Creating insights into the requirements of consumer packaging of Europastry Oldenzaal for future improvements.

Master thesis IDE, April 2025

Wendie van der Meer s1728113

europastry
We are bakers

UNIVERSITY OF TWENTE.

Document Information

Master graduation assignment: DPM 2183

Title:
Creating insights into the requirements of consumer packaging of Europastry Oldenzaal for future improvements

Company:
Europastry Oldenzaal
Coulissenweg 1
7572 PJ Oldenzaal

Education:
Institution: University of Twente
Department: Design, Production and Management
Study programme: Industrial Design Engineering
Specialization: Management of Product Development

Student:
Wendie van der Meer
s1728113

Supervisory committee:
Chairman: Prof.dr.ir. R. ten Klooster
Daily supervisor: I. Ilhan PhD
External member: Prof.Dr.-Ing. S. Thiede
Supervisor Europastry: Robert Bosman

Publication date:
30-04-2025

Confidentiality:
To ensure the confidentiality of the company information, all sensitive information is moved to the appendix of this thesis. Next to that, all sensitive numbers shown in the thesis are multiplied by an unknown number.

Summary

The research objective of this study was to create insight into the requirements of the consumer packaging of the doughnuts produced at Europastry Oldenzaal. Europastry is a multinational company that specialises in producing and distributing frozen bakery products, like croissants, doughnuts and bread. There are 27 production locations and Europastry Oldenzaal is one of them. The current consumer packaging portfolio in Oldenzaal consists of blister packaging, flowpackaging without U-tray and flowpackaging with U-tray (Figure 0.1).

Figure 0.1: Current consumer packaging of the doughnuts

At the production location in Oldenzaal, eight different doughnut types are produced and packaged at lines 1 and 3. Around 15% of the doughnuts divided over these eight subfamilies are packaged in consumer packaging. Europastry Oldenzaal remarks a shift in packaging preference towards more consumer packaging, especially for retail customers. This means that more customers prefer consumer packaging over bulk packaging. As the packaging portfolio is mostly customer-driven at Europastry, this results in a lot of different preferences. This requires a lot of flexibility of the packaging lines or unsatisfied customers if their packaging preference is not available. All those different preferences also result in a lot of different requirements from the different customers. Next to the customer requirements, there are also legislation requirements from the packaging and packaging waste directive (Directive 94/62/EC) that have changed. The core problem of this study is that there is no clear overview of the requirements of consumer packaging. This leads to a portfolio that might not suit the current requirements. Next to that, it is not clear if the consumer packaging options that are offered now are suitable for the future. This leads to chaos, demands flexibility on the packaging lines and unsatisfied customers. The main research question that is chosen for this study is as follows:

Can a quality function deployment (QFD) and a cost estimation create insight into the requirements of the consumer packaging of Europastry Oldenzaal to determine future improvements?

To be able to find an answer to this question, the following steps were performed. First, an analysis was performed of the doughnut types, the current consumer packaging, its customers and its packaging lines to get a better overview of the problem. Afterwards, a literature study was performed to create the theoretical basis of this study and to determine how the tools and methods would be used. Based on the context analysis and literature study, the methodology was determined. The methodology consists of 5 parts. These are displayed in Figure 0.2 and explained below.

