

Modeling using Vensim

Vensim PLE, version 6.3

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1. Background

There are skills that one learns only by doing – not by seeing, reading or listening. Deep Systems Thinking requires understanding of dynamic complexity. The best way to get that understanding is through developing and testing formal models. In this tutorial you will build a system dynamics simulation model of a problem that an IT-company is facing – it is losing customers. The company and its problem are based on Kim Warren's (2014) case study.

Medium sized IT-support company

The company provides all types of IT services to medium sized companies, such as small retailers, small accounting and law firms, and small construction and logistics firms. The company supports its customers' equipment, software and communication needs, and employs young skilled workers. After a few successful years, the company started the implementation of a new growth strategy. For a while all went well but now the company has awoken to a situation where their customers are experiencing a lot of problems and the company is losing a lot of their customers.

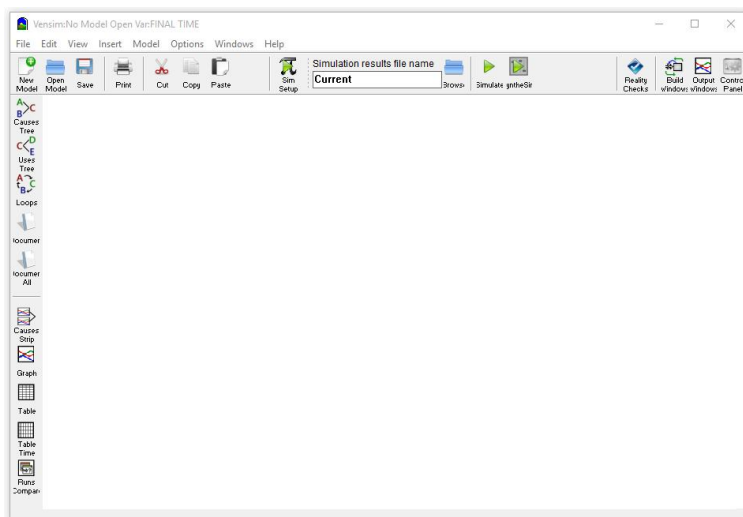
2. Getting started

To start modeling the problem you will first have to install Vensim PLE (Personal Learning Edition). The latest version can be downloaded from <http://vensim.com/free-download/>. You will be asked to fill in the following form and provide an email address to which a download link will be sent.

Anti-spam	<input checked="" type="checkbox"/> Please tick this box
Product	<input checked="" type="radio"/> Vensim PLE 6.3G <input type="radio"/> Vensim PLE 5.11A <input type="radio"/> Model Reader
Platform	<input checked="" type="radio"/> Windows (XP/Vista/7/8/8.1) <input type="radio"/> Macintosh OSX (10.4+)
Vensim newsletter	<input type="checkbox"/> Subscribe Name <input type="text"/> PLEASE NOTE: DOWNLOAD INSTRUCTIONS WILL BE EMAILED TO YOU, A FAKE EMAIL ADDRESS HERE WILL NOT WORK. Email address <input type="text"/> Retype email address <input type="text"/> <small>The Vensim newsletter is used for announcements of software updates, courses, and related information. Frequency is low – typically quarterly – and addresses are never shared.</small>

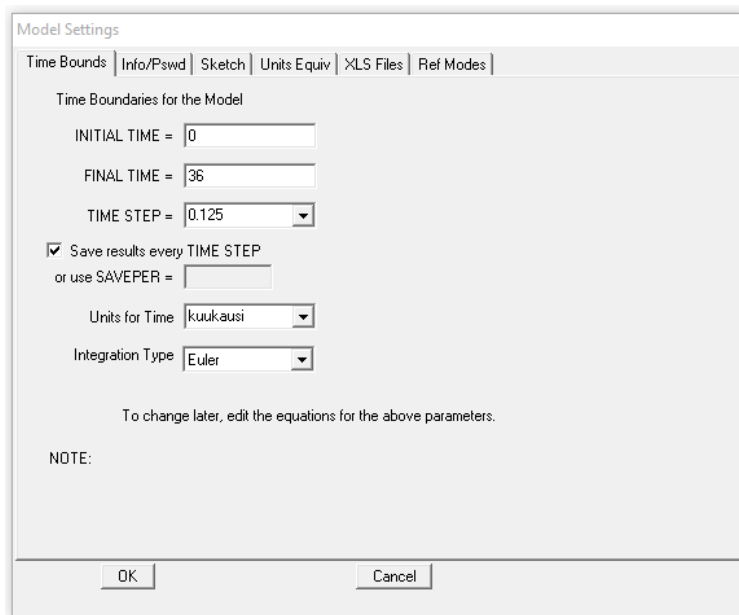
[Download software](#)

After starting Vensim you should see an empty modeling window and different type of tools and option bars.

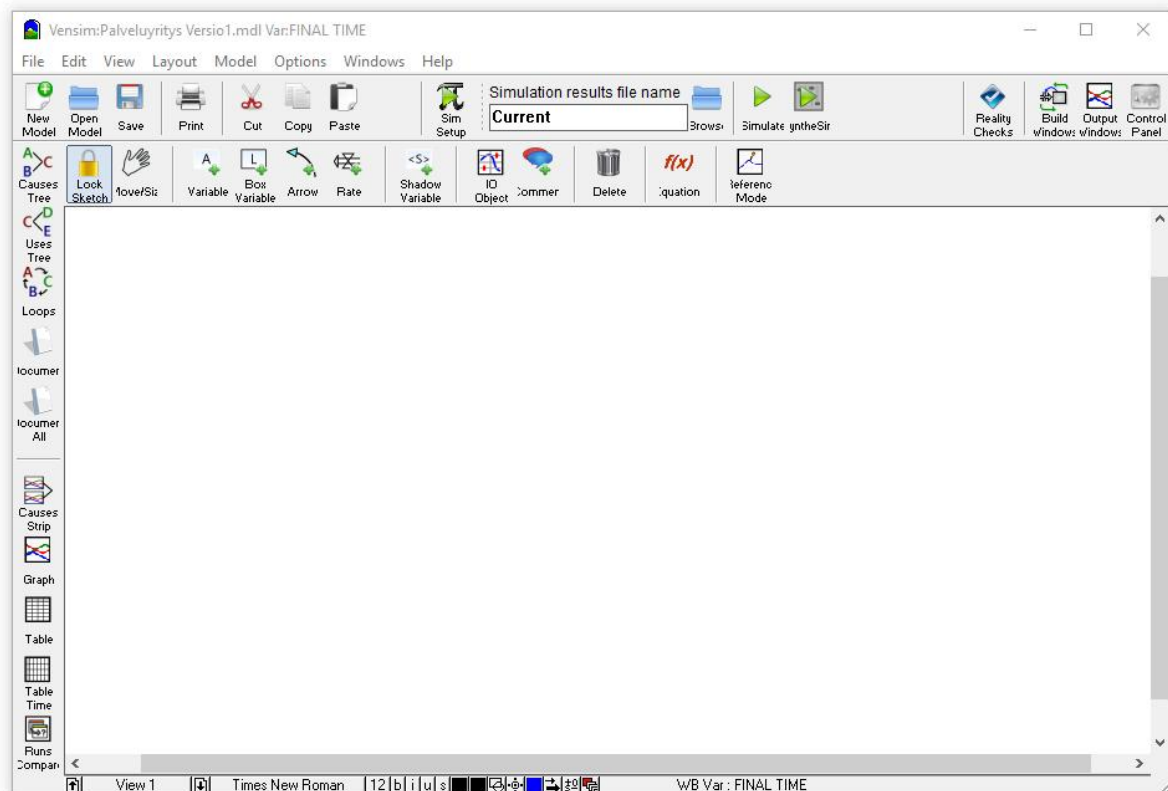


To start working on a new model go to the File menu and select New Model. A popup window will appear with different model setting on it (Model Settings). When starting a new

model Vensim will always ask you: the time bounds of your model (when does simulation start and end), appropriate time step (how precisely do you want to do your simulations), units of time, and the integration method. Set the start (INITIAL TIME) to 0 and the end (FINAL TIME) to 36. Set the time step (TIME STEP) to 0.125 select (Units for Time) to be Month. Check the box saying (Save results every TIME STEP) and leave the integration method as it is (Integration Type) Euler. Click OK.



