Supply Chain Optimization using anyLogistix:

A Case Study of Polarbear Bicycle

Meghan Stewart, Jannes Zuch, Chantal Reimann, Moritz Albrecht, Stephanie Paeschke

Berlin School of Economics and Law
MA Program Global Supply Chain Management | GSCOM
10825 Berlin, Germany

Written under the guidance of

Professor Dr. habil Ivanov, Berlin School of Economics and Law
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1. Introduction

Supply chain network design 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 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 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.

Along these lines, we will examine a case study of the fictional German company Polarbear Bicycle, which must optimize its supply chain 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. Using the models available in AnyLogistix, we will conduct analyses to (1) determine an optimal location using Greenfield Analysis for a new warehouse for Polarbear, given the location of their current customers and those customers relative demands, (2) compare alternative network paths given an opportunity Polarbear has to rent another factory in Poland and another warehouse in the Czech Republic, and (3) perform a Simulation of the recommended network path to further determine whether the proposed path sufficiently meets all of Polarbear’s KPIs.

The paper is structured as follows: in Section 2 we will set the context of the paper within current research and literature on the topic; in Section 3 we will introduce the case study in more detail, elaborate the objectives of the analyses, and describe the performance and initial results of the study. Given these results, in Section 4 we will discuss our recommendations concerning the decisions which Polarbear’s managers should take in order to improve the profitability and cost effectiveness of their SC. Section 5 will conclude the paper.

2. Literature Analysis

Many companies have realized that the success of their supply chain is key to the success of their company and gaining a competitive edge in the market. A supply chain (SC) is made up of suppliers, plants, warehouses, and the flow of products from each origin to the final customer. The number and location of facilities is critical to the effectiveness and efficiency of the SC.
Supply Chain Network Design determining the best facility locations and product flows through all facilities (Watson et al. 2013, p. 1). According to Watson et al. (2013, p. 4), network design projects answer questions such as

How many warehouses should we have, where should they be, how large should they be, what products will they distribute and how will we serve our different types of customers? How many plants or manufacturing sites should we have, where should they be, how large should they be, how many production lines should we have and what products should they make, and which warehouses should they service? What is the impact of change in demand, labor costs, and commodity pricing on the network? How can we reduce the overall SC costs?

Finding the best possible answer to these questions constitutes the work of supply chain management (SCM) (Watson et al. 2013, p. 4). To do this, SC managers can utilize software, such as anyLogistix, to support their decision making.

2.1 anyLogistix

Changes in the network of a supply chain, e.g. opening or closing factories and warehouses, are called network design decisions. According to Chopra and Meindl (2016) network design decisions are made within a framework of four steps, which will be explained briefly. The first phase is about defining a supply chain strategy/design in a general way, e.g. what the stages in the supply chain are and whether each stage will be done in-house or be outsourced. The next phase is to Define the Regional Facility Configuration. In this phase, potential regions for the facilities and which role they will play in the supply chain network are identified. In the next phase, several potential locations for the facilities are selected, and then all relevant decisions made. For the company, the aim of a network design decision is to generate maximal total profits according to all conditions in the market, e.g. taxes, demands, logistics, and, of course, costs (Chopra and Meindl 2016).

To support decision making processes in the SC, several software programs are used. One of these is ALX (anyLogistix), which has been utilized for the case study in this research paper. Within the program, real life scenarios can be analyzed. This analysis is then used by supply chain managers as a support for making decisions concerning the following: facility location planning, capacity planning of distribution centers, sourcing and transportation policies, and assessment of different effects such as the Bullwhip or Ripple Effect (Ivanov 2017).

Using anyLogistix, supply chain managers can easily conduct Greenfield analyses (GFA), network optimization (NO), simulation, and variation analysis, and the results of each kind of
analyses can be transferred to another, e.g. the results of the GFA can be transferred and used for the NO, meaning that data about the SC only needs to be input into the software once.