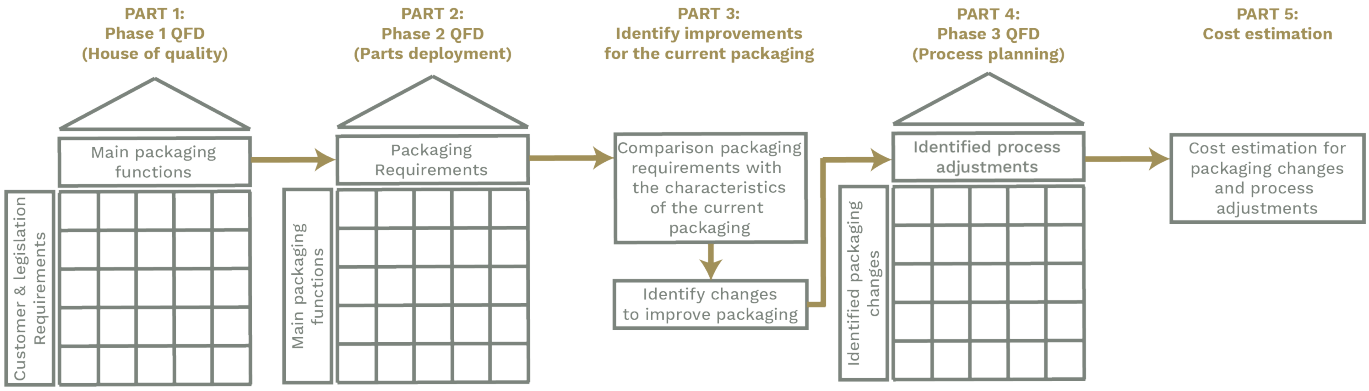

Figure 0.2: Summary of the methodology used

Part 1 is phase I of the QFD to determine the customer and legislation requirements and translate those into technical requirements. There are 24 requirements in total, of which 6 are obligatory legislation requirements. All the requirements were collected and/or rated on importance based on the customer survey and expert opinions from multiple account managers of Europastry Oldenzaal. The obligatory requirements from legislation were rated most important. Part 2 of the methodology consists of phase II of the QFD, which helped create the list of packaging requirements. Again, the requirements based on legislation were very important. Other requirements, like moisture permeability or impact resistant, were also high on the list.

The comparison between the packaging requirements from part 2 and the current packaging characteristics was done in part 3 of the methodology. From the target values of parts 1 and 2 of the QFD phases, a maximum value could be determined that a packaging type could reach. This maximum value, of 9,77, would be reached if all requirements were completely fulfilled by the packaging characteristics. The blister packaging scored 5,76, the flowpackaging without U-tray 5,59 and the flowpackaging with U-tray 5,82. From those scores, changes were identified for the applicable packaging characteristics to improve them. There were 6 changes identified for the blister packaging, 8 for the flowpackaging without U-tray and 9 for the flowpackaging with U-tray. From these changes, 3 are obligatory for the blister packaging, 2 for the flowpackaging without U-tray and 3 for the flowpackaging with U-tray. If all these suggested changes were implemented, the score of the blister packaging would increase to 7,82, the flowpackaging without U-tray to 8,78 and the flowpackaging with U-tray to 8,46. For each packaging type, it was not possible to reach the maximum score due to the fact that some requirements just could not be fulfilled by that packaging type.

In part 4 of the methodology, the packaging changes were discussed in more detail to determine process adjustments for packaging lines 1 & 3. In total, there were 12 process adjustments needed to implement all the packaging changes. Of those 12 adjustments, four are needed at line 1, five at line 3 and three for both lines or general processes. The potential added costs for these packaging changes from part 3 and process adjustments of part 4 were determined in part 5 of the methodology, the cost estimation. This cost estimation described how the changes or adjustments would influence the material, inventory or manufacturing costs of the doughnuts. Next to the estimation of the packaging changes and process adjustments for each packaging type, the possibility of consumer packaging the doughnuts at a third party was also theoretically described.

Afterwards, the flow of each requirement from part 1 of the methodology was evaluated based on the requirement, its corresponding packaging characteristic, its potential packaging change, its potential process adjustment and finally, the potential added (manufacturing) costs. This way, it was easy to see how the requirement was translated through all the parts of the methodology. Next to that, it was possible to evaluate the added score for a packaging type compared to the costs that this specific requirement would need. In conclusion, this study provided an overview of the customer and legislation requirements of the consumer packaging of the doughnuts of Europastry Oldenzaal. Afterwards, the current packaging types were compared to the requirements to see how these would score. Based on the score, changes were identified to improve it. These packaging changes needed process adjustments in some cases. From these packaging changes and process adjustments, the added costs have been described.

Contents

Document Information I

Summary II

Table of content IV

List of figures VI

List of tables VIII

Glossary IX

1 Introduction 1
- 1.1 Company background . . . 1
- 1.2 Problem statement & research motivation . . . 1
- 1.3 Scope . . . 2
  - 1.3.1 Research objectives . . . 4
- 1.4 Research questions . . . 4
  - 1.4.1 Sub-questions . . . 4
- 1.5 Outline . . . 5

2 Context analysis 6
- 2.1 Customers . . . 6
- 2.2 Products (SKUs) . . . 6
  - 2.2.1 Guarantee of freshness . . . 7
- 2.3 Packaging . . . 8
  - 2.3.1 Consumer packaging . . . 8
- 2.4 Packaging lines . . . 9
  - 2.4.1 Scheduling . . . 10

