Case study for lecture “Einführung in Produktion und Logistik”

Summer term 2023

Table of contents

Introduction

Welcome to “Einführung in Produktion und Logistik”!

During the semester, you are going to learn the fundamentals of production systems and supply chains in the context of sustainable development. In addition to theoretical knowledge, you will become familiar with qualitative and quantitative methods that you will use to model and analyze production systems. You are going to learn about the interrelations of production with procurement, distribution, and (reverse) logistics. Additionally, this lecture will discuss economic (and to a smaller extent, environmental and social) assessment concepts.

In this case study, we aim to illustrate several production processes and planning steps with real-world examples. We chose a small beer manufacturer (or “microbrewery”) for three main reasons. First, different production processes can be shown here on a small scale. Second, beer brewing is a relatively simple production process yet complex enough to understand certain processes. Finally, beer is a popular good in Germany and – as we’ve heard – among students as well.

This case study contains several exercises linked to the contents of the lecture. The objective for you is to obtain a better understanding of economic planning and assessment methods and to understand how certain algorithms or calculations solve real-world problems.

Before starting with the exercises, let’s introduce the brewery.

The original *National Jürgens Brewery* (**National-Jürgens-Brauerei**, NJB) was founded in Braunschweig in 1838. Until the brewery closed in 1977, they produced several draft and bottle beers (e.g., *Gala Doppelbock, Gala Export, Gala Krone, Gala Vita-Malz* or *Brunswiek Alt*).

In 2017, the brewery was reestablished under its old name and on the original site on Rebenring (close to TU’s main campus). The reestablishment brings a 140-year-old Braunschweig tradition into modern day.

Currently, the brewery produces four artisanal varieties of beer

- Crab#1 Pale Ale (most famous variety, a top-fermented beer)
- Südsee IPA (referring to Braunschweig´s Südsee)
- Gala Hell
- Brunswiek Alt (as in the original brewery)

As the brewer team says: "In the original cellars, we are reviving the brewing tradition of the old National Jürgens Brauerei in Braunschweig with the idea of craft beer".

Njb-brauerei.de

Wirtshausfreunde.de

Kraftbier0711.de

Craft beer is characterized by unconventional flavors as well as traditional production methods. The craft beer movement developed in the United Kingdom in the 1970s. For some years now, the development can also be observed in Germany. A microbrewery differs from a "normal" brewery not only in that it has a lower production volume and is independent of larger brewing groups, but also because microbreweries offer an alternative approach to brewing beer. Craft beer production places a special emphasis on methods, taste, quality, and customer proximity. As microbrewers used to say, "The smaller the brewery, the easier it is to dedicate itself to specific beer styles. The size of a brew and the small number of consumers necessary to appreciate it allows for the individuality of the product.”

NJB’s headquarter and only production place is in Braunschweig. The beer is distributed mainly in and around Braunschweig, to supermarkets, restaurants, and private customers.

Throughout this case study, it is assumed that you support the brewers in taking entrepreneurial decisions concerning the beer production. The brewery staff is going to need support for decisions soon and is happy to rely on the expertise of motivated economics students.

Please note that some of the exercises and/or provided values are fictitious and were compiled for educational reasons.

Have fun!

Tutorial I: Modeling

Exercise 1: Morphological box

After having learned a little about beer brewing, you would like to share and discuss with the brewers your new knowledge about production types. In the lecture, you got to know the **morphological box** which is a method for creative thinking but also for characterizing systems or products. The morphological box provides an overview of different attributes and characteristics of (in this case) production types.

Please identify and mark the characteristics of beer brewing in the morphological box below.

