

A Business Culture of Reflection

Part 3

Quantitative Optimization and Risk Analysis
of Projects and Processes

by Kai Neumann



About

This paper describes a quantitative model about the start-up of an enterprise that develops an electric vehicle (E-car) with plans to then manufacture and sell this car. It is only a rough model that shows the general methodology of quantitative modeling using the iMODELER's (by Consideo: www.consideo.com) process and project factors and its features which allow for analysis of likelihoods of developments (e.g. for risk management or project management of complex projects) and optimization of parameters (e.g. for Operations Research or Six Sigma with iM Optimizer). In fact, it provides a wide range of applications, including financial planning, consideration of the Theory of Constraints, corporate forecasting and many more.

This paper comes in a series of papers for "A Business Culture of Reflection" in line with:

1. Systemic Strategy Development including Risk and SWOT analysis
2. Systemic Product Development featuring Idealized System Design
3. Quantitative Optimization and Risk Analysis of Projects and Processes
4. Systemic Project Management
5. Systemic Management and Organizational Development featuring KNOW-WHY Method

The series describes the application of the software the iMODELER (both the freeware and the full version) using the example of a start-up enterprise (either newly founded or a profit center within a company) that plans to become successful by developing, manufacturing and selling a revolutionary electric car.

The business culture of reflection captures the idea that any enterprise could leverage the collective potential of its employees by collaboratively looking at the interconnections of all the existing arguments within the enterprise and from the stakeholders outside. Not only the all-too-common phenomenon of endless and repeated meetings with little progress but also that of reluctant or simply unfounded decision-making can be tackled with this change of corporate culture.

The iMODELER (www.imodeler.info), being probably the most important app in the world, allows for the visualization and analysis of interconnections behind any challenge. It works bionically; mimicking yet extending our brain power to capture thousands of arguments with the possibilities of either modeling them qualitatively (comparable to Fuzzy Cognitive Maps) using so-called Insight Matrices to see what would be comparably the most effective measure or risk, or quantitatively (based on System Dynamics and more), to simulate the extent and likelihood of possible developments. The iMODELER comes with a number of unique features like process factors to identify constraints (Theory of Constraints), the iM Optimizer (Operations Research), the iM Data Manager (to integrate data e.g. from Excel), extremely powerful collaborative modeling, sophisticated simulation game functionality, and KNOW-WHY.NET - the platform for building collective intelligence.

Projects and strategies fail if crucial factors are not considered

or their effects are underestimated

The major difference compared to other tools is that it is not a mere visualization such as mind mapping or concept mapping. However, it is also not overly complicated and yet still avoids mere simple linear depictions of processes. Rather, the iMODELER allows for direct translation (with no need to learn a complicated business modeling notation) of any kind of argument and the consideration of any linear or non-linear, dynamic phenomena that we find in the complexity of the real world, where often soft factors cause major effects by triggering reinforcing feedback loops of virtuous or vicious cycles. Arguments are simply translated into the intuitive notation of “more of one factor leads directly to more/less of another factor”, using factors and connections that either depict a - or a +.

You can use the iMODELER to reflect on business issues such as those described in this series or indeed for any other challenge in which you have to consider the interplay of several factors (hint: nearly all challenges are multifactorial). Whether it is a personal challenge like family topics, vacation or career planning, or societal goals like the transition of our society towards a better world, the iMODELER can help. The long list of possible applications includes horizon scanning, change management, six sigma, asset allocation, corporate foresight, etc..

Note: the models of this series are fictitious generalizations designed to nevertheless provide instruction through useful examples. For some models you will find a list of further details in the model’s description (Menu ... Model properties).

Here the links to the model and its variants:

https://www.know-why.net/model/COfweXMDN6IXVjBu_L73gRw

The version using iM Optimizer:

<http://www.imodeler.info/ro?key=Cv-vW-0iM4jA9XyEX5IUQcw>

The version using Monte Carlo simulations:

<http://www.imodeler.info/ro?key=C3e5iEZDsZINOLEwDCa786w>

The business case

The aim of this model is to quantitatively simulate the project of developing an electric vehicle, setting up a factory, and manufacturing and selling the car to understand the relative financial and other resources as inputs and outputs. .

It thus features both project factors and process factors that come as a unique feature of the iMODELER. Initially, the model shows the development as planned by the management. A copy of the model will then show a range of possible developments by exchanging fixed parameters for a likelihood of their values, e.g. the time it takes to set up the factory or get the mandatory certificates. From these variations a Monte Carlo simulation will then show the likelihood of certain developments and thus their associated risks and potentials.

A third application of the model is the optimization of parameters, namely allocated resources to the project and the process. In our example the iM Optimizer allows one to identify for a given demand the optimal number of engineers and factory workers to maximize the enterprise's profit.

As was stated in the previous section, the model is just a rough, generalized description of a potential reality. A more in-depth simulation could easily include many more details such as the optimization of the price of the car with its effect on demand, the different rounds of financing that could be related to different milestones, the economies of scale that come with different phases of demand once the car has entered the market, or of course all the physical components and their associated development and processes of assembly.

How to start

There are two ways in which one can start this kind of quantitative model, chosen depending on whether the model will describe an existing arrangement in reality or go beyond and explore new possible arrangements. In other words, either you already know all the steps (project steps and process steps) that need to be taken and you can descriptively model from scratch including all dedicated Process, Project, Milestone, and Resource factors, or you first have to exploratively sketch the project and the process to later add the

more detailed factors.

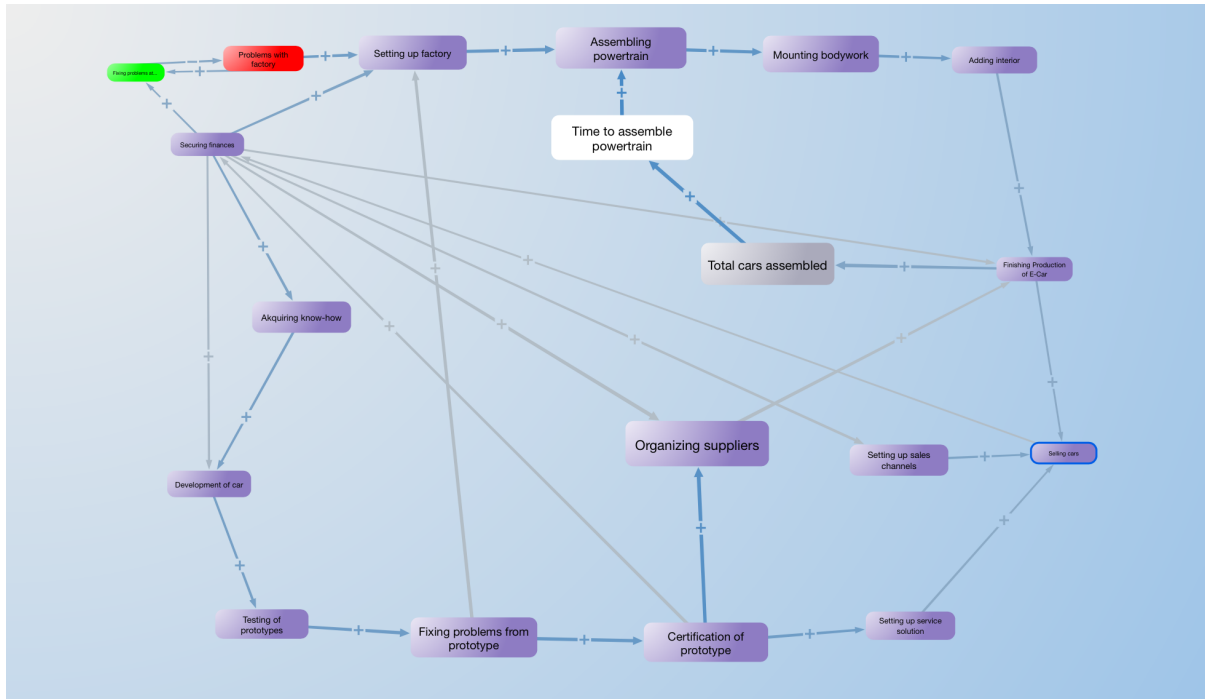


Fig. 1: A first explorative sketch of the model to be quantified later

Modeling the project and the process

As described at the beginning, the iMODELER does not require the use of any particular modeling notation. Using Process and Project factors, however, you have to follow some rules, as a Project factor needs to be connected with a Milestone factor and a Process factor with a Level Resource factor. Resource and Level Resource factors as well as Milestone factors are then connected to both Process and Project factors. The iMODELER's help feature will explain and guide you if changes are needed. Normal factors

are used for any kind of additional calculation or serve as parameters for the processes.