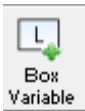
At any point in time you can always come back and change these by selecting Model and Settings... Now to save your model and to name it select File and Save As... Enter a name for your model, for example, Service Model Version 1. Vensim will automatically add the model file extension *.mdl. Your view should now look like this:



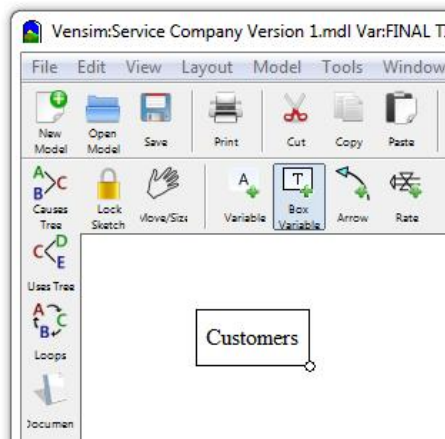
The large white area in the middle is your work area where you will build and analyze your models. The tool bar right on top of the white area gives you tools to build your models. The bar on the left contains tools for analyzing your models and simulation results. Below the white area you will find tools to adjust the visuals of your model (e.g. changing fonts and colors). The tools to run you models are at the very top. You will get more familiar with these tools as you follow the modeling tutorial.

You are now ready to start building your model.

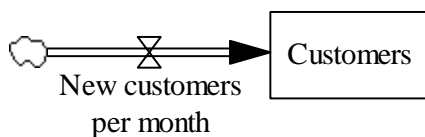
3. Adding variables and feedback structures



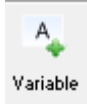
To start modeling the service company, add a stock of customers to your model. Click on the stock variable tool (Box Variable) button. Then click on the middle of the white area. Use this tool whenever you need to add a stock variable. Vensim will create an empty box with a flashing cursor inside. Give the variable a name by typing Customers and press enter. If the name does not fit inside the stock you re-size it by “grapping the circular handle in the lower right corner”. Your screen should now look like this:



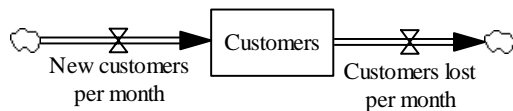
Next, add the flow of new customer to your model. Click on the (Rate) button. Now, click and on the left of the stock and release. Move the cursor inside the stock and click and release again. An empty text field will appear. Write the name for that flow New customers per month and press enter. You have now created an inflow of new customers that can increase the stock of customers. A cloud icon ☁ appeared to the starting point of the flow. That icon reflects the boundaries of our model – at the moment we are not interested where the new customers come from, we are only interested on how many we can win.



Now, add an outflow Customers lost per month from the stock of customers. Make sure that the Rate tool is selected then click on the stock of Customers and release, then click on the right side of the stock and release.



Next, we will need to add auxiliary variables that describe how the company has started to lose its customers. Start by adding two auxiliary variables: Total service demand hours per month and Service demand hours per customer per month. To add these variables select the (Variable) button. Then click on an empty area below the stock and add the name of the first variable. Similarly add the second variable. As opposed to stock and flows these auxiliary variables do not have any shape or icon attached to them.

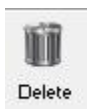
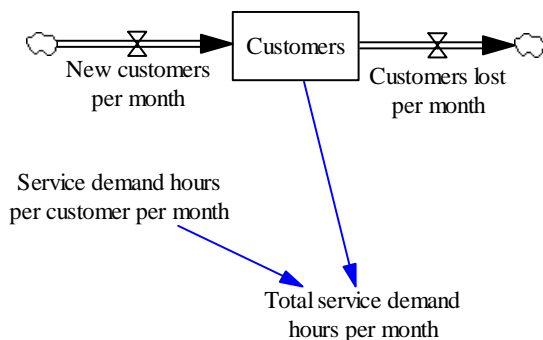


Service demand hours
per customer per month

Total service demand
hours per month



To represent that total service demand hours is dependent on the total amount of customers and the time required to service one customer, connect the variables with a causal arrow. First, press on the (Arrow) tool, then press and release inside the Customers stock. Then take the cursor to the Total service demand hours, click and release again. In the same way connect also the Service demand hours per customer to the Total service demand. Make sure that both arrows point to the Total service demand hours.

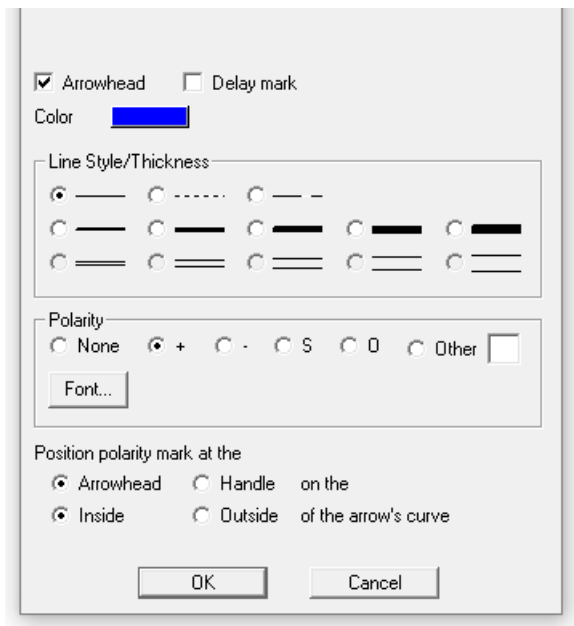


You can delete model elements using the (Delete) tool or selecting the elements and pressing Delete.

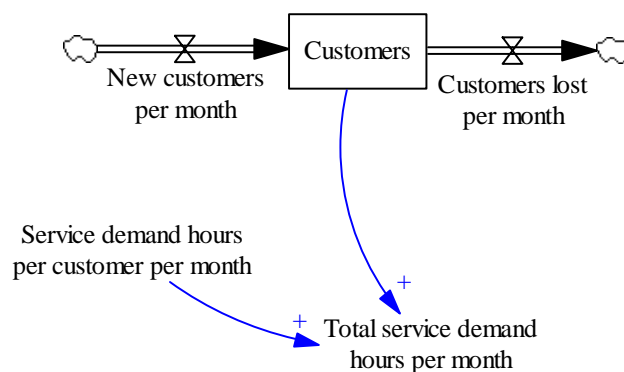


Using the (Move/Size) tool you can select the variables, links, and other model elements you have created. With the tool you can move an element from one place to another and for