Output:				
Type of connectedness	Substitute production		By-production	
Number of main product types	Multi-product production		Single-product production	
Desirability of by-products	Desirable by-products	Undesirable by-products	Neutral by-products	
Degree of relationship	Variety production (High relationship)		Species production (Low relationship)	
Input:				
Desirability of the input factors	Desirable input factors	Undesirable input factors	Neutral input factors	
Process:				
Natural/Engineering processes	Physical processes		Chemical and biological processes	
Degree of repetition	Individual production/ project production	Series production	Mass production	
Structure of the material flow	Smooth	Convergent	Divergent	Regrouped

Figure 1: Classification matrix of production systems

++

<u>Solution:</u>

Output:				
Type of connectedness	**Substitute production**		By-production	
Number of main product types	**Multi-product production**		Single-product production	
Desirability of by-products	Desirable by-products	**Undesirable by-products**	**Neutral by-products**	
Degree of relationship	**Variety production (High relationship)**		Species production (Low relationship)	
Input:				
Desirability of the input factors	**Desirable input factors**	Undesirable input factors	Neutral input factors	
Process:				
Natural/Engineering processes	Physical processes		**Chemical and biological processes**	
Degree of repetition	Individual production/ project production	**Series production**	Mass production	
Structure of the material flow	Smooth	Convergent	Divergent	**Regrouped**

Exercise 2: Production program planning

The brewery encounters plenty of problems due to the current crises. Particularly influential are the energy crisis, which **limits the maximum running times** of the machines~~,~~ and the supply **bottlenecks for CO_2**. During the brewing process, CO_2 is needed to maintain the beer for a longer period of time. The CO_2 is used to avoid contact with the air during the bottling process, preventing foaming of the beer. This is particularly important for their beer "Gala Hell" because, unlike "Crab #1," they want to distribute it in regions further away, which makes a longer shelf life mandatory. Beyond these issues, raw material suppliers (e.g. for malt) require **minimum purchase quantities** to create more planning security for themselves.

Since these problems lead to massive restrictions in production, the brewers of the NJB are interested in updating their business planning methods for beer brewing.

The planning should illustrate the production possibilities of the NJB under the current circumstances for the two types of beer "Gala Hell" and “Crab #1".

In recent years, the demand for NJB’s craft-brewed beer has been steadily increasing. Production planning was usually based on the production volume of the previous months, without considering resources or capacity. You impressed the brewers with your expertise during the last exercise. They are calling you again to help them plan the upcoming production program.

You start by determining the maximum sales program based on demand forecasts and data from the past. In addition, several wholesalers have already ordered certain quantities of beer that must be produced and delivered in any case.

Table 1 shows the determined maximum sales quantities and the delivery commitment of the two beer types.

Table 1: Sales volumes and process of the 3 types of beer (fictitious prices)

Type	Delivery commitment [unit]	Maximum sales quantity [unit]
Gala Hell	5	-
Crab #1	-	80

To determine the optimal production program, you are supposed to apply some of the methods that you learned during the PSSC lecture, like the determination of the production space Z or sketching a production diagram.

You realize that you need detailed information about the brewing process to determine the production space Z. The NJB team provides you the following overview with all relevant object types as a so called “black box model”, see Figure 2.