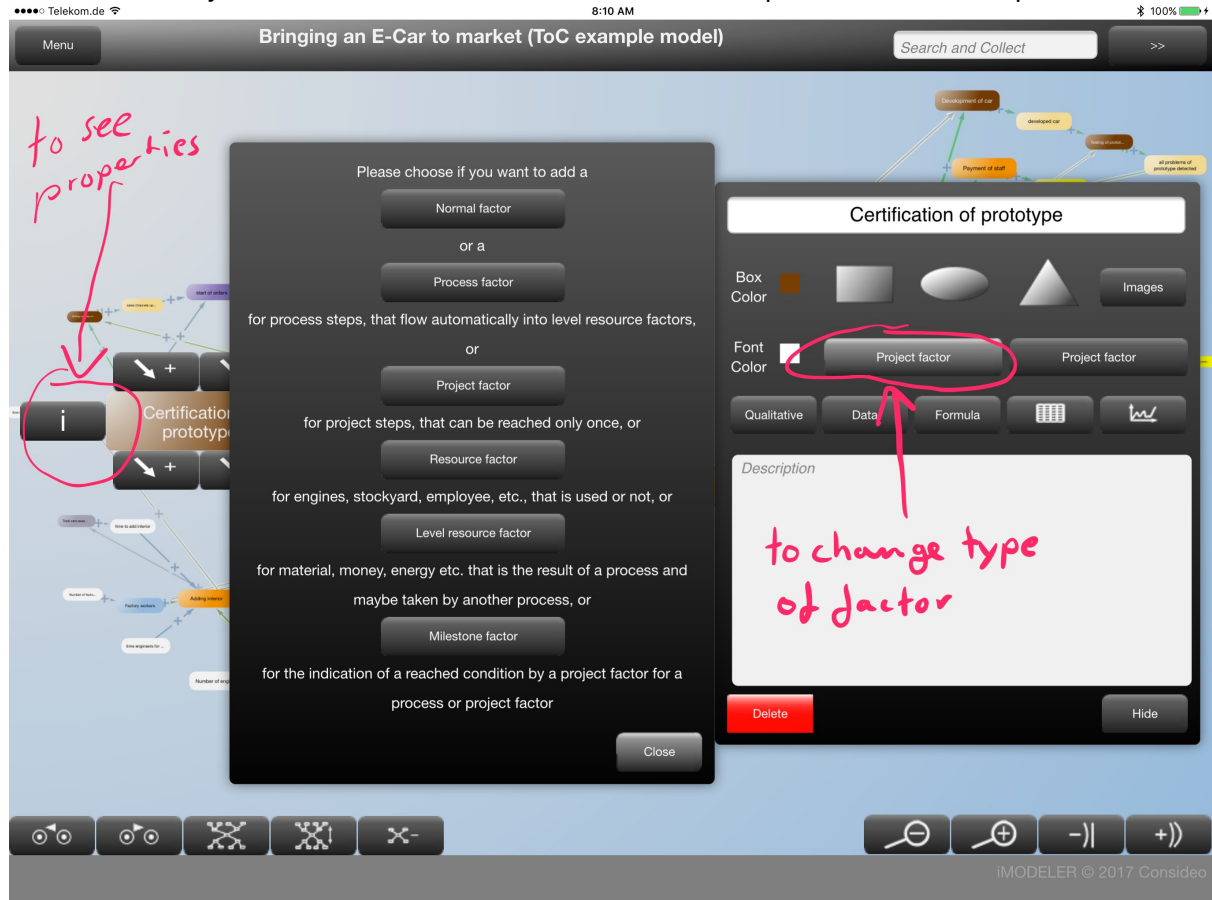


Fig. 2: Changing the type of factor to model processes and projects

To start a model you simply go to www.imodeler.info (with or without an account) to start a new model.

For quantitative models I recommend that you define the time span and unit (Menu ... Model properties) you want to use before building the model. Note that you have to use the smallest time unit that any process or project step takes as you cannot define a duration of something with a value smaller than 1. For this model the time unit is “weeks” and the unit for cars is “10 cars”, as the shortest process to be modeled takes a week for 10 cars. Of course, choosing days would have been an alternative but would have required integrating a calendar in order to account for weekends. These are crucial considerations and form part of the modeling process.

Rename the title and click on the initial factor called “target” to edit its properties, starting by also renaming it. You then can use the buttons above or below a factor to define incoming or outgoing connections to new (or later to existing) factors in order to define the chain of project and process steps as well as the needed resources and parameters for each step.

The parameters could be defined within the formulas but the use of explicit factors allows you to easily and explicitly alter them in scenarios. Figure 3 shows a project step with its parameters (in white). It also shows the iMODELER’s features for switching the perspective in order to view the model from any selected factor’s incoming and outgoing connections and for reducing the level of connections that is shown - in this case just one level of

connections from the perspective of the factor “Development of car”. This is particularly useful with large models which can quickly become visually overwhelming.

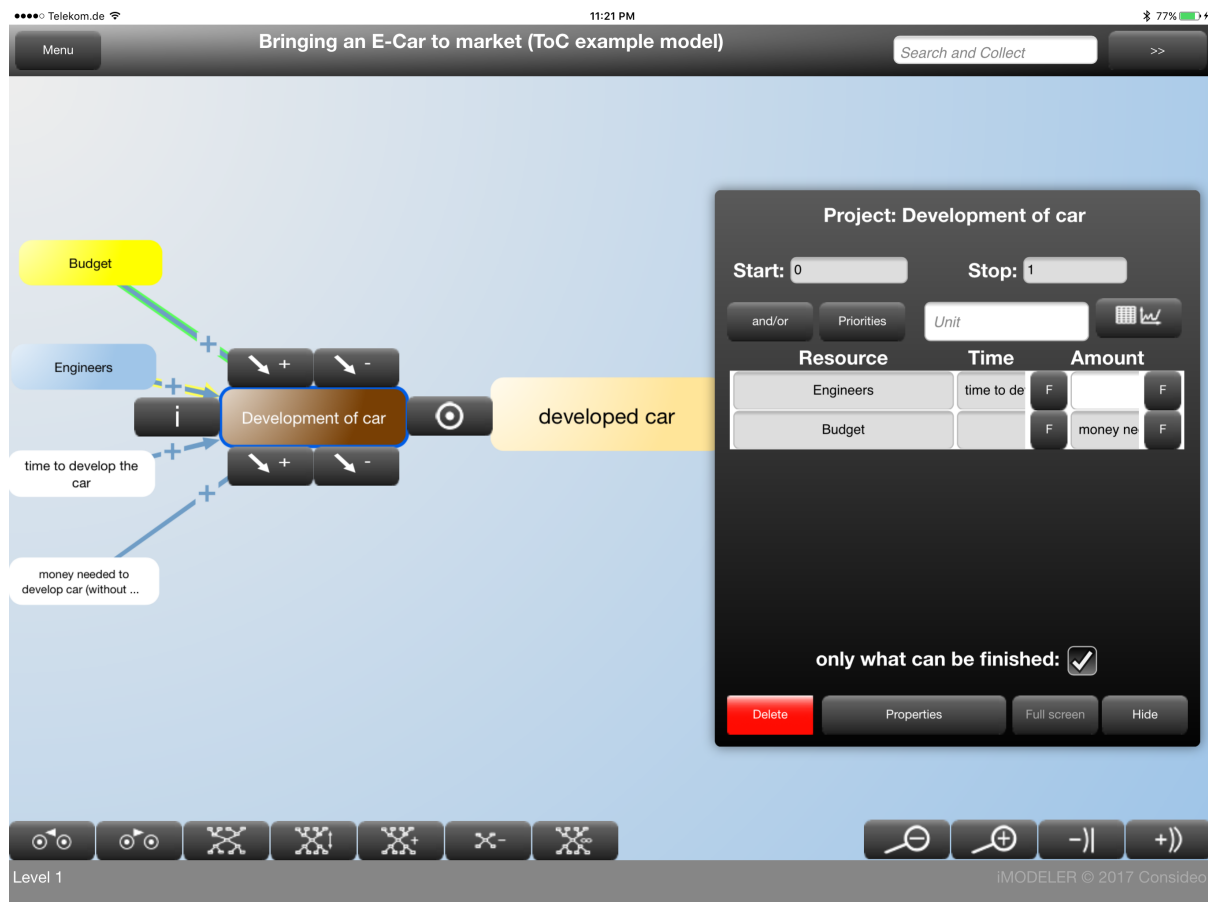


Fig.3: The model from the perspective of factor “Development of car” showing just one level of connections. The brown factors are project steps, light yellow are milestones, blue are resources, yellow ones the so-called level resources, and white are parameters. Parameters are used within formulas for project steps.

As depicted by Figure 3, each project step (and process step accordingly) is influenced by Resources (blue), Level Resources (yellow) and parameters (white) which in turn exert influence on either a Milestone (light yellow) in the case of Project factors or a Level Resource (yellow) in the case of Process factors.