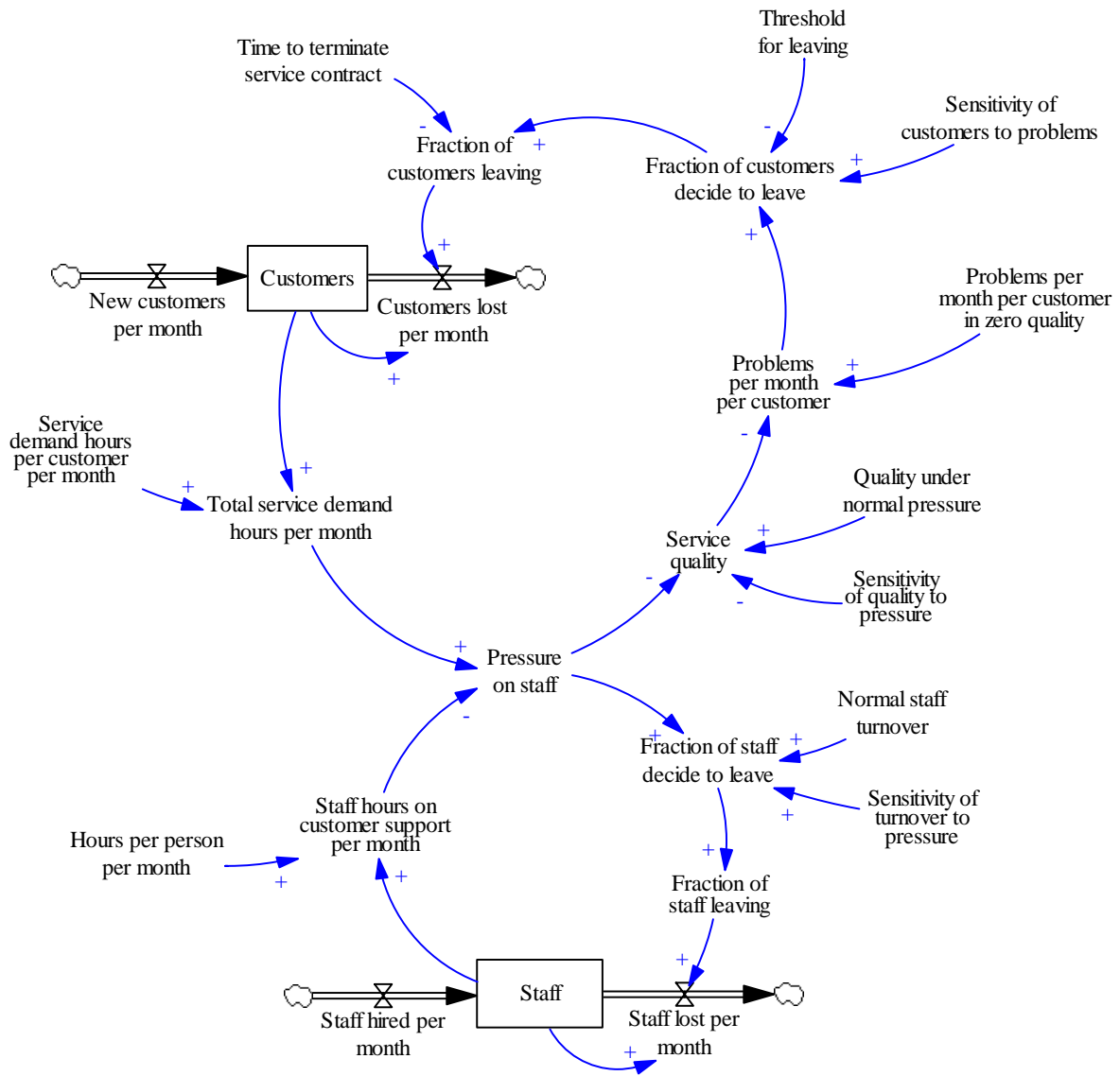
instance curve arrows by clicking on the small circles inside the arrows and moving them. Now, add polarities (+/- signs) to the causal links. Select the (Move/Size) tool and press the right mouse button on the arrow's small circle or on the arrow head. Vensim will open the following popup window:



Select the right polarity for the causal links. With the same option you can also adjust the position of the polarity mark so they will be easily associated with the right arrow.



Now, using the same steps discussed above, add variables to complete the model diagram as shown below. You can zoom in and zoom out by pressing control and scrolling your mouse wheel (Ctrl + Mouse wheel). You can also move the view to different areas by pressing the right mouse button down on an empty area and moving your mouse.



Variable	Type	Description
Customers	Level	The amount of customers is equal to the amount of customer at the start plus all new customers minus all lost customers.
Time to terminate service contract	Auxiliary	The time it take for customers to search new service providers and terminate their existing contacts.
Staff	Level	The amount of people the IT company employs to services its customers. The staff level is equal to the amount of staff at the start plus all the new hires minus all the staff that have left.
Threshold for leaving	Auxiliary	How many problems per month customers will tolerate before they will start to leave.
Sensitivity of quality to pressure	Auxiliary	How sensitive service quality is to the changes in work pressure. The larger the values the more will pressure affect quality.
Quality under normal pressure	Auxiliary	The level of quality when work pressure is at normal levels. Even if there is no excess pressure service quality is not necessarily perfect.
Customers lost per month	Flow	How many customers leave every month. It is the amount of current customers multiplied by the fraction of customers leaving.
Normal staff turnover	Auxiliary	Fraction of staff that decides to leave each month even if there is no pressure.
Problems per month per customer	Auxiliary	Low service quality will create problems for customers and delays in fixing those problems. Problems are at their maximum level when service quality is zero and when quality is one problems disappear.
Problems per month per customer in zero quality	Auxiliary	The maximum level of problems that from when quality is zero.
Sensitivity of customers to problems	Auxiliary	The fraction of customers that decide to leave for every problem that is over the acceptable level.
Fraction of customers leaving	Auxiliary	Customers cannot leave the service provider instantly. They have to find new providers and terminate their contracts.
Fraction of customers decide to leave	Auxiliary	Customers decide to leave when the amount of problems they encounter exceed their acceptable level.
Fraction of staff leaving	Auxiliary	Employees cannot leave instantaneously. It takes time to find new employers and to terminate their contracts.
Fraction of staff decide to leave	Auxiliary	The fraction of staff that decides to leave is the normal turnover plus the ones that decided to leave because of work pressure. Work pressure will effect turnover only after it exceeds the normal 100 percent.
Staff hired per month	Flow	Relating to the firms growth strategy, every month 2 more workers are hired.
Service quality	Auxiliary	As the work pressure on staff increases the quality of service goes down. If work pressure goes below normal 100 percent the quality does not improve above normal levels.
Staff hours on customer support per month	Auxiliary	Total man hours the firm has in its disposal towards providing IT-support services to its customers. It is the product of total staff and hours worked towards providing services per person per month.
Total service demand hours per month	Auxiliary	The effort needed to service the existing customers is the time required to service one customer multiplied by the total amount of customers.

Service demand hours per customer per month	Auxiliary	Average man hours it takes to services one customer for a month. The value has remained unchanged for a long time.
Staff lost per month	Flow	The amount of staff leaving every month is the product of total staff and the fraction of staff leaving each month.
Pressure on staff	Auxiliary	Pressure on staff is the ration of required man hours to service existing customers and the total man hours available to service those customers.
Sensitivity of turnover to pressure	Auxiliary	The fraction of additional staff that decides to leave each month if the work pressure is twice the normal. Good and young workers had no trouble in finding new employment opportunities in the IT sector at that time.
Time to terminate employment	Auxiliary	How long the employees still work at the company after they have decided to leave. It takes time to find new employers and to terminate employment contracts.
Hours per person per month	Auxiliary	Average hours on person works in a month. Data Source: employee work time system.
Uudet asiakkaat per kuukausi	Flow	New customers per month is modeled as an exogenous data variable as it is not necessary to explain the factors affecting it to understand the relevant dynamics of the case company's problems. Data Source: customer management system.