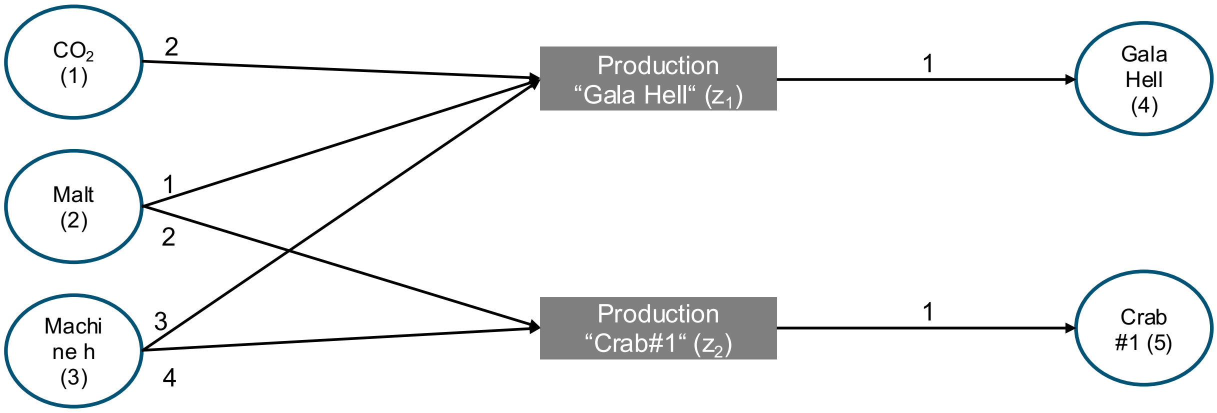


Figure 2: Black box model of beer brewing

Due to the current energy crisis, the NJB wants to limit the running time of the machines to save money. Both types of beer are produced in the same brewery; therefore, the maximum capacity of the machines is 400 machine hours. Additionally, the brewery provides you with the following table, which contains CO_2 quantity currently in stock. Due to current supply bottlenecks, there are long unpredictable delivery times for new CO_2, which is why the quantity in stock represents the current maximum quantity available. In addition, the table shows the minimum purchase requirement from the malt suppliers.

Table 2: Raw material quantities in stock and minimum purchase quantities (fictitious numbers)

Raw material	Quantities in stock [unit]	Minimum purchase quantity [unit]
CO_2	100	-
Malt	-	75

a) Based on this information, you start working. First, determine the lower and upper limits z^{min} and z^{max}. Lower limits define the maximum input quantities for input object types and minimum output quantities for output object types.

+++

Solution:

$$\boldsymbol{z^{min}} = \begin{pmatrix} -100 \\ -\infty \\ -400 \\ 5 \\ 0 \end{pmatrix} \qquad \boldsymbol{z^{max}} = \begin{pmatrix} 0 \\ -75 \\ 0 \\ \infty \\ 80 \end{pmatrix} \begin{matrix} \text{CO}_2 \\ \text{Malt} \\ \text{Machine hours} \\ \text{Gala Hell} \\ \text{Crabs \#1} \end{matrix}$$

+++

b) Set up production space Z of the beer production and describe briefly how Z is defined (what it is composed of). Then, establish the algebraic inequalities for it and illustrate it graphically.

++

Solution:

Production space Z: the intersection of technology T and the restriction space R

$$Z = T \cap R = \left\{ z \,\epsilon\, \mathbb{R}^5 \,\middle|\, \underbrace{\begin{pmatrix} -100 \\ -\infty \\ -400 \\ 5 \\ 0 \end{pmatrix}}_{z^{min}} \leq \begin{pmatrix} -2 \\ -1 \\ -3 \\ 1 \\ 0 \end{pmatrix} \cdot \lambda_1 + \begin{pmatrix} 0 \\ -2 \\ -4 \\ 0 \\ 1 \end{pmatrix} \cdot \lambda_2 \leq \underbrace{\begin{pmatrix} 0 \\ -75 \\ 0 \\ \infty \\ 80 \end{pmatrix}}_{z^{max}}, \lambda_1, \lambda_2 \in \mathbb{R}^+ \right\}$$

Graphical illustration of the production space ***Z***

Step 1: Formulation as algebraic inequalities

(1):	x_1	$=$	$-z_1$	$=$	$2 \cdot \lambda_1$	+	$0 \cdot \lambda_2$	$\leq$	100
(2):	x_2	$=$	$-z_2$	$=$	$1 \cdot \lambda_1$	+	$2 \cdot \lambda_2$	$\geq$	75
(3):	x_3	$=$	$-z_3$	$=$	$3 \cdot \lambda_1$	+	$4 \cdot \lambda_2$	$\leq$	400
(4):	y_4	$=$	z_4	$=$	$1 \cdot \lambda_1$	+	$0 \cdot \lambda_2$	$\geq$	5
(5):	y_5	$=$	z_5	$=$	$0 \cdot \lambda_1$	+	$1 \cdot \lambda_2$	$\leq$	80

