Hochschule für
Wirtschaft und Recht Berlin
Berlin School of Economics and Law

Exercises

in Supply Chain Optimization and Simulation

using anyLogistix

Level 1 Basic

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1. Introduction

Supply chain network design and operational planning decisions can have a drastic impact on the profitability and success of a company. Whether to have one warehouse or two, close a factory or rent a new one, or to choose one network path over another are all consequential decisions a supply chain (SC) manager must make. However, these decisions must be the result of more than experience or intuition, and, as a result, research in SC management (SCM) is geared towards providing the data, tools, and models necessary for supporting SC managers' decisions. One of these decision-supporting tools is anyLogistix, a software which facilitates Greenfield Analysis, Network Optimization, and Simulation.

anyLogistix has become more and more popular with the provision of the free PLE version, and because it is an easy-to-use software, includes simulation and optimization, and covers all standard teaching topics (center-of-gravity, efficient vs responsive SC design, SC design through network optimization, inventory control simulation with safety stock computations, sourcing (single vs. multiple) and shipment (LTL vs FTL) policy simulation, and milk-run optimization). This guide has been developed to support a course in Supply Chain Optimization and Simulation using anyLogistix software using two sample project reports. The following themes will be considered:

- Facility Location Planning (COG, Trade-off Efficiency vs Responsiveness)
- Supply Chain Design (Network optimization, CPLM)
- Inventory Control Policy (simulation, safety stocks, ordering policies)
- Sourcing Policy (simulation, single vs multiple sourcing)
- Shipment Policy (LTL/FTL, aggregation rules)

This collection of exercises is designed as an application add-on to the main ALX Handbook which provides technical descriptions of how to build ALX models. The main ALX handbook is available at www.anylogistix.com.

The ALX exercise book addresses the application of quantitative analysis methods and software to decision-making in global supply chains and operations. Understanding of optimization and simulation methods in SCM is the core of the course. Technical skills for using simulation and optimization software in praxis can be acquired with the help of anyLogistix software. This course is designed to stimulate and enhance conceptual and analytical decision-making skills in actual operating situations, and will lean heavily on case studies developed throughout the

course. Class sessions will be spent mainly discussing the cases and software implementation, where students will be required to evaluate actual business situations and apply their relevant skills, experience, and judgment to develop viable resolutions to business problems using professional software for decision-making support. Cases are drawn from both industry and service environments, calling for decisions in different facets of supply chain and operations management (SCOM). The case method requires you to prepare a decision based on careful evaluation of case facts and numbers to the extent possible. As with all business situations, there may be insufficient facts, ambiguous goals, and dynamic environments.

Upon completing the course, students should be able to do the following:

- Develop critical thinking skills, be able to identify, generalize, prioritize, isolate, and reduce complexity in complex and ambiguous operational situations,
- Understand how strategic considerations influence operational decisions,
- Apply analysis and improvement tools learned in previous courses to actual business situations,
- Strengthen qualitative and quantitative reasoning skills for operational decision-making.

This course seeks to convey the following skills:

Analytical Skills: Students will possess the analytical and critical thinking skills to evaluate issues faced in business and professional careers.

Technical Skills: Students will possess the necessary technological skills to analyze problems, develop solutions, and convey information using optimization and simulation software.

Along these lines, throughout the course we will examine two case studies:

- Building a new SC from scratch - a case study of the Polarbear Bicycle company, which must create and optimize its SC in order to maintain profitability and keep its competitive edge in an increasingly global market where sales prices are driven down while costs remain stable and
- Improving the existing SC - a case study of the beer producer BERLIN BREWERY, which seeks to analyze the performance of their existing SC and optimize its distribution network, while considering the risks and ripple effect.

Using the models available in anyLogistix, we will conduct analyses to (1) determine an optimal location using Greenfield Analysis (GFA) for a new warehouse, given the location of their current customers and those customers relative demands, (2) compare alternative network designs

using Network Optimization (NO), (3) perform a Simulation of different scenarios, (4) validate the models using Validation, Comparison experiments, and (5) analyze SC behavior under uncertainty using the Risk Analysis experiment.

The author thanks The AnyLogic Company for their invaluable feedback, comments and scenario updates to this exercise book. The author also wishes to thank Ms. Meghan Stewart for a thorough proof-reading. The author thanks students Meghan Stewart, Jannes Zuch, Chantal Reimann, Moritz Albrecht, Stephanie Paeschke, Julia Dyck, Lily Creed, Christin Kemper, Ragna Maria Berg in MA Program Global Supply Chain and Operations Management | GSCOM at Berlin School of Economics and Law for case-study samples used in this exercise book. Finally, the author thanks Mr. Nurlan Mammadzada, a former student in the GSCOM master program for the updates of all exercises.

2. Case study 1

2.1 Description of Case Study

We consider a company called Polarbear Bicycle. Polarbear Bicycle has been newly founded as an e-commerce start-up selling bicycles. Polarbear's portfolio includes four different types of bicycles: x-cross, urban, all terrain, and tour bicycles. Polarbear needs to find a good location for a new distribution center (DC). First, they estimate customer demand. Polarbear distributes their bicycles to four locations throughout Germany: Cologne, Bremen, Frankfurt am Main, and Stuttgart. Table 1 shows customer demand, which is equal to 245 bicycles per day.

Customer	Bicycle Type	Demand per day
Cologne	x-cross	2
Cologne	urban	50
Cologne	all terrain	15
Cologne	tour	10
Bremen	x-cross	7
Bremen	urban	30
Bremen	all terrain	20
Bremen	tour	20
Frankfurt am Main	x-cross	6
Frankfurt am Main	urban	5
Frankfurt am Main	all terrain	4
Frankfurt am Main	tour	5
Stuttgart	x-cross	15
Stuttgart	urban	15
Stuttgart	all terrain	1
Stuttgart	tour	40

Table 1. Customer demand

Polarbear Bicycle has hired a consulting firm to analyze supply and distribution network alternatives and to develop a best-case scenario for Polarbear Bicycle. They are charged with conducting a GFA to determine the possible location of a new DC in Germany, as well as a network optimization to compare several options for network paths. The consulting firm was also asked to run a simulation to validate several KPIs and plan inventory, and to conduct a sensitivity analysis to verify all results as well.

2.2 Greenfield Analysis (GFA) for Facility Location Planning: Selecting the Best Warehouse Location for Polarbear Bicycle

Now we conduct a GFA for the outbound network of Polarbear Bicycle considering the four customers located in Cologne, Bremen, Frankfurt am Main, and Stuttgart. The aim of this GFA is to determine the optimal location of one new DC in Germany subject to total minimum transportation costs.

Creating an ALX model

Step 1. Open scenario PB GFA Level 1.

Step 2. Check the tables Customers, Demand, and Products. The data in these tables should correspond to Table 1.

Performing experiments

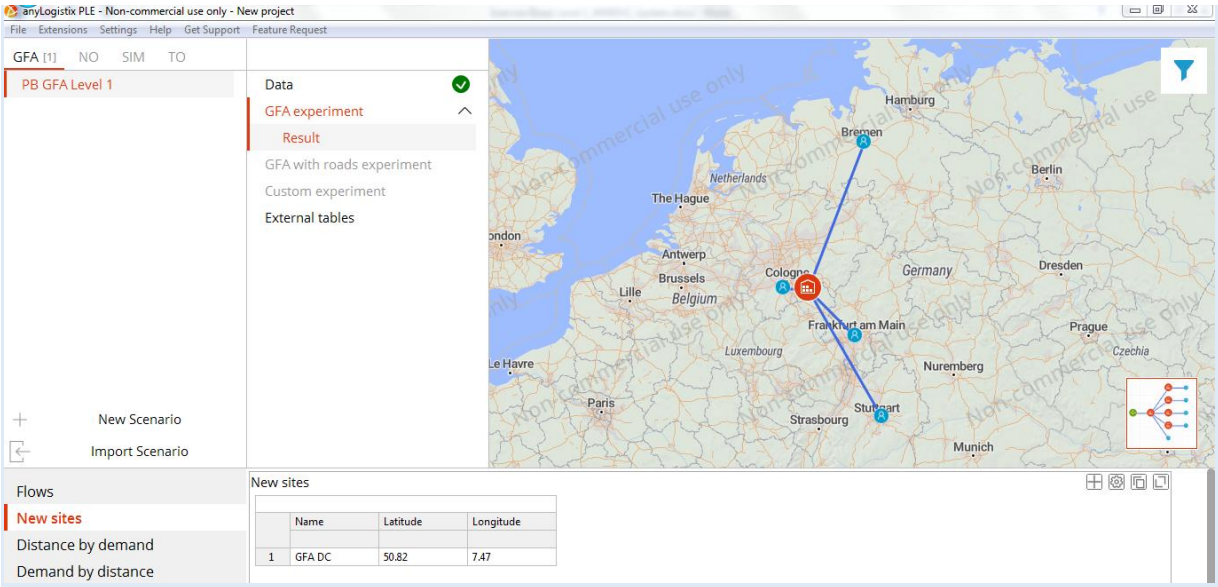
Step 1. Go to GFA Experiment and run it for "Number of sites = 1" and the period of two months.