2.2 Green Field Analysis

The GFA is used to find the optimal location within a network to setup a new production facility or warehouse, while a “brown” field analysis, utilizing the same technique, can be used to adjust existing networks (Ivanov et al. 2017, p. 235). Identifying the optimal location for a production or warehousing facility is determined by finding the point at which the sum of the distances from all suppliers to the factory (demand point), weighted by the volume of product flow between each supplier and the potential factory, is minimal. Likewise, to determine the optimal location for a warehouse, the distances from the customers to the warehouse, weighted by their respective demands, are calculated.

To conduct the GFA, a high level of abstraction with a minimum number of details is used. Existing data such as customer locations, demand per customer, the number and location of DCs, and/or service distances, are used as inputs to the analysis. Program parameters for the GFA include how many possible results the program should calculate, and whether the program should use real roads. The output of the analysis is an approximate, optimal location for a production or warehousing facility (Ivanov 2017). This optimal point is called the “center or gravity” (Ivanov et al. 2017). As explained, these so called “Gravity models” determine the location at which the costs of all in- and outbound transportations are minimized (Chopra and Meindl, 2016).

In addition to the mathematical result of the GFA, supply chain managers should also consider several variables: a potential increase in production volume and future expansion needs; quality of the potential infrastructural network; qualifications of prospective employees; options for suppliers; and the regional availability of logistics service providers who could take handle inbound and outbound transports. In addition, certain taxation benefits provided by the local government can influence a company’s decision about a location (Ivanov et al. 2017, p. 181-182).

2.3 Network Optimization

Network optimization is another decision-supporting quantitative model for supply chain and operations management (SCOM), which allows a supply chain manager to easily compare
alternative network paths according to a customizable set of KPIs. In contrast to the GFA, through an optimization analysis networks paths can be compared according to their respective revenues, costs, lead times, service levels, inventory, backlog etc. As a whole, the results provide a comparison of the maximal profitability of each potential alternative network (Chopra and Meindl 2016). However, since a real supply chain is complex and under uncertainty, and this is difficult to show in software, the model simplifies reality to provide a solution (Ivanov et al. 2017).

2.4 Simulation

According to Ivanov et al., “Simulation is imitating the behavior of one system with another” (2017, p. 61). In a simulation, which is a quantitative model for SCOM, a supply chain is described according to real data inputs. By changing input parameters, the goal of the simulation is to understand the dynamics and material flow of the SC: “[A] Simulation is an ideal tool for further analysing the performance of a proposed design derived from an optimization model” (Ivanov et al. 2017, p. 61). To run a simulation, some critical data is needed, such as product definitions, bills of material, customer demands, locations, routes, and initial inventory (Buckley et al. 2005, p.19f). A SC simulation can be of strategic and operational support. Strategic support might include decisions concerning the number and location of facilities, stock levels, and transportation and supply planning policies (Buckley et al. 2005, p.27f). Operational support might include process control, predictions of developments in upcoming periods, trends detection, or decision support for choosing alternatives in unexpected situations (Buckley et al. 2005, p.33f).

2.5 Validation

The results of supply chain model analyses, such as the simulation model described above, must be validated through sensitivity analysis. Conducting a sensitivity analysis with different iterations, a so called “variation” analysis, highlights the best result in the model and provides a check for robustness (Watson et al. 2013, p. 63-77). This can best be done by altering various key input parameters such as demand, inventory, or costs. The results then show whether any changes will have severe impacts on the network with regards to cost increases and savings decreases (Watson et al. 2013, p. 77).
3. Case Study

3.1 Description of Case Study

This research paper focuses on analysis of fictional case study about a company called Polarbear Bicycle. The company has been producing bicycles since 1913, and today it is still a family business with 150 employees at the headquarters in Nuremberg. Their production facility is also in Nuremberg and 250 bikes are produced each day. The only distribution center (DC) they utilize is rented, not owned, and is located immediately next to the factory in Nuremburg. Polarbear’s portfolio includes four different types of bicycles: x-cross, urban, all terrain, and tour bicycles. Eight different suppliers supply parts for the bicycles, and every bicycle consists of six parts which are assembled in Nuremberg. Some of the parts are received by the factory as modules. All parts are single sourced. Polarbear distributes their bicycles to four bicycle wholesalers in locations throughout Germany: Cologne, Bremen, Frankfurt am Main, and Stuttgart. Fig. 1 shows the general structure of the network.