3 Literature study 11
- 3.1 Quality Function Deployment (QFD) . . . 11
  - 3.1.1 Phases QFD . . . 12
  - 3.1.2 Sustainability in QFD . . . 16
  - 3.1.3 QFD as an improvement tool . . . 16
- 3.2 Survey design . . . 17
- 3.3 Life cycle cost and cost estimation . . . 19
  - 3.3.1 Cost in the whole product life cycle . . . 19
  - 3.3.2 Product price . . . 20
  - 3.3.3 Manufacturing costs . . . 21
  - 3.3.4 Cost estimation methods . . . 22

4 Methodology 23

5 Part 1 - QFD phase 1 24
- 5.1 Step 1.1: Collecting the customer and legislation requirements (WHAT) . . . 24
  - 5.1.1 Requirements of the customers . . . 24
  - 5.1.2 Legislation sustainability . . . 26
  - 5.1.3 List of requirements & importance ratings . . . 28
- 5.2 Step 1.2: Identify technical requirements (HOW) . . . 29
  - 5.2.1 Correlation matrix . . . 32
- 5.3 Step 1.3: Relationship between WHAT and HOW . . . 32
- 5.4 Step 1.4: Conduct a competitor assessment . . . 33
- 5.5 Step 1.5: Prioritise & evaluate technical requirements . . . 35

6 Part 2: QFD - Phase 2 37
- 6.1 Step 2.1 & 2.2: WHAT and HOW of phase 2 . . . 37
- 6.2 Step 2.3: Relationship matrix . . . 39
- 6.3 Step 2.4: Prioritise and evaluate part requirements . . . 40

7 Part 3: Comparison results QFD phase 2 & current consumer packaging 41
- 7.1 WHAT and HOW comparison QFD . . . 41
- 7.2 Relationship matrix . . . 45
  - 7.2.1 Blister packaging . . . 45
  - 7.2.2 Flowpackaging without U-tray . . . 46
  - 7.2.3 Flowpackaging with U-tray . . . 47
- 7.3 Evaluate current consumer packaging . . . 48
- 7.4 Identify the changes and actions . . . 49
  - 7.4.1 Moisture permeability . . . 49
  - 7.4.2 Impact resistant . . . 50

7.4.3 Chemical safety . . . 50
7.4.4 Protection outside contamination . . . 50
7.4.5 Number of doughnuts . . . 50
7.4.6 Type of doughnuts . . . 50
7.4.7 Doughnuts storage in packaging . . . 51
7.4.8 Easy to open/access . . . 51
7.4.9 Disposal logo & material composition . . . 51
7.4.10 Recycle score c or higher . . . 51
7.4.11 Recycled content . . . 51
7.4.12 Minimum amount of material . . . 52
7.4.13 Colour packaging . . . 52
7.4.14 Biodegradable plastics . . . 52
7.4.15 Place for ingredient list, bar code & disposal logo . . . 52
7.4.16 Required information present . . . 52
7.4.17 Design of the customer . . . 52
7.4.18 Adaptable language . . . 53
7.4.19 Sustainable choice of material . . . 53
7.4.20 Sustainable perception to the customers . . . 53
7.4.21 Packaging has to be closed correctly . . . 53
7.4.22 Packaging, material & number of doughnuts as agreed . . . 54
7.5 Suggested changes and actions . . . 54
7.5.1 Conclusion suggested changes . . . 61

8 Part 4: QFD - Phase 3 62
8.1 Step 3.1 & 3.2: WHAT and HOW . . . 62
8.1.1 Packaging line 1 . . . 63
8.1.2 Packaging line 3 . . . 64
8.1.3 Both lines & general processes . . . 66
8.2 Step 3.3: Relationship matrix . . . 66
8.3 Step 3.4: Evaluation . . . 68
8.4 Conclusion QFD phases . . . 68

9 Part 5: Cost estimation 71
9.1 Scenarios . . . 71
9.1.1 Scenario 1: Changes blister . . . 71
9.1.2 Scenario 2: Changes flowpackaging without U-tray . . . 72
9.1.3 Scenario 3: Changes flowpackaging with U-tray . . . 74
9.1.4 Scenario 4: Package consumer packaging at third party . . . 75
9.2 Evaluation scenarios . . . 76

10 Evaluation consumer and legislation requirements 79
10.1 Evaluation of requirements . . . 79
10.2 Conclusion evaluation of requirements . . . 87

11 Discussion 92
11.1 Answers to the research questions . . . 92
11.2 Reflection on the research activities and used tools . . . 95
11.3 Limitations . . . 97
11.4 Recommendations . . . 97
11.5 Future research . . . 98

12 Conclusion 98

References 99

13 Appendix 104
A Packaging Europastry Oldenzaal . . . 104
B Complaints customers . . . 106
C Complete matrix Phase 1 . . . 107
D Survey design . . . 108
E Survey results . . . 112
F Comparison matrix AHP . . . 115
G Complete matrix Phase 2 . . . 116
H Complete matrix Phase 3 . . . 117
I Cost estimation - confidential parts . . . 118
I.1 Current manufacturing costs & production rate . . . 118
I.2 Comparison current cost - scenarios . . . 118

List of Figures

0.1 Current consumer packaging of the doughnuts . . . II
0.2 Summary of the methodology used . . . II
1.1 Current packaging Doughnuts Europastry Oldenzaal . . . 1
1.2 Problem cluster . . . 2
1.3 Design process approach (ten Klooster, 2020) . . . 3
2.1 Pie chart customer categories . . . 6
2.2 Products per line . . . 7
2.3 Guarantee of freshness . . . 7
2.4 Consumer packaging flow . . . 8
2.5 Overview doughnuts - consumer packaging . . . 9
2.6 Complete flow doughnuts EO, from van der Meer (2024, Chapter 2.5) . . . 9
2.7 Consumer packaging lines flow doughnuts EO, from van der Meer (2024, Chapter 2.7) . . . 10
3.1 Phases of the QFD process, adapted from Erdil & Arani (2018, Chapter 3) . . . 11
3.2 A road map for QFD within the food industry, adapted from Benner (2005, Chapter 2.3) . . . 12
3.3 Framework phase 1: House of Quality, adapted from Kiran (2017, Chapter 2.3) . . . 13
3.4 Correlation symbols, adapted from Burge (2007, Appendix A) . . . 14
3.5 Framework phase 2, 3 and 4, adapted from Kiran (2017, Chapter 2.3) . . . 15
3.6 Matrix QFD phase 1 with legislation, adapted from Utne (2009, Chapter 2.2) . . . 16
3.7 Matrix QFD phase 1 for sustainability, adapted from Horan (2022, Chapter 3.1) . . . 16
3.8 Framework for QFD as an improvement tool, adapted from Erdil & Arani (2018, Chapter 3.3) . . . 17
3.9 QFD process to improve the hospitality industry, adapted from Paryani et al. (2010, Chapter 3) . . . 17
3.10 Overview of the survey process, adapted from Biemer & Lyberg (2003, Chapter 2.1) . . . 18
3.11 Overview of the life cycle of a product, adapted from Asiedu & Gu (2010, Chapter 2) . . . 19
3.12 Cost breakdown for each phase of the life cycle, adapted from Asiedu & Gu (2010, Chapter 2.1) . . . 20
3.13 Cost elements of a product selling price, adapted from Chuang (2013, Chapter 6.2) . . . 20
3.14 Traditional approach for cost estimations, from Lembersky (2016, Chapter 2.2) . . . 22
3.15 Overview of the ABC method, adapted from Almeida & Cunha (2017, Chapter 2.3) . . . 22
4.1 Methodology . . . 23
5.1 Question 5 in the survey . . . 25
5.2 Correlation matrix - HOW . . . 32
5.3 Relationship matrix - QFD phase 1 . . . 33
5.4 Competitor assessment . . . 34
6.1 Doughnuts for moisture loss test . . . 38
6.2 Relationship matrix - QFD phase 2 . . . 39
7.1 Relationship matrix - Comparison Packaging - QFD . . . 41
7.2 Relationship matrix - Comparison Blister packaging . . . 46
7.3 Relationship matrix - Comparison Flowpackaging (without U-tray) . . . 47
7.4 Relationship matrix - Comparison Flowpackaging (with U-tray) . . . 48
7.5 Relationship matrix - Blister packaging with suggested changes . . . 56
7.6 Packaging at different locations of Europastry . . . 57
7.7 Relationship matrix - Flowpackaging without U-tray with suggested changes . . . 58
7.8 Relationship matrix - Flowpackaging with U-tray with suggested changes . . . 60
8.1 Matrix Phase 3 - process planning . . . 62
8.2 Matrix Phase 3 . . . 67
8.3 Obligatory and top 5 requirements of each phase . . . 70
10.1 Flow requirement: The guarantee of freshness is three days . . . 79
10.2 Flow requirement: The packaging protects the doughnuts (mechanical damage) . . . 80
10.3 Flow requirement: The packaging has to be free from toxic chemicals and plastics . . . 80
10.4 Flow requirement: The doughnuts have to be protected from outside contamination . . . 80
10.5 Flow requirement: The packaging can fit either 1, 2, 3, 4, 5, 6 or more mini-sized doughnuts & The packaging can fit either 1, 2, 4, 5, 6 or more normal-sized doughnuts . . . 81
10.6 Flow requirement: The packaging has either the same type of doughnuts or a mix of doughnut types . . . 81
10.7 Flow requirement: The doughnuts can be stored within the packaging . . . 82
10.8 Flow requirement: The packaging is easy to open . . . 82
10.9 Flow requirement: Primary packaging must feature the disposal logo and material composition information on the packaging . . . 82
10.10 Flow requirement: The packaging is effectively recyclable for at least 70% . . . 83
10.11 Flow requirement: The plastic parts of the primary packaging must consist of the right amount of recycled content from post-consumer plastic waste . . . 83
10.12 Flow requirement: The packaging consists of the minimum amount of material possible . . . 84
10.13 Flow requirement: The packaging is effectively recyclable for at least 70% of its weight . . . 84
10.14 Flow requirement: No use of biodegradable plastics . . . 84
10.15 Flow requirement: Label with all required information . . . 85
10.16 Flow requirement: The design of the company can be used . . . 85
10.17 Flow requirement: The language on the packaging needs to be adaptable . . . 86
10.18 Flow requirement: The packaging needs to use less plastic . . . 86
10.19 Flow requirement: The packaging has to be closed correctly . . . 86
10.20 Flow requirement: The packaging type, material and number of doughnuts must be as agreed . . . 87
10.21 Example packaging . . . 87