Step 2. Analyze the results using statistics "Flows" and "New Sites":

a) What are the optimal coordinates of the DC?
b) What is the maximum distance from the optimal DC location to a customer?
c) What is the minimum distance from the optimal DC location to a customer?
d) What are the total costs of the SC? (Note: to compute the sum of costs or flows in GFA Results, just slightly drag the heading of the column "Period" or "From" in table "Product flows" in the space over the table).
e) Compare the data in statistics "Flows" and Table "Demand". Do we satisfy all customer demand from the optimal DC location?
f) What other costs were not considered in selecting the optimal facility location in the GFA?

Solution:

Step 1. Go to GFA Experiment and run it for "Number of sites = 1".



Step 2. Analyze the results using statistics "Flows" and "New Sites":

a) What are the optimal coordinates of the DC?

50.82; 7.47

b) What is the maximum distance from the optimal DC location to a customer?

266.11 km to Bremen

c) What is the minimum distance from the optimal DC location to a customer?

43.55 km to Cologne

d) What are the total costs of the SC?

$16,351,067

e) Compare the data in statistics "Flows" and table "Demand". Do we satisfy all customer demand from the optimal DC location?

Yes, total flows equal total demand. (we compare data in Table "Demand" and flows in the statistics "Flows").

g) What other costs were not considered in selecting the optimal facility location in the GFA?

Fixed facility costs, inventory holding costs, processing costs.

2.3 Network Optimization (NO) for Facility Location Planning: Comparing Polarbear's Supply Chain Design Alternatives

After selling the bicycles from the newly established DC according to the GFA results, Polarbear decided to produce their own bicycles. Their production facility has now been established in Nuremberg and 250 bikes are produced each day. Recently, they have received an offer from

a Polish production factory to rent a DC in the Czech Republic at a reasonable price. The same company also wants to offer them rental of a factory in Warsaw, Poland, even though they already have one factory in Germany. Polarbear must now decide which SC design is more profitable:

- Option 1: DC in Germany and Factory in Germany
- Option 2: DC in Germany and Factory in Poland
- Option 3: DC in Czech Republic and Factory in Poland
- Option 4: DC in Czech Republic and Factory in Germany

In Fig. 1, the different possibilities for the path networks are shown. The dotted lines show possible alternatives and the solid lines the existing structure of Polarbear's SC.

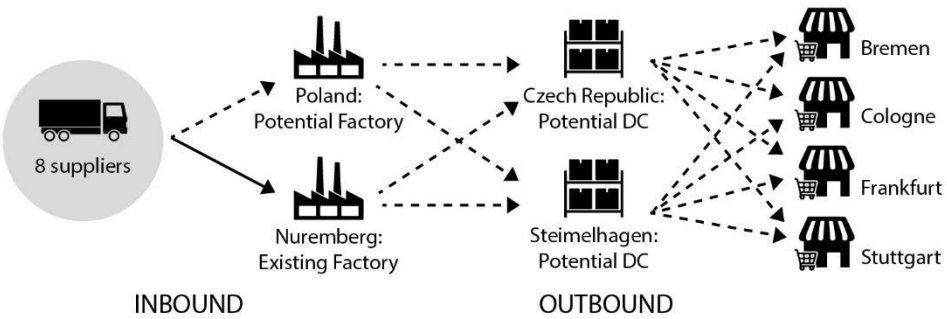


Figure 1. Network optimization alternatives

The aim of the NO is to determine which network design is optimal based on Polarbear's selected KPIs, e.g., profit.

Therefore, the factory in Warsaw, Poland, the DC in the Czech Republic, and the DC in Steimelhagen were added as inputs to the model along with the Nuremburg factory. To enable the model's calculation, the reality of the case must be simplified: all demand is assumed to be deterministic without any uncertain fluctuations. To define the two-stage NO problem (transport between factories and DCs and between DCs and customers) from a mathematical perspective, several parameters must be input as data. These are shown in Table 2.

Costs	Value in USD
Factory Nuremberg: fixed (other) costs, per day	15,000
Factory Poland: fixed (other) costs, per day	5,000
DC Germany: fixed (other) costs, per day	15,000
DC Germany: carrying costs (per bicycle)	3.00
DC Czech Republic: fixed (other) costs, per day	5,000

DC Czech Republic: carrying costs	2.00
DC Germany: processing costs (inbound and outbound shipping per pcs)	2.00
DC Czech Republic: processing costs (inbound and outbound shipping per pcs)	1.00
Factory Nuremberg: production costs (per bicycle)	250
Factory Poland: production (per bicycle)	150
All bicycles: product purchasing costs	30
Transportation costs; Paths: from factory - to DCs	0.01 * product(pcs) * distance
Transportation costs; Paths: from DCs - to customers	0.01 * product(pcs) * distance
Unit revenue	499

Table 2. Cost inputs to optimization model

The costs of the rent for the factory in Poland and the DC in Czech Republic are included in "other costs". For transport, it is always assumed that each truckload fits 80 bicycles, and trucks travel at a speed of 80 km/h.

Creating an ALX model

Step 1. Open scenario PB NO Level 1.

Step 2. Check data from Table 2 and Fig. 1 in tables "DCs and Factories", "Facility Expenses", "Paths", "Processing Costs", "Product Flows", "Product Storages", "Production", "Products", and "Vehicle Types". Explain the data in the aforementioned tables. The data in these tables should correspond to Fig. 1 and Table 2.

Performing experiments

Step 1. Go to NO Experiment and run it with the Demand variation type "95-100%".

Step 2. Analyze the results using statistics "Optimization Results", "Flow Details", "Production Flows", "Demand", and "Overall Stats":

a) What is the most profitable SC design?
b) Is demand for all customers satisfied?
c) What is the total revenue of the most profitable SC?
d) What is total profit of the most profitable SC?
e) Compare the data in statistics "Production Flows" and Table "Demand". Does the production quantity correspond to the total demand?

f) Compare the optimal SC design as computed in the NO and the initial SC design (factory and DC in Germany) in terms of profit.

g) What other costs should be considered when redesigning the SC according to NO results?

h) What other factors, apart from costs, should be considered when re-designing the SC according to the results of the NO?

Solution:

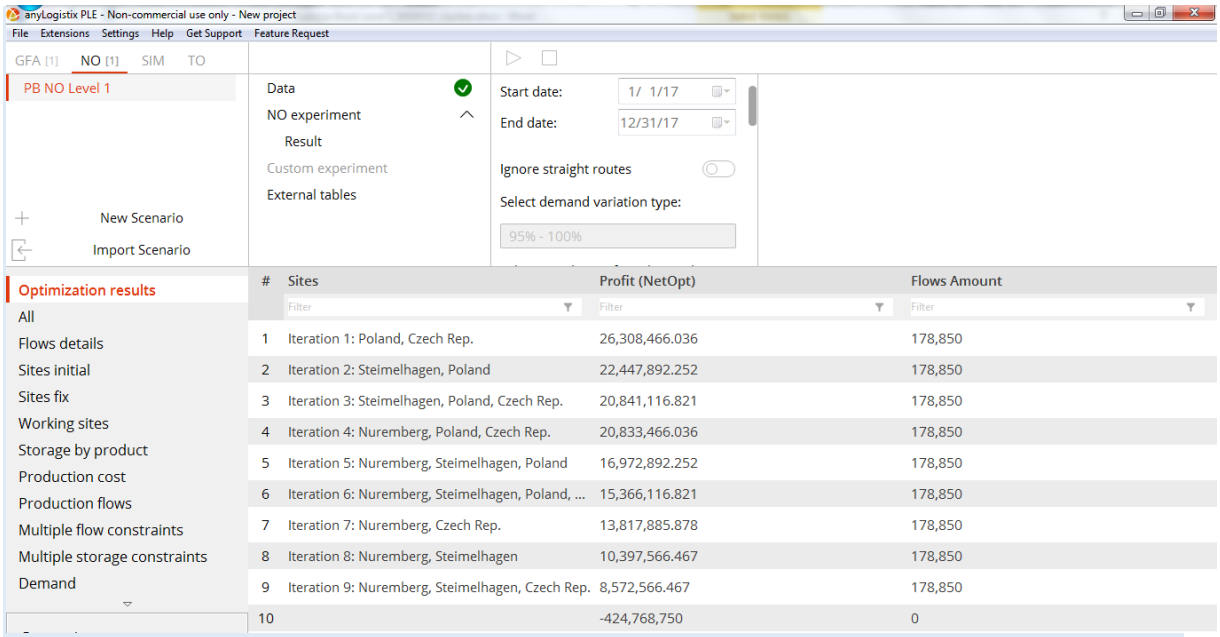
Step 1. Go to NO Experiment and run it.

NOTE! In order to run the NO experiment, you need to change the units in experiment settings from m^3 to pcs to align it with product data.

Step 2. Analyze the results using statistics "Optimization Results", "Flow Details", "Production Flows", "Demand", and "Overall Stats":

a) What is the most profitable SC design?