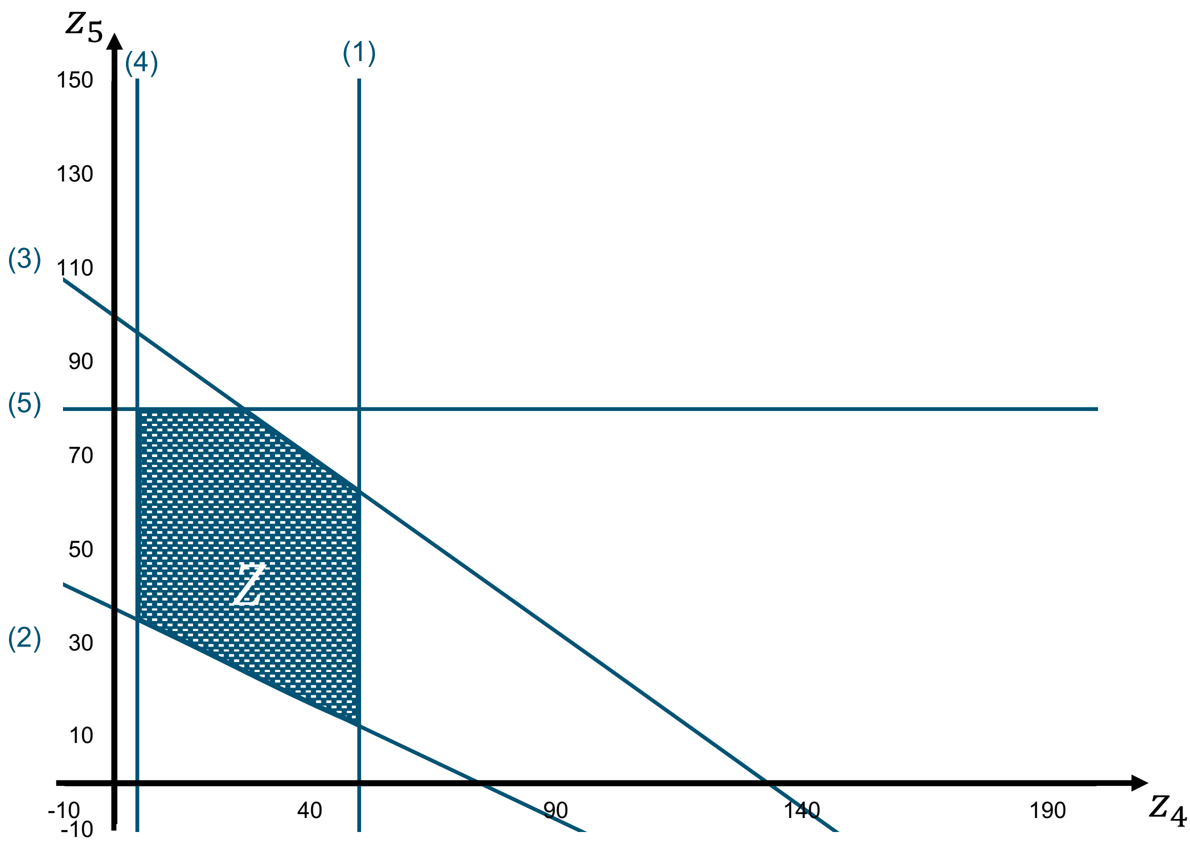
Step 2: Substitution of activity level $(\lambda_1 = z_4, \lambda_2 = z_5)$

(1):	$-z_1$	$=$	$2 \cdot z_4$	+	$0 \cdot z_5$	$\leq$	100
(2):	$-z_2$	$=$	$1 \cdot z_4$	+	$2 \cdot z_5$	$\geq$	75
(3):	$-z_3$	$=$	$3 \cdot z_4$	+	$4 \cdot z_5$	$\leq$	400
(4):	z_4					$\geq$	5
(5):	z_5					$\leq$	80

Step 3: Transformation

(1)	z_4	$\leq$	50
(2)	z_4	$\geq$	$75 - 2 \cdot z_5$
(3)	z_4	$\leq$	$133{,}33 - 1{,}33 \cdot z_5$
(4)	z_4	$\geq$	5
(5)	z_5	$\leq$	80