10.22Comparison matrix example packaging Albert Heijn . . . 88
10.23Example packaging . . . 90
10.24Comparison matrix example packaging Dirk . . . 91
11.1 Summary of potential added (manufacturing) costs . . . 94
13.1 Packaging options line 1 . . . 104
13.2 Packaging options line 3 . . . 105
13.3 Complete matrix Phase 1 . . . 107
13.4 Survey . . . 108
13.5 Survey (continued) . . . 109
13.6 Survey (continued) . . . 110
13.7 Survey (continued) . . . 111
13.8 Results question 2 (satisfaction options consumer packaging) . . . 112
13.9 Results question 5 & 6 (type and satisfaction consumer packaging) . . . 113
13.10Results question 9 & 12 . . . 113
13.11Results question 10 & 11 . . . 114
13.12Results question 17 & 18 . . . 114
13.13Comparison Matrix - AHP . . . 115
13.14Complete matrix Phase 2 . . . 116
13.15Complete matrix Phase 3 . . . 117

List of Tables

3.1 Symbols used in relationship matrix . . . 14
3.2 Overview manufacturing cost . . . 21
5.1 Recycling targets Directive 94/62/EC . . . 26
5.2 Recycled content from post-consumer plastic waste, from (EuropianCommission, 2024) . . . 27
5.3 Recycle scores packaging . . . 27
5.4 WHAT - House of quality + Importance ratings . . . 29
5.5 Packaging functions . . . 30
5.6 Packaging functions (continued) . . . 31
5.7 Packaging Functions - HOW in house of quality . . . 31
5.8 Target Values Packaging Competitors (sorted high to low) . . . 35
5.9 Target Values Packaging functions (sorted high to low) . . . 36
6.1 HOWs - QFD phase 2 . . . 37
6.2 Results moisture loss tests . . . 38
6.3 Target Values Packaging requirements (sorted high to low) . . . 40
7.1 Maximum moisture loss blister packaging . . . 42
7.2 Maximum moisture loss flowpackaging . . . 43
7.3 Recycle criteria and their relation to the current packaging . . . 43
7.4 HOW comparison matrix - packaging characteristics (Blister) . . . 44
7.5 HOW comparison matrix - packaging characteristics (Flowpackaging (without U-tray)) . . . 44
7.6 HOW comparison matrix - packaging characteristics (Flowpackaging (with U-tray)) . . . 45
7.7 Target values per packaging characteristic . . . 49
7.8 Suggested changes/actions - summary . . . 54
7.9 Suggested changes/actions - blister . . . 55
7.10 Suggested changes/actions - flowpackaging without U-tray . . . 57
7.11 Suggested changes/actions - flowpackaging with U-tray . . . 59
7.12 Final suggested changes/actions . . . 61
8.1 WHAT QFD Phase 3 . . . 63
8.2 HOW QFD Phase 3 . . . 63
8.3 Target Values process changes (sorted high to low) . . . 68
8.4 Final suggested changes/actions . . . 69
9.1 Summary costs scenario 1 - 3 . . . 77
11.1 Suggested changes for each packaging type . . . 93
11.2 Suggested changes for each packaging type . . . 94
13.1 Complaints customers 2019 - 2024 . . . 106
13.2 Answers question 1, 3 & 5 . . . 112
13.3 Importance general requirements . . . 113
13.4 Importance sustainability requirements . . . 114
13.5 Manufacturing costs blister 6 minidots - line 1 . . . 118
13.6 Manufacturing costs flowpackaging (with U-tray) 4 doughnuts - line 3 . . . 118
13.7 New manufacturing costs blister 6 minidots - line 1 . . . 120
