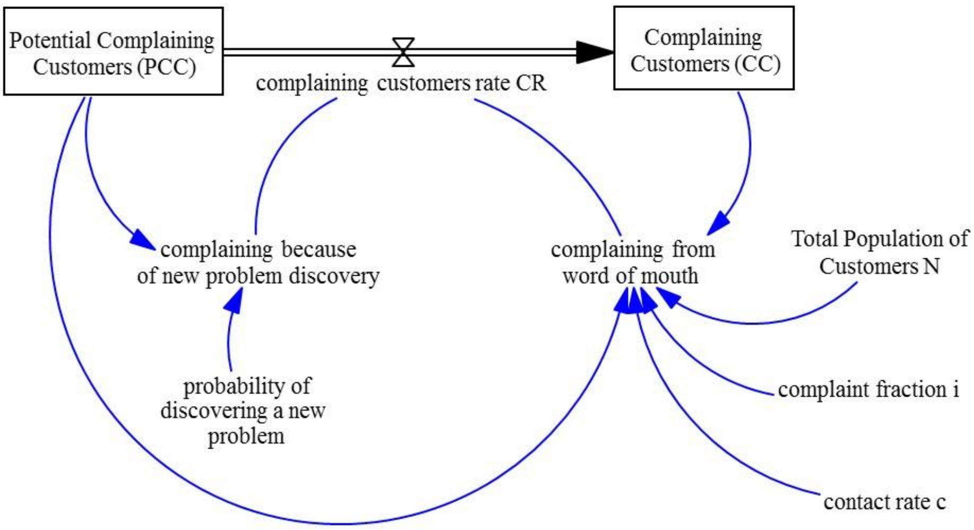
<table>
<tr><th></th><th></th></tr>
<tr><td>5.4a</td><td>The following causal loop diagram describes typical behavior of handling complaints in a large supermarket. Employees try to deal with customer complaints as fast as possible, because an angry customer is a customer that may start shopping in a different supermarket and persuade friends and family members to do the same. The standard way to resolve complaints (also known as a “quick fix”) is to give the complaining customer a discount. This may please the customer for a short time, but it doesn’t take away the cause of the complaint. As such, the same thing could happen to another customer after a while, and this customer can also start complaining.


What is the polarity of Loop 1 and Loop 2 in this causal loop diagram?

A) Loop 1 is negative (balancing), Loop 2 is negative (balancing)
B) Loop 1 is negative (balancing), Loop 2 is positive (reinforcing)
C) Loop 1 is positive (reinforcing), Loop 2 is negative (balancing)
D) Loop 1 is positive (reinforcing), Loop 2 is positive (reinforcing)</td></tr>
<tr><td>5.4b</td><td>Continue with the causal loop diagram described in the previous questions.
What is the polarity of link 1 and 2?

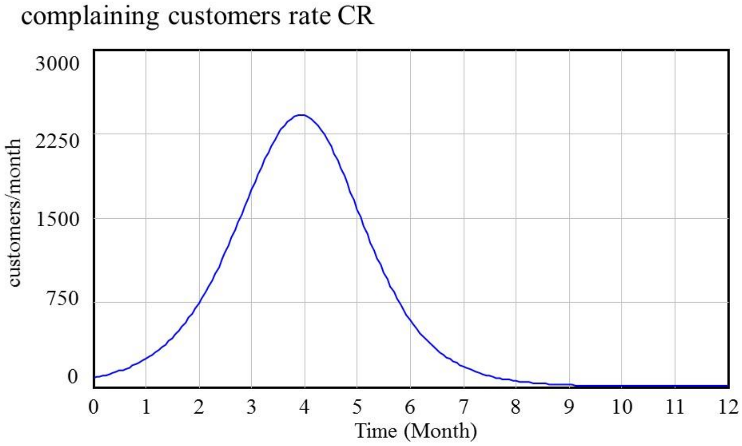
A) Link 1 is positive, Link 2 is positive
B) Link 1 is positive, Link 2 is negative
C) Link 1 is negative, Link 2 is positive
D) Link 1 is negative, Link 2 is negative</td></tr>
<tr><td>5.4c</td><td>Continue with the causal loop diagram described in the previous questions.
What is the polarity of link 3 and 4?

A) Link 3 is positive, Link 4 is positive
B) Link 3 is positive, Link 4 is negative
C) Link 3 is negative, Link 4 is positive
D) Link 3 is negative, Link 4 is negative</td></tr>
</table>

5.4d	Continue with the causal loop diagram described in the previous questions. Sometimes the pressure to deal with complaints gets so high, that employees try a different approach: floating goals. They increase the desired number of complaints waiting (indicated by the dashed arrow). Now a new loop (loop 3) arises. What is the polarity of the new loop and link 5 (from desired number of complaints waiting to deviation)? A) Loop 3 is negative (balancing), link 5 is negative B) Loop 3 is negative (balancing), link 5 is positive C) Loop 3 is positive (reinforcing), link 5 is negative D) Loop 3 is positive (reinforcing), link 5 is positive
5.4e	Continue with the causal loop diagram described in the previous questions. If you would turn this causal loop diagram into a stocks & flows diagram, which variable would make a good stock? A) Actual number of complaints waiting B) Desired number of complaints waiting C) Complaints arrival rate D) Complaints resolution rate
5.4f	We continue with the case of complaining customers. Complaining customers can also be modeled by using the Bass Diffusion model. An example is given below.  This model explains that for any type of problem that can arise in a supermarket, potential complaining customers can discover this problem by themselves ("complaining because of new problem discovery", or they can start complaining because another complaining customer told them to do so ("complaining from word of mouth"). You can practice your Vensim skills by making this model yourself. Run the model for 12 months. The equations are similar to the ones used in the Bass Diffusion model. You can use the following numbers: PCC(0) = 7600 CC(0)= 0 probability of discovering a new problem = 0.01, Total Population N = 7600, complaint fraction i = 0.25, contact rate c = 5

5.4g

The graph of the “complaining customers rate (CR)” is given below.



As you can see in the graph, there is a peak around month 4. Which of the following statement(s) is(are) true? (You do not have to build the model to answer this question.)

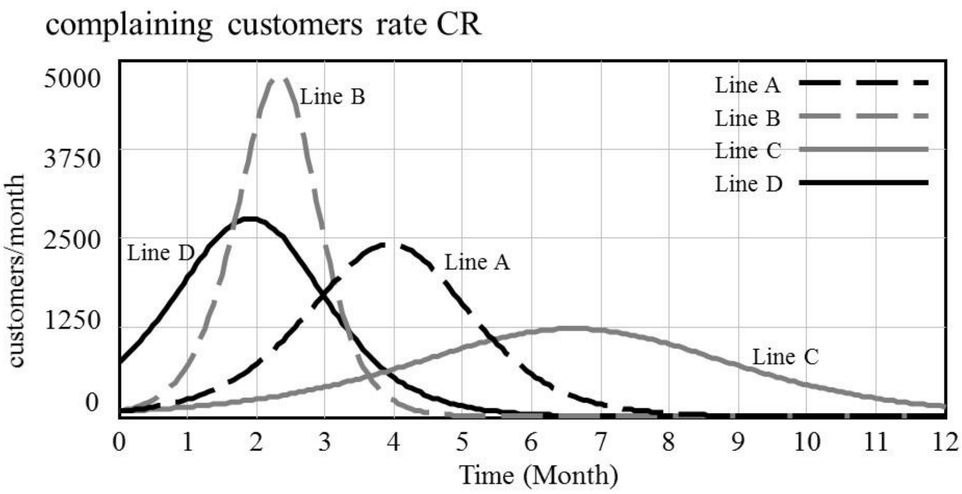
(I) Until month 4 the number of “Complaining Customers (CC)” will be increasing, after month 4, this number will be decreasing

(II) In month 4 the number of “Potential Customers Complaining (PCC)” decreases the most (that is: the decrease is higher than in all other months)

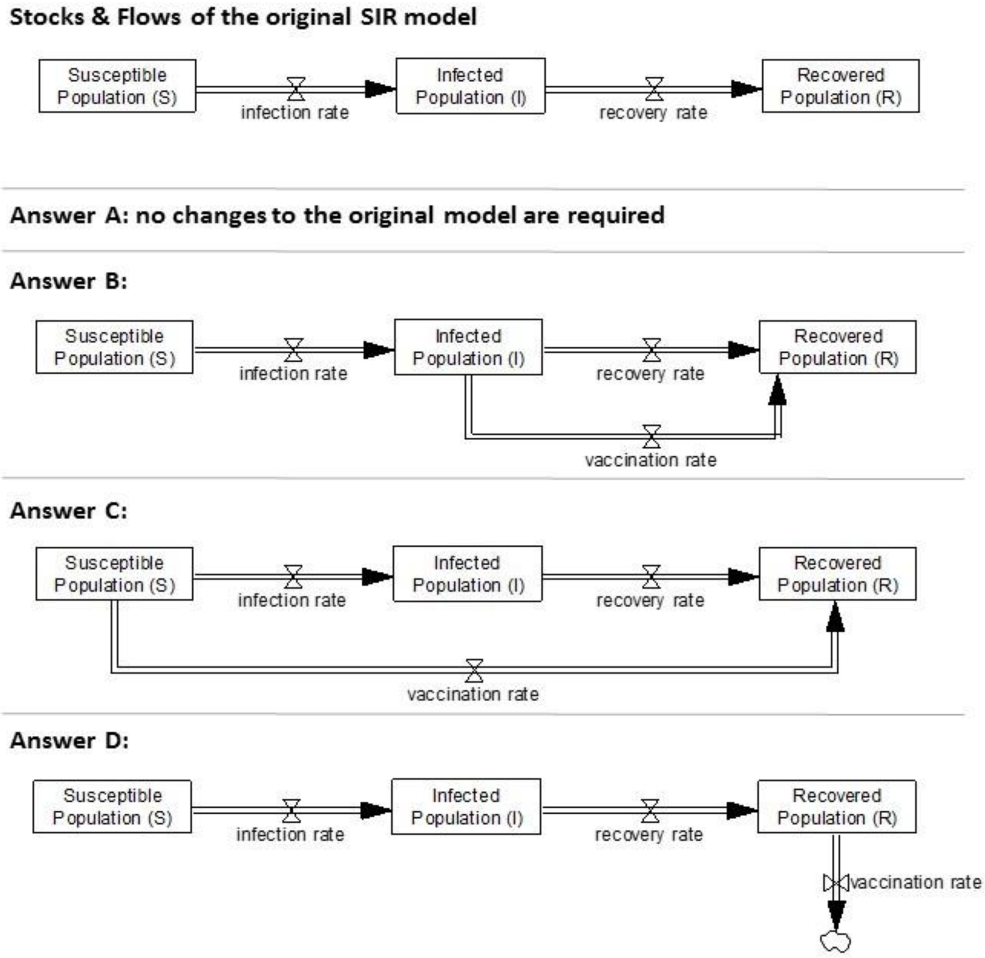
A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is true
D) Statement I is false, and Statement II is false

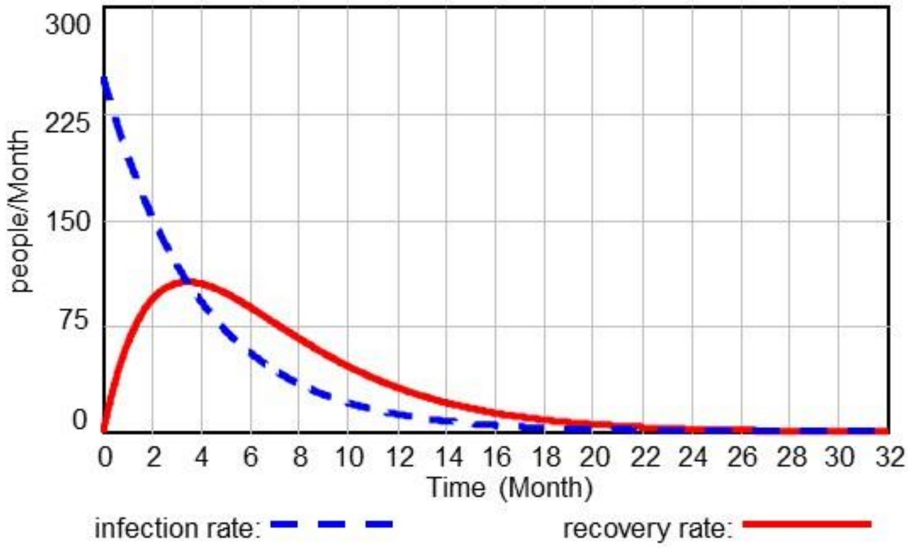
5.4h

Continue with the model described in the previous question.
What would happen if the “contact rate c” would be doubled (from 5 to 10, for example)? You do not have to build the model to answer this question.
Which line in the graph below represents the new situation? (Note that Line A is the same graph as in the previous question, in other words, if you select Line A, you are saying that doubling “contact rate c” will not influence the “complaining customers rate CR”.)



A) Line A
B) Line B
C) Line C
D) Line D

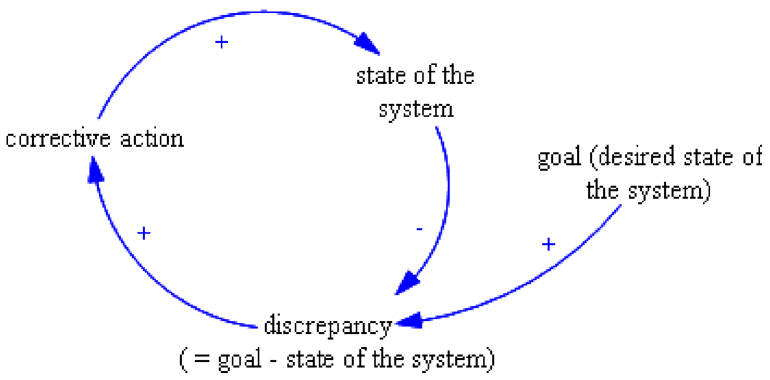
5.5a	The SIR model of an epidemic (Susceptible, Infected, Recovered Population) relates to illnesses that produce permanent immunity and a typical lifecycle that includes the three states S, I, and R. This does not mean that all the individuals of the population must pass through these stages. A vaccination program prevents people from getting infected. This vaccination can immunize people artificially. But not everyone gets this vaccination. What would be the best way to model this vaccination program? (You only have to think about the stocks & flows, you do not have to worry about any other variables.)  A) No changes to the original model are required B) A new flow from (I) to (R) C) A new flow from (S) to (R) D) A new outflow from (R)
5.5b	Continue with the original SIR model (so without the vaccination program) described in the previous question. Not all people that recover will be permanently immune. 25% (repetition percentage = rp) of the recovered population may get this disease multiple times in their lives. We will call this process the "repetition rate". What is the equation for this repetition rate? A) Repetition rate = rp * R B) Repetition rate = rp * I C) Repetition rate = rp * S D) Repetition rate = (1-rp) * I

5.5c	Continue with the equation described in the previous question. What would be logical units for the repetition percentage, rp? A) No units (= dimensionless) B) People C) People/month D) Dimensionless/month (= no units/month = 1/month)
5.5d	Continue with the <u>original</u> SIR model (so without vaccination or repetition). You can assume that initially there are hardly any infected people (and no recovered people). The graphs below depict the infection and recovery rate:  Which statement(s) is(are) true? (I) Around time 3 and after time 30 the Infected Population is stable (II) Around time 3 the Infected Population is at its peak A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
5.5e	Continue with the original SIR model (without vaccination or repetition) and the infection and recovery rates described in the previous question. Which statement(s) is(are) true? (I) Infection rate is modeled as a fractional decrease rate (II) Recovery rate is modeled as a pipeline delay A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false

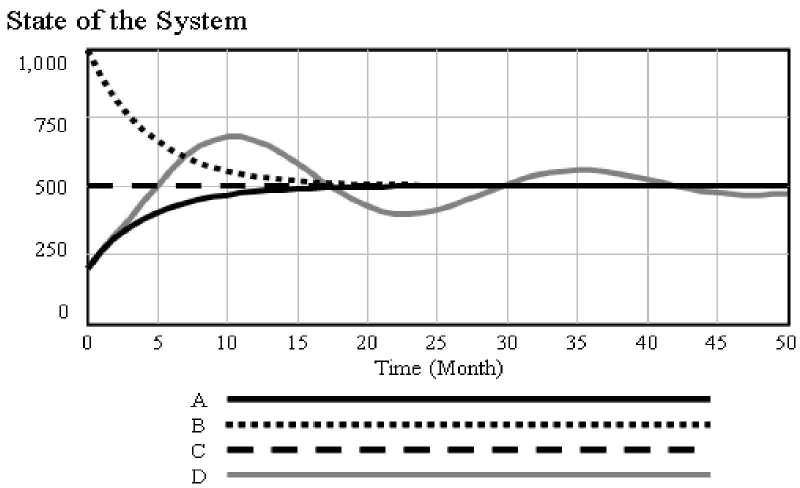
5.5f	Continue with the original SIR model (without vaccination or repetition) and the infection and recovery rates described in the previous question. Which statement(s) is(are) true? (I) The Infected Population will show S-shaped growth (II) The behavior of the Susceptible Population can be described by a balancing loop A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
5.5g	Continue with the original SIR model (without vaccination or repetition) and the infection and recovery rates described in the previous question. Estimate how many people are recovered at time 2 (remember, initially, there are no recovered people)? A) It is impossible to estimate this based on the graph of the recovery rate alone B) 0 people C) A little over 50 people D) A little over 100 people
5.5h	Continue with the original SIR model (without vaccination or repetition) and the infection and recovery rates described in the previous question. Estimate how many people are still susceptible at time 2 (you can assume that initially, there are 1000 susceptible people)? A) It is impossible to estimate this based on the graph of the infection rate alone B) Around 900 people C) Around 600 people D) Around 300 people
5.5i	Continue with the original SIR model (without vaccination or repetition) and the infection and recovery rates described in the previous question. What is a correct equation for the susceptible population (S)? A) S = INTEGRAL(infection rate) B) S = INTEGRAL(infection rate) + 1000 C) S = INTEGRAL(- infection rate) D) S = INTEGRAL(- infection rate) + 1000
5.5j	Continue with the original SIR model (without vaccination or repetition) and the infection and recovery rates described in the previous question. How many people are recovered at time 32? A) It is impossible to estimate this based on the information provided B) 1000 people C) 900 people D) 800 people

Lecture 6: Dynamics of stocks & flows

6.1 Consider the following causal loop diagram:

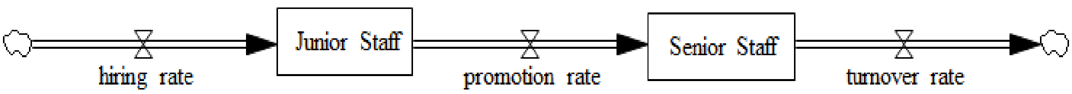


Assuming that the goal is always 500. Which of the graphs below cannot follow from the causal loop structure shown above?



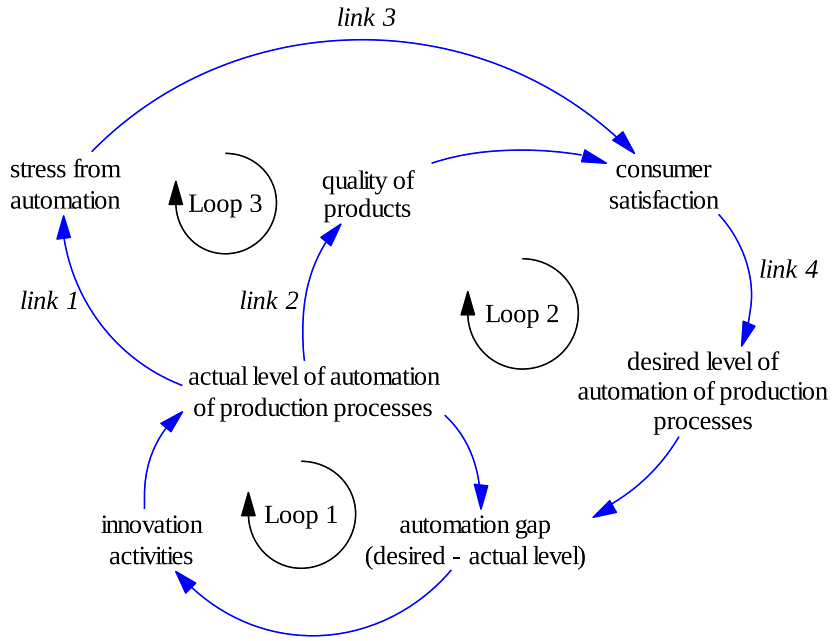
A) Line A
B) Line B
C) Line C
D) Line D

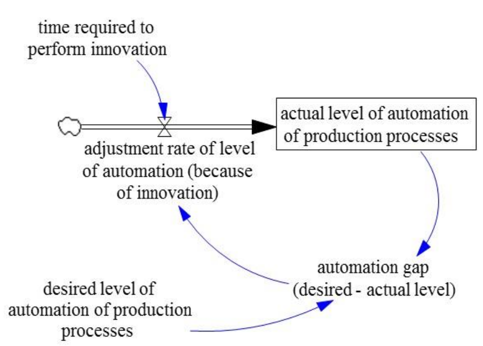
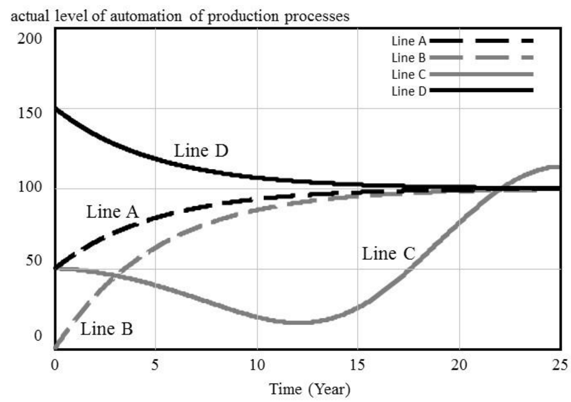
6.2 Consider the following system:

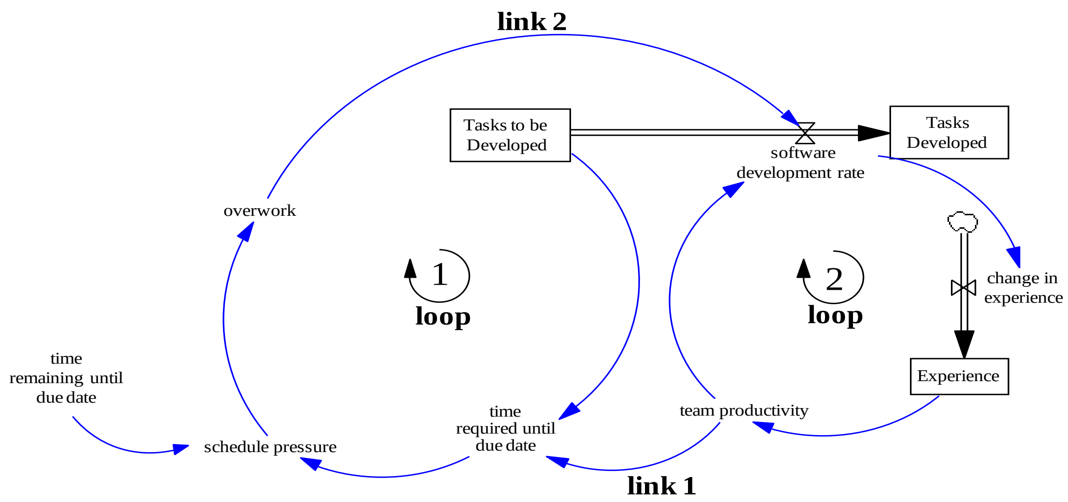


What is the order of this system?

A) First-order
B) Second-order
C) Third-order
D) Fourth-order

6.3a	Companies need to decide to what extent they want to automate production processes or services. When the actual level of automation falls below the desired level, companies execute more innovation activities to increase the level of automation. Using new technologies and machines (i.e., more automation) can improve the quality of products. This increases consumer satisfaction. When consumers are satisfied with the quality, they will demand more automation. However, consumers could also be stressed by new technologies. For example, calling a service line and being greeted by a machine operator instead of being able to talk to a person can be unnerving. Stress has a negative effect on consumer satisfaction. The story described here can be captured by a causal loop diagram that consists of three loops, see below:  What is the polarity of link 3 and 4? A) Link 3 is positive, Link 4 is positive B) Link 3 is positive, Link 4 is negative C) Link 3 is negative, Link 4 is positive D) Link 3 is negative, Link 4 is negative
6.3b	Continue with the causal loop diagram described in the previous question. Remember that automation eventually has both a positive and negative effect on consumer satisfaction. What is the polarity of link 1 and 2? A) Link 1 is positive, Link 2 is positive B) Link 1 is positive, Link 2 is negative C) Link 1 is negative, Link 2 is positive D) Link 1 is negative, Link 2 is negative
6.3c	Continue with the causal loop diagram described in the previous questions. Which of the loops in this diagram are balancing? A) Loop 1 and Loop 2 B) Loop 1 and Loop 3 C) Loop 2 and Loop 3 D) Loop 1, Loop 2 and Loop 3

6.3d	Continue with the causal loop diagram described in the previous questions. A simplified model of this situation is sketched below. You can assume that the "desired level of automation of production processes" is constant at a level of 100 automation units. The initial level of the stock is 50 automation units.   How will this stock behave over time? Which line represents the correct behavior? A) Line A B) Line B C) Line C D) Line D
6.3e	Continue with the model described in the previous questions. How long is the time required to perform innovation? A) 1 years B) 5 years C) 20 years D) 25 years
6.3f	Continue with the model described in the previous questions. What would happen if the time required to perform innovation is doubled? A) The actual level of automation reaches the desired level sooner B) Nothing changes to the actual level of automation C) The actual level of automation reaches the desired level later D) The actual level of automation starts to oscillate around the desired level
6.3g	Continue with the model described in the previous questions. You can check your answers to the previous three questions by making this simplified model, containing only one stock and one flow in Vensim. Run the model for 25 years to check your results.
6.4a	The stocks and flow structure below describes two loops in a typical software development project. Developing software increases the experience level of the project team, which increases the team productivity. Higher team productivity means the team can do more work in the same amount of time. Therefore, higher team productivity reduces the time the team still requires to finish the project. Consequently, it reduces the schedule pressure. Schedule pressure is defined as the ratio of time required until due date and time remaining until due date. The lower the schedule pressure, the lower the amount of overwork. When the team works less over time, they get less work done.



What is the polarity of Link 1 and Link 2?

A) Link 1 is positive, Link 2 is negative
B) Link 1 is positive, Link 2 is positive
C) Link 1 is negative, Link 2 is negative
D) Link 1 is negative, Link 2 is positive

6.4b Continue with the model described in the previous question.
What is the polarity of Loop 1 and Loop 2? (Note that Loop 1 does <u>not</u> include team productivity.)

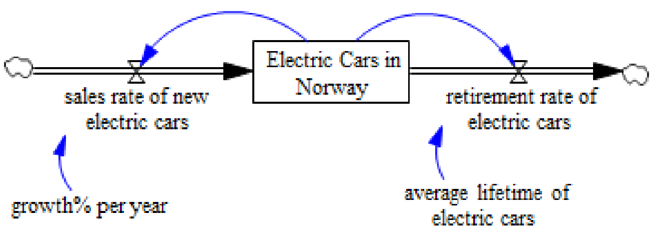
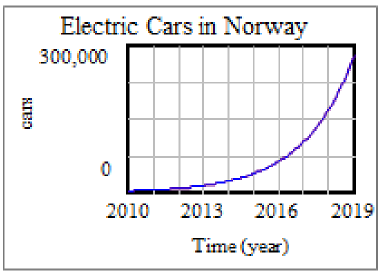
A) Loop 1 is positive, Loop 2 is negative
B) Loop 1 is positive, Loop 2 is positive
C) Loop 1 is negative, Loop 2 is negative
D) Loop 1 is negative, Loop 2 is positive

6.4c Continue with the model described in the previous question.
If the units of "time required until due date" are defined as person*weeks and the units of "time remaining until due date" are defined as person*weeks, than how should you define the units of schedule pressure if you were to model this in Vensim?

A) Person*weeks
B) Dimensionless (no units)
C) Pressure
D) Weeks

6.4d Continue with the model described in the previous question.
If the units of "Tasks to be Developed" are defined as tasks, how should you define the units of "software development rate" if you were to model this in Vensim?

A) Dimensionless (no units)
B) Tasks
C) Tasks/day
D) Tasks/week

6.4e	Continue with the model described in the previous question. When people work overtime for a while, they become tired (“exhaustion”). Exhaustion can have two side-effects. A) Exhaustion leads to mistakes that eventually need to be corrected; B) People that are exhausted are vulnerable to developing an illness, which forces them to stay home for a couple of days. If you would include these two effects (A and B) in the model you used for the previous questions by introducing two extra loops (Loop A and Loop B), what would the polarity of Loop A and Loop B be? A) Loop A is positive, Loop B is positive B) Loop A is positive, Loop B is negative C) Loop A is negative, Loop B is positive D) Loop A is negative, Loop B is negative
6.4f	Suppose you had to make a stocks and flows diagram of the causal loop diagram discussed in the previous question, how would you model “exhaustion”? A) As an exogenous variable (constant) B) As a stock C) As a flow D) As a variable
6.4g	What can you say about the most likely behavior of schedule pressure when you would run the model described in the previous questions, including the two extra loops you developed in the previous question(s)? Assuming schedule pressure starts very high at t = 0, and exhaustion starts low: A) Schedule pressure keeps decreasing B) Schedule pressure keeps increasing C) Schedule pressure first decreases but increases due to the side-effects of exhaustion D) Schedule pressure first increases but then decreases due to the side-effects of exhaustion
6.5a	The number of electric cars in Norway shows clear exponential growth from 2010 to 2019.  Suppose the initial value of Electric Cars in Norway, in 2010, is 3347 cars and the growth% per year is 60%. The following equations are given: sales rate of new electric cars = growth% per year * Electric Cars in Norway retirement rate of electric cars = Electric Cars in Norway / average lifetime of electric cars We know that the stock Electric Cars in Norway shows exponential growth, so what does this mean for the average lifetime of electric cars?

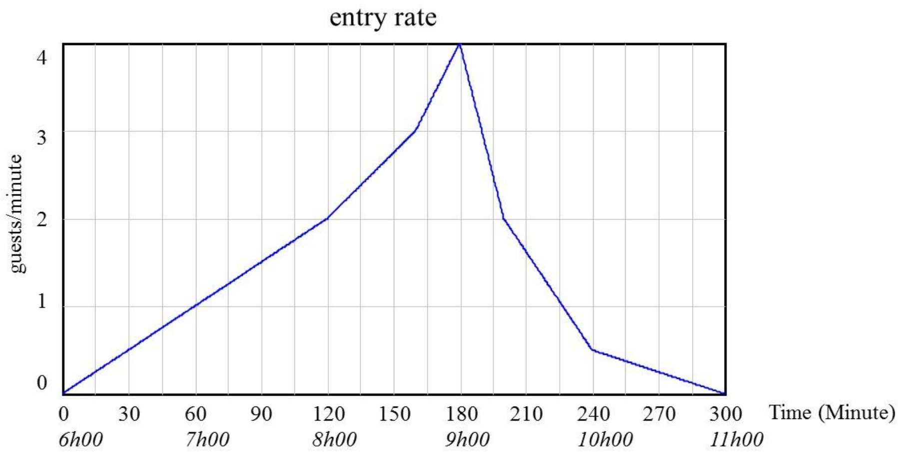
	A) The average lifetime of electric cars is zero years B) The average lifetime of electric cars has to be shorter than 1.67 years (= 1/0.6) C) The average lifetime of electric cars has to be equal to 1.67 years (= 1/0.6) D) The average lifetime of electric cars has to be longer than 1.67 years (= 1/0.6)
6.5b	Continue with the model described in the previous question. The number of electric cars in Norway cannot continue to grow exponentially of course, because there is a limit to the number of electric cars that the Norwegians need. This is also known as the carrying capacity. Which of the following statement(s) is(are) true? (I) Because of the carrying capacity, the number of electric cars in Norway is likely to show S-Shaped growth on the long term (e.g., from 2010-2030). (II) The carrying capacity will have a direct effect on the outflow of the model (retirement rate) depicted in the previous question (carrying capacity influences the outflow; a blue arrow in Vensim). A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is false D) Statement I is false, and Statement II is true
6.5c	Continue with the model described in the previous questions. You can assume that the carrying capacity is an exogenous variable in the model (a constant). Because of the carrying capacity, eventually, the stock of electric cars in Norway will stabilize. When this happens (stabilization), what does it mean for the sales (inflow) and retirement rate (outflow) of electric cars? A) It is impossible to say something about inflow and outflow based on this information B) Sales rate is higher than retirement rate C) Sales rate is equal to retirement rate D) Sales rate is lower than retirement rate
6.5d	Continue with the model described in the previous questions. Thanks to technological developments, it is likely that the average lifetime of electric cars will increase over the years. What will happen to the stock of electric cars in Norway when the average lifetime of electric cars increases with 50% after year 2022? A) Longer lifetime means a higher outflow which reduces the stock B) Longer lifetime means a higher outflow which increases the stock C) Longer lifetime means a lower outflow which reduces the stock D) Longer lifetime means a lower outflow which increases the stock
6.5e	Continue with the model described in the previous questions. You can check your answer to the previous question by building the model in Vensim. (You can ignore the carrying capacity.) Run the model for about 10 years with two different values of the average lifetime of electric cars.

Lecture 7: Repetition and recap of previous lectures

7.1a

A large hotel in Oslo is trying to figure out how many employees should be working at the front desk each morning to deal with guests wanting to check out. Guests can check out between 06h00 and 11h00, but there is always a peak at 09h00. The number of guests at the Front Desk can be modeled as a stock. The entry rate and check-out rate are the flows, as depicted below:

On a normal day, the entry rate (number of guests entering the front desk per minute) has the following behavior over time:



Suppose that all employees are asleep until 8h00 (this means that the check-out rate is 0 until 8h00). How many guests will be at the front desk at 7h00 (after 60 minutes)?

A) 1 guest
B) 15 guests
C) 30 guests
D) 60 guests

7.1b

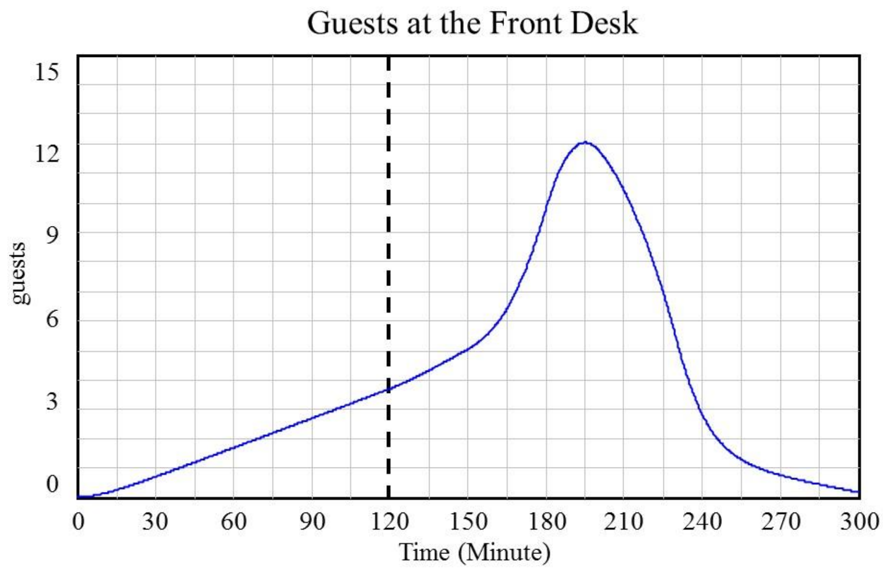
Continue with the model described in the previous questions.
What is the order of this model and why?

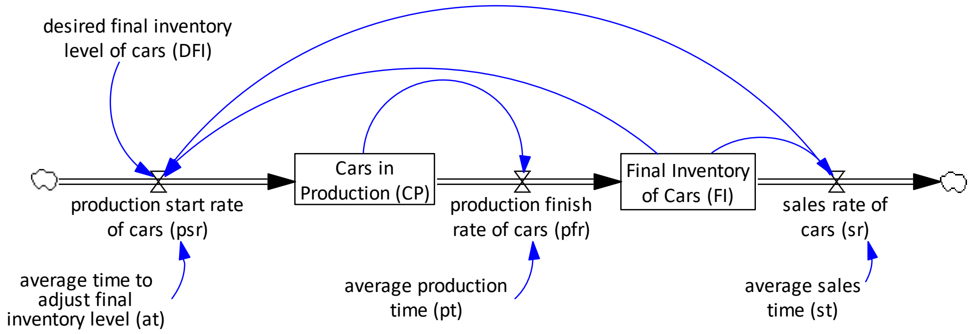
A) First order, because there is one inflow
B) First order, because there is one stock
C) Second order, because there is one inflow and one outflow (two flows)
D) Third order, because there are two flows and one stock

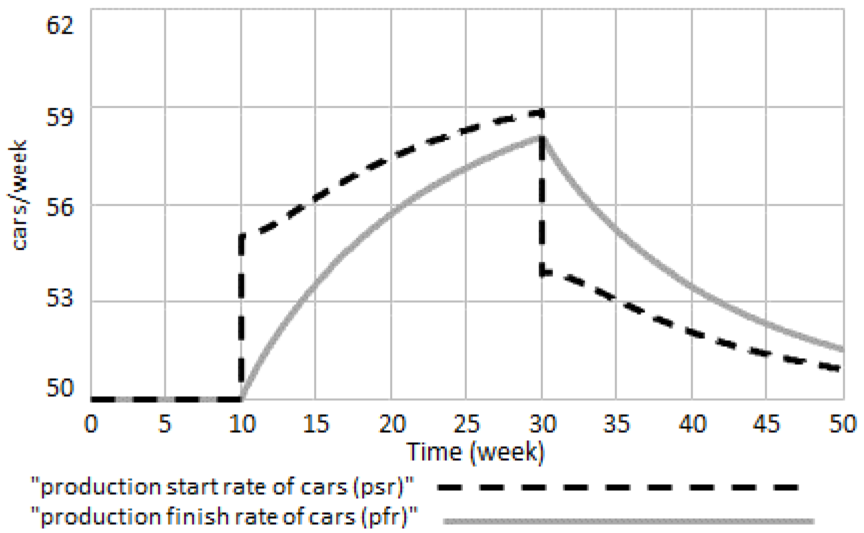
7.1c

Continue with the model described in the previous questions.

If you want to know the total number of guests that have checked out on a particular morning (“total check-outs”) from minute 0 to minute 300, how would you calculate this? In other words: what would you add/change to the existing model (consisting of one stock and two flows, depicted previously)?

	A) “Total check-outs” would become a new stock in the model, and the “check-out rate” would become its inflow. B) “Total check-outs” would become a new outflow from the existing stock Guests at the Front Desk. C) There is no need to introduce a new variable, you can simply find the value of the “check-out rate” at time = 300 with the existing model. D) “Total check-outs” would become a new variable in the model that is equal to the entry rate.
7.1d	Continue with the model described in the previous questions. Suppose that on a relatively quiet morning the stock of “Guests at the Front Desk” displays the following behavior (note that the entry rate on a quiet morning is lower than displayed in a graph in one of the previous questions):  What is the netflow at time = 120 minutes (depicted by the dashed line)? A) The netflow is about 18 guests/minute B) The netflow is about 9.5 guests/minute C) The netflow is about 3.5 guests/minute D) The netflow is about 0.035 guests/minute
7.1e	Continue with the graph of “Guests at the Front Desk” described in the previous question. Which of the following statement(s) is(are) true? (I) The netflow is never equal to 0 (II) After minute 195 the netflow is decreasing, but still positive (i.e., larger than 0) A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false

7.2a	The following model describes the production process and inventory of a car manufacturer.  Although the loops are not explicitly depicted in this stocks & flows diagram, how many causal loops in this diagram contain the variable “Final Inventory of Cars (FI)”? A) Zero loops B) One loop C) Two loops D) Three loops
7.2b	Continue with the car model described in the previous question. The units for Cars in Production (CP) are cars. The units for desired final inventory level of cars (DFI) are also cars. Average sales time (st) is expressed in weeks. What are the units for production finish rate (pfr) of cars? A) Cars B) Weeks C) Cars/week D) It is impossible to answer this question based on the information provided above
7.2c	Continue with the car model described in the previous questions. You can assume that the system is in equilibrium again (so DFI = FI). Which of the following equations using final inventory (FI) is wrong? A) FI = FI(0) + INTEGRAL (pfr – sr) B) FI = FI(0) + INTEGRAL (-sr + pfr) C) dFI/dt = pfr – sr + FI(0) D) dFI/dt = pfr – sr
7.2d	Continue with the car model described in the previous questions. Consider the following behavior of the production start rate (psr) and production finish rate (pfr) of cars (see the graph below).

<table>
<tr><td></td><td>


Which statement(s) about the Cars in Production (CP) is(are) true?
(I) CP will increase from week 10 to week 30
(II) CP increases faster (higher slope) in week 25 than in week 15

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is true
D) Statement I is false, and Statement II is false
</td></tr>
<tr><td>7.2e</td><td>Continue with the car model described in the previous questions and with the graph of psr and pfr described in the previous question.

Which statement(s) is(are) true about the netflow?
(I) The netflow in week 40 is positive.
(II) The netflow in week 5 is 0.

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is true
D) Statement I is false, and Statement II is false
</td></tr>
<tr><td></td><td></td></tr>
<tr><td>7.3a</td><td>Virtual stores are getting more and more popular. Consumers buying in a virtual store (ordering products on the internet) need to log in to that store. To prevent the risk of identity theft, many virtual stores recommend consumers to make difficult passwords, consisting of letters, numbers, and symbols. These difficult passwords reduce the probability that someone else can “hack” these passwords. However, there is a side-effect. When passwords are getting more complex, consumers have more difficulty remembering them, and as a result, they write down these passwords or use the same password for all stores they order from. This makes it easier for hackers to figure out what the password is.

The story described here can be visualized by the following causal loop diagram.
</td></tr>
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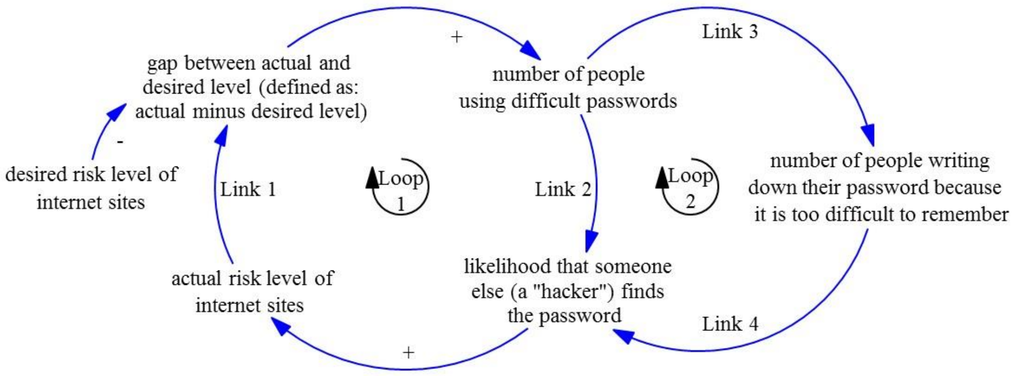
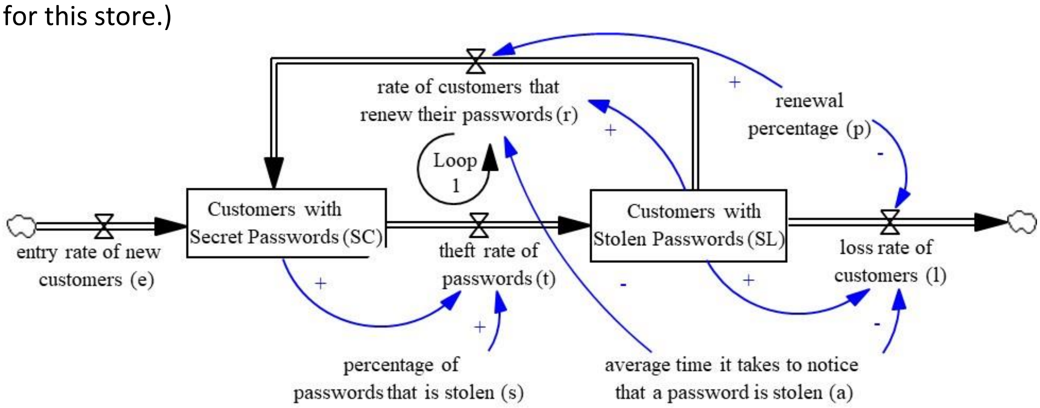
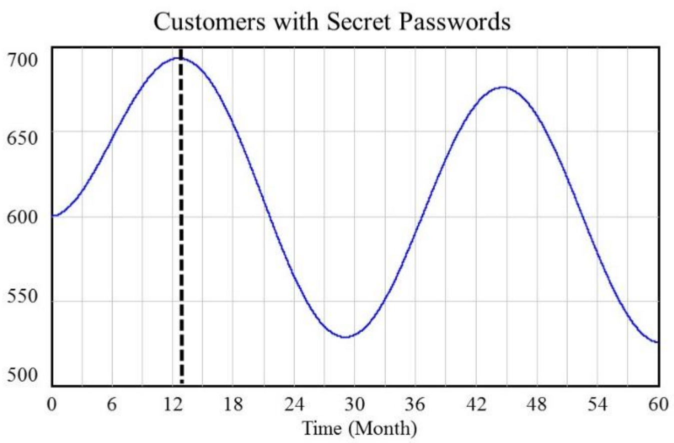
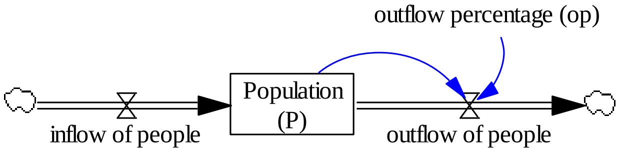
	 What is the polarity of link 1 and link 2? A) Link 1 is positive, Link 2 is positive B) Link 1 is positive, Link 2 is negative C) Link 1 is negative, Link 2 is positive D) Link 1 is negative, Link 2 is negative
7.3b	Continue with the causal loop diagram described in the previous question. What is the polarity of link 3 and link 4? A) Link 3 is positive, Link 4 is positive B) Link 3 is positive, Link 4 is negative C) Link 3 is negative, Link 4 is positive D) Link 3 is negative, Link 4 is negative
7.3c	Continue with the causal loop diagram described in the previous questions. What is the polarity of loop 1 and loop 2? A) Loop 1 is positive, Loop 2 is positive B) Loop 1 is positive, Loop 2 is negative C) Loop 1 is negative, Loop 2 is positive D) Loop 1 is negative, Loop 2 is negative
7.3d	Continue with the causal loop diagram described in the previous questions. Regardless of the complexity of passwords, accounts get hacked anyway. When customers find out that their password has been stolen, they can react in two ways: either they never buy anything from that store again, or they change their password and start ordering products from the same store again. This behavior (for just one virtual store) is depicted by the stocks & flows diagram below. (Note that one customer only needs one password for this store.) 

	The stock “Customers with Secret Passwords” is part of two loops. The first one (loop 1) goes from “Customers with Secret Passwords” to “theft rate of passwords” to “Customers with Stolen Passwords” to “rate of customers that renew their passwords” back to “Customers with Secret Passwords”. The other loop (loop 2) is one that you need to figure out yourself. Which of the following statements is true? (I) Loop 1 described above is positive (II) Loop 2 is positive A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
7.3e	Continue with the model described in the previous question. The inflow “entry rate of new customers” has the value of 72 customers per month. What are the units for “theft rate of passwords”? A) Passwords per week B) Passwords per month C) Customers per week D) Customers per month
7.3f	Continue with the model described in the previous questions. Suppose now that the “entry rate of new customers” is no longer a constant but it is oscillating. As a result, the behavior over time of the “Customers with Secret Passwords” now looks like this (see graph):  What can you say about the netflow in month 13 (indicated with the dotted line)? A) The netflow is 0 B) The netflow is increasing C) The netflow is decreasing D) It is not possible to say something about the netflow because this stock has two inflows and one outflow
7.3g	Continue with the model described in the previous questions. How would you define the stock “Customers with Stolen Passwords” (SL)?

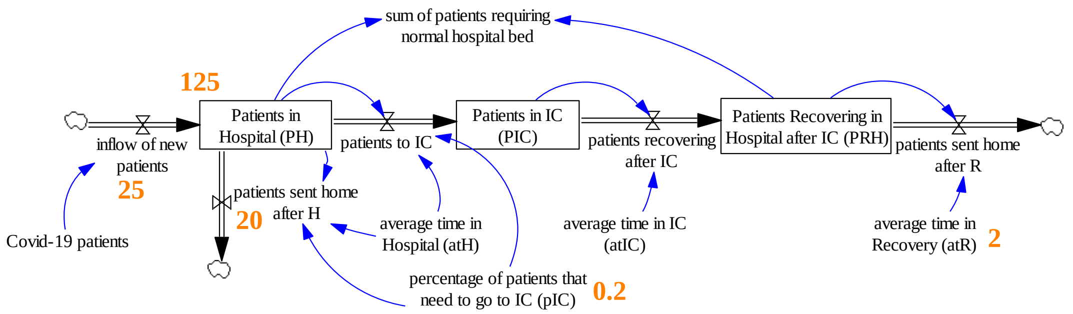
	A) SL = INTEGRAL (t – l) + SL(0) B) SL = INTEGRAL (t – l + r) + SL(0) C) SL = INTEGRAL (t – l – r) + SL(0) D) SL = INTEGRAL (-t + l + r) + SL(0)
7.3h	Continue with the model described in the previous questions. Suppose the "entry rate of new customers" is oscillating. What would happen to the behavior of "Customers with Stolen Passwords" when it takes customers 3 months to notice that their password is stolen instead of 1 month (a = 3 months, instead of 1 month)? A) Nothing will happen to "Customers with Stolen Passwords" B) "Customers with Stolen Passwords" will be lower when a = 3 compared to the scenario in which a = 1 C) "Customers with Stolen Passwords" will be higher when a = 3 compared to the scenario in which a = 1 D) "Customers with Stolen Passwords" will sometimes be lower and sometimes higher when a = 3 compared to the scenario in which a = 1
7.3i	Continue with the model described in the previous questions. Suppose the system is in equilibrium. The "entry rate of new customers" is 72 customers per month (so it is not oscillating as in the previous questions), the "Customers with Stolen Passwords" is 180 customers, and the "average time it takes to notice that a password is stolen" is 1 month. Furthermore, you can assume that the loss rate of customers = (1-p) * SL / a; and the rate of customers that renew their passwords = p * SL / a What is the "renewal percentage" (p)? A) It is impossible to calculate (p) based on the information given B) p = 0.6 C) p = 0.4 D) p = 0.25
7.3j	You can answer the previous question about the renewal percentage without building the model in Vensim. But you can also check your answer by building the system described in the previous questions yourself and check your selected renewal percentage (p). Values for constants and initial levels of stocks are given in previous questions or you need to calculate them by using the fact that the system is in equilibrium. Assume that the entry rate is constant (thus not oscillating).

Lecture 8: Delays	
8.1	Which of the following examples of delays is NOT an "Information Delay": A) Perception delay B) Measurement delay C) Production delay D) Reporting delay
8.2	Which of the following statement(s) is(are) true? (I) In a first-order material delay, items flow out of the stock in the same order and after exactly the same time as they entered the stock (II) Stocks in a system give the system delay (also known as inertia) A) Statement 1 is true, and Statement II is true B) Statement 1 is true, and Statement II is false C) Statement 1 is false, and Statement II is true D) Statement 1 is false, and Statement II is false
8.3	A company has 25000 unprocessed orders (= stock) and receives new orders with an average of 5000 per month (= inflow), the delivery rate to customers is the outflow. Assuming this system is in equilibrium, and the delay is modeled as a first-order material delay, how long is the average time a customer has to wait for the delivery of an order? A) 1 month B) 2 months C) 5 months D) 10 months
8.4	Which of the following statement(s) is(are) true? (I) Oscillations can arise if there are material delays in the negative loop (II) Oscillations can arise if there are information delays in the negative loop A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
8.5a	Consider the following first-order system in which:  Population P(0) = 100 [people] Inflow of people = 20 [people/year] Outflow of people= op * P [people/year] op = 0.05 [percent/year]

<table>
<tr><td></td><td>How long will people on average stay in this Population before they flow out of the system?
A) 40 years
B) 20 years
C) 5 years
D) 2 years</td></tr>
<tr><td>8.5b</td><td>Continue with the model described in the previous question.
Which of the following statement(s) is(are) true?

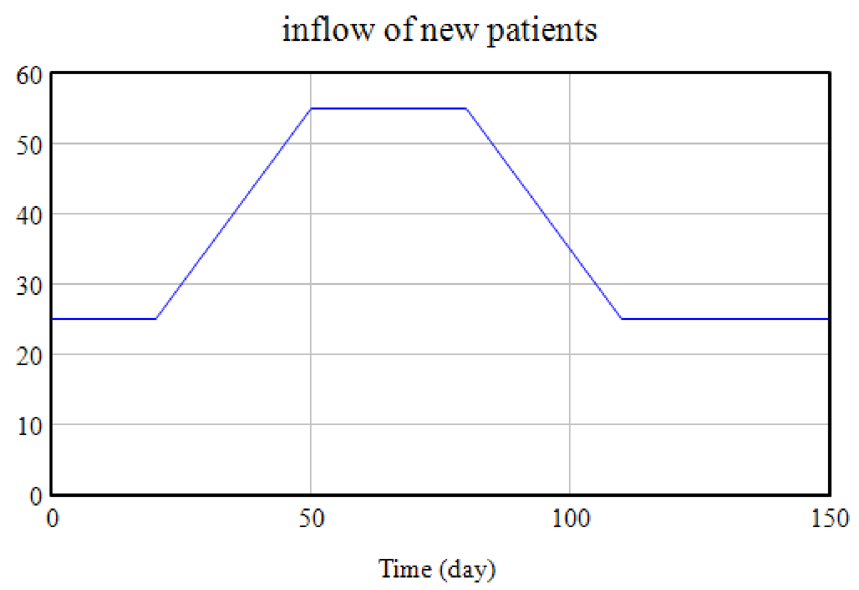
A) The population will eventually decrease to 0 (and then stay 0)
B) The population will remain 100
C) The population will oscillate around 100
D) The population will increase and eventually will reach an equilibrium (= a value that stays constant/stable over time)</td></tr>
<tr><td>8.5c</td><td>Continue with the model described in the previous questions.
How large is dP/dt(0)?
In other words what is the slope or the change of P around t = 0? Please choose the answer that comes closest to your estimate.

A) -30
B) -15
C) 15
D) 30</td></tr>
<tr><td></td><td></td></tr>
<tr><td>8.6a</td><td>The Stocks & flows diagram below describes patients in a hospital. New patients arrive in a hospital, where they remain for an average time (atH). After this time, a percentage of these patients will need to go to the Intensive Care (IC), the rest is sent home. After an average time in the IC, all IC patients will need to recover in a “normal” hospital bed (not in the IC) for a few days before they are sent home. We assume that no patients will die. (The orange numbers in the model will be explained in one of the next questions.)



How many loops does this model have?
A) Zero loops
B) Two loops
C) Four loops
D) Six loops</td></tr>
</table>

8.6b	Continue with the model described in the previous question. You can assume that the system is in equilibrium and all outflows from all stocks are modeled as first-order material delays. What is the order of the entire system? A) First-order system B) Second-order system C) Third-order system D) Fourth-order system
8.6c	Continue with the model described in the previous questions (with the same assumptions). What is the correct equation for the flow “patients to IC”? A) Patients to IC = (pIC * PH) / atH B) Patients to IC = (1-pIC) * PH / atH C) Patients to IC = pIC + (PH / atH) D) Patients to IC = inflow of new patients – patients sent home after H
8.6d	Continue with the model described in the previous questions. You can assume that the system is in equilibrium and all outflows from all stocks are modeled as first-order material delays. What is the correct equation for the stock “Patients in IC (PIC)”? A) PIC = INTEGRAL(patients recovering after IC – patients to IC) + PIC(0) B) PIC = INTEGRAL(patients to IC – patients recovering after IC) + PIC(0) C) PIC = patients recovering after IC – patients to IC D) PIC = patients to IC – patients recovering after IC
8.6e	Continue with the model described in the previous questions (with the same assumptions). The time units for this system are *days*. The time step is 0.25 days (= 6 hours). The units for the stock Patients in Hospital (PH) are *patients.* What are the units for “patients sent home after R”? A) Patients/6 hours B) Patients C) Patients/day D) Patients/hour
8.6f	Continue with the model described in the previous questions (with the same assumptions). Suppose the inflow of new patients is 25. There are 125 patients in hospital (i.e., in the first stock: PH). The percentage of patients that needs to go to IC (pIC) is 0.2 (20%). The outflow “patients sent home after H” is 20. The average time in recovery is 2 days. These values are shown in orange numbers (see one of the previous questions). What is the average time in Hospital (atH)? A) 2 days B) 5 days C) 6.25 days D) 25 days

8.6g	Continue with the model described in the previous questions (with the same assumptions and values of the variables). How many patients are recovering in the hospital after having spent some time on the IC (what is the value of the stock: PRH)? A) PRH = 10 B) PRH = 12.5 C) PRH = 25 D) PRH = 62.5
8.6h	Continue with the model described in the previous questions (including the values of the variables). The outflows from all stocks are still modeled as first-order material delays. But we will change the inflow of new patients. We will model an extra inflow over a period of time due to the outbreak of Covid-19. More specifically, the new inflow is depicted in the graph below:  As the graph shows, the inflow is 25 until day 20. From this day it increases linearly to 55 on day 50. It stays at the level of 55 until day 80 after which it decreases linearly to 25 again. From day 110 to day 150 it remains 25. Which of the following statement(s) about the last outflow (patients sent home after R) is(are) true? (I) The graph of the outflow shows roughly the following behavior: first horizontal, then increasing, then stabilizing, then decreasing and finally horizontal again (II) The increase of the outflow will also start at day 20 (similar to the inflow of new patients) A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is false D) Statement I is false, and Statement II is true

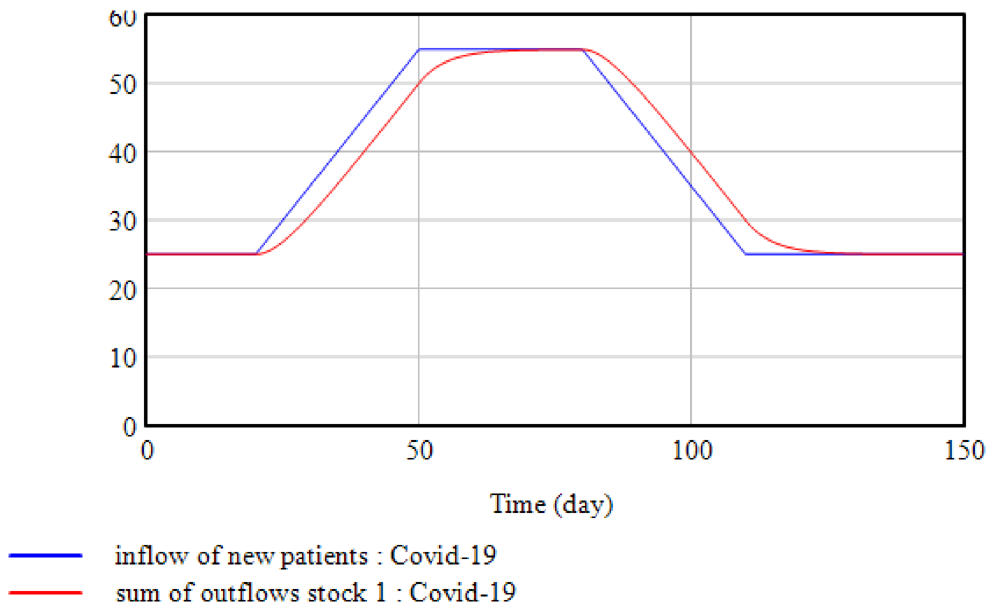
<table>
<tr><td>8.6i</td><td>Continue with the model described in the previous questions (including the values of the variables and the new inflow with Covid-19 patients). The outflows from all stocks are still modeled as first-order material delays.

Suppose that the number of beds on the Intensive Care (IC) is limited. Therefore, the hospital tries to find ways to reduce the Patients in IC (PIC).

Which of the following statement(s) is(are) true?
(I) PIC is reduced when the average time in Recovery (atR) is reduced
(II) PIC is reduced when the average time in IC (atIC) is reduced

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is false
D) Statement I is false, and Statement II is true</td></tr>
<tr><td>8.6j</td><td>Continue with the model described in the previous questions (including the values of the variables and the new inflow with Covid-19 patients). The outflows from all stocks are still modeled as first-order material delays.

The graph below shows the inflow of new patients and the sum of the two outflows from the first stock (patients to IC + patients sent home after H):



Which of the following statement(s) about Patients in Hospital (PH) is(are) true?
(I) On day 75, the number of Patients in Hospital is not changing (it is stable)
(II) On day 150, the number of patients in Hospital is decreasing

A) Statement I is true, and Statement II is true
B) Statement I is true, and Statement II is false
C) Statement I is false, and Statement II is false
D) Statement I is false, and Statement II is true</td></tr>
<tr><td></td><td></td></tr>
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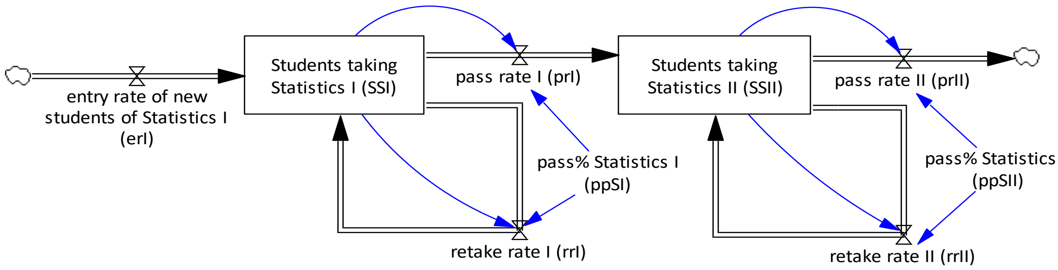
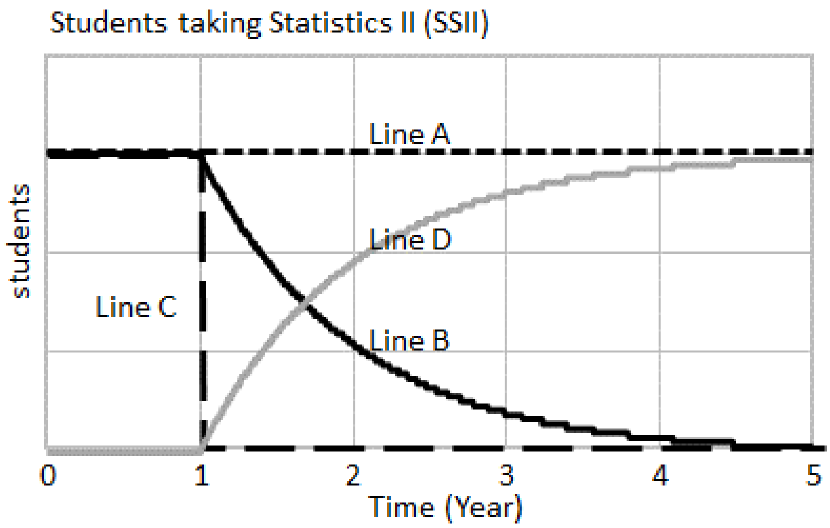
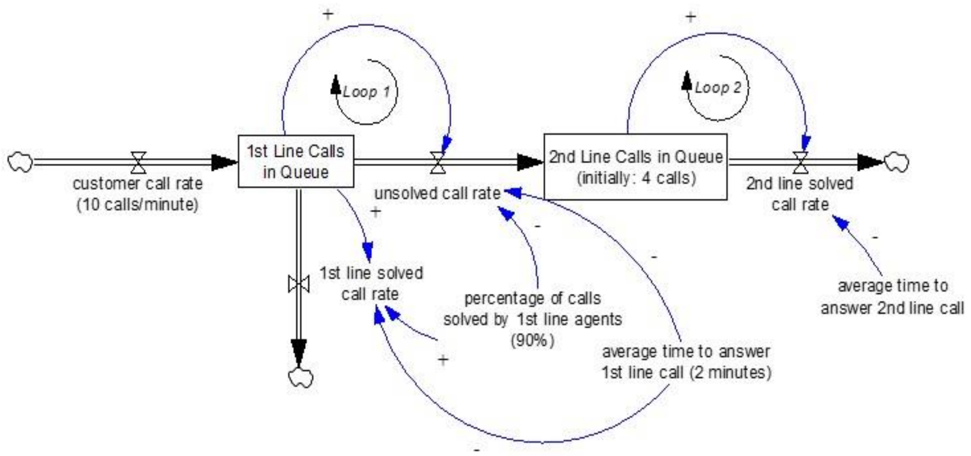
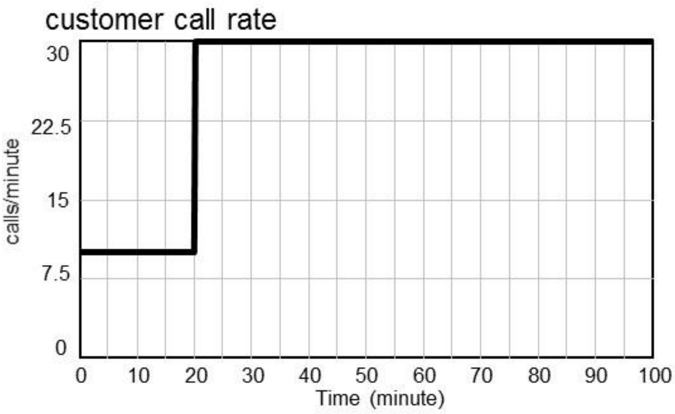
8.7a	The model shown below simulates students taking the course Statistics I. If they pass the exam, they are allowed to take the course Statistics II. If they fail, they must do the course over again. After passing the course Statistics II the students leave the system. When they fail Statistics II, they have to do this course over again. You can assume that the system is in equilibrium. Each year 90 new students enter the system (erl = 90 students/year). The initial value of Students taking Statistics I (SSI) is 100 students.  What is the percentage of students that pass the Statistics I exam (ppSI)? A) 0% B) 50% C) 90% D) 100%
8.7b	Continue with the model described in the previous question. The percentage of students that pass Statistics II (ppSII) is 0.75 (or 75%). What is the initial value of Students taking Statistics II (SSII)? (Note, assume that the system is in equilibrium). A) 90 students B) 100 students C) 120 students D) 190 students
8.7c	Continue with the model described in the previous questions. Instead of using the percentage of students that pass Statistics II (ppSII), which is 0.75 (or 75%) per year, we can also use the average time students need to pass Statistics II. What is this average time? (Note: the model is still in equilibrium.) A) 0.75 year B) 1 year C) 1.33 year D) 1.75 year
8.7d	Continue with the model described in the previous questions. Suppose that as of year 1 (the model starts at year 0) the pass percentage of Statistics II (ppSII) is set to 1 (or 100%). In other words: no student fails this course as of year 1. Which of the lines below represent the behavior of the stock of students taking Statistics II (SSII)? (There are no numbers on the vertical axis, so you only have to evaluate the behavior over time, not the actual number of students.)

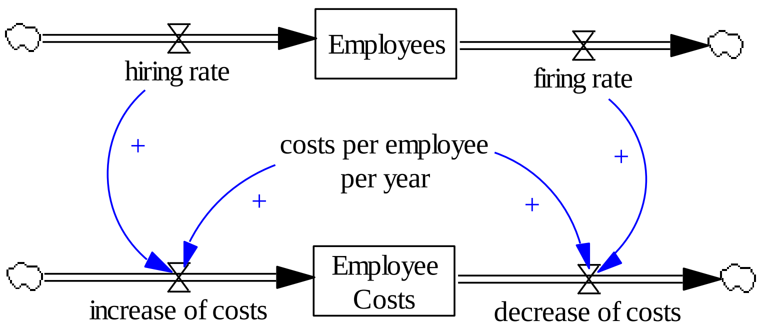
	 A) Line A B) Line B C) Line C D) Line D
8.7e	Continue with the model described in the previous questions, including the 100% pass percentage (ppSII) of Statistics II as of year 1. Which of the following statement(s) is(are) true? Because of the increase of ppSII to 100% ... (I) The stock of students taking Statistics I (SSI) will not be influenced (II) We now need a MIN function in the equation of prII to prevent the stock SSII from going negative A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
8.7f	Continue with the model described in previous questions. You would like to calculate the total number of students that have taken the Statistics I course over a period of 5 years (including the students that have taken the course more than once). Let's call this TSSI. What is the correct equation of TSSI that will give you this number? A) TSSI = INTEGRAL(erI+rrI)+TSSI(0) B) TSSI = INTEGRAL(erI-rrI)+TSSI(0) C) TSSI = INTEGRAL(SSI) D) TSSI = INTEGRAL(erI-prI)+TSSI(0)

8.8a	The call center of IKEA (a company that sells furniture) deals with customer problems. Customers who call usually have to wait, so these calls are placed in a queue. As soon as an agent is free, s/he tries to solve the problem raised by the customer. When the agent can't fix the problem, the call is transferred to a 2nd line. Sometimes there is also a waiting queue in this 2nd line. A more experienced agent will deal with these 2nd line calls. This situation can be modeled using the following stocks, flows and variables:  Which statement about this model is true? A) This is a first-order model because there is only one inflow B) This is a second-order model because there are two outflows C) This is a second-order model because there are two stocks D) This is a second-order model because there are two loops
8.8b	Continue with the call center model described in the previous question. The values of most of the exogenous variables are given between brackets in the stocks & flows diagram. You can assume the model is in equilibrium right from the start and all flows (except the customer call rate) are modeled as a first-order material delay. What is the initial value of the 1st Line Calls in Queue (how many calls are waiting at the start of the simulation, at minute 0)? A) 0 calls B) 2 calls C) 20 calls D) 200 calls
8.8c	Continue with the call center model described in the previous questions and all assumptions described earlier. What is the average time to answer the 2nd line call? A) 2 minutes B) 4 minutes C) 20 minutes D) 40 minutes

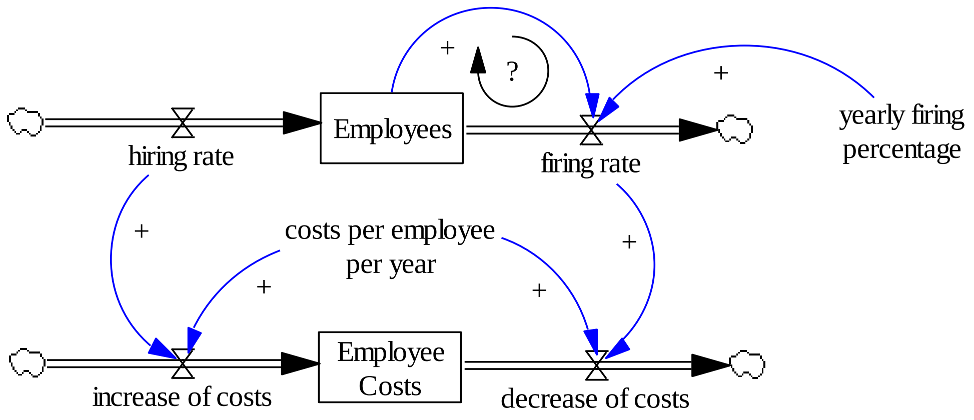
<table>
<tr><td>8.8d</td><td>Continue with the call center model described in the previous questions and all assumptions described earlier. At time 20 IKEA’s website is down. As a result, suddenly the number of incoming calls increases to 30 calls/minute. The graph below shows this behavior.


What can you say about the behavior of the stock of the 1st Line Calls in Queue?

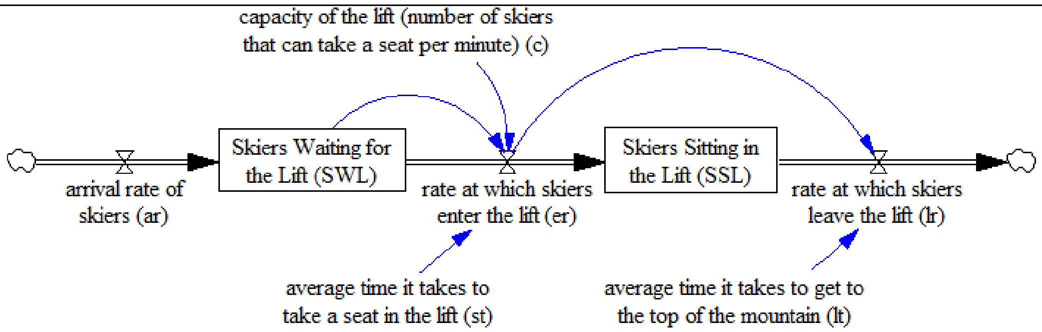
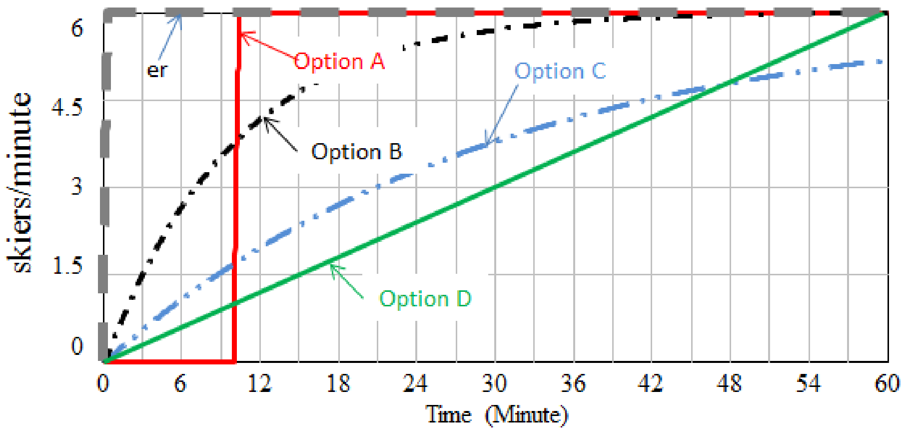
A) The stock stays in equilibrium (it has the same value as I answered in one of the previous questions)
B) The stock first increases and then decreases again
C) The stock keeps on increasing
D) The stock increases until it reaches a new equilibrium that is higher than the equilibrium calculated in one of the previous questions</td></tr>
<tr><td>8.8e</td><td>Continue with the call center model described in the previous questions and all assumptions described earlier. This model is not realistic, because we need to include the productivity of the agents answering the calls. If you add “productivity of 2nd line agents” to the model, which of the existing variable(s) will be influenced by this new variable? (Productivity is expressed in number of calls per minute.)

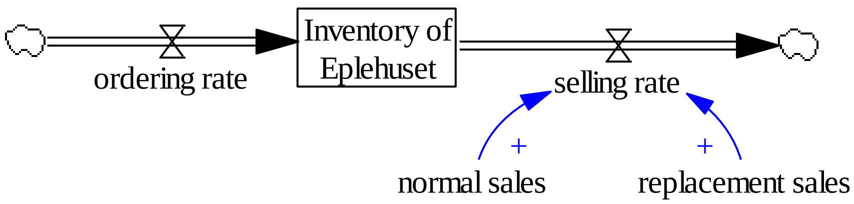
A) Unsolved call rate
B) 2nd line calls in queue
C) 2nd line solved call rate
D) Average time to answer 2nd line call</td></tr>
<tr><td></td><td></td></tr>
<tr><td>8.9a</td><td>Have a look at the model below:

</td></tr>
</table>

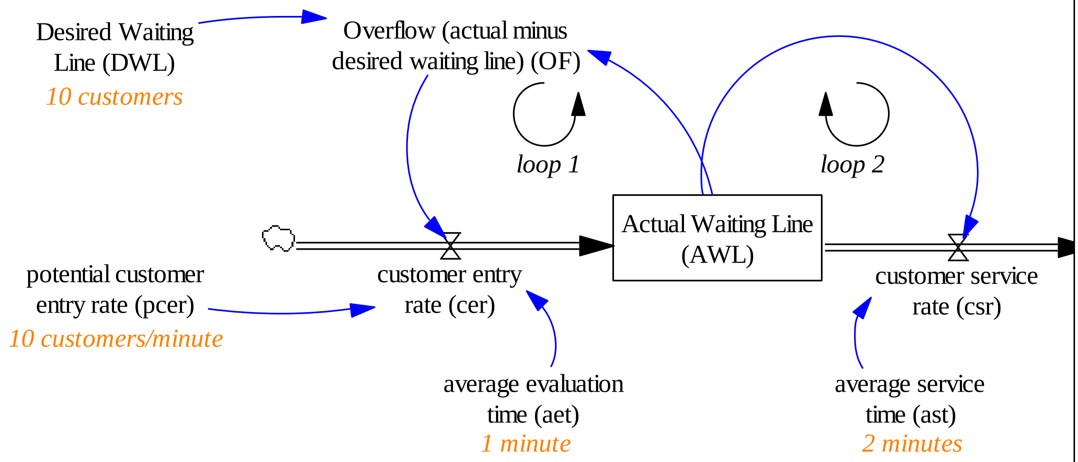
	"Employee Costs" and its in- and outflow is modeled as a ... with respect to "Employees" and the in- and outflow of "Employees" (fill in the correct term for "..."): A) Netflow B) Oscillation C) Co-flow D) Goal-seeking behavior
8.9b	Continue with the model described in the previous question. The units for "hiring rate" are [employees/year], the units for "Employee Costs" are [NOK]. What are the units for the "increase of costs"? A) NOK B) NOK/year C) NOK/employee/year D) Costs/year
8.9c	Continue with the model described in the previous questions. Suppose that from the start (year 0) until year 5 the "hiring rate" has been higher than the "firing rate". The "costs per employee per year" are constant. Which of the following statement(s) is(are) true? (I) The number of "Employees" has been increasing from year 0 until year 5 (II) The "Employee Costs" have been increasing from year 0 until year 5 A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
8.9d	Continue with the model described in the previous questions. Suppose that from year 6 until year 10 the "hiring rate" is equal to the "firing rate". Which of the following statement(s) is(are) true? (I) The number of "Employees" will not change from year 6 until year 10 (II) The "Employee Costs" will continue to increase from year 6 until year 7 because of a delay, then they stabilize (after year 7) A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false

8.9e	The previous call center model has been updated. The “firing rate” is no longer a constant, but now it is modeled as a fractional decrease rate (firing rate = Employees * yearly firing percentage):  The “yearly firing percentage” is 0.05 per year. What can you say about the polarity of the loop that is shown in the model? A) It is not possible to determine the polarity because it is not a loop B) It is a reinforcing loop because there is a positive link between “Employees” and “firing rate” and a positive link between “yearly firing percentage” and “firing rate” C) It has to be a positive loop because the model only has positive links D) It is a negative loop because there is a positive link between “Employees” and “firing rate” and a negative link between “firing rate” and “Employees”, although this link is not shown in the picture
8.9f	Continue with the model described in the previous question. Remember that from year 6 until year 10 the “hiring rate” is equal to the “firing rate”. The “yearly firing percentage” is 0.05 per year. In year 7, there are 40 employees (in stock). What is the “hiring rate” in year 7? A) 0 employees/year B) 0.05 employees/year C) 2 employees/year D) 20 employees/year
8.9g	Continue with the model described in the previous questions. Remember that from year 6 until year 10 the “hiring rate” is equal to the “firing rate”. In year 7, there are 40 employees (in stock). How long do employees work for this company on average? A) 0 year B) 0.05 year C) 2 year D) 20 year

8.9h	Continue with the model described in the previous questions. Suppose that in year 11, the hiring and firing rate are still equal and there are 40 employees in stock. The “hiring rate” is 3 employees per year. The “costs per employee per year” are 500 000 NOK. Which of the following statement(s) is(are) true? (I) The “firing rate” is -3 [employees per year] (II) The “Employee Costs” are 500 000*40 = 20 000 000 [NOK] A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is true D) Statement I is false, and Statement II is false
8.9i	Continue with the model described in the previous questions. What is the equation of “Employees”? (Note that Employees(0) is the number of employees at the beginning of the simulation, at time 0) A) Employees = INTEGRAL(hiring rate – firing rate) B) Employees = INTEGRAL(hiring rate – firing rate) + Employees(0) C) Employees = INTEGRAL(firing rate – hiring rate) + Employees(0) D) Employees = hiring rate – firing rate + Employees(0)
8.9j	Continue with the model described in the previous questions. You can assume that the “hiring rate” is 3 employees/year, and initially you have 40 employees (Employees(0) = 40). First, this model was developed with “years” as the unit for time. Suppose that you want to change the time unit into “months”. What will be the new “hiring rate” and the new initial number of employees, after you changed the units of time into months instead of years? A) Hiring rate = 3 employees/month, Employees(0)= 40 employees B) Hiring rate = 36 employees/month, Employees(0)= 40 employees C) Hiring rate = 0.25 employees/month, Employees(0)= 3.33 employees D) Hiring rate = 0.25 employees/month, Employees(0)= 40 employees
8.10a	The Stocks & flows model below describes a small ski resort in Norway. On a normal day 10 (downhill) skiers arrive at a chair lift per minute (arrival rate of skiers), then they wait for an empty seat in this lift, after which they enter the lift. The chair lift takes these skiers to the top of the mountain in 10 minutes. (Skiers can’t change their seats when they are in the lift.)

	 What type of delay describes the rate at which skiers leave the lift? A) First-order material delay B) Second-order material delay C) First-order information delay D) Pipeline delay
8.10b	Continue with the model described in the previous question. The behavior over time of the rate at which skiers enter the lift (er) is depicted in the graph below (dashed gray line): as soon as the lift opens (at t = 0) 6 skiers enter the lift per minute. Which of the four options show the correct behavior over time of the rate at which skiers leave the lift (lr)?  A) Option A B) Option B C) Option C D) Option D
8.10c	Continue with the model described in the previous questions. How would you define the Skiers Sitting in the Lift (SSL)? A) SSL = INTEGRAL(er - lr) + SSL(0) B) SSL = er – lr + SSL(0) C) SSL = er / lt D) SSL = lr * lt

Lecture 9: Modeling decision-making	
9.1	Eplehuset is a company that sells iPhones in Oslo. Sales come from new customer that buy their first iPhone (normal sales), and customers that want to replace an old, broken or stolen iPhone (replacement sales). When the selling rate is higher than the ordering rate, Eplehuset risks running out of inventory. Running out of inventory means that the level of inventory will become 0 (and not negative). You can assume that the initial inventory of Eplehuset in the beginning of the simulation is 100 iPhones.  To prevent the stock in the model from becoming negative, what kind of equation would you use (note that this equation may involve new links or variables)? A) Inventory of Eplehuset = MAX(0, INTEGRAL(ordering rate – selling rate) + 100) B) Inventory of Eplehuset = MIN(ordering rate, selling rate) C) Selling rate = MIN(ordering rate, normal sales + replacement sales) D) Selling rate = MIN(Inventory of Eplehuset/selling time, normal sales + replacement sales)
9.2a	The model below describes a coffee shop at BI. Customers enter the waiting line and leave again after being served. During breaks between lectures, many customers would like to buy coffee, but not every customer is patient enough. Some customers just look at the shop and when they see lots of customers in the waiting line, they leave the shop immediately. This behavior is modeled like goal-seeking behavior. When the "overflow" (actual minus desired waiting line) is larger than zero, customers will not enter the waiting line and leave. When the overflow is negative, customers will enter the waiting line. This customer entry rate can however never be larger than a so-called potential customer entry rate. The potential customer entry rate is 10 customers/minute during the 15-minute break. The desired waiting line is 10 customers. It takes on average 1 minute to evaluate whether to get into the waiting line. It takes on average 2 minutes to order, receive and pay for a cup of coffee. The system starts with 0 customers in the stock, and the simulation runs for 15 minutes.

	 What is the polarity of loop 1 and loop 2? A) Loop 1 is positive, loop 2 is positive B) Loop 1 is positive, loop 2 is negative C) Loop 1 is negative, loop 2 is negative D) Loop 1 is negative, loop 2 is positive
9.2b	Continue with the model described in the previous question. When using the “overflow” as a decision rule to determine whether to enter the waiting line (as described earlier), will the actual waiting line (stock) ever reach 10 customers? A) No, never B) Yes, but it will oscillate around 10 for a while (sometimes higher, sometimes lower) C) Yes, within 5 minutes there will be 10 customers in the waiting line D) Yes, but it will take longer than 5 minutes before there are 10 customers in the waiting line
9.2c	Continue with the model described in the previous questions. What is the correct equation for the customer entry rate (cer)? A) MIN (pcer, MAX (0, -OF)) / aet B) pcer + MIN (0, OF)) / aet C) pcer * MAX (0, -OF) / eat D) MAX (pcer, MIN (0, -OF)) / eat
9.2d	Continue with the model described in the previous questions. Suppose the coffeeshop manages to reduce the average service time by 50% during the break time (average service time is reduced from 2 to 1 minute). Which of the following statement(s) is(are) true in this situation? (I) The customer service rate will become twice as high eventually (II) The customer entry rate will become twice as high eventually A) Statement I is true, and Statement II is true B) Statement I is true, and Statement II is false C) Statement I is false, and Statement II is false D) Statement I is false, and Statement II is true

9.2e

Continue with the model described in the previous questions. The average service time is always 2 minutes again. Suppose the customer entry rate behaves as follows:

What is the total number of customers that will get served during the 15-minute break based on this customer entry rate? (Choose the answer that comes closest to your estimate.)

A) Around 3 customers
B) Around 50 customers
C) Around 100 customers
D) Around 150 customers

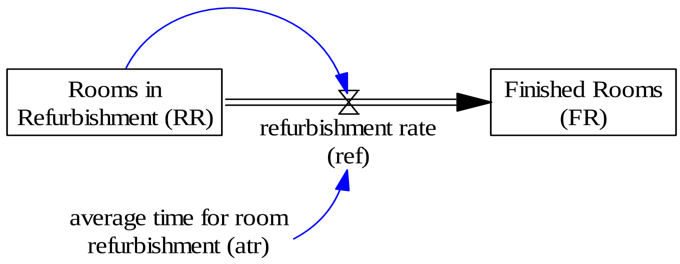
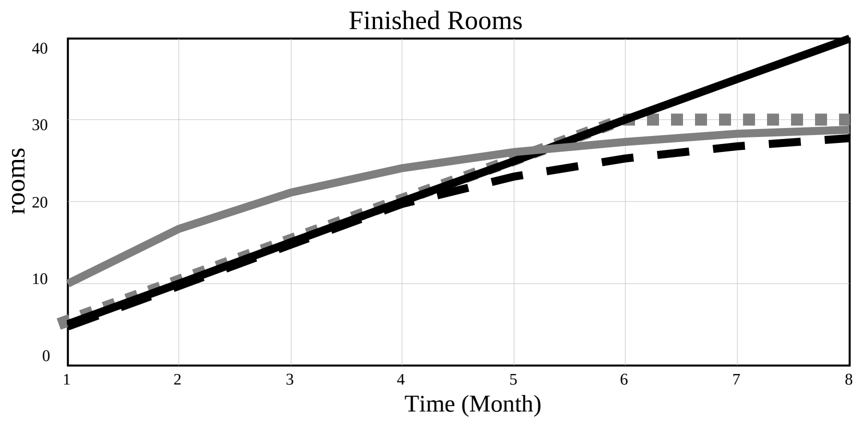
9.2f

Continue with the model described in the previous questions.
Suppose you want to calculate the total number of lost customers during this 15-minute break (this is not yet in the model). What would be the correct equation?

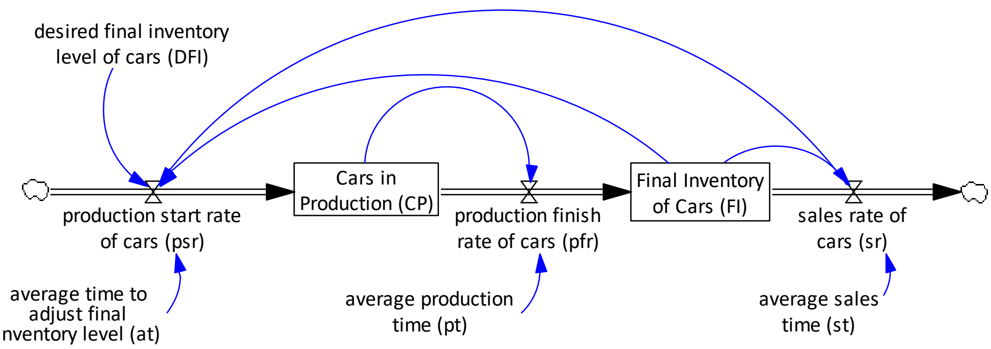
A) Total number of lost customers = INTEGRAL(pcer + cer) + 0
B) Total number of lost customers = INTEGRAL(pcer – cer) + 0
C) Total number of lost customers = INTEGRAL (pcer + cer – csr) + 0
D) Total number of lost customers = INTEGRAL(pcer – cer – csr) + 0

9.3a

Suppose a hotel is going to refurbish 30 rooms, which will include, new bathrooms, beds, furniture, carpets, televisions, coffee machines, and a new heating system. The average time it takes to refurbish one room is 3 months. The simulation model below describes this refurbishment project:
You can assume that the refurbishment rate is modeled as a first-order material delay. How many rooms are expected to be refurbished after 3 months?

	 A) 0 rooms B) Around 10 rooms C) Around 21 rooms D) Around 30 rooms
9.3b	Continue with the model described in the previous questions, but we will add a new variable. The refurbishment rate (ref) is not only influenced by the Rooms in Refurbishment (RR) and the average time for room refurbishment (atr), but also by the refurbishment capacity (rc) which is not shown in the model. This capacity may limit the refurbishment rate, meaning that the refurbishment rate can never be larger than the refurbishment capacity. So, when the refurbishment capacity is 5 rooms/month, the refurbishment rate cannot be higher than 5, but it can be lower. What is the correct equation for the refurbishment rate (ref)? A) ref = rc B) ref = rc – (RR/atr) C) ref = MIN(rc, RR/atr) D) ref = MAX(rc, RR/atr)
9.3c	Continue with the model (and the new equation for “ref”) described in the previous questions. You can assume that the refurbishment capacity if 5 rooms/month. Which lines in the graph below represent the number of Finished Rooms correctly?  A) Line A B) Line B C) Line C D) Line D 

<table>
<tr><td>9.4a</td><td>The following model describes the production process and inventory of a car manufacturer.

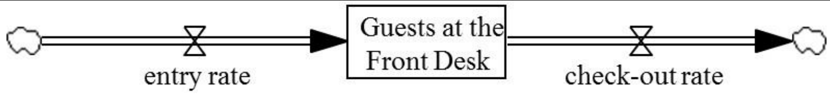


The production start rate is modeled as a stock management structure.

What is the equation for this production start rate?
A) psr = (DFI – FI – sr)/at
B) psr = (DFI – FI + sr)/at
C) psr = sr + (DFI – FI)/at
D) psr = sr + (DFI + FI)/at</td></tr>
<tr><td>9.4b</td><td>Continue with the car model described in the previous questions. You can assume that this system is in equilibrium, all delays are first-order material delays, DFI = 100 cars, and st = 2 weeks.

What is the sales rate of cars (sr)?
A) sr = 0
B) sr = 50
C) sr = 100
D) sr = 200</td></tr>
<tr><td>9.4c</td><td>Continue with the car model described in the previous questions. Suppose now that initially, the final inventory (FI) is lower than the desired final inventory (DFI), and that the average time to adjust final inventory level (at) is 4 weeks and the average production time (pt) is 5 weeks.

How long will it take before FI is equal to DFI?
A) About 4 weeks
B) About 9 weeks
C) About 11 weeks
D) More than 11 weeks</td></tr>
<tr><td></td><td></td></tr>
<tr><td>9.5a</td><td>A large hotel in Oslo is trying to figure out how many employees should be working at the front desk each morning to deal with the guests that want to check out. Guests can check out between 06h00 and 11h00, but there is usually a peak at 09h00. The number of guests at the Front Desk can be modeled as a stock. The entry rate and check-out rate are the flows, as depicted below:</td></tr>
</table>



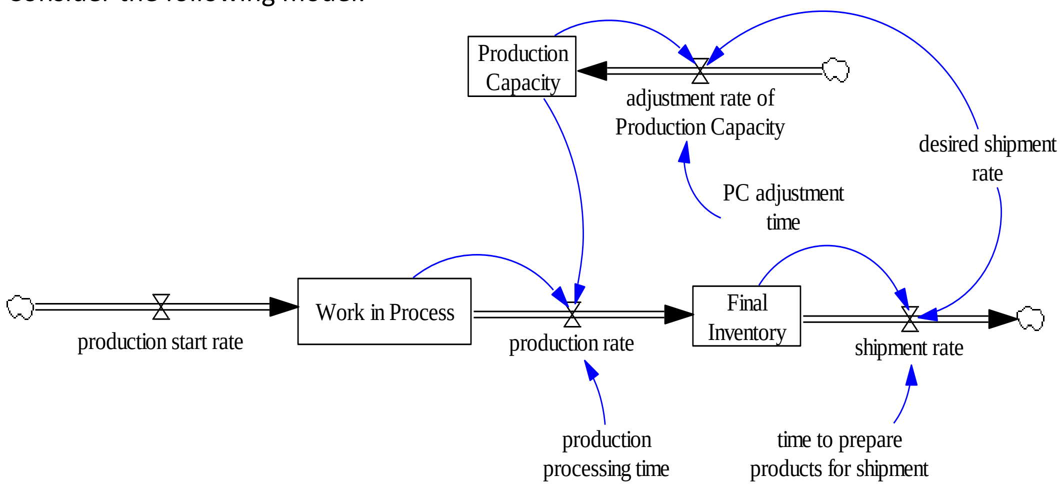
The average check-out time is 10 minutes (not shown in the model above). The check-out rate is modeled as a first-order material delay. Only 5 employees are working at the front desk. Because it takes on average 10 minutes to check out a guest, 1 employee can check out 6 guests per hour (or 0.1 guest per minute). You can also assume that all guests are single travelers, sleeping in a single room. This gives us a new variable in the model called “front desk capacity”, with a value of 0.5 guests/minute (because there are 5 employees). Which equation will you use in your model to include this capacity?

A) Check-out rate = front desk capacity
B) Check-out rate = MIN(Guests at the front desk/average check-out time, front desk capacit
C) Guests at the front desk = entry rate – front desk capacity
D) Guests at the front desk = INTEGRAL(entry rate – front desk capacity)

9.5b Continue with the model and the graph of “Guests at the Front Desk” described in the previous question.
To prevent the situation that too many guests are at the front desk at the same time, the employees can work harder but they only do this when there are a lot of guests at the front desk. As a result, the “average check-out time” in busy times can be reduced by at least 50%. The average check-out time is therefore no longer a constant. If you would model this behavior, what will you be adding to the model?

A) Nothing needs to be added, but the “average check-out time” needs to be 5 minutes instead of 10 minutes.
B) A new balancing loop needs to be drawn that includes a causal link between “Guests at the front desk” and “average check-out time”
C) A new reinforcing loop needs to be drawn that includes a causal link between “Guests at the front desk” and “average check-out time”
D) A causal link needs to be drawn between “Guests at the front desk” and “average check-out time” but this will not lead to a new loop in the model

9.6a Consider the following model:



	This model describes a company that produces products and ships these products to customers. The equation for Production Capacity (PC) is: $$\frac{dPC}{dt}=\frac{\text{desired shipment rate}-PC}{PC\ \text{adjustment time}}$$ *PC* adjustment time = 50 months *PC*(0) = 5 products/month What are the units of the desired shipment rate? A) Production capacity / Month B) Products C) Products / Week D) Products / Month
9.6b	Continue with the model described in the previous question The Production Capacity influences the production rate. This means that the higher the production capacity, the higher the production rate (but of course the production rate is also constrained by work in process and the production processing time). What is the equation for "production rate"? A) Production rate = PC B) Production rate = MIN(PC, production processing time) C) Production rate = MIN(PC, Work in Process/ production processing time) D) Production rate = PC + Work in Process/ production processing time

Answers

Lecture 1	
1.1	D
1.2	B
1.3	D
1.4	B
Lecture 2	
2.1	A
2.2	B
2.3	D
2.4	C
2.5	B
2.6	C
2.7a	A
2.7b	B
2.7c	C
2.8a	A
2.8b	C
2.8c	A
2.9a	B
2.9b	C
2.9c	C
2.9d	A
2.9e	C
2.10	*
Lecture 3	
3.1	C
3.2	A
3.3	B
3.4	A
3.5	C
3.6	B
3.7	B
3.8	A
3.9	B
3.10	B
3.11a	B
3.11b	B
3.11c	D
3.11d	B
3.11e	C
3.12a	D
3.12b	A

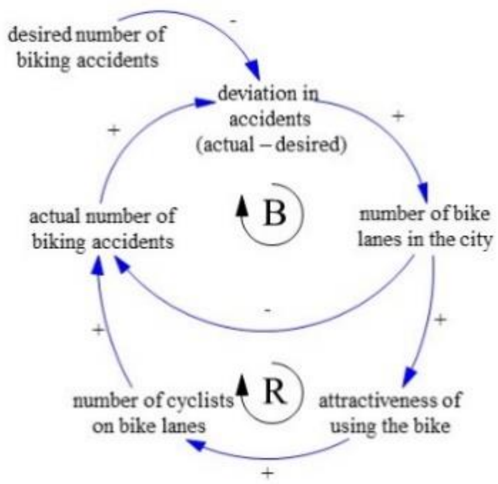
3.13a	A
3.13b	D
3.14a	B
3.14b	D
3.14c	C
3.14d	A
3.14e	C
3.14f	**
Lecture 4	
4.1	C
4.2	B
4.3	A
4.4	A
4.5	C
4.6a	A
4.6b	C
4.6c	D
4.6d	B
4.6e	B
4.7a	B
4.7b	D
4.7c	C
4.7d	D
4.7e	A
4.7f	
4.8a	B
4.8b	B
4.9a	D
4.9b	D
4.10a	D
4.10b	B
4.10c	B
4.10d	D
Lecture 5	
5.1	B
5.2a	B
5.2b	A
5.2c	C
5.2d	A
5.2e	B
5.2f	C
5.3a	A
5.3b	A
5.3c	D

5.3d	C
5.4a	B
5.4b	B
5.4c	A
5.4d	A
5.4e	A
5.4f	
5.4g	C
5.4h	B
5.5a	C
5.5b	A
5.5c	D
5.5d	A
5.5e	B
5.5f	C
5.5g	D
5.5h	C
5.5i	D
5.5j	B
Lecture 6	
6.1	D
6.2	B
6.3a	C
6.3b	A
6.3c	B
6.3d	A
6.3e	B
6.3f	C
6.3g	
6.4a	D
6.4b	D
6.4c	B
6.4d	D
6.4e	A
6.4f	B
6.4g	C
6.5a	D
6.5b	B
6.5c	C
6.5d	D
6.5e	

Lecture 7	
7.1a	C
7.1b	B
7.1c	A
7.1d	D
7.1e	D
7.2a	D
7.2b	C
7.2c	C
7.2d	B
7.2e	C
7.3a	B
7.3b	A
7.3c	C
7.3d	B
7.3e	D
7.3f	A
7.3g	C
7.3h	C
7.3i	B
7.3j	
Lecture 8	
8.1	C
8.2	C
8.3	C
8.4	A
8.5a	B
8.5b	D
8.5c	C
8.6a	C
8.6b	C
8.6c	A
8.6d	B
8.6e	C
8.6f	B
8.6g	A
8.6h	B
8.6i	D
8.6j	B
8.7a	C
8.7b	C
8.7c	C
8.7d	B
8.7e	B

8.7f	A
8.8a	C
8.8b	C
8.8c	B
8.8d	D
8.8e	C
8.9a	C
8.9b	B
8.9c	A
8.9d	B
8.9e	D
8.9f	C
8.9g	D
8.9h	C
8.9i	B
8.9j	D
8.10a	D
8.10b	A
8.10c	A
Lecture 9	
9.1	D
9.2a	C
9.2b	A
9.2c	A
9.2d	C
9.2e	B
9.2f	B
9.3a	C
9.3b	C
9.3c	A
9.4a	C
9.4b	B
9.4c	D
9.5a	B
9.5b	B
9.6a	D
9.6b	C

* Question 2.10



** Question 3.14f