Step 4: Drawing in the coordinate system (Output/Output diagram)



++

Exercise 3: Gutenberg technology

The following Gutenberg technology describes the production of a product (y_3, in QU) using two input factors (x_1 and x_2, in QU). The intensity ρ with which the process is executed describes the output of the product in QU/hour. The following time-specific consumption and output functions are given for the individual object types:

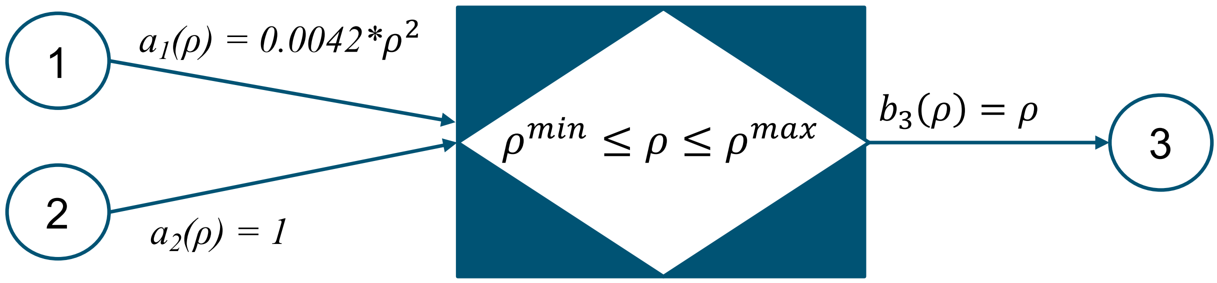
Table 3: Time-specific consumption and output functions

Object Type	Time-specific consumption and output functions
x_1	$0.0042 \cdot \rho^2$
x_2	1
y_3	ρ

a) Sketch the input/output graph of the Gutenberg technology.

++

Solution:



++

b) What distinguishes a Gutenberg technology from a finitely generable technology?

++

Solution:

The difference between a Gutenberg technology and finitely generable technology is that the **input and output coefficients of an activity are not constants but rather a function of intensity**. These are also called output or consumption functions.

Thus, the consumption and output of factors (inputs and outputs) depend on the intensity with which the process is operated and are therefore not constant. Therefore, the **Gutenberg technology cannot be described by a finite number of basic activities**.

++

c) Set up the Gutenberg technology *T* formally in *time-specific* notation.

++

Solution:

$$T = \left\{ z \in IR^3 | \ z = \begin{pmatrix} -0.0042 * \rho^2 \\ -1 \\ \rho \end{pmatrix} * \lambda. \ with\ \lambda \in \ [0,\ t^{max}]\ and\ \rho^{min} \leq \rho \leq \rho^{max} \right\}$$

++

d) Calculate both *product-specific* consumption functions.

++

Solution:

General equation: $a_{i,3} = \frac{a_i(\rho)}{b_3(\rho)}$

Specifically: $\boldsymbol{a_{1,3}} = \frac{a_i(\rho)}{b_3(\rho)} = \frac{0.0042*\rho^2}{\rho} = 0.0042 * \rho$ $\qquad \boldsymbol{a_{2,3}} = \frac{a_2(\rho)}{b_3(\rho)} = \frac{1}{\rho}$

++

e) To approximate a Gutenberg technology, one can perform an intensity splitting. For this, the continuous variable intensity ρ is replaced by π discrete intensity levels. For intensities $\rho = 30, 50, 70$, enter the corresponding x_1 and x_2 values into the table. Assume that the consumption functions are product-specific.

Table 4: Product-specific intensity

ρ	30	50	70
x_1			
x_2			

++

Solution:

ρ	30	50	70
x_1	0.126	0.21	0.294
x_2	0.033	0.02	0.014

++

f) Draw the single-stage technology resulting from intensity splitting as an input/output graph. Let the output be one unit.

++

Solution: