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Case study: GBI enters the Trolley Market in Brazil
LOGI0015-1: ERP Solutions for Supply Chain 2017 – 2018

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ERP Solutions for Supply Chains

Report Case Study: “GBI Enters to the Trolley Market in Brazil”

1. Introduction

During the last decade, a rising importance is observed concerning the integration of various departments and their business processes into one system. Although the cost of implementing an ERP system in a company is not negligible, it can lead to numerous advantages such as improving productivity, increasing efficiency and even reducing costs.

The objective of this course was to apply acquired logistical concepts on a realistic case study. This included different decision-making steps in the supply chain like the planning of procurement, production and transport. The enterprise of this case study, situated in Heidelberg (Germany), decided to enter the Brazilian market with “Industrial trolleys”. This new product is designed to fulfil the needs of mining, quarrying and manufacturing companies.

In this paper, the aim was to calculate the selling price of an “Industrial Trolley”. This price is based on the determined material cost, unit production cost and unit transportation cost of the raw materials and of the end-product. The calculations of these costs, rely on an estimation of the future demand of trolleys as well as some fundamental assumptions. All the calculations and figures are provided in the attached excel file. Where needed, an exchange rate was used to convert the currency into Euros. Moreover, we always used the same exchange rate in order to standardize our computations.

2. Trolley demand for the next three years

The first task of this project was to determine the trolley demand that we will face during the next three years. This needed to be done for the six different states where our product will be sold. In total, four steps were necessary to obtain this demand.

2.1 Calculate the total demand in Brazil

First, we analyzed statistical figures about the industrial enterprises located in Brazil according to their number of employees. Different categories concerning the number of employees, as well as the trolley consumption rate of the corresponding enterprises were given in the case. The demand per category was computed by multiplying the number of enterprises having an equivalent number of employees with the consumption of trolleys per year. Finally, we obtained the total demand in Brazil by summing up these results.

2.2 Calculate the demand of each state

In the case study was mentioned that we could assume the following:

$$\frac{Trolley\ demand\ in\ the\ six\ states}{Total\ trolley\ demand\ of\ Brazil} = \frac{Number\ of\ enterprises\ of\ the\ six\ states}{Total\ number\ of\ enterprises\ in\ Brazil}$$

Consequently, we first needed to find the number of enterprises with five or more employees in each of the six states. This was found on the same website as for the previous data. Then, we divided the number of enterprises in each state by the total number of enterprises in Brazil, which was computed in the first step. Next, we multiplied the ratio obtained for each state by the total demand of the country calculated also in the first step, to get the trolley demand in each of the six states. Finally, we added these demands to get the total demand for the six states. The result is rounded up to the nearest integer, because only complete products are sold and we want to at least fulfill all the demand.

2.3 Calculate the desired market share at the end of the 6th year

The objective of the company was to obtain the same market share as the 2^{nd} competitor at the end of the 6^{th} year and to obtain a market share of 30% after 15 years. Additionally, given the market shares of our competitors and the fact that we capture their shares proportionally, we could estimate the market share that our enterprise will have at the end of the 6^{th} year. To do so, we solved the following equation in which y represents our market share at the end of the 6^{th} year.

$$1 = (0{,}38 - 0{,}38y) + y + y + (0{,}14 - 0{,}14y) + (0{,}1 - 0{,}1y) + (0{,}06 - 0{,}06y)$$

$$<=> 1{,}32y = 0{,}32$$

$$<=> y = 0{,}242424242$$

As a result, we estimate that the enterprise's market share at the end of the 6^{th} year will be approximately equal to 24,24%.

2.4 Determine the demand during the first three years

In order to represent the evolution of our market shares in relation to the time (x), the following increasing function was used:

$$f(x) = c.e^{\frac{-a}{x}}$$

First, the value of the parameters a and c of this function needed to be determined. In the previous section we found that our market share at the end of the 6th year would be around 24,24% and it was given that the objective is to obtain a market share of 30% after 15 years. Therefore, after transforming the original function by using the "ln method", we constructed and solved a system of two equations with two unknowns. In what follows, the different steps are given.

Transformation of function

$y = c * e^{-\frac{a}{c}}$

$<=> \ln(y) = \ln\left(c * e^{-\frac{a}{x}}\right)$

$<=> y = \ln(c) + (-\frac{a}{x})$

We set $Y = \ln(y)$, $C = \ln(c)$ and $X = -\frac{1}{x}$ which allowed us to get the following expression:

$$\boxed{Y = C + aX}$$

Solving system of two equations with two unknowns

$$\begin{cases} Y_1 = C + aX_1 \\ Y_2 = C + aX_1 \end{cases}$$

$$\begin{cases} C = Y_1 - aX_1 \\ Y_2 = c + aX_2 \end{cases}$$

$$\begin{cases} C = Y_1 - aX_1 \\ Y_2 = Y_1 - aX_1 + aX_2 \end{cases}$$

$$\begin{cases} C = Y_1 - aX_1 \\ aX_1 - aX_2 = Y_1 - Y_2 \end{cases}$$

$$\begin{cases} C = Y_1 - aX_1 \\ a = \dfrac{Y_1 - Y_2}{X_1 - X_2} \end{cases}$$

Result:

$X_1 = -\frac{1}{6}$

$X_2 = -\frac{1}{15}$

$Y_1 = \ln(0{,}242424242)$

$Y_2 = \ln(0{,}30)$

$C = \ln(c)$

Computation of parameters

With the results from the previous step, we determined the value of a and c.

$$\boldsymbol{a} = \frac{\ln(0{,}242424242) - \ln(0{,}30)}{\frac{-1}{6} - \frac{-1}{15}} = \mathbf{2{,}1309}$$

Next, we computed the value of C by substituting a with its new value.

$$C = \ln(0{,}242424242) - \left(2{,}1309 * \frac{-1}{6}\right) = -1{,}061916022$$

Since $C = \ln(c)$, we can determine the value of c.

$$\boldsymbol{c} = e^{-1{,}061916022} = \mathbf{0{,}3458}$$

Market shares

In this step, we can determine our market share for the first three years by substituting the parameters in the increasing function by its corresponding values.

- Market share year 1: $f(x) = 0{,}3458 * e^{\frac{-2{,}1309}{1}} = 0{,}041016691$
- Market share year 2: $f(x) = 0{,}3458 * e^{\frac{-2{,}1309}{2}} = 0{,}119097822$
- Market share year 3: $f(x) = 0{,}3458 * e^{\frac{-2{,}1309}{3}} = 0{,}16990971$

Finally, to get the trolley demand during the first three years, we multiplied the market share of $year_i$ by the total demand of the 6 states. Additionally, we decided to consider a growth in GPD to be closer to the economic reality of the country.

The final demand was obtained by using the following formula:

$$Market\ share\ of\ year\ i * Total\ demand * (1 + Growth\ in\ GPD)$$

The results were rounded up since we do not sell half a trolley and they are given in the table below.

Year	Market share	Total demand	Growth in GDP	Demand
2018	0.0410166911	182565	1.75%	7620
2019	0.119097822	182565	1.95%	22168
2020	0.169909717	182565	2.00 %	31640

3. Product

3.1 Bill of materials structure

To calculate the net weight and material cost of the end product, we first needed to obtain the cost of each main component that composes a whole trolley, *level 0* . These main components correspond to *level 1* semi-finished products in the table below. These products are ready to be assembled into a finished trolley. All the *level 2* and *level 3* items and raw materials still need some operations in order to respectively form its corresponding *level 1* and *level 2* part.

BOM level	Quantity	Part name	Part code	Description
Level 0	1	Trolley, 4 wheeled	TROLLEY808	
Level 1	1	Plywood tray	PLTRAY808	1200 mm x 800mm x 12mm
Level 2	0,333333333	Plywood plate	PLYWOOD808	2440mm x 1220 mm x 12mm
Level 1	1	Steel frame	FRAME808	3,74
Level 2	2	Width parts (800mm)	FRWIDTH808	0,8
Level 3	0,1	Rectangular tubes	RECTST808	10 pieces out of 1 tube
Level 2	2	Length parts (1070mm)	FRLENGTH808	1,07
Level 3	0,142857143	Rectangular tubes	RECTST808	7 pieces out of 1 tube
Level 1	2	Fixed castors	FCASTOR808	box of 24
Level 1	2	Swivel castors	SCASTOR808	box of 24
Level 1	20	Screw	M10SCREW808	M10, 16 attach wheels to steel frame and 4 fix plywood tray to steel frame
Level 1	1	Plywood back	PLBACK808	770 mm x 500mm
Level 2	0,166666667	Plywood plate	PLYWOOD808	2440mm x 1220mm
Level 1	1	Steel handle	HANDLE808	745mm + 800mm+ 745mm+(0,05^2+(0,950-0,5-0,205)^2)^1/2 = 2300mm
Level 2	1	Cutted round tubes	CUTROUND808	2300mm
Level 3	0,50	Round tubes	ROUNDST808	1 tube of 6m
Level 2	2	Screw	M20SCREW808	M20
Level 2	2	Nut	M20NUT808	M20
Level 1	4	Parker screw	PARKERSCREW808	

In the table above, the bill of materials is shown. For each level, the part name is given with its matching part code and a small description. Additionally, most of the quantities we needed of each part were given. However, we still needed to calculate the quantity of the raw materials. Therefore, we had to decide how to cut these tubes and plates to minimize waste and operation costs. The decision making of the cutting operation will be discussed in the section *Unit production costs*. Based on the number of parts we can cut out of each raw material, we obtained the quantity by dividing a unit by this number of parts.