Now, we need to name the loops that were formed. You can use the comment tool to add elements that will help in understanding the structure but do not change its structure in any way. To name the loops, select the (Comment tool). Then click inside the lower loop in an empty area. You should see the following popup window:

Comment

Comment Description

Appearance

☐ None
 ☐ Triangle
 ☐ Hexagon
☐ By Type
 ☐ Up Triangle
 ☐ Diamond
☐ Box
 ☒ Loop Clkwise
 ☐ Circle
☐ Clear Box
 ☐ Loop Counter

Color ☐ Background color

Comment

Behaviour

☒ Use as arrow junction
 ☐ Hide Level
☐ no cause

Font

Calibri
 @Arial Unicode MS
 @DengXian
 @Malgun Gothic
 @Malgun Gothic Semil
 @Microsoft JhengHei
 @Microsoft JhengHei L
 @Microsoft JhengHei L

☐ Bold
 ☐ Strikethrough
☐ Italic
 ☐ Vertical
☐ Underline
 ☐ down

Color Example

Size

Text Position

☐ Center
 ☐ Left
 ☐ Above
☐ Right
 ☐ Below

Graphics

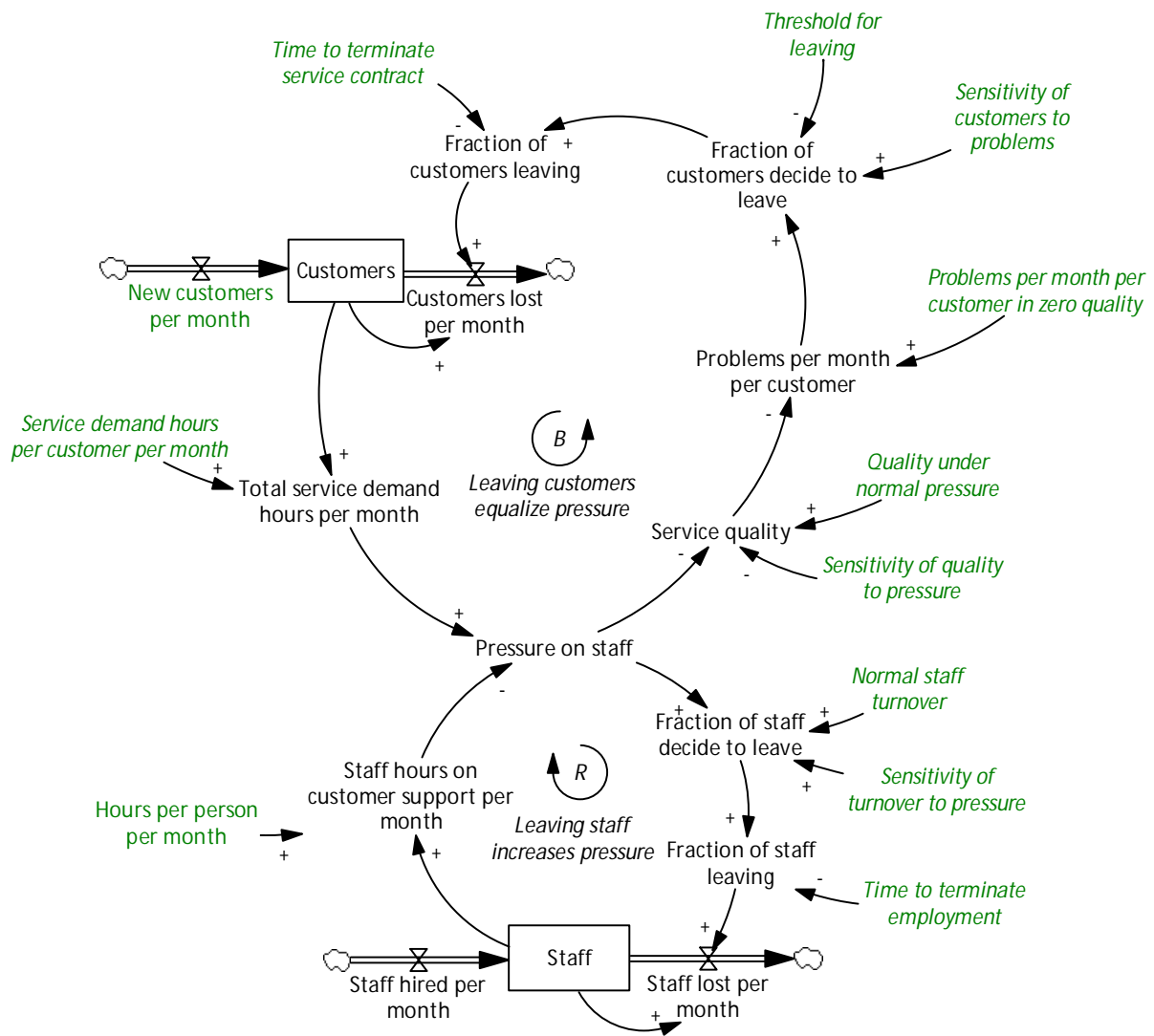
☒ None
 ☐ Image
☐ Bitmap
 ☐ Metafile

As the lower loop run in a clock wise direction select the Appearance Loop Clkwise. The loop is reinforcing so type R into the Comment field then press. The loop symbol should now be in the model:



Keep the Comment tool selected and click little below your loop symbol. Now, give the loop a name by writing it to the comment field and press Ok. You should now have the loop sign and a descriptive name for it below the sign. You can use for example the name “Leaving staff increases pressure”. Naming the loop is an important part to help make the diagrams more understandable and to display the relevant feedbacks to others.

You may try to clarify your model even further by using the visual tools at the bottom of Vensim. For example Rahmandad and Sterman (2012) recommend using Sans Serif fonts such as Arial and Helvetica. You can also distinguish parameters (constant values) from variables that change over time by using different colours for instance. Your model should now look something like this:

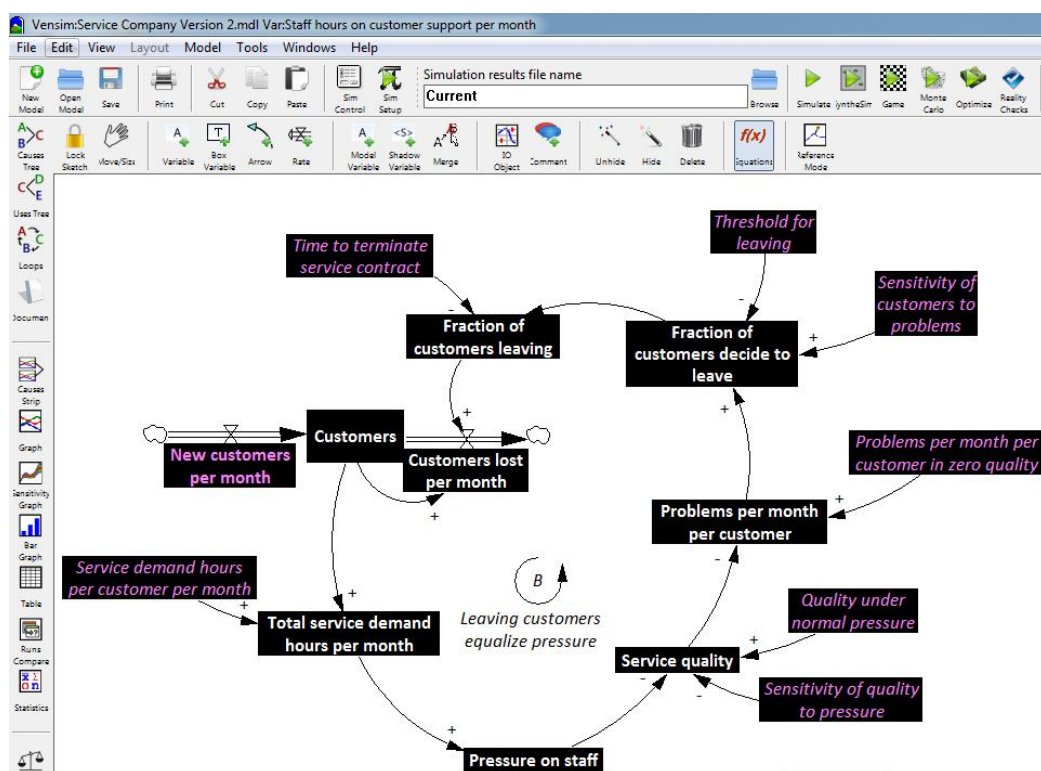


4. Defining equations

Now that you have created a stock, flow and feedback description that might explain the observed system behaviour – losing customers – next you need to form an equation for each variable. Defining variables is a critical part of a modelling process and an important part in gaining deeper understanding.