If you click on “Formula” the Resource factors will be shown in a list, which allows you to define “Time” and “Amount”, either by direct values or via the “F” button and thereby through values from connected normal factors (the white parameters in our case). For a Resource factor you can either define the amount of resources that are needed to process one unit or the milestone of a project step. You could also leave the field empty implying that more resources would accordingly lead to faster processing of one unit without specifying thresholds. Time defines either the time the given number of resources need to process one unit or the time one resource would need, therefore creating the model assumption that more resources would be proportionally faster..

For the development of the car for example we could set the time field at 26 weeks for the resource “Engineers” and leave the amount field empty. That would mean that one engineer would need 26 weeks while two engineers would need just 13 weeks. However, if we were to set the amount field at two engineers, then two engineers would need 26 weeks as it is

still just one car that needs to be developed and any additional engineer wouldn't be used. Sound tricky? Have a look at the models and practice building your own, you will see that it is both simple and powerful.

Start and Stop values (still Figure 3) allow Process factors especially to define until what amount of units for the following Level Resource factor the process is allowed to run. This could be used for example to define a storage capacity at which no further units can be created. The Start value, then, defines at what value of the Level Resource the process should start again.

The and/or and the Priorities buttons shown in Figure 3 I haven't explained yet. Using and/or allows you to combine resources or set them to be used alternatively.

The Priorities button allows for creation of an order in which you want the processes to run although the actual order will nevertheless be defined by the availability of resources. If you set the processes to run from the beginning to the end, each process step will run until its stop criteria. If you set the processes to run from the end to the beginning, automatically the first step would start as all the following steps would have no predecessor level resources available. However, the first available unit would then be used by the following steps in order to get a result at the end of the chain as soon as possible. In other words, the steps build upon previous outputs. For this example model I have set it up so that each car finishes before the next car is started.

The "only what can be finished" check box prevents a process step from starting if there are not enough resources available to finish the unit. If it has started it gets a high priority to be finished in the following time step(s).

A feature I haven't used with this model is the possibility to define the costs per unit of resources. It allows for a powerful simulation of associated costs, whether they are known and described by the model inputs or potential savings want to be explored through scenarios.

The project to develop the car and set up the factory

Basically, this model is a chain of project steps to develop the prototype for an electric vehicle and set up a factory to manufacture the car, followed by the chain of process steps of its production. If you change the type of factor from a factor's properties (click on the "" after you have clicked on a factor) from normal to process, project, resource, milestone or level resource, the factor will automatically get the corresponding category. In addition you can assign any category to any factor and easily define different colors or even shapes for certain types of factors. Once you have created categories you can use Menu... Filter/Cluster to display just a certain type of factor(s). Figure 4 shows just the project (brown) and the process (orange) steps of the model, as all others have been visually excluded.

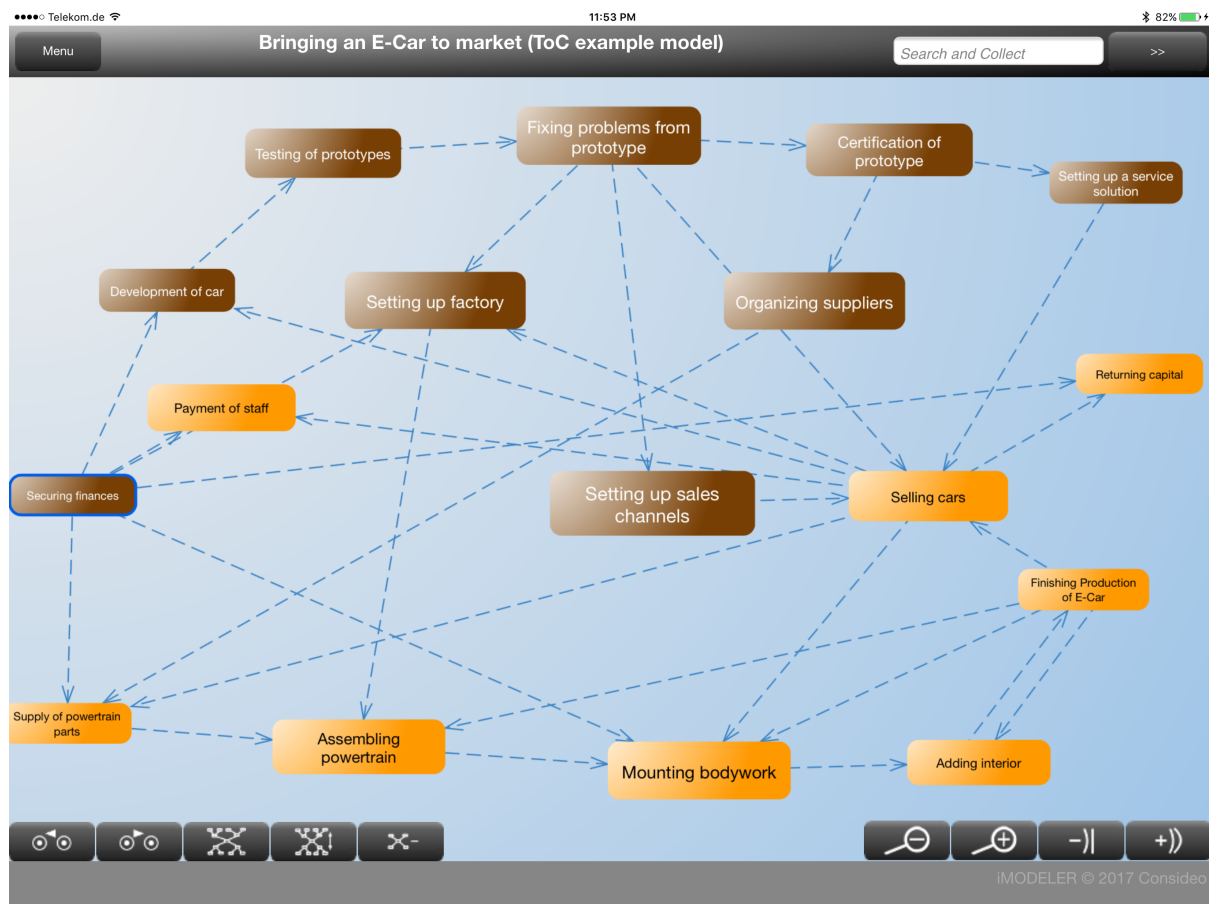


Fig. 4: Using Menu...Filter/Cluster to just show the project and process factors

The project steps include securing finances, development of the car, testing of the prototypes etc, as well as setting up the factory, organizing suppliers, setting up a service solution and setting up sales channels.

The process steps other than paying the staff are the assembling of the powertrain with the supply of powertrain parts followed by mounting of bodywork and the addition of the interior. The final step is the finishing of the E-Car (including its testing) in order to have it market-ready in order to sell. Subsequently, the capital invested at the beginning of the process is returned.

To follow the chain it is best to show only one or two levels of connections and then switch perspectives from one project or process factor to another. In Figure 5 you see the model

from the perspective of factor “Mounting bodywork” (indicated by the blue frame around the factor). From there you could navigate back along the chain switching to “Assembling powertrain” or advance forward in the chain by clicking on “Adding interior” and then selecting the button to the right of the factor.