3.2 Net weight of end product

Given the volume of a plywood tray and back, we could compute its net weight by making a ratio of this volume per part to the total volume of a plywood plate. Additionally, for the steel frame and handle, the weight per meter was given. Therefore, we only needed to multiply this value by the length of the part to obtain its net weight. The length of the steel frame was easily found by adding the length of the four sides. Next, the length of the steel handle was calculated by using the formula of Pythagoras since we are dealing with two curved sides:

$$2 \times \left(0.5 + \sqrt{0.05^2 + (0.95 - 0.205 - 0.5)^2}\right) + 0.8 \approx 2.3\, m$$

For the different castors, screws and nuts, a net unit weight was given. Thus, we multiplied the weight per part by the required number of units in order to obtain their total weight. Finally, the net weight of the trolley is determined by adding the weight of the different parts.

3.3 Material cost of end product

When determining the material cost of the raw materials, we needed to consider the waste. Therefore, in the case of the plywood plates, we started by determining the total volume of the waste per plate. This was done in the following way:

$$Total\ volume\ waste\ per\ plate =$$
$$Total\ volume\ plate - (volume\ semi - finished\ product \times number\ of\ parts\ per\ plate)$$

As mentioned before, the decision of how we cut the raw materials, will be discussed in the next section. Next, the waste per tray or back was obtained by dividing the total volume of the waste per plate by the number of parts cut. Since for the plywood plates a cost per cubic meter was given, this volume of waste per semi-finished product was later added to the volume of a tray or back. This enabled us to equally distribute the cost.

The steel frame is made out of four rectangular tube parts with two different lengths. Therefore, we assumed that each rectangular tube is only used to obtain either the width or the length part, to reduce the waste and simplify the cutting process. For the rest of the calculations of the steel frame and handle, a similar reasoning was applied as for the plywood plates. Finally, for the remaining components a unit price was given. In some cases, an exchange rate was needed to convert values into Euros. We used the rate of the 4th of October 2017 for all our calculations. In the table below an overview is given of the net weight and material cost per part as well as the final net weight and material cost of the trolley.

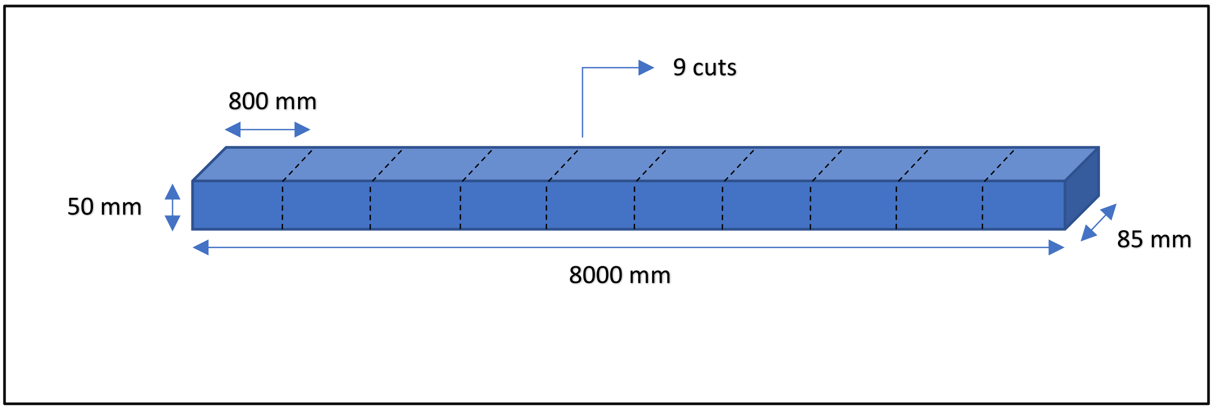
Part name	Weight(kg)/unit		Net weight	Cost/Unit		Net cost
Trolley, 4 wheeled						
Plywood tray			8,64			2,38144
Plywood plate	26,80	per plate		200	per m3 ($)	
Steel frame		Steel frame (width parts + length parts)	11,97			
Width parts (800mm)	2,56		5,12			3,072
Rectangular tubes	3,20	per m		600	per ton ($)	
Length parts (1070mm)	3,42		6,848			4,388571429
Rectangular tubes	3,20	per m		600	per ton ($)	
Fixed castors	0,60		1,198	10	per unit (€)	20
Swivel castors	0,84		1,686	14	per unit (€)	28
Screw	0,03	per unit	0,522	0,02	per unit ($)	0,4
Plywood back			3,4661			1,19072
Plywood plate	26,80	per plate		200	per m3 ($)	
Steel handle	4,14		4,140179982			3,24
Cutted round tubes						
Round tubes	1,80	per m		600	per ton ($)	
Screw	0,27	per unit	0,544	0,52	per unit ($)	1,04
Nut	0,11	per unit	0,222	0,08	per unit ($)	0,16
Parker screw	0,01	per unit	0,032	0,012	per unit ($)	0,048
		Total weight	32,42			
					Total cost (euro)	48
					Total cost (dollar)	15,92073143
					(4/10) 1 dollar=(euros)	0,85004
					Total (euro)	61,53325854

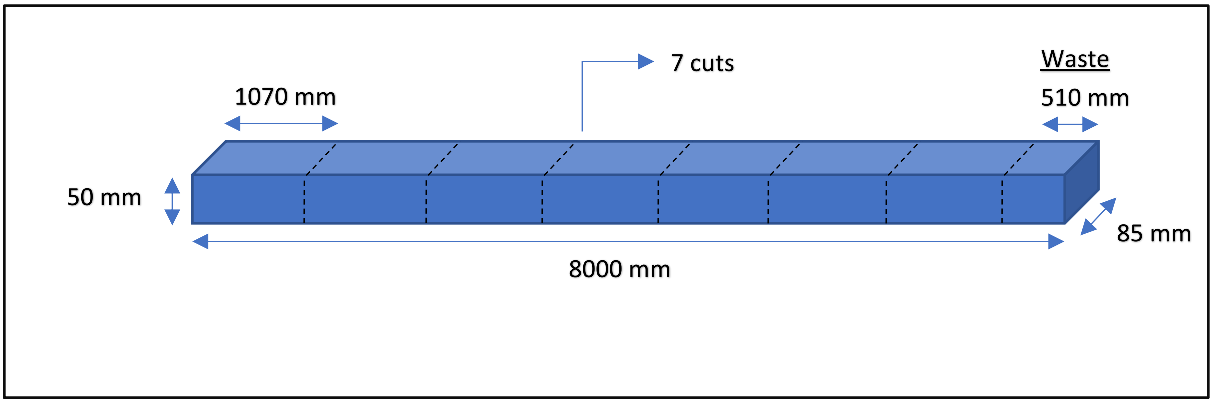
4. Unit production cost

In order to calculate the production cost of a trolley, various production operations must be taken into account. Hence, each part of the end-product mentioned in the previous section is provided with their corresponding operations. In this section, a clarification is given for certain calculation methods and assumptions that were made per part.

Frame

To obtain 800 mm tubes, rectangular steel tubes are cut as shown in the illustration below. As can be observed from the illustration, the tubes are cut over their shortest width (50 mm) to reduce operation time. For the different cutting processes, the assumption was made that there is no cutting kerf. This means that no material is removed due to the process. Subsequently, the optimal number of cut tubes is 10. Since it is assumed that the operator of the steel tube saw will consecutively cut all the pieces of the tube, the setup time is divided over the number of pieces obtained. The cutting of rectangular tubes with a length of 1070 mm is done similarly. The only difference with the previous operation is that there is some unavoidable waste. Finally, the remaining operations consist out of welding the tubes, drilling and tapping holes. The total operation time of each part is shown in a table on page 12.