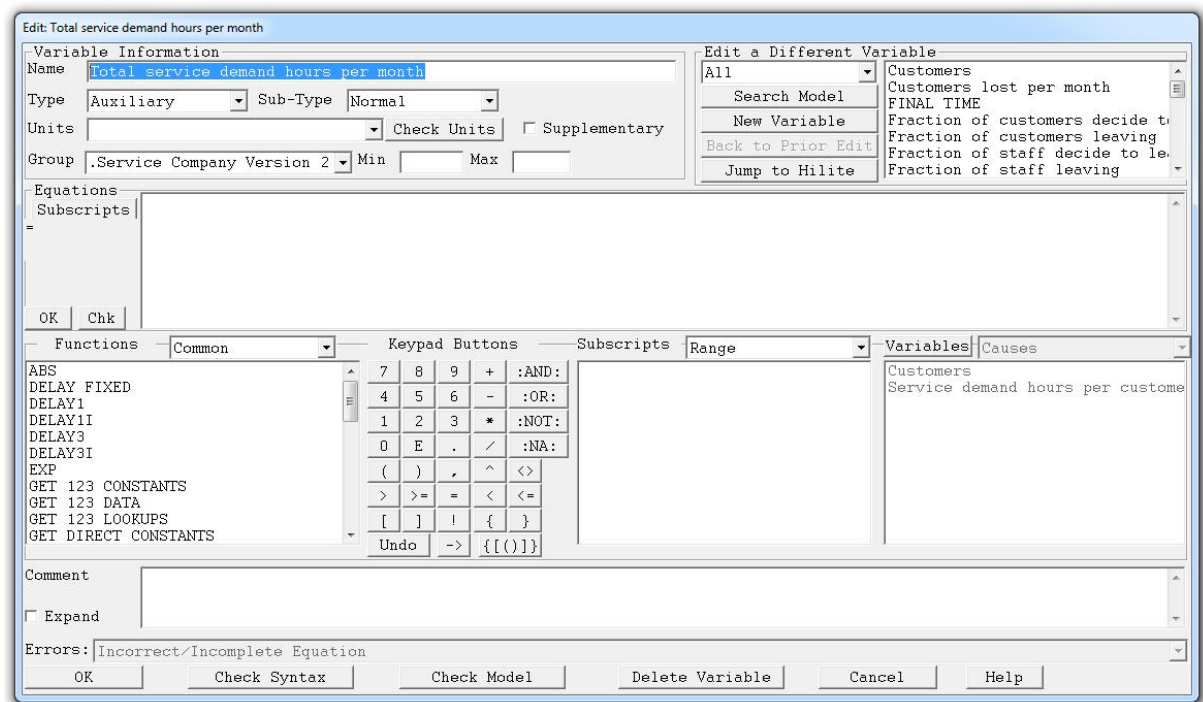
Start formulating equations by selecting the (Equations) tool. All variables in your model will be highlighted with a black background. It indicates that the equations for those variables are incomplete.



Variables in system dynamics models are classified as either exogenous or endogenous. Exogenous variables are those that are defined independent of other variables of the model. They are functions of time (i.e., Exogenous Variable = $f(t)$). Of course the exogenous variables may be constants, in which case they are called parameters. Endogenous variables are influenced by other variables in the system (Endogenous Variable = $f(x, y, z)$, where x, y, z are other variables in the model).



Start by writing the equations for the endogenous variables. Good modelling practise (Rahmandad ja Sterman, 2012) Good modelling practice requires that each equation in a model have three elements: 1 the equation itself; 2 specified units of measure; and 3 complete documentation. Start filling these by selecting the (Equation) tool and clicking on Total service demand hours per month. You then see the following dialog box:



You'll be entering the equation in the box adjacent to the word Equations and the units of measure in the text field to the right of the word Units. Equation documentation is entered in the box to the right of the word Comment.

Begin writing the equation first by clicking in the equations box. Now, look in the box below it on the right, where Causes are listed. Here Vensim has provided you with the two variables that your model diagram shows as influencing the Total service demand hours, Customers and Service demand hours per customer. A simple and plausible formulation for the Total service demand is simply to multiply the number of Customers by the Service demand hours per customer.

To enter this equation click on the Customers variable, which will now appear in the equation box. Now either click or type "*" to present multiplication. Complete the equation by clicking Service demand hours. Your equation should now read:

$$\text{Customers} * \text{Service demand hours per customer per month}$$

Next fill in the units. Total service demand hours per month represents the total man-hours per time unit needed to service the existing customers. Type ManHours/Month in the Units field.

Finally, provide a description of this equation in the comment field. A good comment will be brief but also explain the logic behind the equation and state the key assumptions. For example, one might write for this equation:

The effort needed to service the existing customers is the time required to service one customer multiplied by the total amount of customers.

Your equation box should now look like this:

Variable Information

Name: Total service demand hours per month

Type: Auxiliary Sub-Type: Normal

Units: ManHours/Month Check Units ☐ Supplementary

Group: .Service Company Version 2 Min: Max:

Equations-Subscripts: Customers*Service demand hours per customer per month

OK Chk

Functions: Common

Keypad Buttons

Subscripts: Range

Variables: Causes

Comment: The effort needed to service the existing customers is the time required to service one customer multiplied by the total amount of customers.

Errors: Equation Modified

OK Check Syntax Check Model Delete Variable Cancel Help

Press Ok to go back to the model diagram. Paina nyt Ok palataksesi takaisin mallinnusdiagrammille. Total service demand hours per month is no longer highlighted because its equations is complete.

Now write the equation for the stock of customers. Begin by clicking on the Customers stock. You should get a dialog box that looks like the following. Notice that the equation editor for a stock looks different from the one we just saw for the flow, containing a box for an equation, and below it for the Initial Value that the stock takes on.

The value of a stock at any moment in time is equal to the sum of all that stock's inflows less all of its outflows from the start time of the simulation, plus the initial value. This is the concept of an integral in calculus, and so the term INTEG appears to the left of the equation box, indicating that its value is an integral.

Input into the equations field (if Vensim does not automatically provide them) all the inflows as additions and all the outflows as subtractions. Your equation for Customers should be:

New customers per month - Customers lost per month

Stock always have to have initial values. The IT-company of our case study has detailed knowledge about its customers and at the initial time of the simulation models time horizon it had 90 customers. Input 90 to the Initial Value field. You can also input other variables to the field but for now we know that it is 90 and there is no need to change it. Also input the units Customers into the unit field and add documentation:

The amount of customers is equal to the amount of customer at the start plus all new customers minus all lost customers.

Following the process described above, fill in the equations for all endogenous variables in the model. Initial Staff is known to be 55 people. Note that the unit Dimensionless (Dmnl) is used to represent if the variable does not have unit (e.g. in the variable represents ratios or fractions).

Variable	Units	Equation
Customers	Customers	New customers per month-Customers lost per month
Staff	People	Staff hired per month-Staff lost per month
Customers lost per month	customers/month	Customers*Fraction of customers leaving
Problems per month per customer	problems/customer/month	(1-Service quality)*Problems per month per customer in zero quality
Fraction of customers leaving	Dmnl/month	DELAY FIXED(Fraction of customers decide to leave, Time to terminate service contract, 0)
Fraction of customers decide to leave	Dmnl/month	MAX(0,(Problems per month per customer-Threshold for leaving)*Sensitivity of customers to problems)
Fraction of staff leaving	Dmnl/month	DELAY FIXED(Fraction of staff decide to leave, Time to terminate employment, Fraction of staff decide to leave)
Fraction of staff decide to leave	Dmnl/month	MIN(1,Normal staff turnover + MAX(0,(Pressure on staff-1)*Sensitivity of turnover to pressure))
Service quality	Dmnl	MIN(Quality under normal pressure,1/Pressure on staff^Sensitivity of quality to pressure)
Staff hours on customer support per month	Person*Hours/month	Staff*Hours per person per month
Total service demand hours per month	Person*Hours/month	Customers*Service demand hours per customer per month
Staff lost per month	People/month	Staff*Fraction of staff leaving
Pressure on staff	Dmnl	Total service demand hours per month/Staff hours on customer support per month

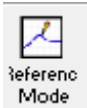
Rest of the model variables are exogenous.

At this time you do not have accurate data for all your parameters. For some you have gotten good estimates from the people working at the IT company, but for others you have to make your own educated guesses. Later on we will discuss how you can find for suitable values and how you can test the sensitivity of the simulations to changes in parameter values. Note that the decimal is indicated with a "." dot in Vensim. Fill in the parameter values below.

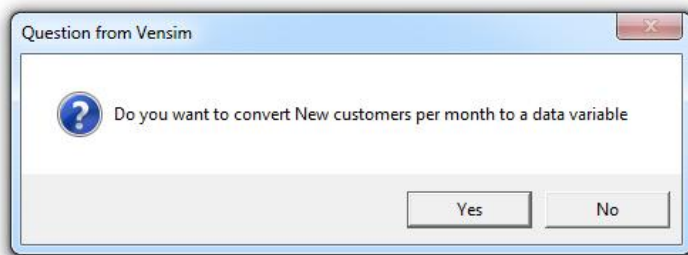
Variable	Unit	Equation
Time to terminate service contract	Months	2
Threshold for leaving	Problems/Customer/Month	0.4
Sensitivity of quality to pressure	Dmnl	4
Quality under normal pressure	Dmnl	0.9
Normal staff turnover	Dmnl	0.03
Problems per month per customer in zero quality	Problems/Customer/ Month	4
Sensitivity of customers to problems	Dmnl/(Problem/Customer)	0.025
Staff hired per month	People/Month	2
Service demand hours per customer per month	Person*Hours/Customer/Month	80
Sensitivity of turnover to pressure	Dmnl/Month	0.15
Time to terminate employment	Months	2

5. Connecting data

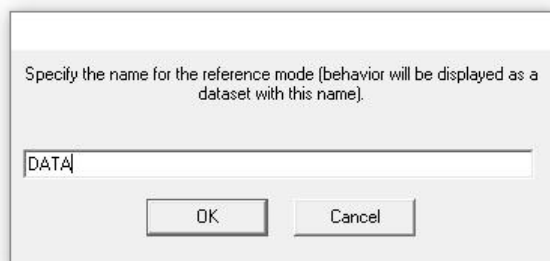
There are still two exogenous variables in your model and their equations need to be defined: Hours per person per month and New customers per month. They have been left as exogenous variables that change over time. You do not have to – at least not yet – explain what affects them as you think that you can explain the IT company's problem without analyzing them and their causes further. For example, you know that the change in New customers per month is mostly related to the hiring of a new sales manager, who immediately after being hired was really efficient in selling their services to new customers.



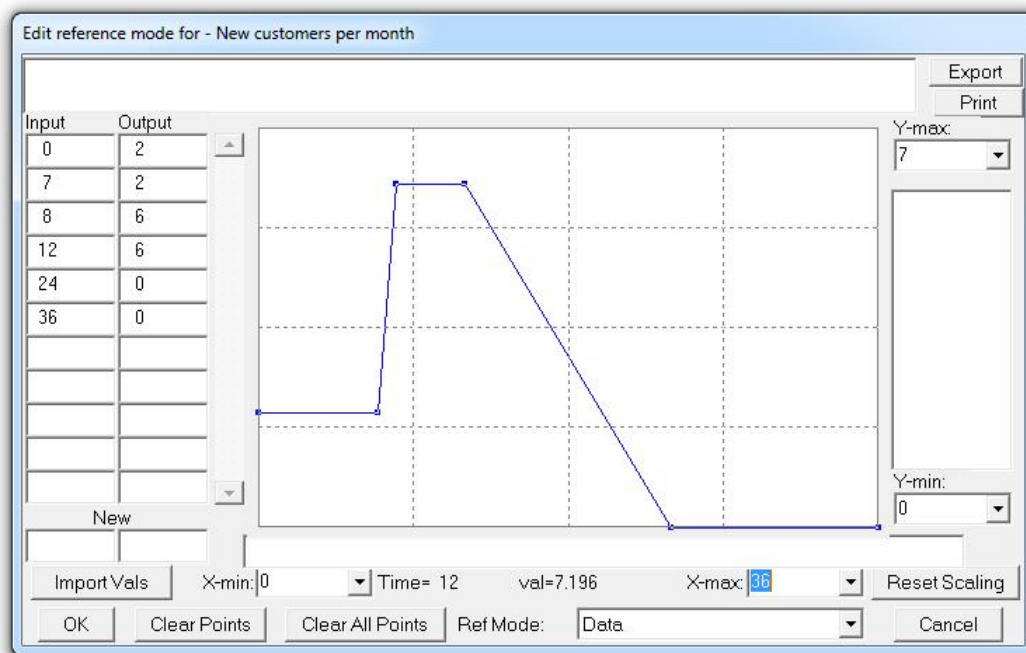
For these variables you have accurate data from your systems (customer management and employee time tracking systems). To input these data series you can use the reference tool. Click on the (Reference Mode) tool and then click on the New customers per month. Because the variable has not yet been defined as a data variable nor has its equation been defined Vensim asks if you want to change it to a data variable. The values for a data variable are defined as a function of time. Click Yes.



Next Vensim asks what name you want to give to the data set. Input DATA and press Ok.



Then you will be able to input or draw the behaviour over time of the selected variable. The Input column is time (here month) and the Output column are the values for your variable. Put the following values into the columns. They depict how the new sales manager was able to win new customer right when hired but winning new ones became harder over time.



Next, give values for the Hours per person per month. We know that at the start people worked on average 140 hours per month. Around month seven staff began slowly to work longer hours and by the start of the second year people were working on average 150 hours per month.

Now fill in also the units and documentation for the variables. Note that you can at any point change the variable type to data from the equations window:

The screenshot shows a window titled "Edit: Uudet asiakkaat per kuukausi". It contains a "Variable Information" section with the following fields:

- Name: Uudet asiakkaat per kuukausi
- Type: Data (selected in a dropdown)
- Sub-Type: Normal (selected in a dropdown)
- Units: asiakasta/kuukausi
- Check Units: ☐ (unchecked)
- Supplementary: ☐ (unchecked)
- Group: .palveluyritys versio3
- Min: (empty)
- Max: (empty)

Below the "Variable Information" section is an "Equations" section, which is currently empty.

With the reference mode tool you can also bring in data for other variables. Then you can easily compare the simulated values against the actual data.

With the tutorial text you will also find the file COMPLETE DATA.vdf which contains reference data for some other relevant variable. Now you are ready to start analyzing your first model.

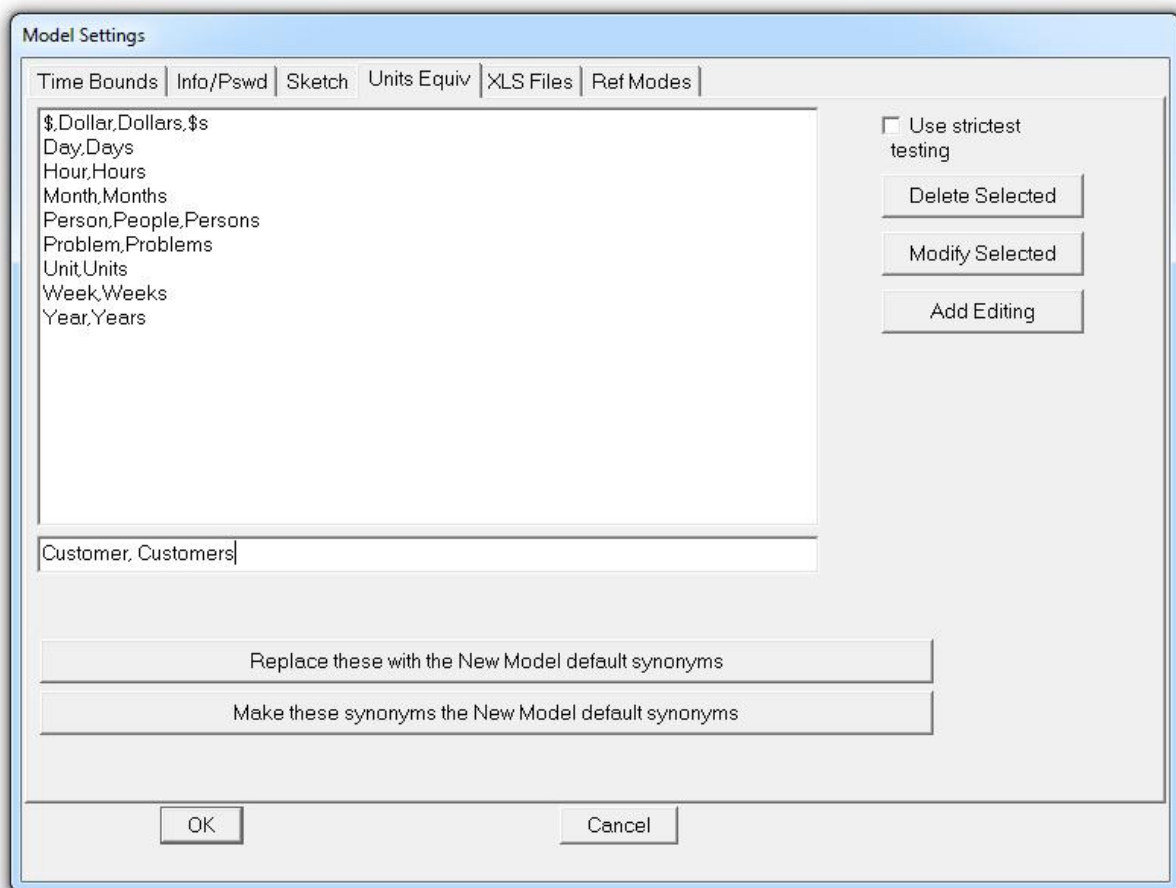
6. Analyzing model structures

Vensim contains multiple tools to analyze your model structure. The most important one is the unit check. But before we can test the units we need to tell Vensim which units are the same (e.g. just a plural or an abbreviation of another unit). You can edit the unit equivalents by going to Model then Settings and selecting the Units Equiv tab. Input your equivalence to the text field and click Add Editing.

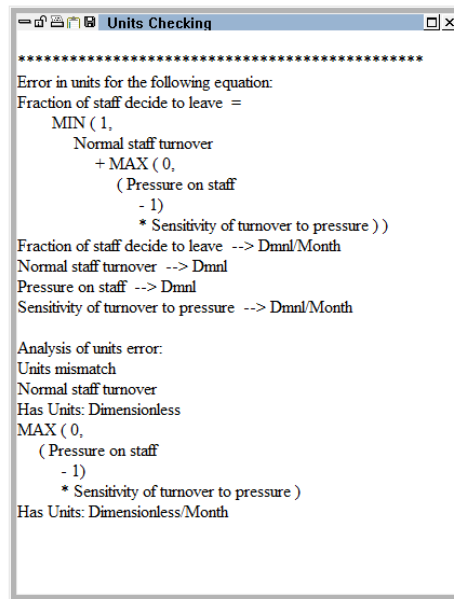
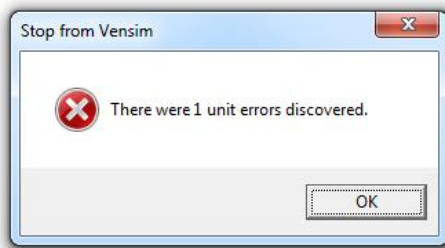
Add the following equivalence:

problem, problems
customer, customers

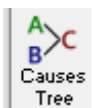
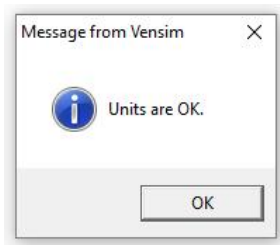
Your window should look like this:



The next step is to test your units. To run the unit test you can go Model tab and select Unit Check or press Ctrl+u. The most important part of any system dynamics equation is unit consistency. This means that the left side of the equation needs to match the right side of the equation in units. For example if you followed the instructions in this tutorial you should get one error from the Unit Check.

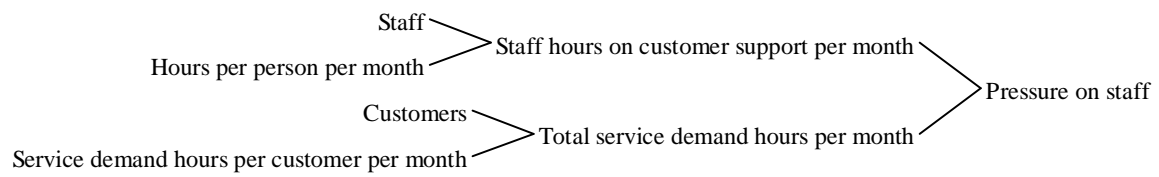


I have lead you astray on purpose so that we might test the tools. From the error message you will see that the units in the variable Fraction of staff decide to leave do not match with the units in its equation. The Normal staff turnover in dimensionless (Dmnl) even though it should say the fractions of people that decide to leave over a certain time period. So its units should be Dmnl/Month. Correct the units and rerun the unit check. Now everything should be Ok:

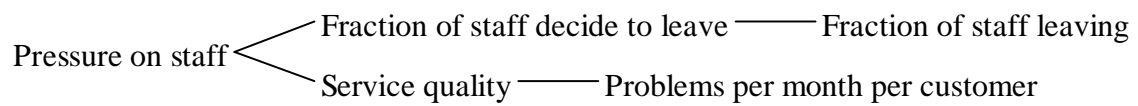


Vensim offers a variety of other useful tools, for instance, the (Causes Tree) and (Uses Tree) tools show all the factors that affect a variable and all the factors that that variable affects. To use these tools you first need to select a variable. Press the Move/size button then select Pressure on staff. That variable is now active on your workbench, you'll see that from the Vensims top bar where it read all the way in the end Var: Pressure on staff. Now click on the causes and uses trees.

Causes:



Uses:

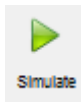


The (Loops) tool lets you view all the feedback loops that are formed through that variable.
The (Document) tool lets you generate lists of you model variables, their equations, comments etc.



7. Model simulation

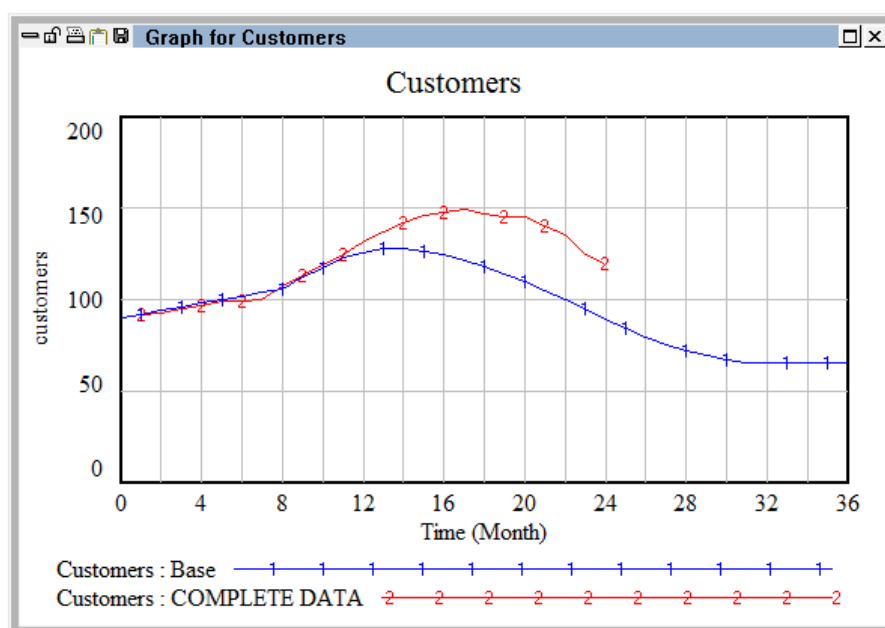
There are other tools to analyze the behavior of your model. Before you can use those tool you, however, need to simulate your model. To run a simulation you need to give a name for your simulation run. Vensim automatically gives a name Current which is displayed on the top bar. Often it is useful to name your simulations in a descriptive way. With your first simulation you will create a base case to compare your next simulations against so a suitable name could be Base. Now change the simulation run name to Base:



To run a simulation press the (Simulate) button. Vensim will calculate a value for each variable at each time step.

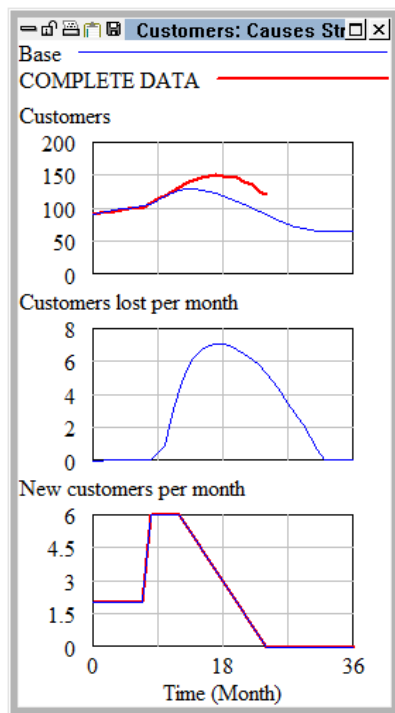


Now you can look at the simulation results. The (Graph) tool is one that your will use very often. To create a graph from the amount of customers the company has, select the Customers variable. You will see how the simulated Base case defers from the actual data and how they developed over time. The simulated behavior of customers depends on the model parameters you chose. If you followed the example values given your graph should look like this:





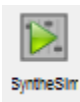
Other tools to look at the behavior are e.g. the Causes Strip. It will show the selected variable and the variables that affecting it, each divided to its own graph:



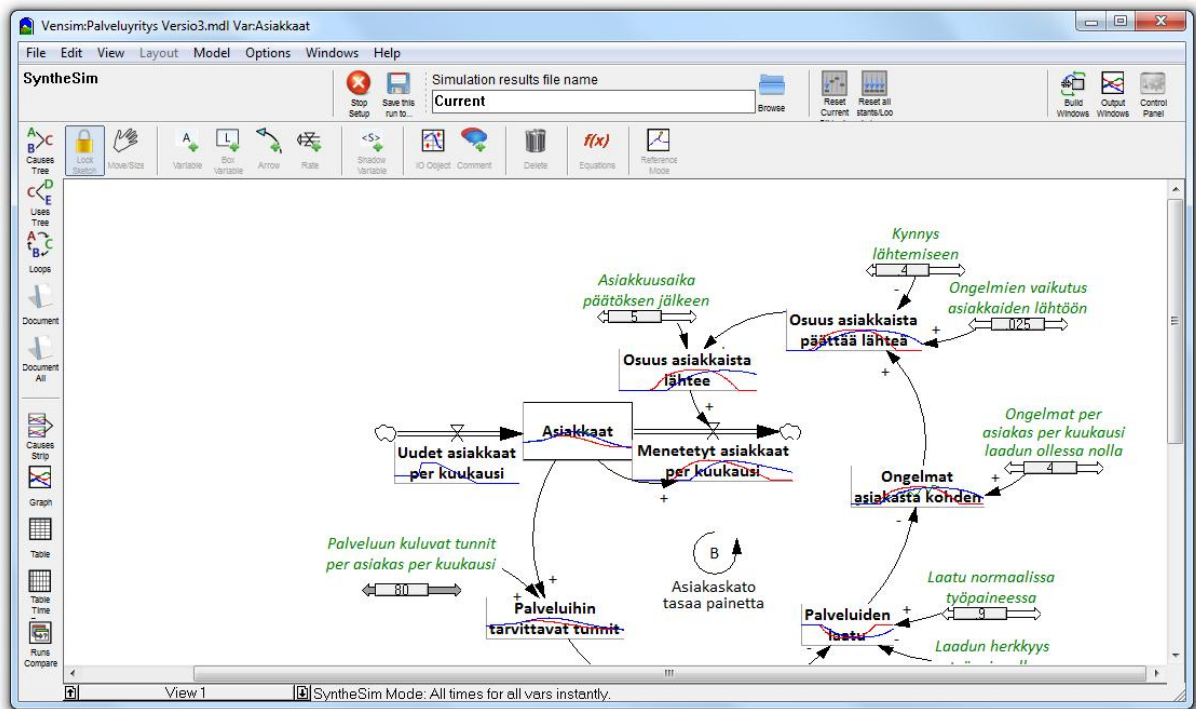
You can also look at the output in a table format by pressing the (Table) tool. It is useful when you want to look at the exact values.



In the newest Vensim you can also compare the differences between two different simulations. It will show if you, for instance, used different parameter values to get the different simulations.



Next try to get the model simulation to match the data by varying the parameter values. The easiest way to do that in Vensim PLE is to use the SyntheSim mode. To put on the mode press the SyntheSim button in the top corner. After you have done each parameter (constant variable) will have a slider under it and each other variable will have a small graph over it. Now, by changing the sliders try different parameter values, Vensim will automatically constantly run simulations as you change the sliders and make changes to the parameter values. With small models like this the simulations are almost instantaneous.



If you want to see some of graphs in more detail you can create a larger graph with the IO Object tool. Press the (IO Object) tool and then press on an empty area where you would like to place the graph. The following window will appear:

Input Output Object settings

Input Output Object settings

Object Type

☐ Input Slider ☒ Output Workbench Tool ☐ Output Custom Graph

Variable name.

Choose:

Asiakkaat

Slider Settings

Ranging from to with increment Units: asiakasta ☒ Label with varname

Custom Graph or Analysis Tool for Output

Select the (Output Workbench) tool and the variable of your choice. Select for example Customers which you will find under stocks (Level...) button. At the bottom select the output type Graph. Now you have created a graph in the area you selected. You can move and resize the graph by using the Move/Size tool. Add also graphs for the Problems per customer and Staff variables. Problems per customer you can find under the (Auxiliary...) button.

Following these graphs use the SyntheSim mode to find parameter values that would make the model behave closely to the actual data.

Resources

Rahmandad, H. ja Sterman, J. (2012), Reporting guidelines for simulation-based research in social sciences. *Syst. Dyn. Rev.*, 28: 396–411. doi: 10.1002/sdr.1481

Repenning, N. ja Sterman, J. (2003), *Formulating Models of Simple Systems Using Vensim PLE*. MIT Sloan School of Management.

Warren, K. (2014), Agile SD: fast, effective, reliable. International Conference of the System Dynamics Society.