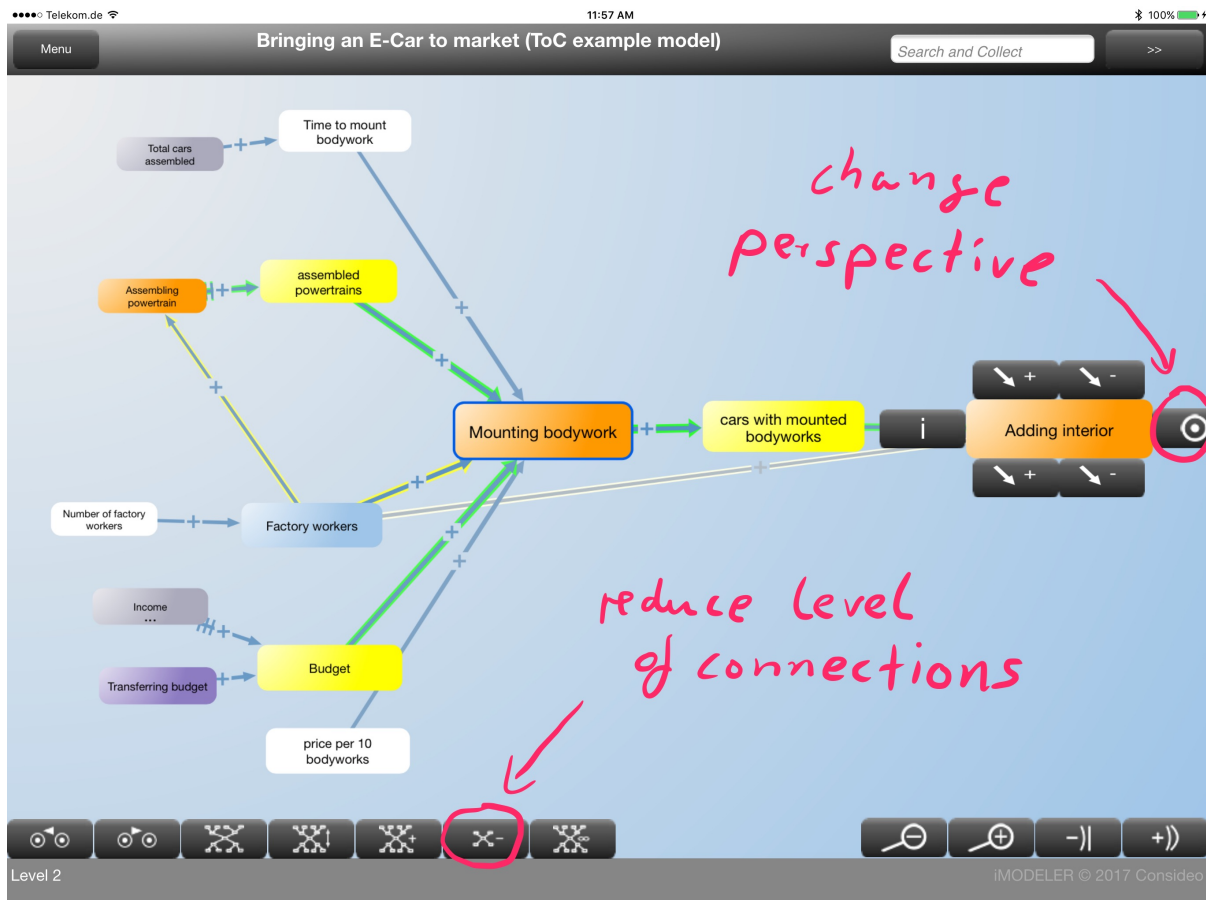


Fig. 5: Switching perspectives to navigate along a chain of project or process steps

You can use Menu ... Filter to exclude a category of factors to reduce how many are visible such as, in this case, parameters.

Running simulations

Once you are done defining parameters and formulas you can check if something is missing or wrong using Menu ... Quantitative validation.

While for normal factors you can define which factor's values you want to compare with the current factor, for Process, Project, Resource and all other factors the cockpit is predefined. Figure 6 shows for the factor "Assembling powertrain" when and to what extent the process is running. Below that additional graphs show the used resources and the resulting level resource. Each graph shows the remaining availability of a resource and the extent to which it is used for the current process.

Grey backgrounds indicate constraints (Curious? For more information see Goldratt's Theory of Constraints featured in his book "The Goal"), showing to what extent at specific points in time an increase of this resource would increase the outcome. Of course, reaching the stop criteria is also indicated and operates as a kind of constraint.

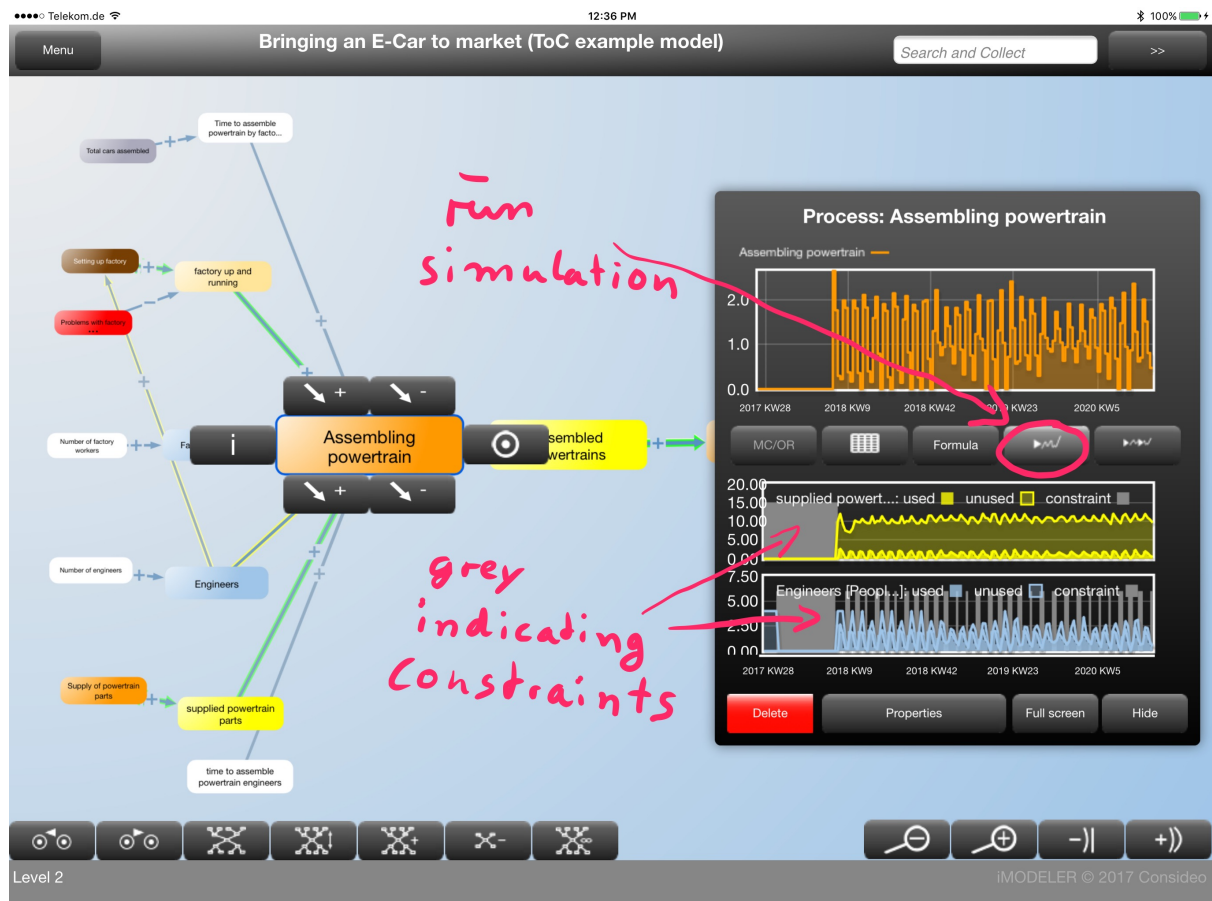


Fig. 6: Simulation results (you just click from factor to factor to see results of each)

The full screen view of the results from a simulation as shown in Figure 7 allows you to define a list with endogenous factors (not influenced by other model factors, e.g. parameters in this model) so you can easily change their values and see with a new run of the simulation how the results would change. Via the Scenario button you can save sets of parameters as scenarios.

Figure 7 shows the development of the budget. First capital needs to be acquired and then it is used for the development of the car and the factory. Once income from selling cars is generated the capital is returned to the investors in order to end up with a big surplus.