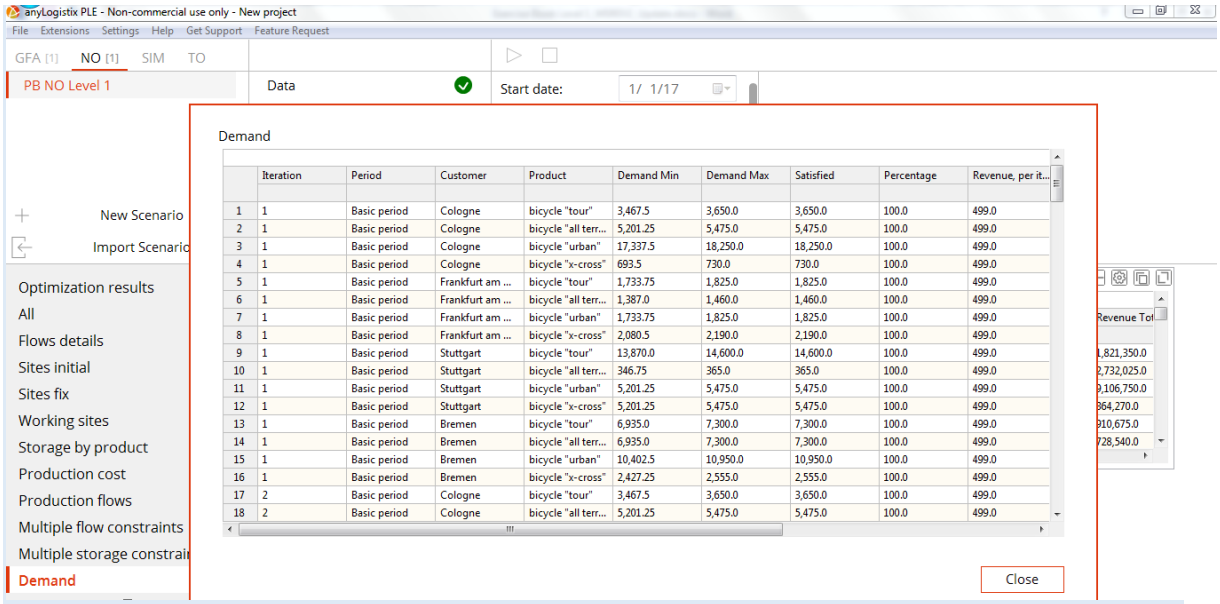
See statistics "Optimization Results": Factory Poland, DC in Czech Republic. **Note: the profits in different experiments can vary slightly (about $1,000-2,000 which equals a deviation of 0.001%) as compared to the values in the table below. This depends on the settings of demand.**



#	Sites	Profit (NetOpt)	Flows Amount
1	Iteration 1: Poland, Czech Rep.	26,308,466.036	178,850
2	Iteration 2: Steimelhagen, Poland	22,447,892.252	178,850
3	Iteration 3: Steimelhagen, Poland, Czech Rep.	20,841,116.821	178,850
4	Iteration 4: Nuremberg, Poland, Czech Rep.	20,833,466.036	178,850
5	Iteration 5: Nuremberg, Steimelhagen, Poland	16,972,892.252	178,850
6	Iteration 6: Nuremberg, Steimelhagen, Poland, ...	15,366,116.821	178,850
7	Iteration 7: Nuremberg, Czech Rep.	13,817,885.878	178,850
8	Iteration 8: Nuremberg, Steimelhagen	10,397,566.467	178,850
9	Iteration 9: Nuremberg, Steimelhagen, Czech Rep.	8,572,566.467	178,850
10		-424,768,750	0

b) Is demand for all customers satisfied?

Yes. See statistics "Demand" and columns "Satisfied" and "Percentage".



	Iteration	Period	Customer	Product	Demand Min	Demand Max	Satisfied	Percentage	Revenue, per it...
1	1	Basic period	Cologne	bicycle "tour"	3,467.5	3,650.0	3,650.0	100.0	499.0
2	1	Basic period	Cologne	bicycle "all terr...	5,201.25	5,475.0	5,475.0	100.0	499.0
3	1	Basic period	Cologne	bicycle "urban"	17,337.5	18,250.0	18,250.0	100.0	499.0
4	1	Basic period	Cologne	bicycle "x-cross"	693.5	730.0	730.0	100.0	499.0
5	1	Basic period	Frankfurt am ...	bicycle "tour"	1,733.75	1,825.0	1,825.0	100.0	499.0
6	1	Basic period	Frankfurt am ...	bicycle "all terr...	1,387.0	1,460.0	1,460.0	100.0	499.0
7	1	Basic period	Frankfurt am ...	bicycle "urban"	1,733.75	1,825.0	1,825.0	100.0	499.0
8	1	Basic period	Frankfurt am ...	bicycle "x-cross"	2,080.5	2,190.0	2,190.0	100.0	499.0
9	1	Basic period	Stuttgart	bicycle "tour"	13,870.0	14,600.0	14,600.0	100.0	499.0
10	1	Basic period	Stuttgart	bicycle "all terr...	346.75	365.0	365.0	100.0	499.0
11	1	Basic period	Stuttgart	bicycle "urban"	5,201.25	5,475.0	5,475.0	100.0	499.0
12	1	Basic period	Stuttgart	bicycle "x-cross"	5,201.25	5,475.0	5,475.0	100.0	499.0
13	1	Basic period	Bremen	bicycle "tour"	6,935.0	7,300.0	7,300.0	100.0	499.0
14	1	Basic period	Bremen	bicycle "all terr...	6,935.0	7,300.0	7,300.0	100.0	499.0
15	1	Basic period	Bremen	bicycle "urban"	10,402.5	10,950.0	10,950.0	100.0	499.0
16	1	Basic period	Bremen	bicycle "x-cross"	2,427.25	2,555.0	2,555.0	100.0	499.0
17	2	Basic period	Cologne	bicycle "tour"	3,467.5	3,650.0	3,650.0	100.0	499.0
18	2	Basic period	Cologne	bicycle "all terr...	5,201.25	5,475.0	5,475.0	100.0	499.0

c) What is the total revenue of the most profitable SC?

$44,623,075.0; see statistics "Overall Stats".

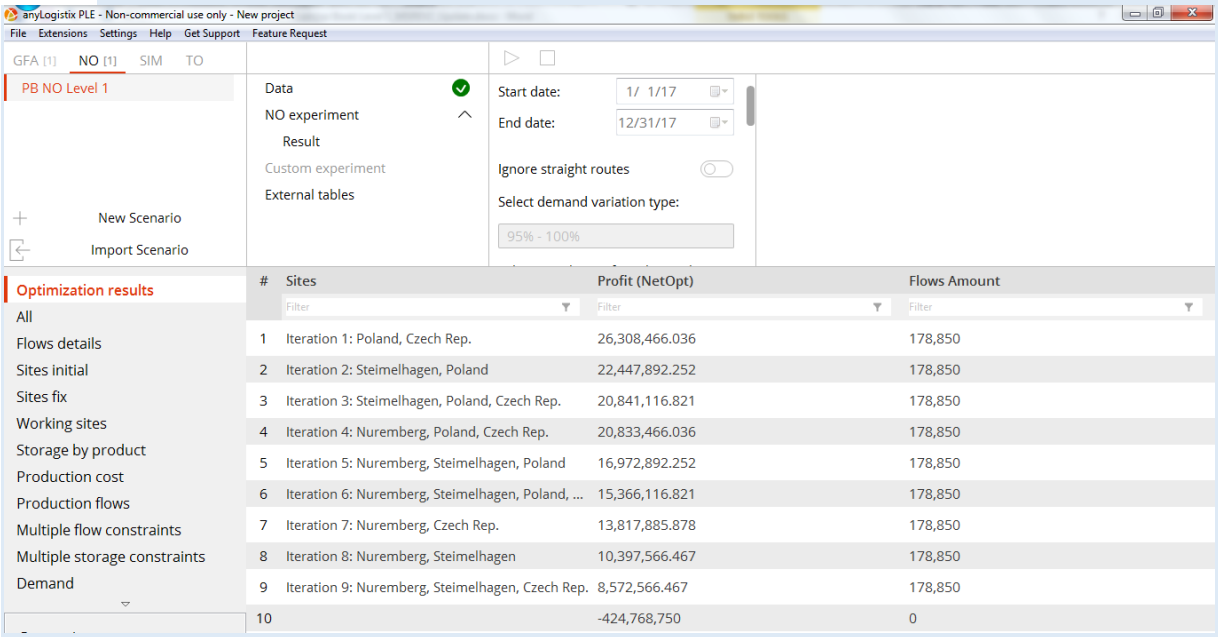
d) What is total profit of the most profitable SC?

$26,308,466.04; see statistics "Overall Stats".

e) Compare the data in statistics "Production Flows" and table "Demand". Does the production quantity correspond to the total demand?

Yes. See statistics "Production Flows".

f) Compare the optimal SC design as computed in the NO and the initial SC design (factory and DC in Germany) in terms of profit.