![Network Diagram](image)

Figure 1. Polarbear Bicycle’s network design

In Fig. 2, the inbound network is shown with all eight suppliers. For seats, brakes, gears, and handlebars, Polarbear single sources parts from one supplier. For the most part, all bicycles use the same parts, but the frames and tires are different for each bicycle. Polarbear sells their bicycles to the wholesalers for $499.
Table 1 shows the demand for each customer/wholesaler. All together, they receive 245 bicycles per day.

<table>
<thead>
<tr>
<th>Customer</th>
<th>Bicycle Type</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cologne</td>
<td>x-cross</td>
<td>2</td>
</tr>
<tr>
<td>Cologne</td>
<td>urban</td>
<td>50</td>
</tr>
<tr>
<td>Cologne</td>
<td>all terrain</td>
<td>15</td>
</tr>
<tr>
<td>Cologne</td>
<td>tour</td>
<td>10</td>
</tr>
<tr>
<td>Bremen</td>
<td>x-cross</td>
<td>7</td>
</tr>
<tr>
<td>Bremen</td>
<td>urban</td>
<td>30</td>
</tr>
<tr>
<td>Bremen</td>
<td>all terrain</td>
<td>20</td>
</tr>
<tr>
<td>Bremen</td>
<td>tour</td>
<td>20</td>
</tr>
<tr>
<td>Frankfurt am Main</td>
<td>x-cross</td>
<td>6</td>
</tr>
<tr>
<td>Frankfurt am Main</td>
<td>urban</td>
<td>5</td>
</tr>
<tr>
<td>Frankfurt am Main</td>
<td>all terrain</td>
<td>4</td>
</tr>
<tr>
<td>Frankfurt am Main</td>
<td>tour</td>
<td>5</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>x-cross</td>
<td>15</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>urban</td>
<td>15</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>all terrain</td>
<td>1</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>---</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>tour</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 1. Customer demand

3.2 Problem Statement

Polarbear Bicycle registered several consecutive years with only minimal profit. Additionally, their supply chain remains almost unchanged since their foundation and the DC next to their factory in Nuremberg is about to be torn down. Polarbear needs to find a good location for a new DC, and decide whether to build or rent. They have received an offer from a Polish production factory to rent a DC in 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.

In order to find the best solution for their SC, Polabear Bicycle has hired a consulting firm to analyze the supply and distribution network alternatives and to develop the best-case scenario for Polarbear Bicycle. They are charged with conducting a Greenfield Analysis 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 ordered to run a simulation to validate several key KPIs and to plan inventory, and finally to do a sensitivity analysis to verify all results.

3.3 Greenfield Analysis (GFA): Project Setting, Iteration 1

In the initial project setting of this research paper, we designed a network for the fictional Polarbear Bicycle which had 50 suppliers, rather than 8, in a single sourcing mode, 2 module-component factories in Berlin and Stuttgart, and a final assembly of the modules in a factory in Nuremberg. The focus was set on the logistics of an inbound network between the suppliers, the module-component factories in Berlin and Stuttgart, and the final assembly in Nuremberg. In Fig. 3 below, initial input data concerning product names, suppliers, origins, destinations, and the necessary number of part pieces per bike are shown.
Figure 3. Initial product and supplier data for Polarbear Bicycle

The parts from all suppliers were used to produce the modules shown in Fig. 4. The modules made in Berlin and Stuttgart were sent to Nuremberg where final assembly for the 4 different bicycles, x-cross, urban, all terrain, and tour bicycles, would take place.

Figure 4. Description of initial modules

Conducting a GFA using the inputs of this initial inbound network was difficult since typically the GFA uses customer location and demand to find an optimal DC location, and this network
was comprised only of suppliers and factories. To manage this, we set factory demand as the “customer demand” input to the model, since we knew the delivery quantity of the suppliers to the factories. In the program, we defined the suppliers as “customers” and assigned them a “demand,” which was equal to their respective delivery quantities to the factories. See Fig. 5 for the results of this analysis.

Figure 5. Initial Greenfield Analysis

In Fig. 5, the suppliers are shown as “customers” (blue), and the result of the GFA was to open a DC in Chemnitz, Germany.

While substituting customer demand with factory demand worked for the GFA, it would have restricted our ability to analyze both the inbound and the outbound parts of the Polarbear network using network optimization and simulation, since following the GFA all data inputs would have had to be reset to so that customers were “customers” and supplies “suppliers.” Because of this, a simpler network structure with eight suppliers, four customers, and one factory and DC was designed, as was described in Section 3.1.
3.4 Greenfield Analysis (GFA): Project Setting, Iteration 2

Following a fictional case study redesign, a second GFA was conducted for the outbound network of Polarbear Bicycle, with the four wholesalers, mentioned earlier, located in Cologne, Bremen, Frankfurt am Main, and Stuttgart. The wholesalers receive and distribute Polarbear’s final products. The aim of this GFA is to determine the optimal location of one new DC in Germany. To ensure that bicycles can be delivered to each wholesaler within one day, the service distance in the GFA model was set to 270 kilometers. In Table 1 above, the wholesalers and their daily demand were shown. Fig. 6 below shows the results this analysis: the optimal place to open a German DC would be in Steimelhagen.

Figure 6. Results of outbound GFA

Table 2 shows the resulting distance each wholesaler would be from the new DC in Steimelhagen.
<table>
<thead>
<tr>
<th>Distance in km</th>
<th>Bremen</th>
<th>Cologne</th>
<th>Frankfurt a. M.</th>
<th>Stuttgart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steimelhagen</td>
<td>260.66</td>
<td>52.25</td>
<td>104.60</td>
<td>252.73</td>
</tr>
</tbody>
</table>

Table 2. Service distances to each wholesaler

3.5 Network Optimization: Comparing Polarbear’s Alternatives

The starting point of the network optimization (NO) is the result of the GFA outbound analysis. Recalling Polarbear’s opportunity to rent a new factory in Warsaw, Poland, rent a new warehouse in Czech Republic, and build a new DC in Steimelhagen, the aim of the NO is to determine which network path is optimal based on Polarbear's selected KPIs.

Therefore, the factory in Warsaw, Poland, the DC in Czech Republic, and the DC in Steimelhagen were added as input to the model alongside the Nuremberg factory. For calculation in the model, the reality of the case must be simplified, therefore all demands are assumed to be deterministic without any fluctuation (Ivanov et al. 2017). To define the two-stage NO (transport between factories and DCs and between DCs and customers) problem from a mathematical perspective, several parameters must be input as data. These can be found in Table 3.

<table>
<thead>
<tr>
<th>Type</th>
<th>Value in USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factory Nuremberg: other costs</td>
<td>30,000</td>
</tr>
<tr>
<td>Factory Poland: other costs</td>
<td>18,000</td>
</tr>
<tr>
<td>DC Steimelhagen: other costs</td>
<td>5,000</td>
</tr>
<tr>
<td>DC Steimelhagen: carrying costs (per bicycle)</td>
<td>3.00</td>
</tr>
<tr>
<td>DC Czech Republic: other costs</td>
<td>2,000</td>
</tr>
<tr>
<td>DC Czech Republic: carrying costs</td>
<td>1.00</td>
</tr>
<tr>
<td>DC Steimelhagen: processing costs (inbound and outbound shipping per pcs)</td>
<td>2.00</td>
</tr>
<tr>
<td>DC Czech Republic: processing costs (inbound and outbound shipping per pcs)</td>
<td>1.00</td>
</tr>
<tr>
<td>Factory Nuremberg: production (per bicycle)</td>
<td>250</td>
</tr>
<tr>
<td>Factory Poland: production (per bicycle)</td>
<td>150</td>
</tr>
<tr>
<td>All bicycles: products costs</td>
<td>30</td>
</tr>
<tr>
<td>Paths: from factory - to DCs</td>
<td>0.01 * distance</td>
</tr>
</tbody>
</table>
Table 3. Cost inputs to simulation model

The costs for the rent of both potential facilities are included in “other costs” for the factory in Poland and the DC in Czech Republic. For transport, it is always assumed that each truckload fits 80 bicycles, and trucks travel at a speed of 80 km/h. In Figs. 7 and 8, 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 supply chain. In the NO, the suppliers were not taken into consideration.

Figure 7. Network optimization alternatives

Figure 8. Location of facilities for initial situation with alternatives
With these parameters, the initial situation for the network optimization was prepared and the program was run over the period 01/01/2017 until 31/12/2017.

To determine the optimal path for the network, the following steps were taken:

1) **Analyze the “as-is” situation:** In the first step, we analyzed the implications of utilizing a DC in Steimelhagen in combination with the original factory in Nuremburg, as determined by the GFA. We constituted that this would be the “as is” scenario since using the original DC in Nuremburg would no longer be possible, and having a DC in Germany would mean the least amount of changes to the original Polarbear SC. The net profit of this SC would be $6,970,000, as shown in Fig. 9.

![Figure 9. Net profit of Polarbear’s “as-is” SC](image)

2) **Analyze the addition of the Polish factory and Czech DC to the as-is SC:** In the second step, we analyzed the as-is SC of Polarbear plus the factory in Warsaw, Poland and the DC in Czech Republic. The net profit in this case would be $7,802,000 as shown in Fig. 10.

![Figure 10. Net profit of scenario with two factories and two DCs](image)
3) **Analyze and compare alternatives:** The third step was to find the best solution within the different alternatives. The NO allowed us to determine the potential net profit of each of the possible nine iterations of network paths, and using this information, we choose the optimal path: rent the factory in Poland and rent the DC in Czech Republic. The highest net profit possible for the Polarbear SC given current parameters would $21,989,000 as shown in Fig. 11.

<table>
<thead>
<tr>
<th>#</th>
<th>Sites</th>
<th>Profit (NetOpt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Iteration 1: Poland, Czech Rep.</td>
<td>21,989,505.025</td>
</tr>
<tr>
<td>2</td>
<td>Iteration 2: Steimelhagen, Poland</td>
<td>19,938,324.951</td>
</tr>
<tr>
<td>3</td>
<td>Iteration 3: Steimelhagen, Poland, Czech Rep.</td>
<td>18,752,028.142</td>
</tr>
<tr>
<td>4</td>
<td>Iteration 4: Nuremberg, Poland, Czech Rep.</td>
<td>11,039,505.025</td>
</tr>
<tr>
<td>5</td>
<td>Iteration 5: Nuremberg, Steimelhagen, Poland</td>
<td>8,988,324.951</td>
</tr>
<tr>
<td>6</td>
<td>Iteration 6: Nuremberg, Czech Rep.</td>
<td>8,568,761.865</td>
</tr>
<tr>
<td>7</td>
<td>Iteration 7: Nuremberg, Steimelhagen, Poland, Czech Rep.</td>
<td>7,802,028.142</td>
</tr>
<tr>
<td>8</td>
<td>Iteration 8: Nuremberg, Steimelhagen</td>
<td>6,970,084.36</td>
</tr>
<tr>
<td>9</td>
<td>Iteration 9: Nuremberg, Steimelhagen, Czech Rep.</td>
<td>5,365,300.402</td>
</tr>
</tbody>
</table>

**Figure 11.** Highest net profit possible for all NO path iterations

Choosing the highest net profit path would mean closing the factory in Nuremberg and not considering opening the DC in Steimelhagen, as shown in Fig. 12.

**Figure 12.** Recommended path network for Polarbear Bicycle

This would mean an increase in net profit for Polarbear three times higher than the approximation of the as-is scenario. This huge increase is mainly the result of the cost savings
possible by renting facilities, rather than building them, in Poland and Czech Republic, which have much lower labor costs than Germany (see Table 3).

3.6 Simulation: Describing the Polish-Czech network path

The results and data of the NO, as shown in Fig. 13, were used to create a simulation of the Poland-Czech network path.

Figure 13. Optimal network path

To simulate the operation of the whole network, the outcome from the NO was transferred to the simulation model and the eight suppliers (green) were added to the network. Several adjustments had to be made to the existing parameters from the NO. In total, 18 parameters were used for the simulation.

First, in order to create the bill of material (BOM) needed for the simulation, the components of the bicycles were input to the model along with their selling prices and costs. From these components, the BOM for all four bicycle types was created, including how many of each component Polarbear needs from each supplier. Next, sourcing policies were defined, outlining where which parts are sourced and where each part needs to be shipped. Given the results of the NO, every supplier should send their parts to the factory in Poland.

For the DC and the factory, three inventory policies were developed. The DC was assigned a “min-max policy,” where the minimum stock was 300, the maximum stock was 750, and the
initial stock was 450 bicycles. Since the factory houses both bicycle components from suppliers and completed bicycles, two inventory policies were needed for the factory. For the components at the factory, Polarbear Bicycle decided to use an order-on-demand policy, while the completed bicycles had a “min-max policy,” with a minimum of 250 and a maximum of 750 bicycles. With these inventory policies, in the event of a production stoppage for any reason, the company can cover up to six days of demand without producing any bicycles. In addition, one path from the suppliers to the factory was added to the two existing paths from the NO with the same cost calculation “product & distance-based cost” with “0.01 * product (pcs) * distance”. The production parameters were extended according to the “simple make policy” and a time of 0.002 (day). For calculating truckload volume and data concerning how many parts and products can be delivered in on truck unit, conversions for each product and part were added as inputs to the software. The transport vehicles are all trucks.

With all of the parameters described, the simulation was run from 1/1/17 until 12/31/2017 so that one year could observed. The resulting network can be seen in Fig. 14 with the factory in Poland (yellow) and the DC in Czech Republic (red).

Figure 14. Simulation of the optimal network path

To evaluate this network path and simulation, six KPIs were considered according to the needs of Polarbear: (1) Profit, (2) Total Costs, (3) Transportation Costs, (4) ELT Service Level by Product, (5) Demand (Products Backlog), Available Inventory Including Backlog and (6)
Produced Products. The estimation of the net profit in the network, which consistently rises in the first year, can be seen in Fig. 15.

Figure 15. Simulation of the net profit of the Polish-Czech SC

With the parameters introduced, Polarbear Bicycle would gain a profit of 14,800,452.57 USD. In the beginning a loss can be observed, but after 10 days the company starts to gain profit. The aberration between the profit which was presented in the NO and the profit from the simulation can be explained with the suppliers. In the NO, the suppliers were not considered, so there were no transportations costs from the suppliers to the factory. When the supplier are included, the result is of course an increase in total costs, which can be seen in Fig. 16.

Figure 16. Total costs of the Polish-Czech SC
The total costs in the end of the period is 30,011,551.23 USD. Breaking this down further, it can be seen that the transportation costs are 7,388,610.15 USD, and therefore represent 24.62% of the total costs.

Figure 17. Transportation costs of the Polish-Czech SC

Therefore, Eq. 1 shows that: \( \text{Total Revenue} - \text{Total Cost} = \text{Total Profit} \rightarrow \)

\[
44,812,003.81 \text{ USD} - 30,011,551.23 \text{ USD} = 14,800,452.57 \text{ USD}
\]  

(1)

The ETL Service Level by Product and Service Level by Orders by Products are both 100% as well as the and. The satisfaction level within that network is positive, as shown in Fig. 1

Figure 18. ELT Service Level by Products of the Polish-Czech SC

In Fig. 19, the red line represents demand and the blue the available inventory in the network. Both numbers are shown in cubic meters. As shown, the requested demand from the customers
can be matched nearly every day. During the whole period, there are some days when Polarbear can’t deliver as many products as requested, but within a few days thereafter the backlog can be recovered. Due to the fact that the service level on the customer’s side is 100% in the whole period, these backlogs do not seem to have a major impact on overall service level.

Figure 19. Products Backlog and Available Inventory Including Backlog

Alternatively, Fig. 20 shows inventory and demand if the actual inventory polices from Polarbear would have been used. This original policy meant that there was an initial stock of 1500 and a max stock within the DC and the factory of 1500. A considerable gap between both lines can be observed. This gap can be closed by reducing the initial stock and the adjusting the min-max policy, as shown in Fig. 19.

Figure 20. Demand and inventory with high initial stock

All in all, 138,134.53 m³ products would be produced in the proposed network path in one year.
3.7 Validation using Variation

In order to verify that the results of the simulation model were valid, a variation analysis was performed. The demand for the tour and urban bicycles were varied with a minimum demand of zero and a maximum demand of 50 in steps of 25. The variation was performed for a period of one month. The extract of the results of the analysis can be seen in Fig. 22 below.

<table>
<thead>
<tr>
<th>Demand Quantities</th>
<th>Profit (USD) per month</th>
<th>Service Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ; 0</td>
<td>-595,097.16</td>
<td>100%</td>
</tr>
<tr>
<td>25 ; 25</td>
<td>925,555.50</td>
<td>100%</td>
</tr>
<tr>
<td>50 ; 50</td>
<td>2,500,783.94</td>
<td>98%</td>
</tr>
</tbody>
</table>

When demand falls to zero, profit decreases and becomes negative, and likewise when demand increases profit does as well. When demand remains under or around the original demand parameters of the NO, service levels remain at 100%, but when demand increases to almost double in some instances of the expected demand, service level drops to 98%, since not all the demand can be met without a backlog delay. These results are consistent with expectations and show that the simulation model is valid.
4. Recommendations

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 reducing the initial stock and the parameters of the min-max policy as shown in Section 3.7, the costs of maintaining inventory drop, without impacting service level too much. Even when demand almost doubles, as shown in Section 3.7, the service level is still 98%: the resulting backlog is small enough to easily manage.

Second, if net profit is the most important KPI for Polarbear, the results of the NO indicate that the best network path option is to take the opportunity to rent the factory in Poland and the DC in the Czech Republic. Along the same lines, this would also mean not opening the DC in Steimelhagen, and actually closing the factory in Nuremberg. However, other factors should be taken into account concerning this option since the closing costs for the factory in Nuremberg were not considered in the software model. If the costs of closing the factory in Nuremberg outweigh the potential profit increase (though this would be unlikely) then closing the German factory would not make sense.

Likewise, as mentioned in the literature analysis, the software models simplify reality to provide usable results, and there are other factors besides net profit which Polarbear may want to consider in adjusting their network path. For example, moving the factory from Germany to Poland could mean a high amount of compensation costs due to support the German workers who will lose their jobs. Along the same lines, as a family company which has been working in Germany for over a century, moving production outside Germany could affect the company’s brand recognition, which has typically been associated with high quality. Moving to cheaper production could change the perception of Polarbear’s product quality on the market, leading to lower demand. In addition, there could be high monetary and time costs associated with starting production and training new employees in Poland, even without the costs of building a new factory. If Polarbear decided to keep all production in Germany, a significant increase in net profit of around $2.0M could still be made by utilizing the factory in Nuremberg and renting the DC Czech Republic rathering than building a warehouse in Steimelhagen.
5. Appendix

Figure i: Initial loss in profit simulation
6. References