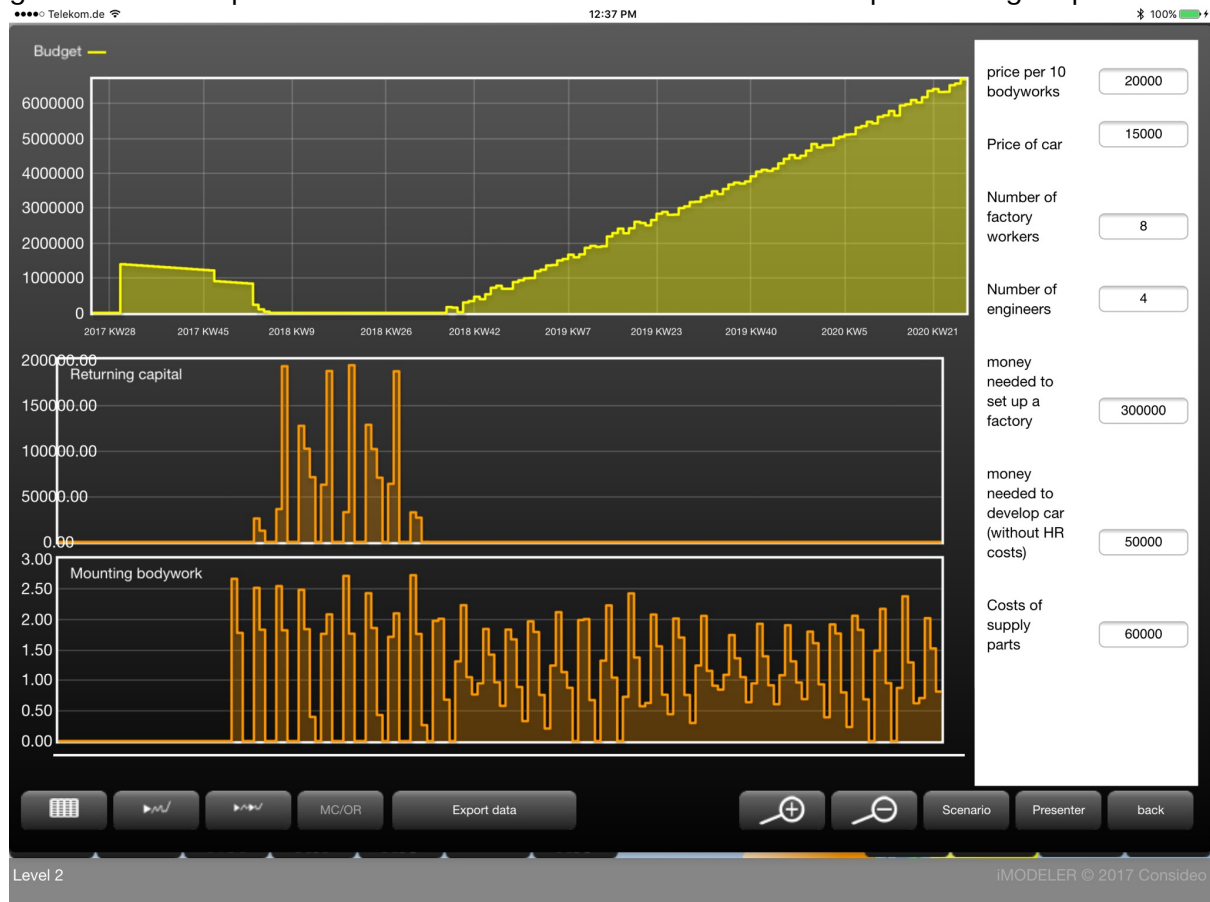


Fig. 7: Full screen view of results that enables you to set a list of parameters

Although the model is just a small rough example it already features some nice results, e.g. the stock of orders that is generated from marketing and then reduced by selling cars, as shown by Figure 8. When modeling a real case I would add a lot of dynamics around the number of orders dependent on the price of the car, the waiting time for delivery, different configurations that come with a different price and attractiveness, as well as the differing relative times their development would take. Following on that point, it may also be wise to add the likelihood of other vendors entering the market with similar concepts.

Figure 9 shows how the time parameter for the processes is reduced over time as the factory becomes more efficient and improves processing after the first 100 units. This is one type of dynamic that a typical process modeling tool cannot show. In order to incorporate such a learning curve the iMODELER offers a relation editor that allows you to define the dependence of one factor's values on those of other connected factors.

So, with this we can conclude the first part of this paper in which you were shown how to model a given plan and how to change its parameters to see different scenarios. Manually changing parameters to see how conditions improve or worsen is called Soft Operations Research (Soft OR). Next I will Hard Operations Research (Hard OR) with the use of algorithms.

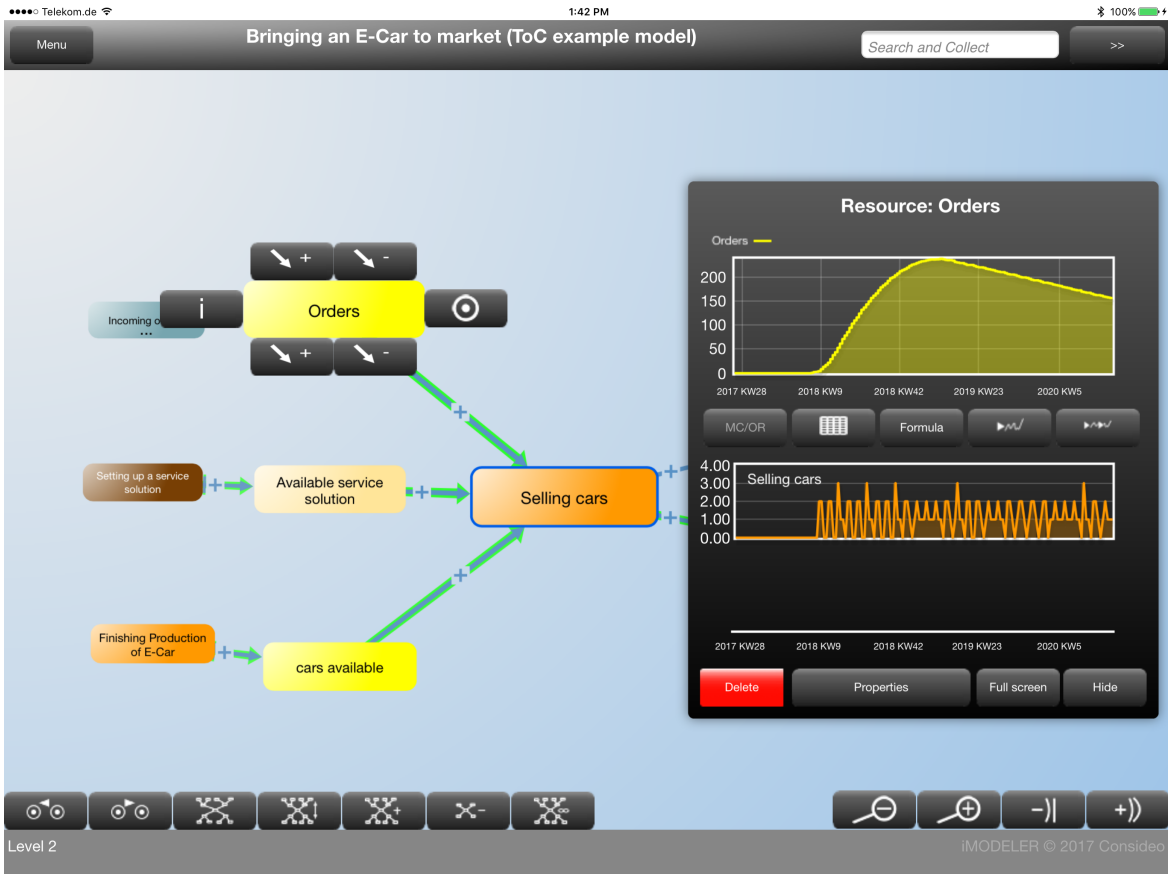


Fig. 8: The increase and decrease of the stock of orders

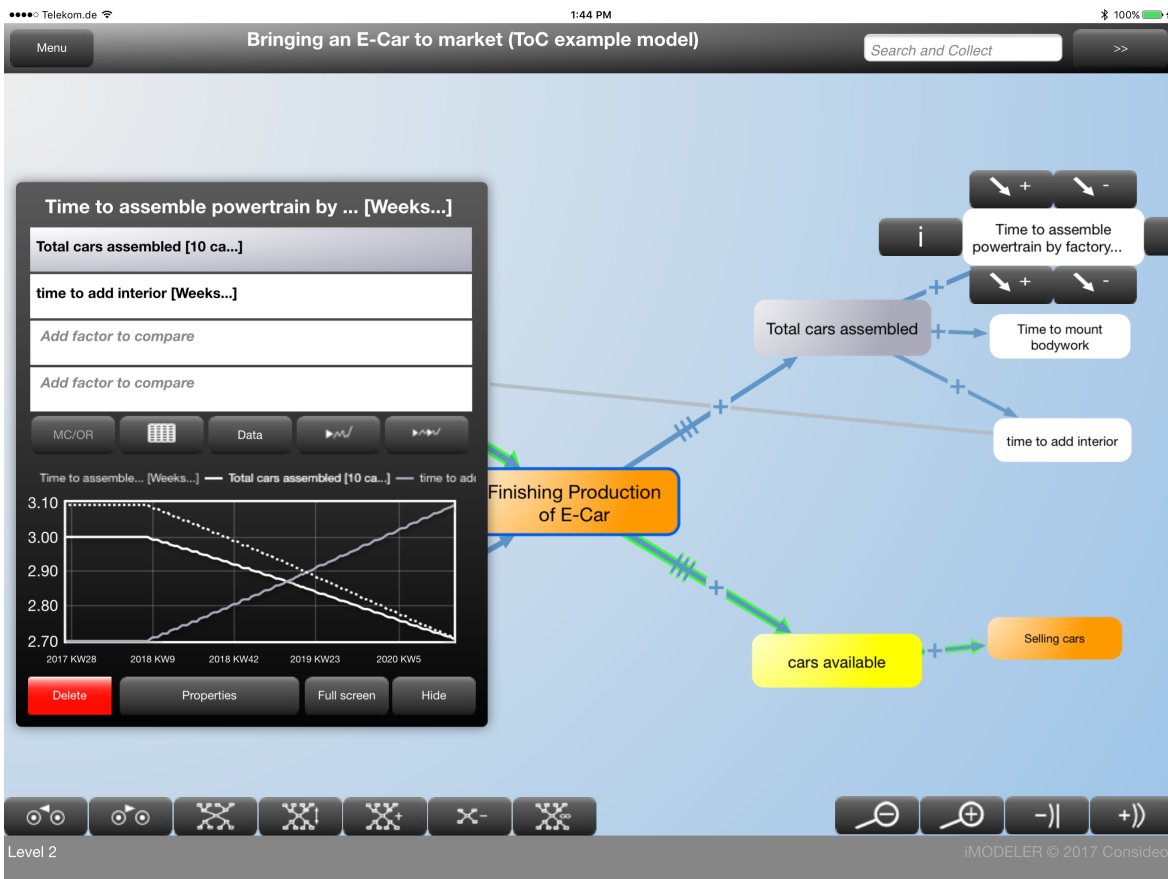


Fig. 9: The learning curve showing how time parameters can be reduced over time

The iM Optimizer to find optimal parameters

Instead of fixed values for all parameters you may use the `range()` function for factors that represent decisions you have to make. With the `range()` function you will run a set of simulations with all the different values you have defined in the function's notation. If you have multiple `range()` functions then all the possible combinations of values from the different `range()` functions in your model will be run.

Once you have created a `range()` function the iM Optimizer will be offered with the start of a simulation. Figure 10 shows the interface of the iM Optimizer. It shows a list of factors that have a `range()` function, e.g. "Number of engineers" that will try 10 values from 2 to 20, step size 2 (2, 4, 6, 8, ...18, 20). Combined with the other `range()` values there would be 7,000 possible combinations. However, the web version of the iMODELER will try to increase the step size of the `range()` functions in order to lower the number of combinations. (Technically, it will then try to improve the results with combinations around the optimal values to ensure that the increased step size has not resulted in missing the optimal combination.)

In addition you can define side conditions, although the feature wasn't necessary for this model. These could be useful for setting constraints on potentially unrealistic values resulting from combinations of `range()` functions. You can also define a target, in this case the maximization of the factor "Budget" at the last time step.

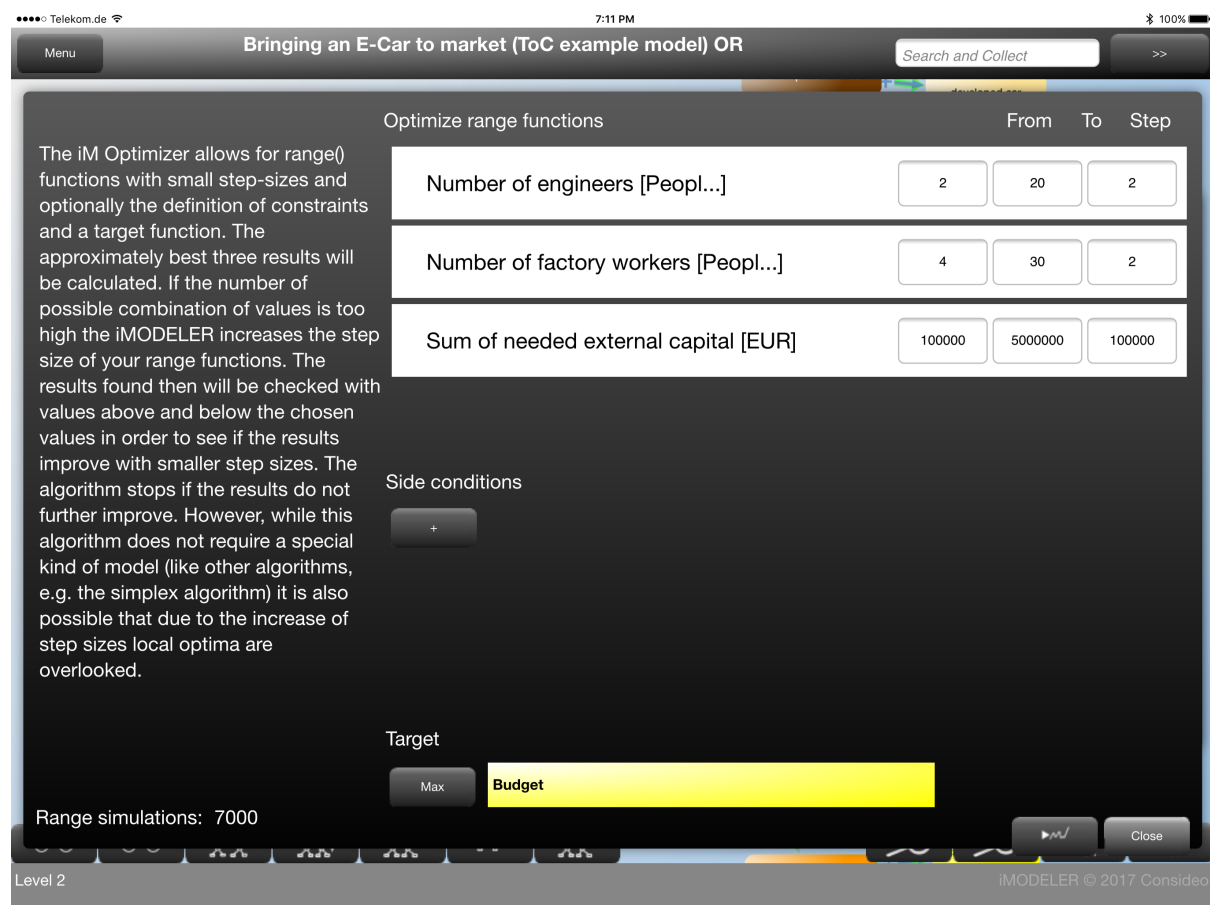


Fig. 10: iM Optimizer offered once you have used `range()` functions

The result is a set of simulation runs that are shown by default in a spaghetti plot (you can alter the kind of diagram by repeatedly clicking on the diagram button). Figure 11 shows the

result and already highlights (red) the optimal run. You can click on any other curve to activate another scenario and the corresponding values will then be shown within any factor of the model.

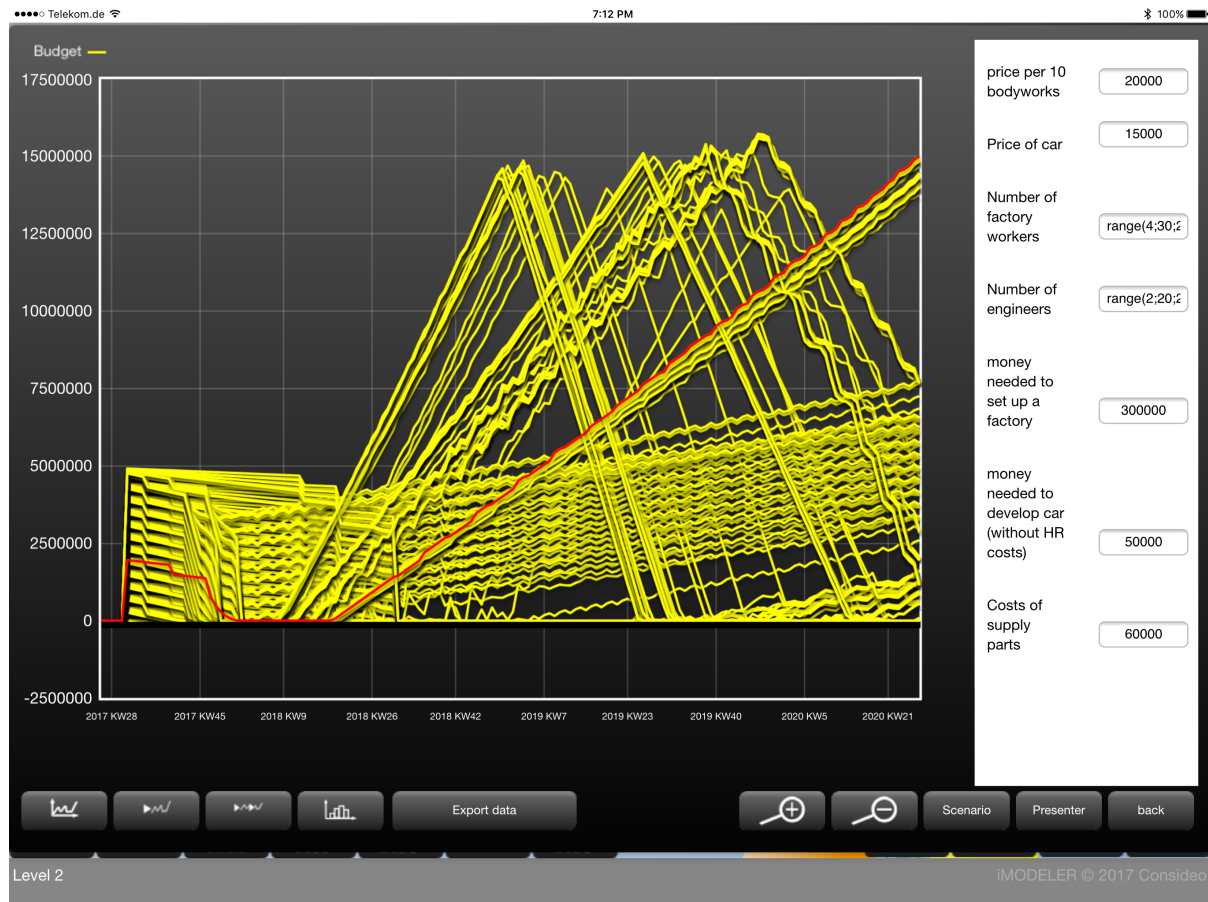


Fig. 11: A spaghetti plot of all the possible model run combinations with one selected (red) scenario

To see which values for the range() factors led to a scenario you can either go directly to those factors to see their result or choose any normal factor to show as additional values those factors with a range() function. Figure 12 shows that the factor “Need for capital” is chosen to show the results for the range() values. It seems the enterprise would reach a maximum profit (budget) if it started with 2.1 million of external capital, 12 factory workers and 10 engineers.

Another approach to inquiry would be to manually look along the chain of process steps for unused stocks or resources or for constraints as shown in the previous section.

Remember, this is a very small model lacking significant details. Usually, you would test the values behind other scenarios as well in order to understand the reason for the optimal results. In this case our optimal result is the combination that manages to serve all the orders until the end of the simulation run while using the least amount of resources. Using too little resources would mean orders are left unfilled and too many would mean that resources are unused or cars are built that cannot be sold.

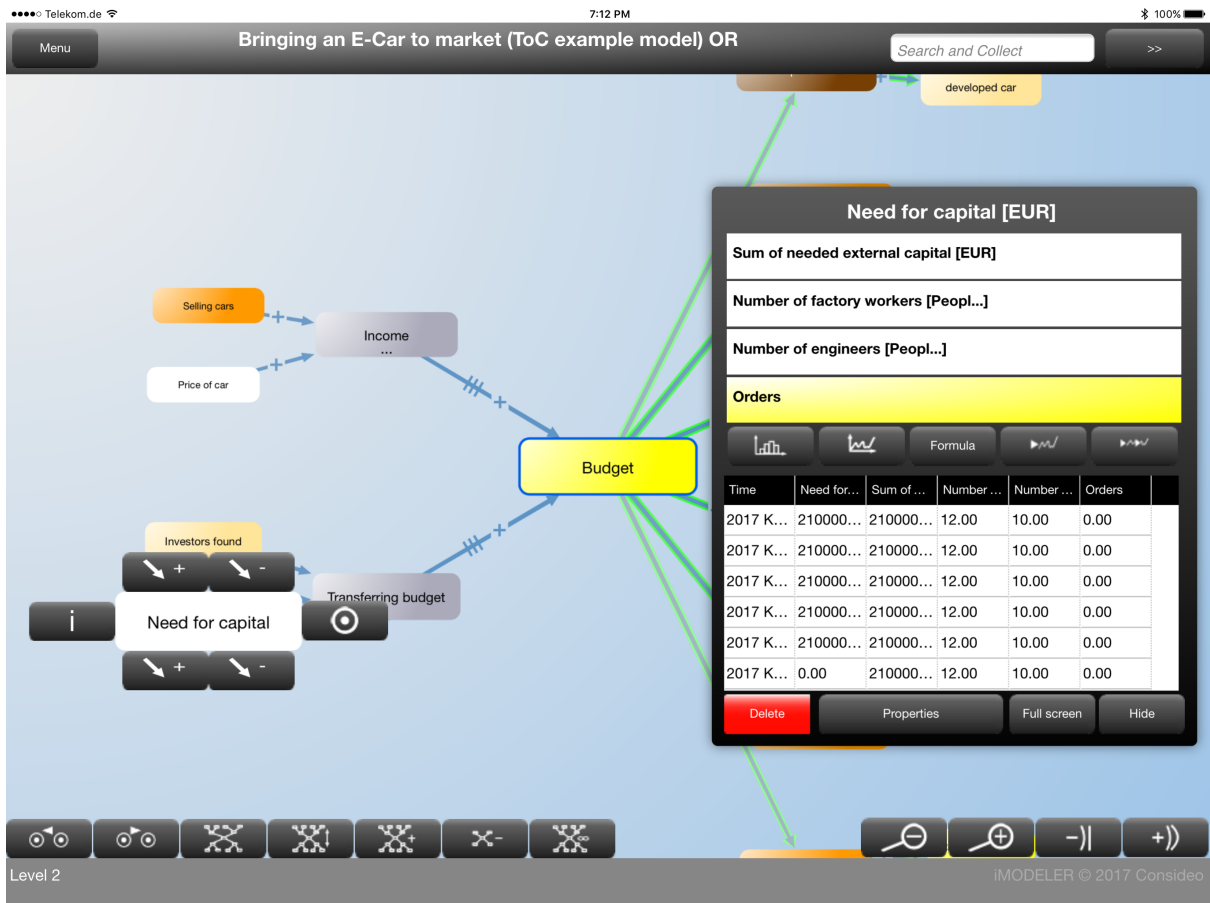


Fig. 12: A randomly chosen factor to show the range values for the selected scenario

Monte Carlo simulations to identify and evaluate risks

So far the model has used fixed assumptions on various parameters that in reality couldn't be exactly predicted, e.g. the time the different project steps take, the number of orders the enterprise can expect, or the occurrence of problems with the factory. By exchanging fixed values with the functions `likelihood()`, `random()`, or `gaussrandom()` (Figure 13) you can define likelihoods for certain values. When using one of these functions, the iMODELER will automatically ask you to run a Monte Carlo simulation; a set of simulation runs each with new randomly chosen values. The result of the Monte Carlo simulation is a spaghetti plot (Figure 14) of all the scenarios and a histogram (Figure 15) that shows the likelihoods of different outcomes.

Combining dynamic interconnections with likelihoods of occurrences allows you to get a more realistic picture of possible developments you can prepare for. For example, results could show not only potential problems but also their relative likelihood and/or duration.

Though such a simulation is far more realistic than one without likelihoods, it is still just a model with no guarantee that reality will behave as predicted. It just helps us to be better prepared. It is also worth remembering that even if we manage to validate a model with data from the past (e.g. using the iMODELER Data Manager) we still cannot be sure that in the future the parameters will remain the same or no other additional factors come into play. Thus a model can never be verified - just falsified.