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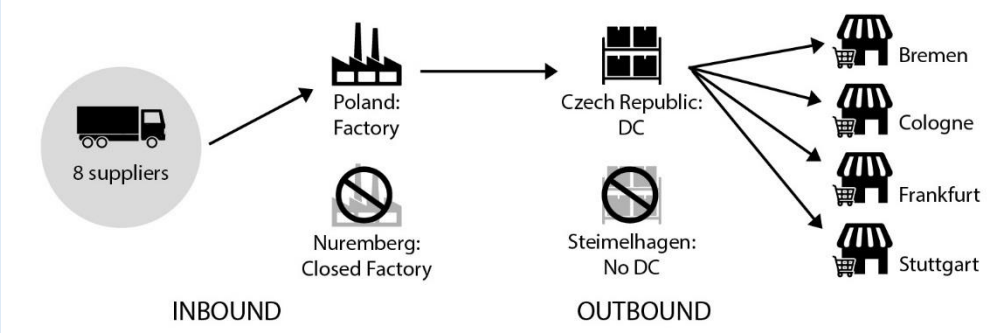
8	Iteration 8: Nuremberg, Steimelhagen	10,397,566.467	178,850
9	Iteration 9: Nuremberg, Steimelhagen, Czech Rep.	8,572,566.467	178,850
10		-424,768,750	0

The initial SC profit is shown in Iteration 8, and optimal SC profit is shown in Iteration 1. The

profit can be increased from $10,397,566.467 to $26,308,466.04 by changing the SC design as follows:

Choosing the highest net profit path would mean closing the factory in Nuremberg and not considering opening the DC in Steimelhagen.



This would mean an increase in net profit for Polarbear which is almost three times higher than the approximation of the as-is scenario. This huge increase is primarily the result of the cost savings possible by renting facilities in Poland and Czech Republic, which have much lower fixed operating costs than is possible in Germany (see Table 2).

g) What other costs should be considered when redesigning the SC according to NO results?

Opening/closure costs.

h) What other factors, apart from costs, should be considered when redesigning the SC according to NO results?

Workforce qualification and know-how, disruption risks, future market trends, changes in supplier structures, risks of outsourcing.

The optimization results show that the highest profit can be achieved in the SC design with a DC in Czech Republic and a factory in Poland. However, the negotiations with the factory in Poland revealed another constraint: the Polish factory would only consider annual quantities of each bicycle type within the range of 10,000 units (minimum capacity utilization) and 25,000 units (maximum capacity utilization). Polarbear must now conduction another NO to include this additional capacity constraint.

Creating an ALX model

Step 1. Open scenario PB NO Level 1 Constrained.

Step 2. Check data in table “Production” in the columns “Min Throughput” and “Max Throughput”.

Performing experiments

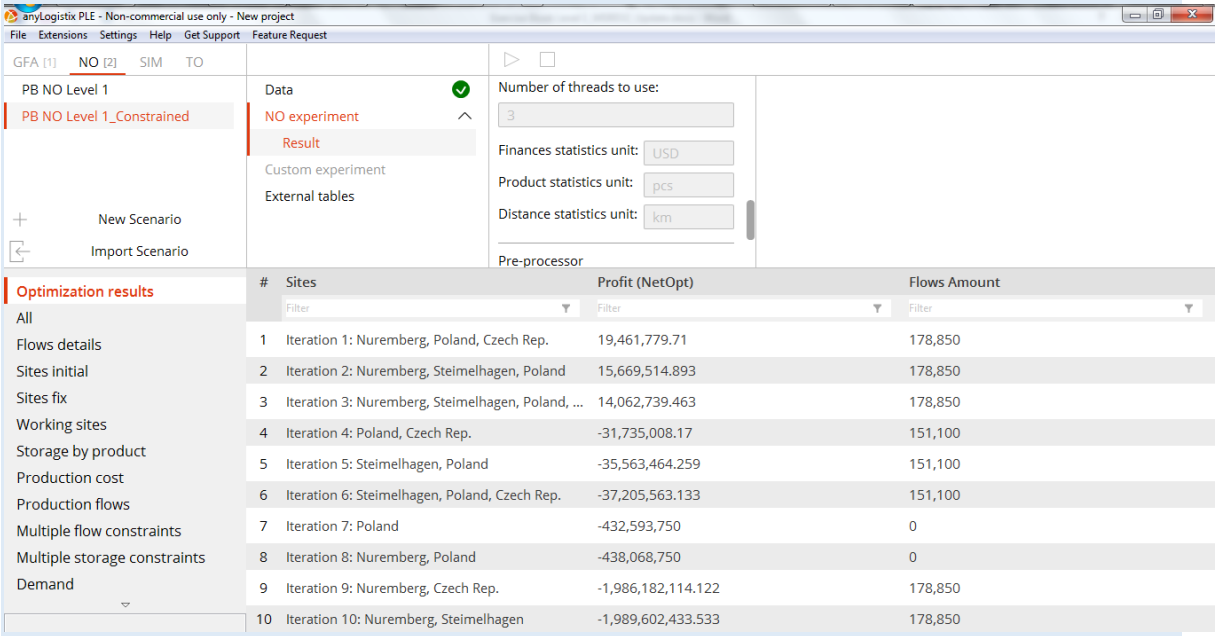
Step 1. Go to NO Experiment and run it.

Step 2. Analyze the results using statistics "Optimization Results", "Flow Details", "Production Flows", "Demand", and "Overall Stats":

a) What is the most profitable SC design considering the capacity constraint of the factory in Poland?
b) What is the total profit of the most profitable SC?
c) Compare the optimal SC design with the capacity constraint, as computed in the second NO, and the optimal SC design without the capacity constraint, as computed in the first NO experiment, in terms of profit.
d) Which differences can be observed? Explain.

Solution:

a) What is the most profitable SC design considering the capacity constraint of the factory in Poland?



#	Sites	Profit (NetOpt)	Flows Amount
1	Iteration 1: Nuremberg, Poland, Czech Rep.	19,461,779.71	178,850
2	Iteration 2: Nuremberg, Steimelhagen, Poland	15,669,514.893	178,850
3	Iteration 3: Nuremberg, Steimelhagen, Poland, ...	14,062,739.463	178,850
4	Iteration 4: Poland, Czech Rep.	-31,735,008.17	151,100
5	Iteration 5: Steimelhagen, Poland	-35,563,464.259	151,100
6	Iteration 6: Steimelhagen, Poland, Czech Rep.	-37,205,563.133	151,100
7	Iteration 7: Poland	-432,593,750	0
8	Iteration 8: Nuremberg, Poland	-438,068,750	0
9	Iteration 9: Nuremberg, Czech Rep.	-1,986,182,114.122	178,850
10	Iteration 10: Nuremberg, Steimelhagen	-1,989,602,433.533	178,850

The optimal SC design now is to have a DC in the Czech Republic and two factories in Germany and Poland.

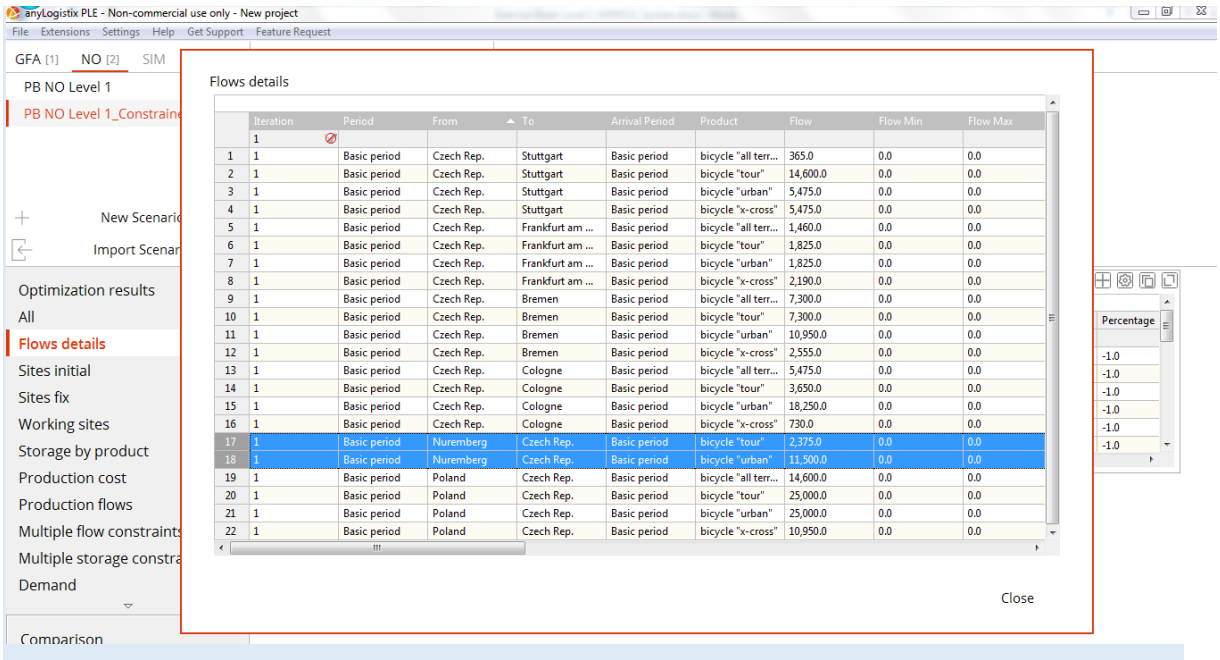
b) What is total profit of the most profitable SC?

$19,461,779.71

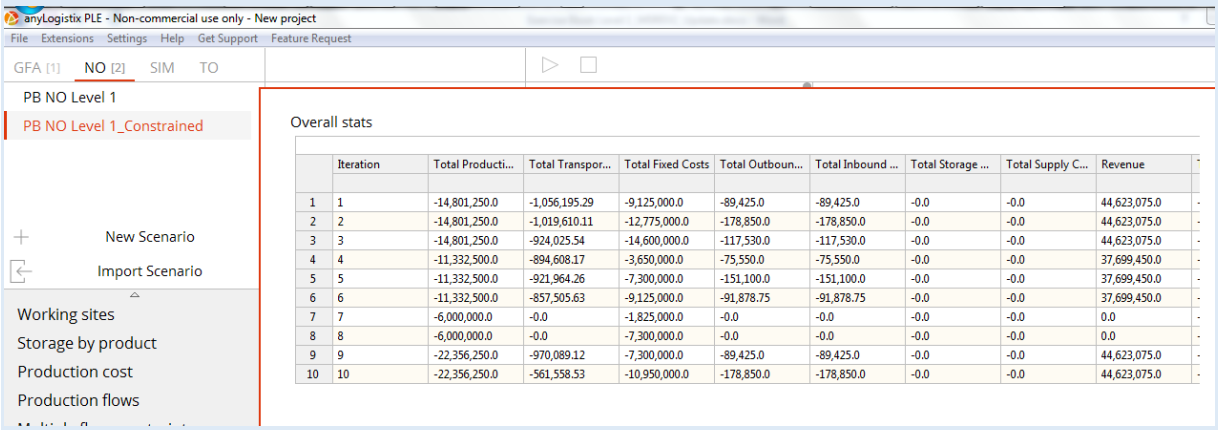
c) Compare the optimal SC design with the capacity constraint, as computed in the second NO, and the optimal SC design without the capacity constraint, as computed in the first NO experiment, in terms of profit.

The profit is reduced from $26,308,466.036 to $19,461,779.71. The optimal SC design now is now to have a DC in the Czech Republic and two factories in Germany and Poland.

d) What differences can be observed? Explain.



As the "Flow Details" statistics show, the capacity of the factory in Nuremberg will be used to produce the "tour" and "urban" bicycles for which the total demand is higher than the maximum capacity of the factory in Poland. This increases costs.



2.4 Simulation: Dynamic analysis of the Polarbear's supply chain design

In simulation, we extend our analysis by adding the following features:

- We transit from flows (as in NO) to orders, i.e., the customer demand is no longer considered an aggregated flow during a period, but it is now generated as orders at certain intervals, e.g., 10 bicycles every day.
- We introduce inventory control to manage ordering processes.
- We introduce sourcing policies (e.g., single vs. multiple sourcing) to manage replenishment processes.
- We introduce shipment control (LTL/FTL) to manage shipment processes.

First, we simulate the SC with two factories in Poland and Germany and a DC in the Czech Republic subject to customer demand from Table 1 (see GFA exercise) and the following data (Table 3).

Object	**Inventory Policy**		**Expected Lead Time (ELT), days**	**Transportation Time, days**	**Production Time per Unit, days**	**Sourcing Policy**	**Transportation Policy**
	Min	**Max**					
Factory Germany	50	100		2	0.1		LTL
Factory Poland	50	100		2	0.07		LTL
DC Czech Republic	50	100		2		Closest dynamic	LTL
Customers			5				

Table 3. Parameters for simulation model

For the DC and the factory, three inventory policies have to be developed. We assign the DC and factories a "min-max policy" for all products, where the minimum stock is 50, the maximum stock is 100, and the initial stock is 50 bicycles.

To evaluate the simulation results, we consider six KPIs according to the needs of Polarbear:

(1) Financial KPIs, such as profit, revenue and costs
(2) ELT service level by product, which is the ratio of products delivered within the expected lead time to the total ordered quantity
(3) Demand fulfillment (product backlog)
(4) Available inventory
(5) Production capacity utilization and

(6) Lead time.

With all of the parameters described, we now run the simulation for a period of one year.

Creating an ALX model

Step 1. Open scenario PB SIM Level 1.

Step 2. Check data from Table 3 in tables "DCs and Factories", "Inventory", "Production", "Sourcing", and "Unit Conversions". Explain the data in the aforementioned tables. The data in these tables should correspond to Table 3.

Performing experiments

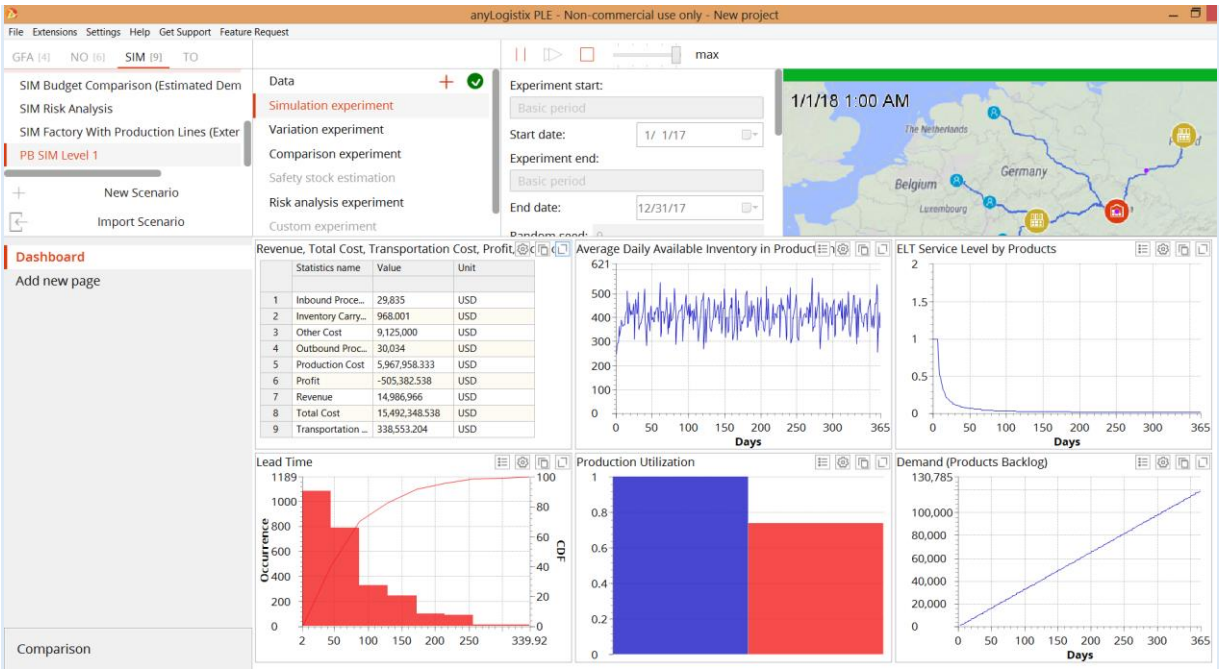
Step 1. Go to Simulation Experiment and run it.

Step 2. Analyze the results using the KPI Dashboard "Revenue, Profit, Costs", "Lead Time", "ELT Service Level", "Production Utilization", "Demand (Product Backlog)", and "Average Available Inventory".

a) What are the profit, revenue, and costs of the SC?
b) Is demand for all customers satisfied? Explain.
c) What is the production utilization of factories in Poland and Germany? Explain.
d) What is your judgment on the inventory dynamics in the SC?
e) What is your judgment on the lead time?
f) What suggestions for improvement do you have which could increase profit and customer satisfaction?

Solution:

Step 1. Go to Simulation Experiment and run it.



Step 2. Analyze the results using the KPI Dashboard "Revenue, Profit, Costs", "Lead Time", "ELT Service Level", "Production Utilization", "Demand (Product Backlog)", and "Average Available Inventory".

a) What are the profit, revenue, and costs of the SC?

Revenue, Total Cost, Transportation Cost, Profit, Produc

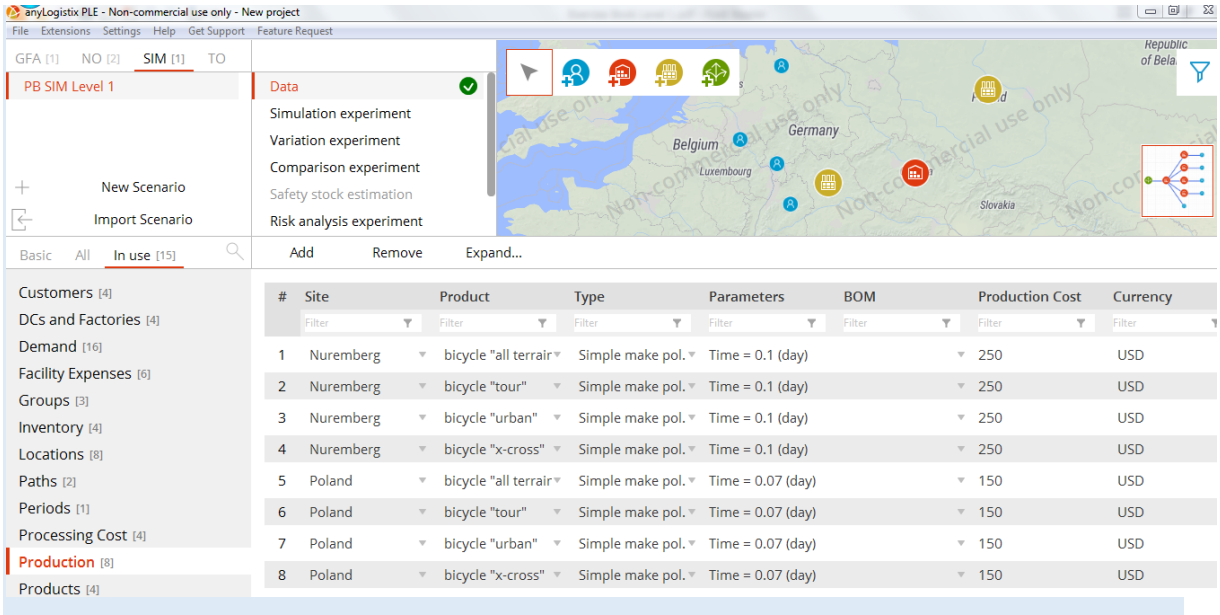
	Statistics name	Value	Unit
1	Inbound Proce...	29,835	USD
2	Inventory Carry...	968.001	USD
3	Other Cost	9,125,000	USD
4	Outbound Proc...	30,034	USD
5	Production Cost	5,967,958.333	USD
6	Profit	-505,382.538	USD
7	Revenue	14,986,966	USD
8	Total Cost	15,492,348.538	USD
9	Transportation ...	338,553.204	USD

b) Is demand for all customers satisfied? Explain.

Not at all. We have a very high backlog and a decreasing service level.

c) What is the production utilization of factories in Poland and Germany? Explain.

100% for the factory in Germany and 75% for the factory in Poland as a result of the production time constraint:



d) What is your judgment on the inventory dynamics in the SC?

Fluctuations with a high amplitude are visible in the diagram.

e) What is your judgment on the lead time?

It is very long and unequally distributed (e.g., high lead time fluctuations).

f) What suggestions for improvement do you have which could increase profit and customer satisfaction?

Revenue is very low because customer demand is not fulfilled (see backlog and ELT service level diagrams). Inventory control policy parameters (i.e., reorder point and target inventory) might need to be adjusted. Production capacity utilization is very high, which indicates a bottleneck. Capacity must be increased and aligned with demand, order frequency, and inventory control policy parameters.

Polarbear's SC managers suggest the following changes to the input parameters (Table 4).

Object	**Inventory Policy**		**Expected Lead Time (ELT), days**	**Transportation Time, days**	**Production Time per Unit, days**	**Sourcing Policy**	**Transportation Policy**
	Min	**Max**					
Factory Germany			5	2			LTL
x-cross	30	60			0.05		
urban	100	200			0.015		
all terrain	40	80			0.04		
tour	75	150			0.02		
Factory Poland			5	2			LTL
x-cross	30	60			0.05		

urban	100	200			0.015		
all terrain	40	80			0.04		
tour	75	150			0.02		
DC Czech Republic				2		Closest dyna-mic	LTL
x-cross	60	120					
urban	200	400					
all terrain	80	160					
tour	150	300					
Customers			5			Closest dyna-mic	

Table 4. Parameters for simulation model

Having changed all parameters, we now run new simulation.

Creating an ALX model

Step 1. Open scenario PB SIM Level 1_Improved.

Step 2. Check data from Table 4 in tables "Inventory" and "Production". The data in these tables should correspond to Table 4.

Performing experiments

Step 1. Go to Simulation Experiment and run it.

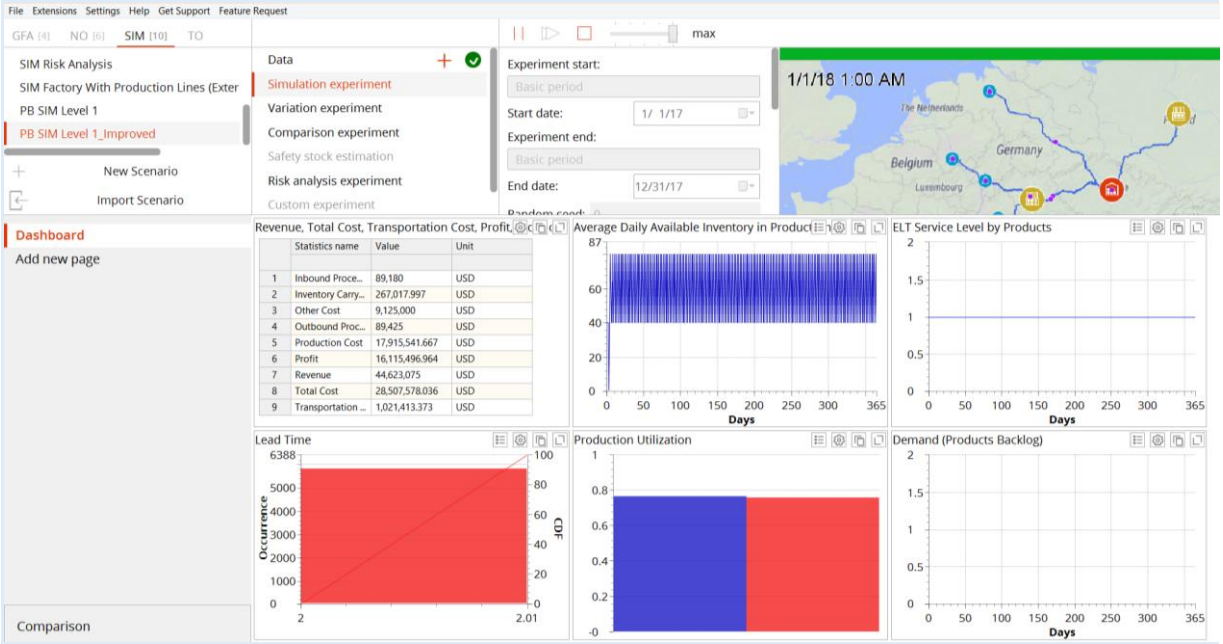
Step 2. Analyze the results using the KPI Dashboard "Revenue, Profit, Costs", "Lead Time", "ELT Service Level", "Production Utilization", "Demand (Product Backlog)", and "Average Available Inventory".

a) What are the profit, revenue, and costs of the SC? Did we improve?
b) Is demand for all customers satisfied? Explain.
c) What is the production utilization of factories in Poland and Germany? Explain.
d) What is your judgment on the inventory dynamics in the SC?
e) Explain how MIN (reorder point) and MAX (target inventory) values have been computed.
f) What is your judgment on the lead time?
g) Explain why the changes made improved SC performance.

h) How can you validate the simulation modelling results using the previous network optimization experiments?

Solution:

Step 1. Go to Simulation Experiment and run it.



Step 2. Analyze the results using the KPI Dashboard "Revenue, Profit, Costs", "Lead Time", "ELT Service Level", "Production Utilization", "Demand (Products Backlog)", and "Average Available Inventory".

a) What are the profit, revenue, and costs of the SC? Did we improve?

Revenue, Total Cost, Transportation Cost, Profit, Produ

	Statistics name	Value	Unit
1	Inbound Proce...	89,180	USD
2	Inventory Carry...	267,017.997	USD
3	Other Cost	9,125,000	USD
4	Outbound Proc...	89,425	USD
5	Production Cost	17,915,541.667	USD
6	Profit	16,115,496.964	USD
7	Revenue	44,623,075	USD
8	Total Cost	28,507,578.036	USD
9	Transportation ...	1,021,413.373	USD

Before:

Yes, we significantly improved revenues and profits.

b) Is demand for all customers satisfied? Explain.

Yes. The service level is 100% and there is no backlog.

c) What is the production utilization of factories in Poland and Germany? Explain.

78%. There is no longer production backlog in the SC.

d) What is your judgment on the inventory dynamics in the SC?

Stable inventory dynamics.

e) Explain how MIN (reorder point) and MAX (target inventory) values were computed.

s=demand per day * transportation time; S=2*s

f) What is your judgment on the lead time?

It became constant at a value of two days because there was no backlog or product shortage.

g) Explain why the changes made improved SC performance.

The adjustment of inventory policy parameters along with increasing production capacity and aligning it with demand, ordering frequency, and inventory policy improved the performance of the SC.

h) How can you validate the simulation modelling results using the previous net-work optimization experiments?

Profit in the simulation experiment is very close to the profit obtained in the network optimization for the same SC design and experimental dataset.

2.5 Comparison experiment

In order to simplify a comparison of two considered simulation scenarios, we run a comparison experiment.

Creating a Comparison Experiment

Step 1. Open scenario PB SIM Level 1 and go to **Comparison Experiment.**

Step 2. Select scenarios PB SIM Level 1_Improved and PB SIM Level 1 to compare.

Step 3. Check KPI dashboard. The KPIs for a comparative analysis of two scenarios should be “Demand (backlog)”, “Profit”, and “ELT Service Level”.

Performing experiments

Step 1. Run Comparison experiment.

Step 2. Analyze the results using the KPI "Demand (backlog)", "Profit", and "ELT service level".

a) What are the profit, ELT service level, and order backlog for the two scenarios? Did we improve in the second scenario?

b) How can you explain the relationship between the Simulation and Comparison experiments?

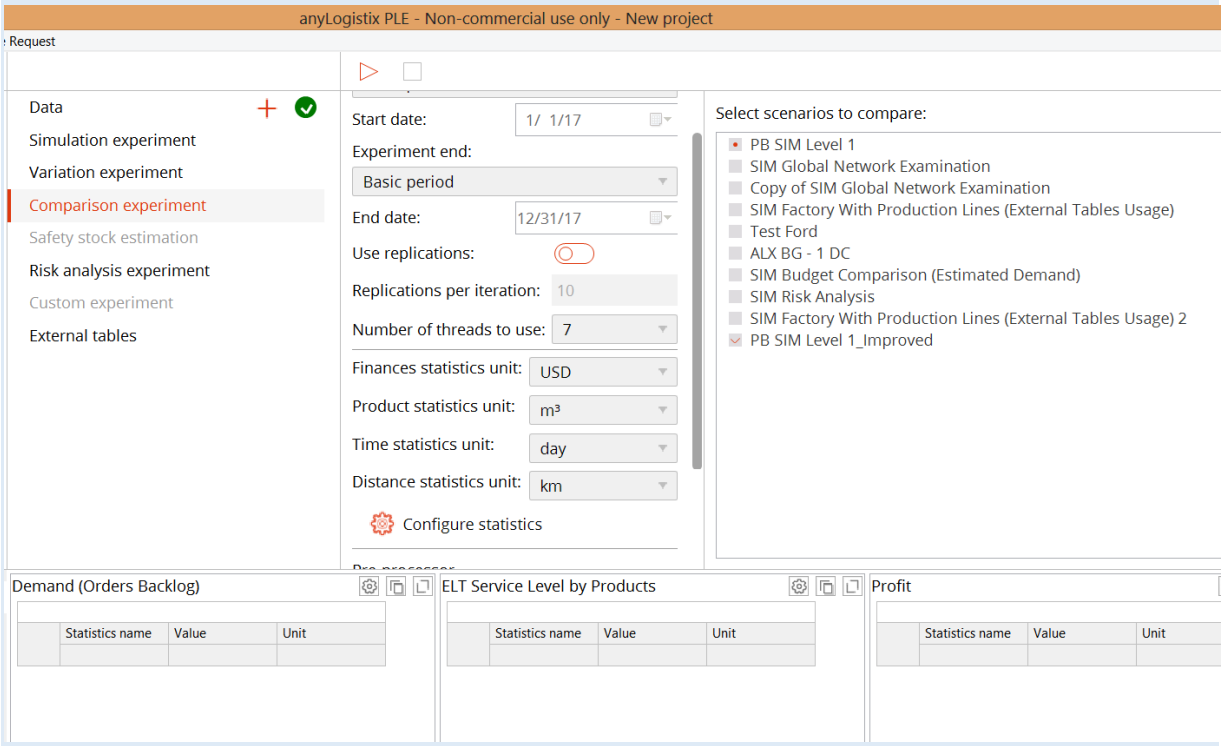
Solution:

Creating a Comparison Experiment

Step 1. Open scenario PB SIM Level 1 and go to **Comparison Experiment.**

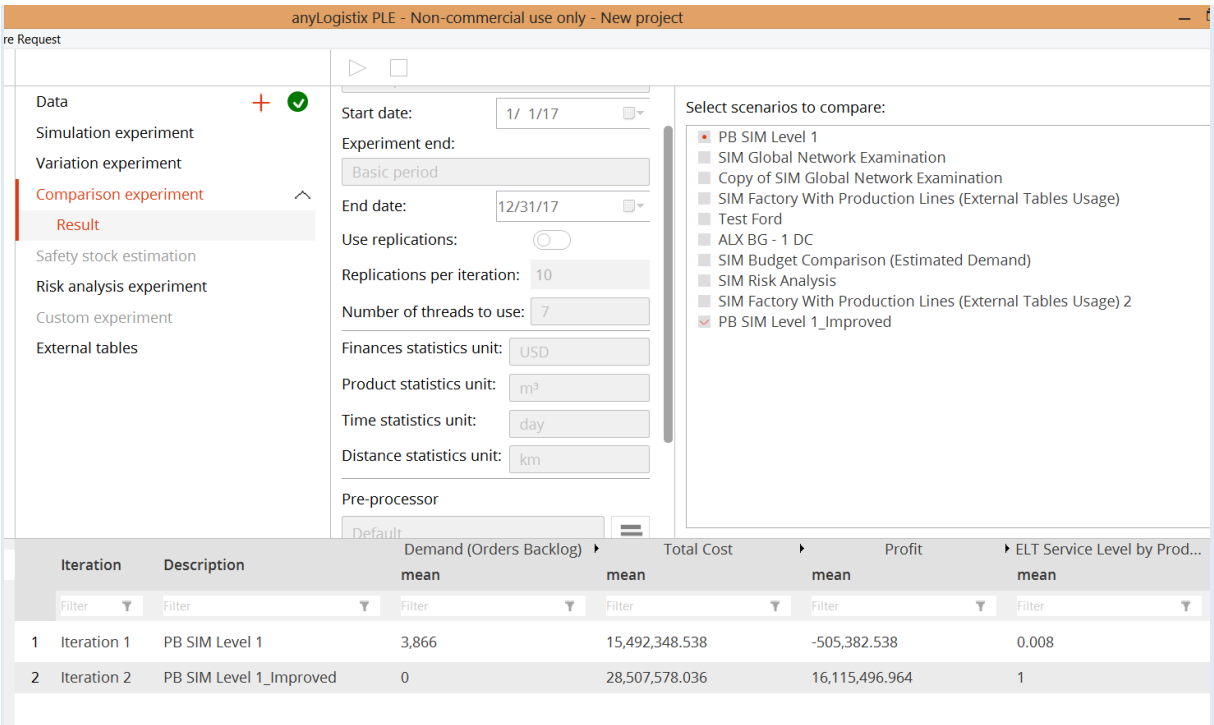
Step 2. Select scenarios PB SIM Level 1_Improved and PB SIM Level 1.

Step 3. Check KPI dashboard. The KPIs for a comparative analysis of the two scenarios should be "Demand (backlog)", "Profit", and "ELT Service Level".



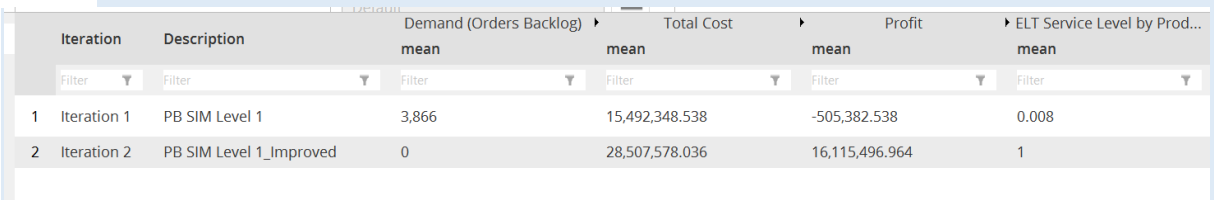
Performing experiments

Step 1. Run Comparison experiment.



Step 2. Analyze the results using the KPIs "Demand (backlog)", "Profit", and "ELT service level".

a) What is the profit, ELT service level, and order backlog in the two scenarios? Did we improve in the second scenario?



	Iteration	Description	Demand (Orders Backlog) mean	Total Cost mean	Profit mean	ELT Service Level by Prod... mean
1	Iteration 1	PB SIM Level 1	3,866	15,492,348.538	-505,382.538	0.008
2	Iteration 2	PB SIM Level 1_Improved	0	28,507,578.036	16,115,496.964	1

Yes, we improved all KPIs.

b) How can you explain the relationship between the Simulation and Comparison experiments?

The Comparison experiment simultaneously runs multiple simulation scenarios. When only the overall KPIs are important for decision-making support, this is much faster than running multiple simulations separately. However, in a Comparison experiment, the process and dynamics of each scenario cannot be observed.

2.6 Validation using Variation

Rather than running the same simulation multiple times with different parameter values or combinations, the variation experiment allows multiple variations of the same simulation to be run

simultaneously. A variation experiment highlights how KPIs change depending on different parameter values. This kind of sensitivity analysis can also be used to verify the validity of the results of the simulation model.

A variation analysis must be performed to check Polarbear's simulation model and the results. The daily demand for "urban" bicycles in Cologne can be varied with a minimum demand of 50 and a maximum demand of 170 in steps of 40. The variation should be performed for a period of one year.

Creating a Variation Experiment

Step 1. Open scenario PB SIM Level 1_Improved and go to **Variation Experiment.**

Step 2. Check the parameter we will vary (i.e., DemandData: bicycle "urban", Cologne; quantity).

Step 3. Check KPI dashboard. The KPIs for a variation analysis should be "Demand (backlog)", "Profit", and "ELT Service Level".

Performing experiments

Step 1. Run Variation experiment.

Step 2. Analyze the results using the KPIs "Demand (backlog)", "Profit", and "ELT Service Level".

a) What is the profit, ELT service level, and order backlog for different demands?
b) Why and how do the KPIs change as demand changes?
c) Is the simulation model sensitive?

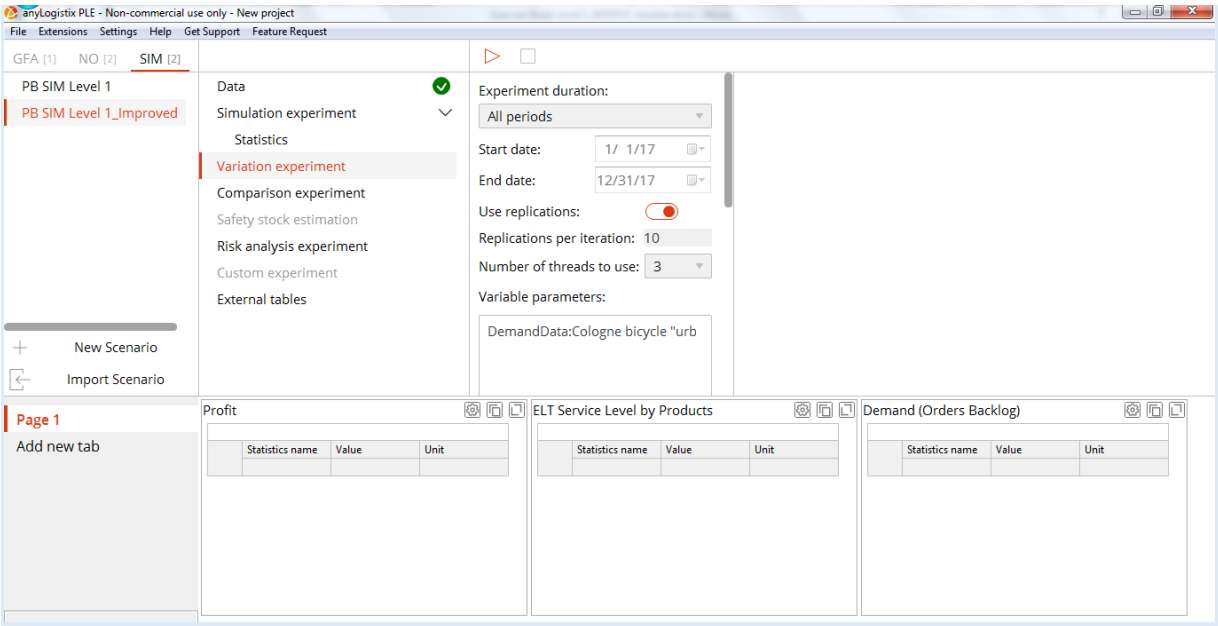
Solution:

Creating a Variation Experiment

Step 1. Open scenario PB SIM Level 1_Improved and go to **Variation Experiment.**

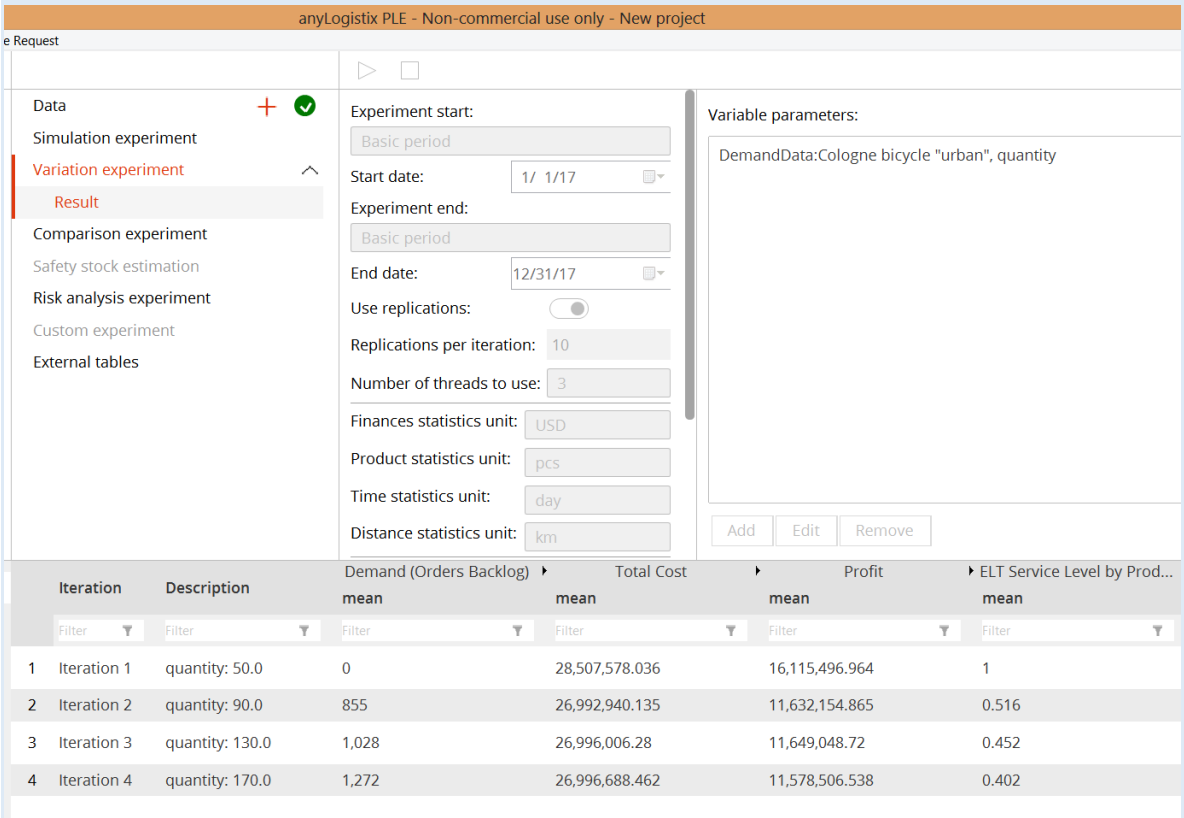
Step 2. Check the parameter we will vary (i.e., DemandData: bicycle "urban", Cologne; quantity).

Step 3. Check KPI dashboard. The KPIs for a comparative analysis of the two scenarios should be "Demand (backlog)", "Profit", and "ELT Service Level".



Performing experiments

Step 1. Run Variation experiment.



Step 2. Analyze the results using the KPIs “Demand (backlog)”, “Profit”, and “ELT Service Level”.

a) What is the profit, ELT service level, and order backlog for different demands?

	Iteration	Description	Demand (Orders Backlog) mean	Total Cost mean	Profit mean	ELT Service Level by Prod... mean
	Filter	Filter	Filter	Filter	Filter	Filter
1	Iteration 1	quantity: 50.0	0	28,507,578.036	16,115,496.964	1
2	Iteration 2	quantity: 90.0	855	26,992,940.135	11,632,154.865	0.516
3	Iteration 3	quantity: 130.0	1,028	26,996,006.28	11,649,048.72	0.452
4	Iteration 4	quantity: 170.0	1,272	26,996,688.462	11,578,506.538	0.402

b) Why and how do the KPIs change as demand changes?

Our SC is not well prepared for an increase in demand in Cologne. Due to limited production capacity and selected reorder points and target inventories, the demand increase in Cologne would result in backlog, and significant decreases in service level and profit.

c) Is the simulation model sensitive?

Yes, it is. Changes in demand have direct impact on service level, profit, and backlog.

2.7 Recommendations

Develop recommendations for Polarbear Bicycle's management. Consider GFA, NO, SIM, Comparison and Variation results. What SC design would you recommend? Consider the impact of inventory control and production capacities. Are there any other factors that should be taken besides the results of the experiments performed?

Solution:

Given the results of all the analyses, several recommendations can be made concerning the how Polarbear Bicycle can improve their SC. First, managing the inventory is key to keeping costs low, and thereby increasing profit. By varying inventory control policy parameters, we could achieve significant improvements in profit and service level.

Second, if net profit is the most important KPI for Polarbear, the results of the NO indicate that the best network design is to take the opportunity to rent the factory in Poland and the DC in the Czech Republic while maintaining production capacity in Nuremberg. Along the same lines, this would also mean not opening the DC in Germany. However, other factors should be taken into account concerning this option since the closing costs for the DC in Germany were not considered in the software model. In addition, a second DC could be useful as backup in case severe disruptions occur in the SC.

Third, the variation analysis showed that profit and service level are highly sensitive to demand changes. As such, capacity flexibility in production and adjustment of inventory control policies should be considered in order to cope with unexpected demand fluctuations.