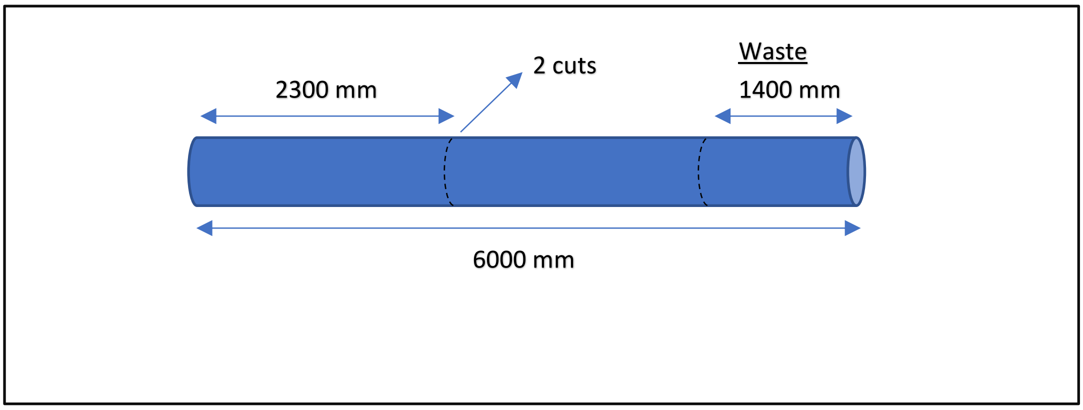




Handle

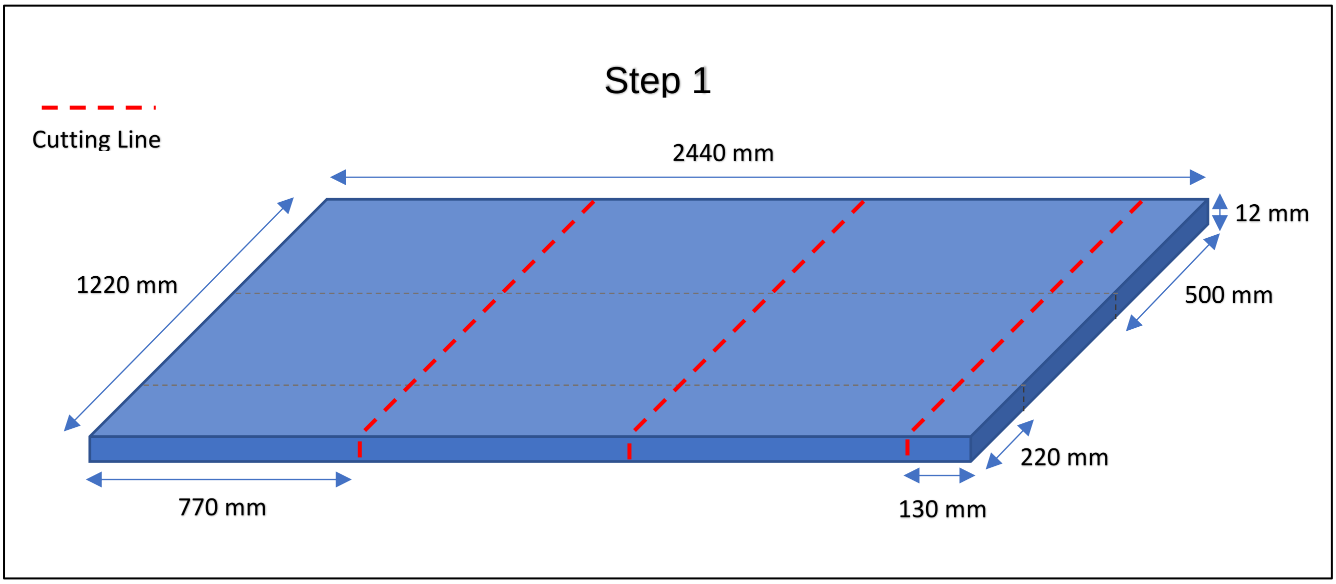
The cutting process of the round steel tubes is illustrated below. In this case the length of the cut is equal to the diameter of the tube, which is 32 mm. Since the required length of the tube is 2300 mm, only two pieces can be made from 1 round tube and this leads inevitably to some waste. After bending these tubes, screws must be welded to the extremities of each handle. The length of the welding corresponds to 94.2 mm, which is obtained by applying the well-known formula to calculate the area of a circle: $\pi . r^2$

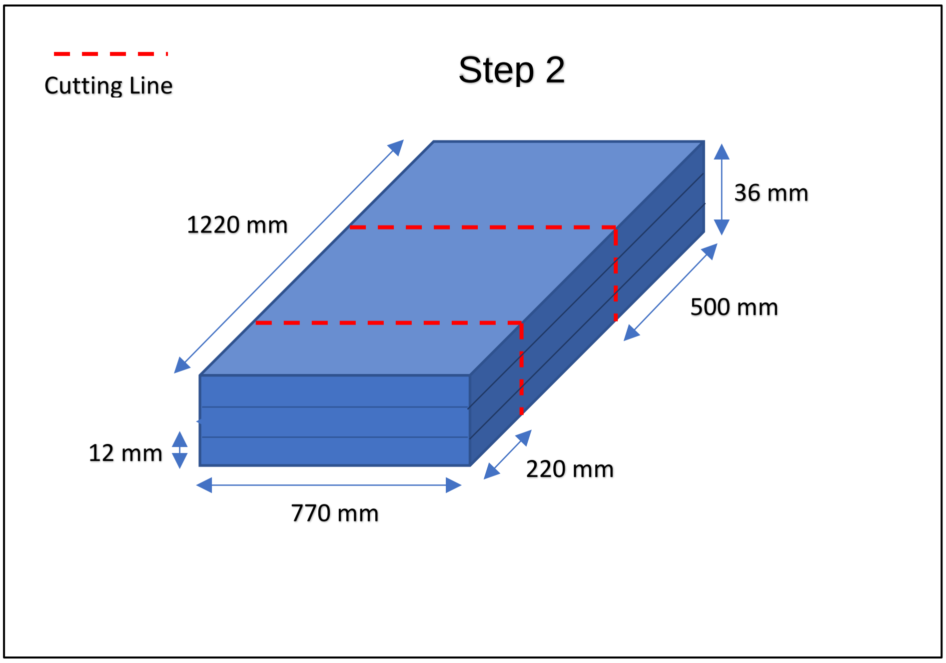
Here, r^2 represents the diameter of the screw that must be welded.



Plywood back

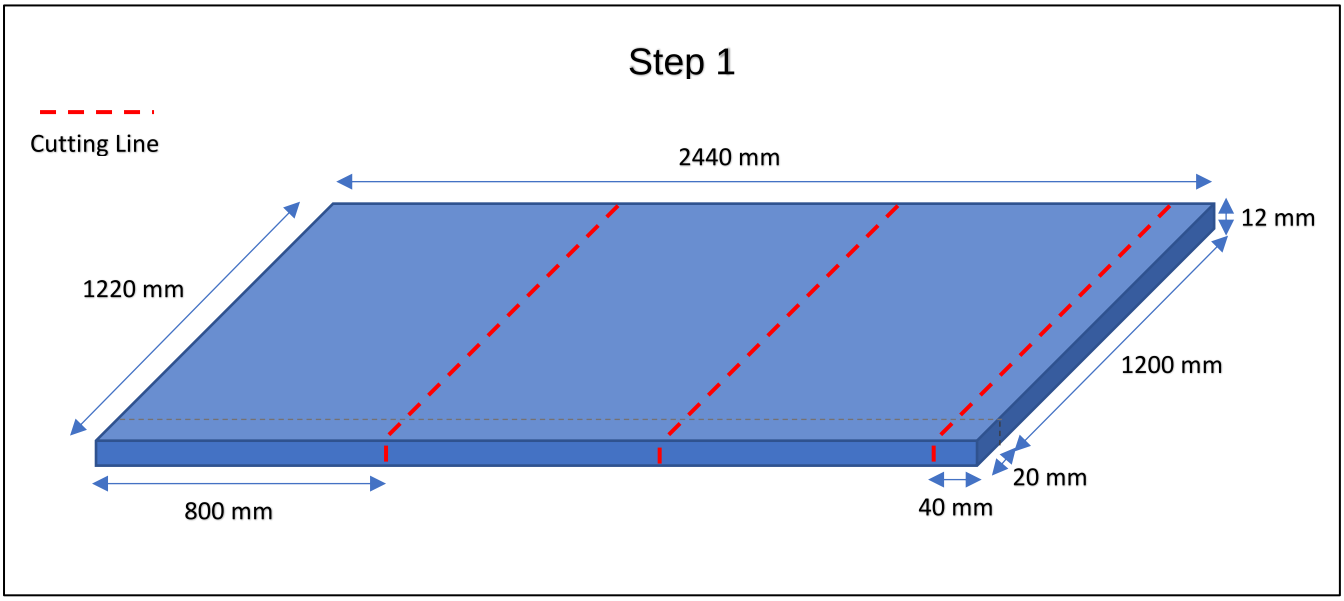
The required plywood back has a size of 770 mm x 500 mm. In order to obtain the shortest operation time corresponding to the optimal number of plywood backs out of one plate, the cutting process is divided in two steps. First the plywood plate must be cut three times in its width. In the second step, the three parts that are acquired from the first step are placed on each other. This is allowed since it does not violate the thickness constraint of the plywood saw (3 x 12 mm < 60 mm). Next, the plates are cut two times in their new width (770 mm). This corresponds to the following: (3 x 1220) + (2 x 770) = 5200 mm

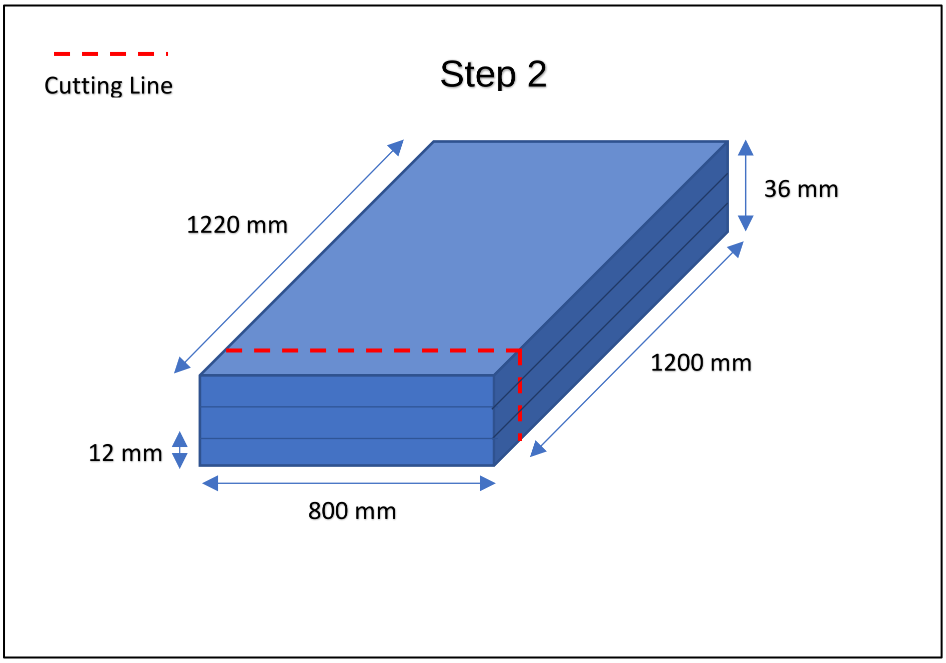




Plywood tray

The desired plywood tray has a size of 800 mm x 1200 mm. The cutting process is also divided in two steps. Similarly, to the plywood back, the plate is first cut three times in its width. After positioning the obtained parts on each other, the parts are cut once in their new width. This is illustrated below.





Painting/ varnishing

For the total operation time of the painting and varnishing, each operation is considered to have its own setup time. For example, before painting the steel frame a setup time must be taken into account.

Finally, the decision was made to not assemble the different parts before transportation. As a result, the trolley can be put in a much smaller box, which leads to significant transportation cost reduction. In the table below an overview is given of the operation time of each part and the final operation cost. In order to calculate the cost per hour, the labor charge must always be included.

	Steel tubes	Plywood Plate	Welding	Assembly	Painting	**Total**
Frame	467,43		388,8	488		1344,23
Handle	298,00		67,82	16		381,82
Plywood back		71,6		16		87,60
Plywood tray		131,36		16		147,36
Painting					960	960
Assembly				64		
Total (s)	765,43	202,96	456,62	600,00	960,00	**2985,01**
Total(h)	0,21	0,06	0,13	0,17	0,27	0,83
Cost per hour	23,4	23,4	28,8	23,4	28,8	**€/hour**
Total cost	4,975285714	1,31924	3,652992	3,9	7,68	**21,53**

5. Management of the inbound flows of the facility in Germany

In this section, we first discuss how the maximum number of units that can be loaded in each type of container was computed. Then, the economic order quantity (EOQ) of each raw material is clarified. This is followed by the justification of the used transportation mode and the destination port of each raw material. Finally, we describe the obtained order tables per raw material which include the number of shipments per year, the quantity of a shipment and ordering and receiving date of the shipment.

5.1 Containers

We had the choice between four types of containers to ship the raw materials from our supplier to our plant in Heidelberg. To facilitate the handling during the loading and the unloading of the materials, we decided to add a marge of two centimeters on each side and on the top of the container. In the excel file the adjusted dimensions of the container are computed. Next, the net weight and maximum gross weight of each container are given in the case. Therefore, we computed the maximum weight of the merchandise that we can put into each container by subtracting the net weight from the maximum gross weight.

Plywood plates

Along the length of a 20 feet container, we can place a maximum of two series of plywood plates. Furthermore, if we place plywood plates horizontally, we can make two piles of 196 plywood plates.

$$\frac{2.360\ (height\ of\ a\ 20\ feet\ container)}{0.012\ (tickness\ of\ a\ plywood\ plate)} = 196\ plywood\ plates$$

Next to each pile, we can place vertically 90 plywood plates because the remaining width is 1.080m $(2{,}3m\ (adjusted\ internal\ width) - 1{,}22m\ (width\ of\ a\ plywood\ plate))$. Therefore, we can calculate the number of plates by using this formula:

$$\frac{1.080\ (remaining\ width)}{0{,}012\ (tickness\ of\ a\ plywood\ plate)} = 90\ plywood\ plates$$

In total, we can place 572 plywood plates in a 20 Feet container.

- 2 piles of 196 plywood plates (horizontally placed) = 392 plywood plates
- 2 series of 90 plywood plates (vertically placed) = 180 plywood plates

Since the weight of the plywood plates is lower than the maximum weight of the merchandise, we are confronted with a volume constraint. Additionally, we decided to always place the plywood plates in the middle of the container in order to respect the weight repartition. This is illustrated in the image below.

Vietnam to Heidelberg (D)
Rapport 001
Container 20Feets HEC (5 885 mm x 2 300 mm x 2 360 mm)
Poids total 15 329,5 kg (71%)
Volume total 20,43 m^3 (64%)
Poser à gauche 0,502 m
Poser à droite 0,008 m
Mètres libre 1,004 m

Légende:
Groupe n ° 1 Plywood plate
- A 572pcs 244 x 122 x 1.2 cm 15,329.6kg inclinaison. empilable. pourrir. Plywood plate

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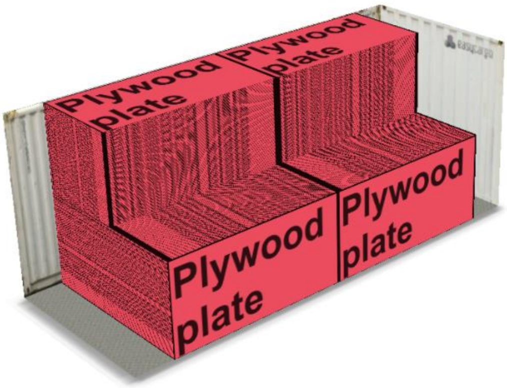
Avant-première:



Screenshot from easycargo3d.com

The shipment of a 20 feet PW Container was determined in a similar way. Computations can be found in the excel file and the shipment is illustrated below.

Vietnam to Heidelberg (D)
Rapport 003
Container 20Feets PW HEC (5 885 mm x 2 400 mm x 2 360 mm)
Poids total 15 811,9 kg (73%)
Volume total 21,08 m^3 (64%)
Poser à gauche 0,502 m
Mètres libre 1,004 m

Légende:
Groupe n ° 1 Plywood plate
- A 590pcs 244 x 122 x 1.2 cm 15,812kg inclinaison. empilable. pourrir. Plywood plate

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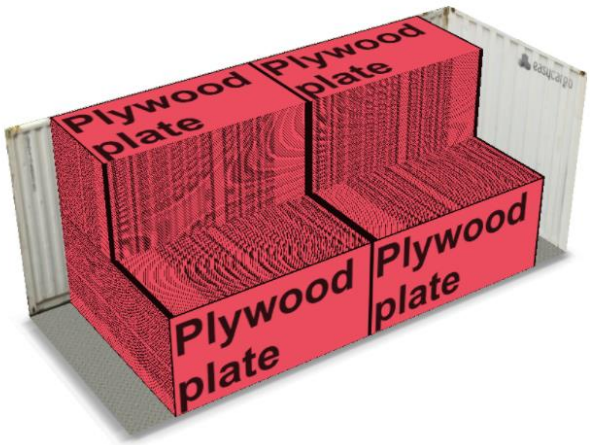
Avant-première:



Screenshot easycargo3d.com

The only difference for the shipment of 40 feet and 40 feet PW containers is that we are confronted with a weight constraint. Therefore, we need to reduce the number of plywood plates loaded into this container. Since the maximum weight for the merchandise is 28 700 kilograms, we can load a maximum of 1070 plates into a 40 feet and 40 feet PW container.

$$\frac{28.700\ (maximum\ merchandise\ weight)}{0.0268\ (weight\ of\ a\ plywood\ plate)} = 1070{,}89552\ plywood\ plates$$

This number was rounded down since we must respect the weight constraint. The shipments are again illustrated below.

Vietnam to Heidelberg (D)
Rapport 004
Container 40Feets HEC (12 060 mm x 2 300 mm x 2 360 mm)
Poids total 28 676,3 kg (100%)
Volume total 38,22 m ^{3} (59%)
Poser à gauche 1,403 m
Poser à droite 0,008 m
Mètres libre 2,299 m

Légende:
Groupe n ° 1 Plywood plate
- A 1070pcs 244 x 122 x 1.2 cm 28,676kg inclinaison. empilable. pourrir. Plywood plate

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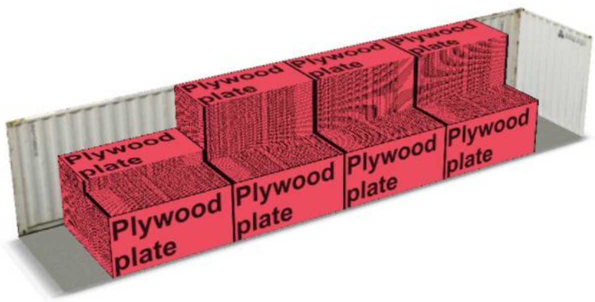
Avant-première:



Screenshot easycargo3d.com

Vietnam to Heidelberg (D)
Rapport 005
Container 40Feets PW HEC (12 060 mm x 2 400 mm x 2 360 mm)
Poids total 28 676,3 kg (100%)
Volume total 38,22 m ^{3} (56%)
Poser à gauche 1,492 m
Mètres libre 2,299 m

Légende:
Groupe n ° 1 Plywood plate
- A 1070pcs 244 x 122 x 1.2 cm 28,676kg inclinaison. empilable. pourrir. Plywood plate

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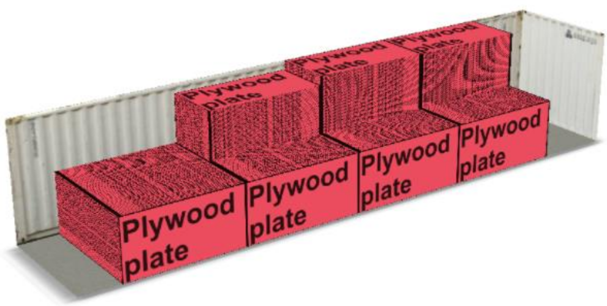
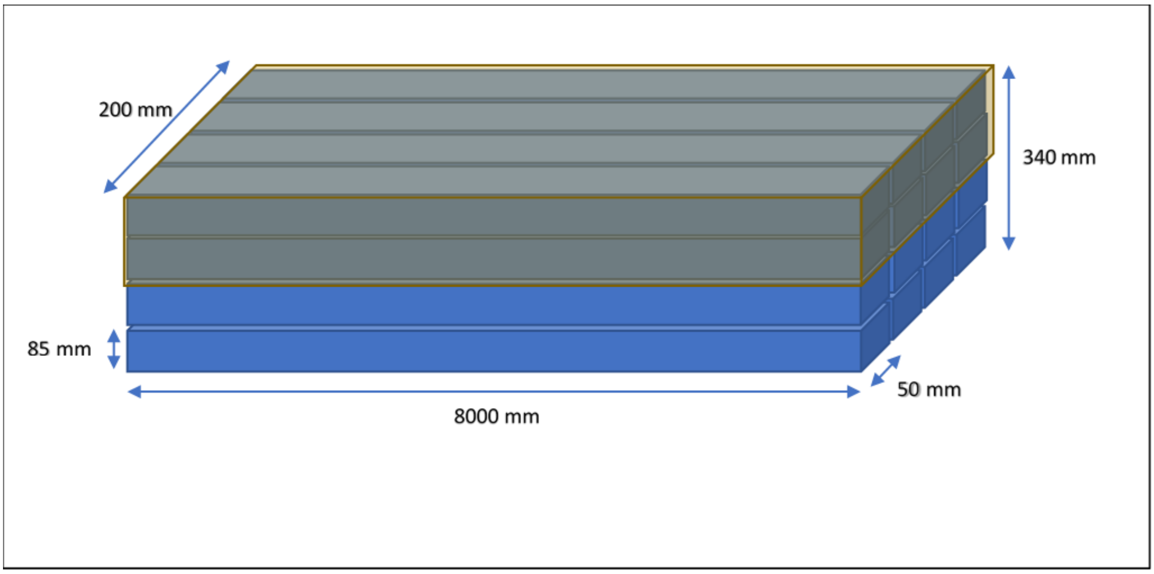
Avant-première:

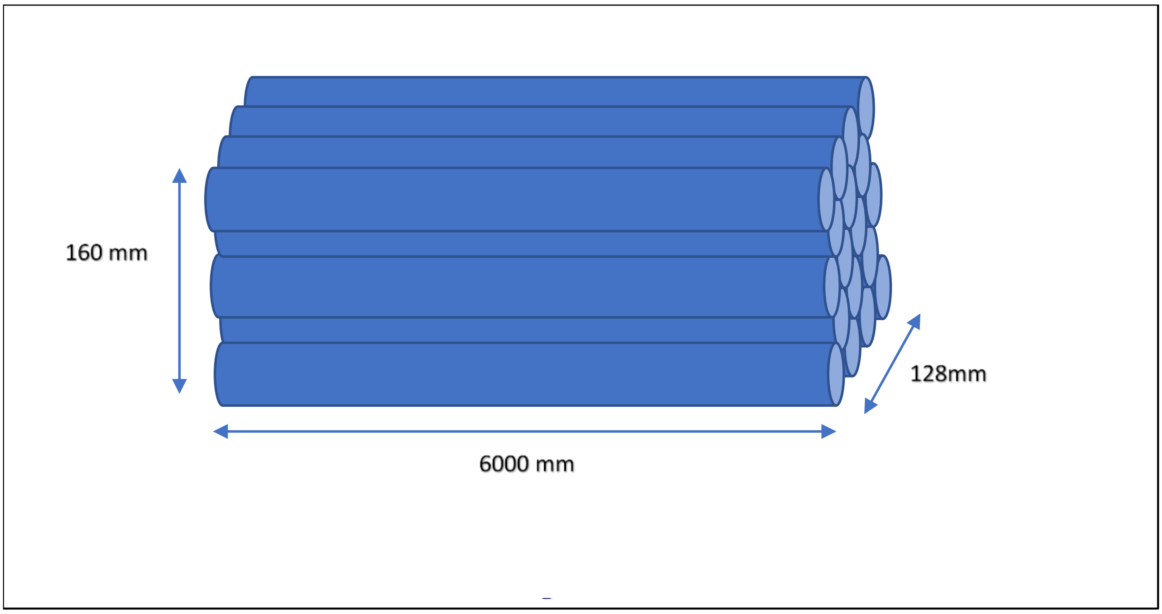


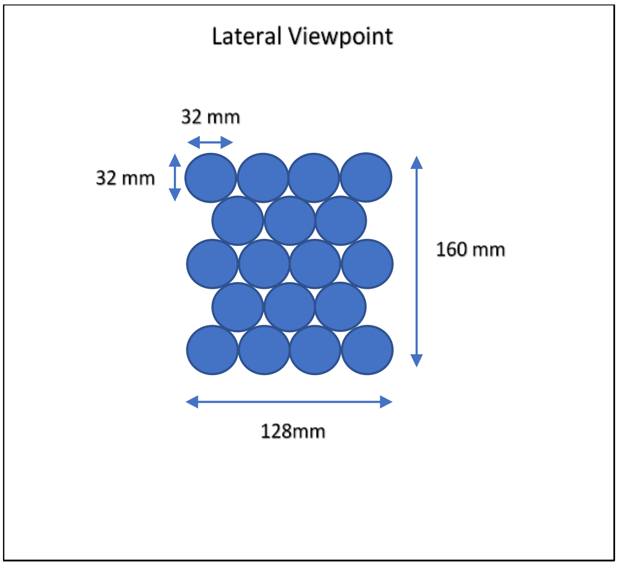
Screenshot easycargo3d.com

Rectangular and round steel tubes

Given the weight of each type of tube and the number of tubes per box, we can easily compute the weight of the corresponding box. Moreover, we decided to place the rectangular and round tubes in boxes as shown below.







Since the rectangular and round steel tubes come from the same supplier in Turkey, we decided to put them in the same container. Moreover, we based our decision of how many tubes of each type we should load in a container, on the demand rates determined in the bill of materials (BOM). Since we do not need the same amount of round and rectangular steel tubes to manufacture a trolley, this was a necessary step.

First, we calculated how much of each type of rectangular tube was needed to build the trolley. Therefore, we added the corresponding quantities determined in the BOM. Afterwards, we computed a ratio of the part of rectangular steel tubes needed per trolley to the part of round steel tubes needed per trolley. This gave the following result:

$$Ratio = \frac{(2 \times 0.1) + (2 \times 0.1428)}{0.5} = 0.9714$$

Next, by applying trial-and-error, and using the software of EasyCargo we searched to load the optimal amount of each type of tube in a container. Since the tubes are at least 6m long, we cannot use a 20 feet container to transport these materials. Finally, we computed the ratio of the number of tubes we load in the container to find the one closest to the ratio calculated above, with respect to the weight constraint. The result is shown in the table below and correspond to the 40 feet as well as the 40 feet PW container.

	Optimal number of boxes	Total number of tubes
Rectangular tubes	49	784
Round tubes	44	792

$$Optimal\ ratio: \frac{784}{792} = 0.9899$$

We decided to place the boxes in the middle of the container to respect the weight repartition, as shown below.

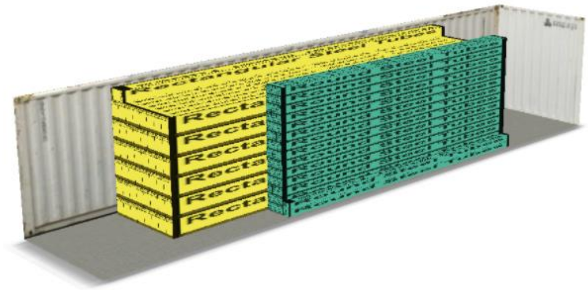
Turkey to Heidelberg (D)
Rapport 001
Container 40Feets HEC (12 060 mm x 2 300 mm x 2 360 mm)
Poids total 28 624,0 kg (100%)
Volume total 32,06 m ^{3} (49%)
Poser à gauche 2,328 m
Poser à droite 0,058 m
Mètres libre 4,059 m

Légende:

Groupe n ° 1 Rectangular Steel Tubes
- B 49pcs 800 x 20 x 34 cm 20,070.4kg inclinaison. empilable. pourrir. Rectangular Steel Tubes

Groupe n ° 2 Round Steel Tubes
- C 44pcs 600 x 12.8 x 16 cm 8,553.6kg inclinaison. empilable. pourrir. Round Steel Tubes

Avant-première:



5.2 EOQ and safety stock

The EOQ was calculated for each year to decide which container would be ordered. The yearly demand of each raw material is obtained by inserting the yearly trolley demand in the BOM and adding the quantity needed to produce this amount of trolleys. At the top of the corresponding excel sheet an overview is given of the raw material demand for each year. Concretely, for the plywood plates we get the following in the first year:

$$2540 + 1270 = 3810$$

BOM level	Quantity	Part name
Level 0	7620	Trolley, 4 wheeled
Level 1	7620	Plywood tray
Level 2	**2540**	**Plywood plate**
Level 1	7620	Steel frame
Level 2	15240	Width parts (800mm)
Level 3	762	Rectangular tubes
Level 2	15240	Length parts (1070mm)
Level 3	1088.571429	Rectangular tubes
Level 1	15240	Fixed castors
Level 1	15240	Swivel castors
Level 1	152400	Screw
Level 1	7620	Plywood back
Level 2	**1270**	**Plywood plate**
Level 1	7620	Steel handle
Level 2	7620	Cutted round tubes
Level 3	3810.00	Round tubes
Level 2	15240	Screw
Level 2	15240	Nut

The unit value cost of a plywood plate was computed by multiplying the surface area of the plate with the cost per cubic meter. For the tubes, a cost per ton was given and the weight per meter. Therefore, we needed to multiply the length of the tube with the weight per meter and the cost per kilogram. Since we want to obtain a value in Euro, the result was always multiplied by the corresponding exchange rate of the 4th of November 2017.

Next, the fixed set up cost is calculated by multiplying the hours needed to prepare a replenishment order with the labor cost per hour of the planning department and adding the labor charge. In the case of the steel tubes two times 45 minutes needed to be taken into account since we decided to put the two types of tubes in one container. Each time a number of units of a product was calculated, for the EOQ or daily demand, the result was rounded down because we cannot order half a product. For the tubes, we had to use other formulas to determine the optimal order frequency and optimal order quantity of each tube. These formulas were given and were based on the same parameters as the formula of EOQ.

For the computation of the safety stock, we based our decision on the minimum lead time of the raw materials. Since this was still a big number, we decided take 50% of this amount and obtained 10 days. The safety stock was then determined by multiplying this number with the daily demand. This is quite a big safety stock considering the ordered amount. Nevertheless, it can be justified by the fact that weekends and holidays are not considered when determining the shipment dates and neither when calculating the daily demand.

5.3 Order tables

In order to determine how inbound flows in the production facility should be managed, it was required to compute a yearly order table for each raw material. The main principles of our calculations are the same for each type of raw material. Nevertheless, some differences exist and those will be emphasized.

First, it was assumed that the production year begins the 14th of November 2017 and we start selling trolleys the 1st of January 2018. The day we need to start producing is based on the first shipment of trolleys to Brazil. Since it was decided to send two 40 feet containers for that shipment, we first need to subtract the lead time to Brazil and production time to fill these two containers from the date we want to start selling. Finally, we need to subtract the lead time of the raw materials from the previous result to obtain the day we need to start producing. The mentioned lead times will be discussed in the section *Transportation costs* and the computation of the production time to fill the containers can be found in the section of *Container trolley*.

Next, it was assumed that containers are loaded or unloaded the same day as the production takes place. This can be assumed since the land distance of transportation, which will be discussed later, is rounded up. As a result, no day is added between the end of production and a shipment or the arrival of a shipment and the start of production. Furthermore, we always order or ship at full container load (FCL) and the surplus at the end of the year is transferred to the following year.

In the orders table, some abbreviations were used to reduce its size and facilitate its comprehension. An overview is provided in the table below.

Q	Quantity of the shipment ordered at FCL (in units)
I_0	Initial inventory level before receiving the shipment (in units)
I_F	Final inventory level after receiving the shipment (in units)
I_C	Inventory level to consume after subtracting the safety stock from I_F (in units)
T_C	Time to consume I_C (in days)

In order to clarify the calculations, we will discuss the plywood plates order table of the first year but the same principle is applied on the other tables.

Order number	Order date	Receiving date	Q	I_0	I_F	I_C	T_C
1	12/10/2017	14/11/2017	1070	0	1070	960	91
2	11/01/2018	13/02/2018	1070	110	1180	1070	102
3	23/04/2018	26/05/2018	1070	110	1180	1070	102
4	3/08/2018	5/09/2018	1070	110	1180	770	70

From the first column, the number of shipments per year can be deduced. Since we want to be able to start producing the 14th of November 2017, this is the date on which the first shipment should be received.

Next, the order date is obtained by subtracting the lead time from the receiving date of the shipment.

The quantity of the shipment is based on the EOQ of that year and the maximum number of units that can be loaded in each type of container. Concretely, we always chose the number of containers that correspond as much as possible to the determined EOQ whilst minimizing the number of containers. This quantity is used for almost every order to obtain a standardized order table. Nevertheless, sometimes we order a smaller quantity for the last order of a year. This enables us to reduce the number of units that will be transferred to the next year.

The initial inventory level of the first year is logically always null for the first order. The next orders have an initial inventory level equal to the safety stock since this is the amount that may not be used for production. Furthermore, the safety stock increases every year according to the demand.

The final inventory level is computed by adding the quantity shipped and the initial inventory level. Additionally, the inventory level that can be consumed, except for the last order, is obtained by subtracting the safety stock from the final inventory level. For the last order, we just multiply the number of days left of that year with the daily demand.

Finally, the last column shows the number of days to consume the allowed inventory level. This number is added to the previous receiving date in order to calculate when the next shipments should be received. Since we do not want to order too late, the consumption time is rounded down. The consumption time of the last order is obtained by subtracting the total consumption time until then from the number of days per year, which is assumed to always be 365 days.

The difference between the final inventory and the inventory that can be consumed, is transferred to the next year. Moreover, if this amount exceeds the safety stock of the following year, this means we do not have to place an order at the start of that year. Therefore, the number of days we can consume in the next year with the surplus of the previous year is computed. This is done in the following way and is also rounded down:

$$\frac{(Amount\ transferred\ to\ next\ year - safety\ stock\ of\ next\ year)}{\frac{Demand\ of\ the\ next\ year}{365}}$$

In the case the result is positive, the receiving date of the second order is determined by adding the consumption time to the start of the production of that year instead of the previous receiving date. Otherwise the total time of consumption will not be equal to 365.

6. Unit transportation cost of purchased materials and selling price of the end-product to the distributor

This section of the report is dedicated to the decision making of the destination port, the computation of the unit transportation cost of each imported raw material and the selling price of the end-product to the distributor in Brazil.

6.1 Unit transportation cost plywood plates

Port of destination

Although the port of origin was given in the case, we still needed to determine the destination port of the shipment. Therefore, we compared the costs of five European ports located close to Heidelberg. We selected the following ports based on their location and importance:

- Antwerp (Belgium)
- Zeebrugge (Belgium)
- Rotterdam (Netherlands)
- Le Havre (France)
- Bremerhaven (Germany)

First, for each of the selected ports, we computed the sea distance that separates the considered port from the port of Hai Phong, while taking into account the port(s) of call[1]. Next, we searched for the sea transportation duration on the CMA-CMG website. Additionally, we determined the duration and distance by truck from the port of destination to the facility in Heidelberg by using Google Maps. Regarding the transport by truck, we rounded up the result to consider the loading and unloading of the truck, and possible delays.

Furthermore, our analysis was based on a 40 feet container (Full container load, FCL) for all the five ports. We considered both the transportation distance and the duration since a cost is incurred for both the number of travelled kilometres and for the renting of the container based on the journey time.

Regarding the maritime transport, there was a forfeit of 1100 x 1.4 € for a FCL 40 feet container that covered a base distance of 5000 kilometres. Given that the sea distance was greater than this base distance, we had to consider a cost of 60 x 1,4 € per additional 1000 kilometre for a FCL 40 feet container. We computed the additional distance by subtracting 5000 from the total maritime distance. To determine the renting cost of the container during the sea journey, we simply multiplied the duration of this journey by the daily cost of renting a 40 feet container (42€).

For the transport by truck, there was also a forfeit of 250 x 1,5 € per 100 kilometres for a FTL 40 feet container. To find the cost of transporting the plywood plates by truck, we divided the road distance by 100 and multiplied the result by 250 x 1,5 €. Here, we also took into account the renting of the container.

In this comparison, we also considered a holding cost for both sea and road transportation. We computed this cost to take into account the cost that results from the immobilization of the raw materials during the transport. It is based on the annual holding cost, the value of the

[1] The sea distances came from http://www.searates.com/reference/portdistance/

merchandise and the transport duration. As a result, we found that the port of Antwerp was the optimal destination port in terms of costs.

Unit transportation cost

To determine the unit transportation cost of the plywood plates, we based our calculations on the orders of the third year. During this year, we ordered fifteen 40 feet containers (Full container load). Since these containers were all filled in the same way and therefore all contained the same number of plywood plates (1070), we decided to compute the price of shipping only one 40 feet container.

The incoterm from Vietnam is Free On Board (FOB), which means the price of the plywood plates includes all the costs incurred until they are loaded on a ship. Consequently, we had to consider all the costs incurred after the loading of the plywood plates on the ship in order to obtain the unit transportation cost. These costs include sea freight, the renting of the container, the terminal handling charge (THC), the insurance (4%), the customs duties, the VAT, the road freight, the truck loading and unloading costs, ….

To determine the cost of the transport by ship, since we imported only 40 feet containers (Full container load), we followed the same steps as those used to determine the destination port. So, to compute the costs that result from the sea transport, we considered the maritime distance and the travel time.

For the customs duties, we found[2] that a rate of 7% (CN code 4412) was applicable to the imported plywood plates. The fact that Antwerp was the first European port encountered during the journey made the computation of the customs duties easier since we could consider all the costs incurred during the maritime transport.

We applied the European VAT of 19% to the sum of the value of the shipment, the transportation costs (sea freight and renting of the container), the insurance, the THC in Antwerp and the customs duties.

Regarding the transport by truck, we also computed its cost in the same way as to select the destination port. We took into account the road distance and the travel time, one day in this case. Next, we added the cost of loading the truck at the port of Antwerp and unloading it in Heidelberg.

To compute the unit transportation cost of the plywood plates, we subtracted the value of the goods (FOB) from the value of the Delivery Duty Paid (DDP) incoterm because we do not want to pay the price of these goods twice. Then, we first divided the total transportation cost by the number of plywood plates in the container. After this, we divided the result obtained by

- Three for the plywood tray since we can make three plywood trays out of one plywood plate.
  The unit transportation cost of the plywood tray was equal to 2,84 €.
- Six for the plywood back since we can make six plywood backs out of one plywood plate.
  The unit transportation cost of the plywood bed was equal to 1,42 €.

[2] This was found on the website of the Official Journal of the European Union.

6.2 Unit transportation cost steel tubes

Port of destination

For the shipment of rectangular and round tubes we made a similar cost comparison as for the plywood plates. Therefore, we selected the same five European ports and used a 40 feet container. In this case, as mentioned before, we were obliged to choose this type of container since the 20 feet container is too short to hold the tubes. This time, it turned out that shipping the tubes to the port of Rotterdam was the best option.

Unit transportation cost of the steel tubes

The unit transportation cost of the steel tubes was determined in the same way as for the plywood plates. Nevertheless, we will emphasize the differences that occurred.

Regarding the customs duties, we found that a rate of 0% (CN code 72****) was applicable to the importation of steel tubes, which simplified our computation. The first European encountered during the journey is Rotterdam and it corresponds to the chosen port.

In the 40 feet container (Full container load), as we mentioned earlier, we decided to transport both rectangular and round steel tubes. Since, in this case the amount of tubes that can be loaded in the container is limited by weight constraints, we decided to compute the part of the transportation cost that can be attributed to each type of tube.

To do so, we calculated the total weight of the shipment. Then we divided the weight of the rectangular steel tubes and the weight of the round steel tubes by the total weight of the shipment. This allowed us to obtain two ratios. After this we multiplied each of these ratios by the total transportation cost. We obtained thus the part of transportation cost that is attributable to the rectangular steel tubes and the one that is attributable to the round steel tubes.

To find the unit transportation cost of a rectangular steel tube, we subtracted the value of the goods (FOB) from the value of the Delivery Duty Paid (DDP) incoterm as we did for the plywood plates. We divided then the transportation cost attributable to the rectangular steel tubes by the number of rectangular steel tubes loaded in the container. Since the steel frame is composed of two “width pieces” and two “length pieces”, we divided the result by

- Ten, since we can make 10 “width parts” out of one rectangular tube. Then, we multiplied this result by two since we need two parts for the steel frame. The transportation cost for two “width parts” was equal to 1,49 €.
- Seven, since we can make 7 “length parts” out of one rectangular tubes. Then, we multiplied this result by two since we need two parts for the steel frame. The transportation cost for two “length parts” was equal to 2,13 €.

The same steps were used to compute the unit cost of the handle. We divided the transportation cost attributable to the round tubes by the number of round tubes in the container. Then, we divided this result by two since we can produce two handles out of one round tube. The unit transportation cost of a handle was equal to 1,57 €.

Transportation costs (€)	
Transportation costs per plywood tray (bed)	2,84
Transportation costs per plywood tray (back)	1,42
Transportation costs for two width pieces	1,49
Transportation costs for two length pieces	2,13
Transportation costs / handle	1,57

6.3 Selling price of the end product to the distributor

In order to compute the cost of the trolley, we simply added the cost of the raw materials needed to build it, the cost of production and the transportation cost of the raw materials.

Raw material	61,53325854
Production	21,53
Transport	9,43
Margin	23,12
Cost/ trolley (€)	115,61

7. Location of the distributor's warehouse in Brazil

To determine the location of our distributor's warehouse in Brazil we applied the Gravity Location Model and solved it by using the Excel solver.

First, we selected the five highest population cities of each considered state. This was done by sorting the data, retrieved from the website of the Brazilian Government, according to the two constraints given in the case. Next, we looked for the geographic coordinates (latitude and longitude) of each city by using the website Latlog.

Then we applied the principles of the Gravity Location Model to determine the optimal location of the distributor's warehouse. In this model, the decisions variables (X, Y) correspond to the coordinates of the location of the new warehouse. For each of the cities we computed $D_i = \sqrt{(X - x_i)^2 + (Y - y_i)^2}$,which represents the distance between the new distributor's warehouse and the $city_i$ and where x_i and y_i correspond respectively to the latitude and the longitude of the $city_i$. The objective here was to minimize total transportation costs, $TC(X, Y) = \sum_{i=1}^{n} f_i q_i D_i$. In this function, f_i corresponds to the cost of shipping one trolley for one kilometre between the warehouse and the $city_i$. We decided to arbitrarily set its value to 1. q_i refers to the quantity to be shipped between the warehouse and the $city_i$. Since the demand of each city is proportional to its population, we equalled q_i to the population of the $city_i$. The table below displays the values obtained for the decision variables $(X, Y)$and the cost function $TC(Y, Y)$.

Decision variables:	
X	**-25.37826747**
Y	**-48.75263014**
Objective function:	**minimise**
TC(X,Y)	**63901203.25**

Finally, if we had decided to locate the warehouse according to optimal solution (X=-25.378267 and Y=-48.75263), it would have been placed in the middle of a river. Consequently, we decided to store the trolleys in a warehouse located in an industrial area of the city of Paranaguá (State of Paraná). The exact address is 3234 Av. Ayrton Senna da Silva, Paranaguá, Paraná, Brazil.

Several reasons justify our decision. First, the city is still located close to the optimal location that we obtained by solving the Gravity Location Model. Secondly, Paranaguá is a medium-sized town that disposes of a direct access to the sea. The presence of a maritime port in the city will thus facilitate the conveyance of the trolleys to Brazil. Moreover, the road and railway networks are well developed around the city. This constitutes thus a substantial advantage for the dispatching of the trolleys around the country. Finally, Paranaguá is situated close to Curitiba, which is a bigger city and where the logistics infrastructure is even more developed (airports, distribution centres, …). Consequently, a relocation to this city could be considered in the case of a quick expansion of the company's activities. Other smaller towns such as Antonina and Ferro were located closer to the optimal location, but these towns did not dispose of the advantages that we previously set out.

The picture below displays the optimal location and the actual location of our warehouse.

Source: Google Maps

The following picture displays the location of our warehouse and the location of the port of Paranaguá.

Source: Google Maps

8. Unit transportation cost of the end product and selling price to final customer

Finally, in this section we first determine from which port we will ship the containers to Brazil and how the containers are filled. Thereafter, we will discuss the order tables of the trolleys. Later, the unit transportation cost of the end product is calculated as well as the selling price to the final customer.

Port of origin

For the shipment of the trolleys, we made a similar calculation to determine the optimal port as for the raw materials discussed previously. Moreover, we selected again the same five European ports but here the sea freight company CMA-CMG did not offer a maritime route from Zeebrugge to Paranaguá. Furthermore, we considered a 40 feet container at FCL since this is the only container that is used for the shipment. In this case, we found that the port of Antwerp was the best option.

Container trolley

Before being able to determine how many trolleys we can load in each type of container, we needed to make decisions concerning the packaging of the trolley. Therefore, we started by drawing and calculating the optimal way to put the trolley in a box. It was already decided that we would not assemble the plywood back to the tray before shipping, in order to simplify the placement in a box and reduce costs. Furthermore, we found that the optimal way to put the different parts in a box, was to place the wheels at the end and next to the plywood bed.

For the external volume, we considered an additional space of 0.5 cm at each side of the box and 1 cm at the top, to easily be able to place the parts in the box. The internal length was obtained by adding the length of the plywood bed and swivel wheels. We decided to place the wheels horizontally to minimize the length but we still needed to consider the length of the largest wheel, namely the swivel wheel. The total length of the swivel wheel needed to be calculated. As can be seen on the image below (left figure), this length is composed out of three parts. First, we have the length until the first yellow line, which is equal to $\frac{125}{5}$. Next, the part between the first and the second line is equal to 80. Finally, the last part is equal to $\frac{(105-80)}{2}$. We obtain the total length of the swivel wheel by adding these three parts.

Next, for the internal width we can just take the width of the plywood bed since this is the largest width. Finally, we found the internal height by adding the height of the plywood bed and the handle. The external dimensions are computed by adding the additional space and thickness of the carton box to the internal dimension.

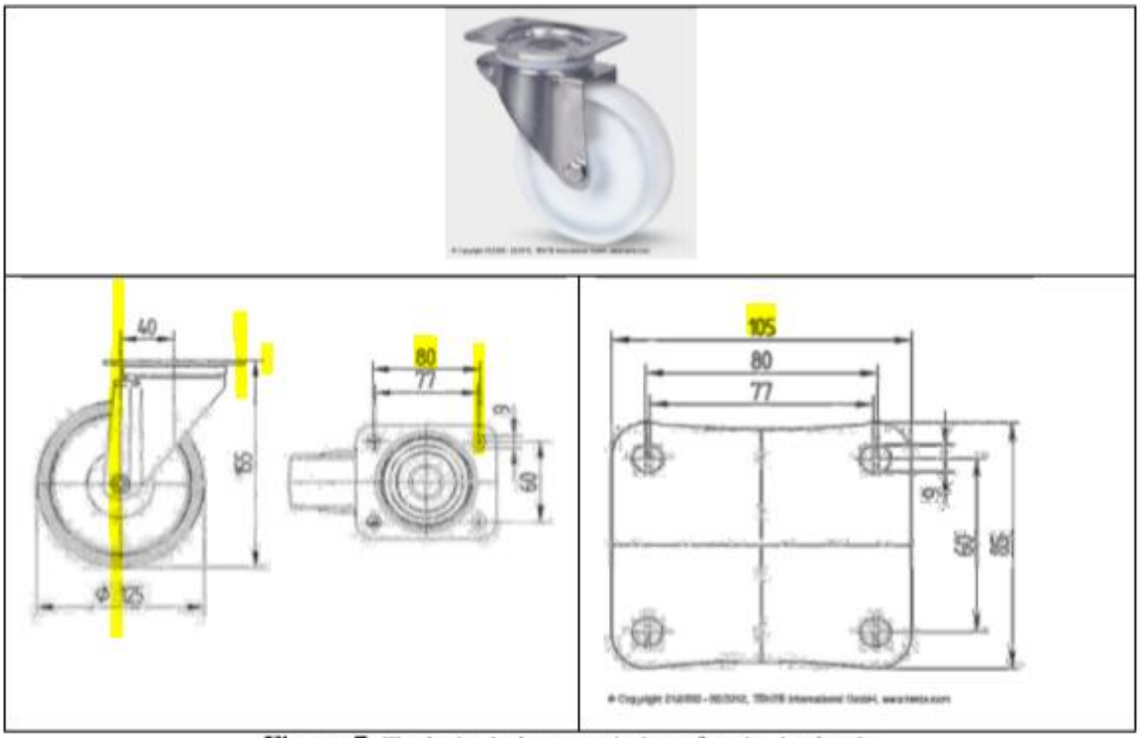
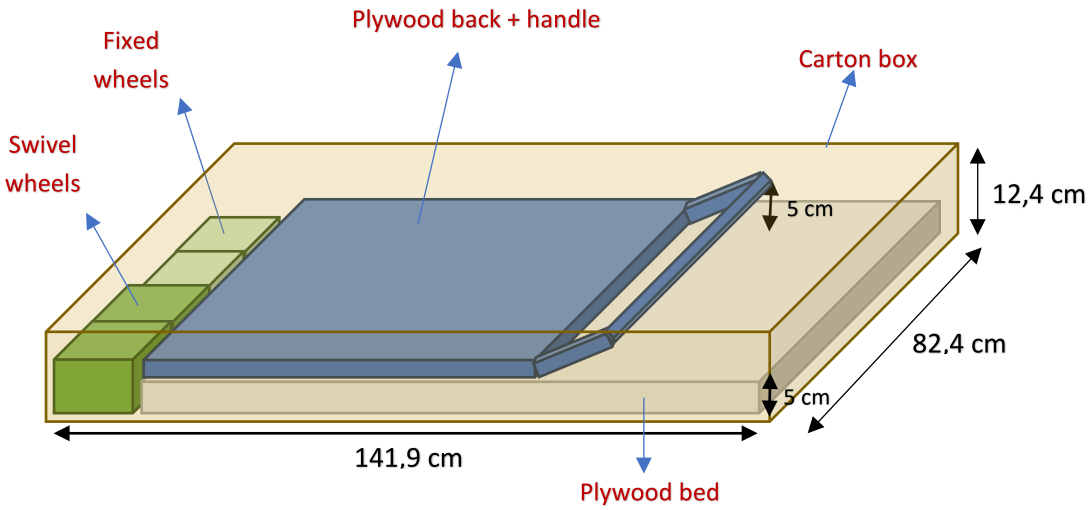


Figure 7. Technical characteristics of swivel wheels

The placement of the different trolley parts in a box and the dimensions are clearly illustrated on the image below. We also provide an overview of the volume, price and weight per box.



Internal volume (m3)	0.1251855
External volume (m3)	0.144987744
Price /box (€)	**2.17481616**
Weight / box (kg)	32.42

Moreover, we decided to place the boxes on pallets to be as close as possible to the reality since this simplifies the loading and unloading of a container. We chose the cardboard pallet for different reasons. First of all, it was the cheapest, which is an important factor considering the number of pallets we will need to transport trolleys every year. Secondly, it was the lightest type of pallet that could still support a significant load. The low height was another important factor that enabled to optimize the used volume of the container.

Next, we determined the number of boxes we can maximum place on a pallet. We found that this number perfectly aligned with the height of trolley considering the height of the pallet. Finally, we calculated the number of pallets we can load in the container in a similar way as for the raw materials. Therefore, we will not discuss these calculations again. We used the same software to illustrate how we load the boxes in the container and in this case, we faced a volume constraint. Here, we considered a pallet with all the boxes placed on it, as one unit. This is shown in the images below.

Shipment to Brazil
Report 004
Container 40' (12,060 mm x 2,400 mm x 2,360 mm)
Total weight 12,920.6 kg (46%)
Total volume 60.24 m ^{3} (89%)
Free meters 0.523 m

Legend:
Group No. 1 Model 20
- A 22pcs 141.9 x 82.4 x 234.2 cm 12,920.6kg tilt. nostack. rot. Trolley

Preview:

Shipment to Brazil
Report 002
Container 40ft (5,885 mm x 2,300 mm x 2,360 mm)
Total weight 6,460.3 kg (30%)
Total volume 30.12 m ^{3} (95%)
Free meters 0.116 m

Legend:
Group No. 1 Model 20
- A 11pcs 141.9 x 82.4 x 234.2 cm 6,460.3kg tilt. nostack. rot. Trolley

Preview:

We also computed the time to produce enough trolleys to fill each container First, we multiply the production time of trolley by the number of trolleys we can load in a type of container. Then we divide the result by 24, since the production time is given in hours and we want to obtain a value in days.

EOQ, safety stock and order tables

The calculations for the EOQ of the trolleys is done in the same way as for the plywood plates. First, the trolley demand is also derived from the bill of materials. Next, the cost per trolley is determined by adding the material cost, production cost and transportation cost of raw materials, and adding a margin of 25% as given in the case. For the fixed set up cost, the labor time and labor cost were also provided. The labor cost is assumed to include the labor charge. Since the cost was given in Brazilian Real, we needed to convert this to Euros.

The obtained yearly EOQ was always rather small. If we would order a container with an amount of trolleys close to the EOQ, we would have to make at least forty orders a year to fulfil the demand. Therefore, we decided to order two 40 feet containers in the first year to reduce the number of orders. In the second and third year, we respectively ordered four and six 40 feet containers for each shipment.

Furthermore, we decided to take five days of demand as the safety stock. As we mentioned in the section *Management of the inbound flows of the facility in Germany,* we decided to start selling trolleys the 1st of January 2018. The order table is computed in the same way as for the raw materials, so we refer to that section for that explanation.

Finally, we wanted to demonstrate that the production will be able to follow these orders considering certain assumptions. Since the demand increases very fast over these three years, the production capacity will have to increase significantly as well. Therefore, we assumed that the production capacity will double the second year, leading to production time that will decrease by half. The same thing is assumed for the third year. In the excel file a table is provided with the date of each planned shipment and the time of production between two shipments. Next, the initial inventory is given, before adding the amount produced and subtracting the amount to be shipped. A final inventory is also computed, which is equal to the initial inventory level of the next period. We can observe that the final inventory is always positive, which means that we can always fulfil the order.

Unit transportation cost

After having determined the port of shipment, we calculated the unit transportation cost. The method we used is again equal to the one used for the raw materials. However, this time, we could not use the incoterm Free On Board (FOB). Indeed, we had to consider all the various costs incurred before the loading of the containers on a ship.

First, we had to determine the cost of the packaging of the goods: cardboard boxes and the cardboard pallets. Therefore, we multiplied the cost of a box by the number of boxes in a 40 feet container and added this to the cost of pallet times the number of pallets in the container.

In total, we obtained a total packing cost of 1024,91 €. The sum of the value of the merchandise and the total packing cost corresponds to the incoterm Ex Works (EXW).

Then we added the costs of the truck loading in Heidelberg, the transport by truck from Heidelberg to the port of Antwerp, the renting of the container, the truck unloading in Antwerp and the terminal handling charges (THC). Outwards customs clearances are neglected. The sum of the value of the Ex Works (EXW) incoterm and all these costs corresponds to the incoterm Free On Board (FOB).

For the maritime transport, we used the same method as for the raw materials. We considered both the maritime distance and the duration of the maritime journey. Regarding the rates of the import duty for industrial trolley and the VAT in Brazil, they were respectively equal to 35 % and 18 %. We also had to take into account the transport of the container by truck from the port of Paranaguá to the distributor's warehouse. The table below shows all the computations needed to calculate the transportation cost of a 40 feet container (Full container load, FCL).

The chosen port is **Antwerp**	
Departure	**Heidelberg (Germany)**
Value of merchandise	45783,50963
Packaging + pallets	1024,907199
EXW	**46808,41683**
Truck loading (Heidelberg)	**25**
Price for road transport FTL / 100KM (FCL 40ft)	312,5
Price for road transport	**1412,5**
Price for hiring a 40 ft container for the road journey	**42**
Truck unloading (Antwerp)	**25**
Outwards customs clearance (neglected)	**0**
THC origin (Antwerp)	**200**
FOB	**48512,91683**
Base distance	5000
Price for base distance (FCL 40ft)	**1540**
Additional distance	5351,33
Price per additional 1000km (FCL 40ft)	84
Price for additional distance (FCL 40ft)	**449,51172**
Price for hiring a 40 feet container /day	42
Price for hiring a 40 ft container for the martime journey	**756**
CPT	**51258,42855**
Insurance	2050,337142
CIF	**53308,76569**
THC destination (Paranaguá)	150
Import customs duties	18710,56799
Subtotal	**72169,33368**
VAT	**12990,48006**
Truck loading at the port of Paranaguá	**20**
Price for road transport FTL / 100KM (FCL 40ft)	312,5
Price for road transport	**15,625**
Price for hiring a 40 ft container for the road journey	**42**
Truck unloading at the warehouse	**20**
DDP	**85257,43875**
Total transportation costs (DDP-EXW)	**38450**

After having computed the value of the Delivery Duty Paid (DDP) incoterm, we subtracted the value of the Ex Works (EXW) incoterm so that we do not pay the merchandise and the packaging twice. Then we divided the result obtained by the number of trolleys loaded in a 40 feet container (396 trolleys) to find the unit transportation cost of the end-product. We arrived at a unit transportation cost of 97,10 € to transport the trolleys from the factory in Heidelberg to the warehouse in Paranaguá.

Finally, to determine the selling price of the end-product to final-customers, we added the unit transportation cost that we just found to the selling price to the distributor that we computed in the *section 6*. We obtained a price equal to 212,71 €. Then we applied the profit margin of 20% and we arrived at a selling price of 255,25 €. This amount represents 971,64 BRL.

9. References

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