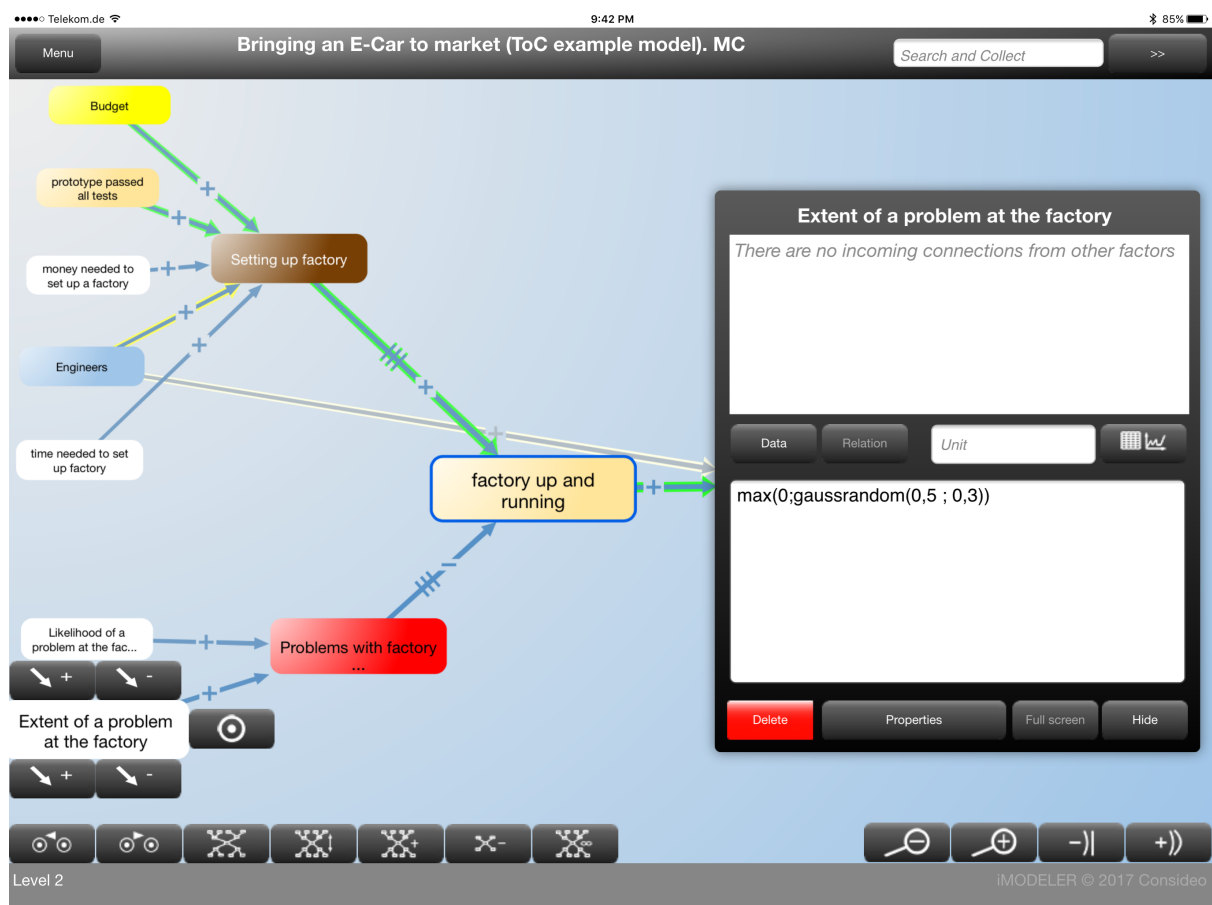


Fig. 13: The use of `gaussrandom()` to describe that a value will be something around 0.5 with a variation of 0.3. The `max(0,...)` prevents the values from becoming negative.

The possibility of problems with the factory is described by two factors. The first describes the likelihood that something will happen at all and the second the extent of the problem.

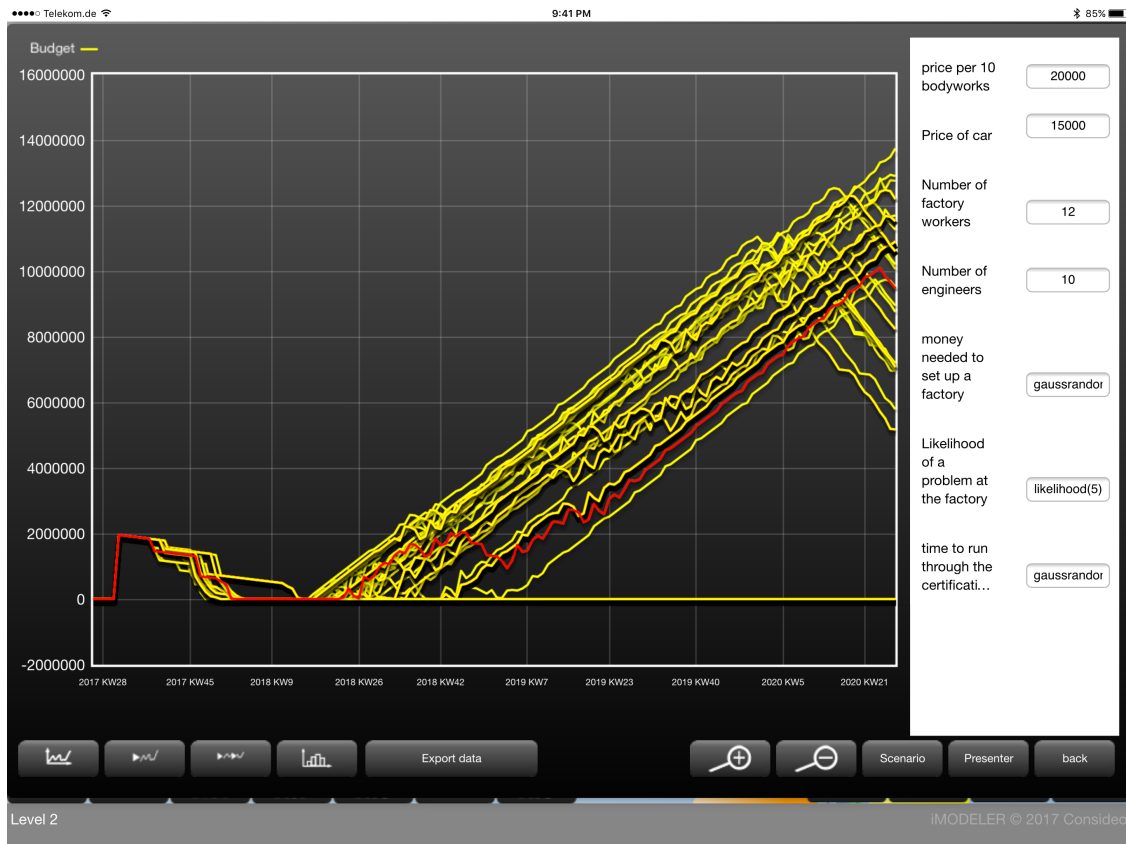


Fig. 14: A spaghetti plot showing possible developments that can be chosen (red) and further examined to reveal the underlying combination of reasons.

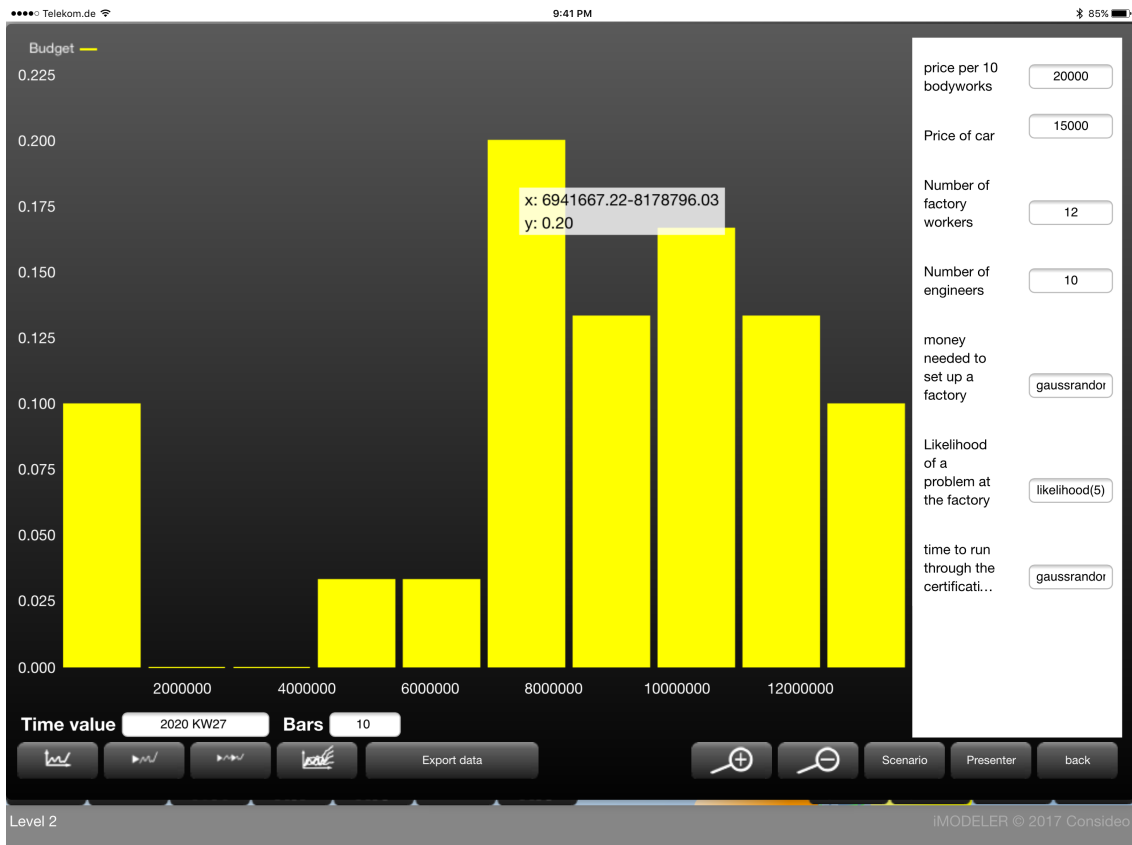


Fig. 15: A histogram showing that with a likelihood of 20 percent the budget in the end will be between 6 and 8 million

Outlook

Because of the unlimited possibility of added details and complexity, there are also numerous more concrete insights that could be gained with such a model.

One useful tool not shown for example is the iM Data Manager, which allows you to use the model as a controlling tool in which you can compare real data with the actual planned developments.

I invite you to use the model, discuss it on KNOW-WHY.NET, place your questions there, and of course also publish your own models there. For a concrete project we offer remote coaching as an alternative to consulting. With remote coaching we help you develop your model via email, telephone and web sessions in what are usually more flexible and efficient sessions where we are there just as you need us.

Contact: info@consideo.com