13.8 New manufacturing costs Flowpackaging without U-tray . . . 121
13.9 New manufacturing costs Flowpackaging with U-tray . . . 121

Glossary

Abbreviation	Definition	Introduced in
EO	Europastry Oldenzaal	Section 1.2
EU	European Union	Section 1.2
SKU	Stock Keeping Unit	Section1.2
QFD	Quality Function Deployment	Section 1.3
DFMEA	Design Failure Mode and Effects Analysis	Section 1.3
PFMEA	Process Failure Mode and Effects Analysis	Section 1.3
MSA	Measurements System Analyis	Section 1.3
DoE	Design of Experiments	Section 1.3
TCO	Total Cost of Ownership	Section 1.3
Dots	Donuts, minidots, crodots	Section 2.2
VOC	Voice Of Customer	Section 3.1.1
AHP	Analytic Hierarchy Process	Section 3.1.1
MCDM	Multi Criteria Decision Making	Section 3.1.1
GQFD	Green Quality Function Deployment	Section 3.1.2
EQFD	Ecological Quality Function Deployment	Section 3.1.2
ABC	Activity Based Costing	Section 3.3
EFSA	European Food Safety Authority	Section 5.1.2
Cobots	Collaborative robots	Section 8.1

1 Introduction

This chapter discusses multiple topics to get an idea about the company and the problem at hand. The introduction will begin with a company background in Section 1.1. In Section 1.2, the problem is stated and the research motivation is described. The introduction continues with the research questions in Section 1.3 and the scope and research objectives (Section 1.4). This chapter ends with a description of the outline of this thesis in Section 1.5.

1.1 Company background

Europastry is a multinational company specialising in the production and distribution of frozen bakery products. The company was founded in Spain in 1987. The main products of Europastry are bread, viennoiserie (croissants, pastries, etc), cakes, doughnuts, pizza dough and gluten-free bakery products. Currently, there are more than 60 locations worldwide, one of them being in Oldenzaal, the Netherlands. This location is used as a production and distribution centre for the central European market. At this location, cookies, croissants, doughnuts and popdots are produced. The doughnuts of Europastry Oldenzaal will be the focus of this study. The cookies, croissants, doughnuts and popdots are produced and packaged at six different lines at the location. At lines 1 & 3 doughnuts are produced and packaged. Europastry's packaging consists of both bulk and consumer packaging, but a large portion of products are packaged in bulk (at the moment around 85%). The bulk packaging is mostly an American box or a top with a tray that fits 9 – 96 products per package. The consumer packaging of Europastry for the doughnuts is a flowpackaging (with or without U-tray) or a blister. In the consumer packaging, 1 – 9 products get packaged, depending on the doughnut type. The packaging options are displayed in the figure below (Figure 1.1).

Figure 1.1: Current packaging Doughnuts Europastry Oldenzaal

1.2 Problem statement & research motivation

At the moment, Europastry's choices in packaging are mostly customer-driven. This results in a lot of different packaging preferences. When these preferences are not available, it results in disappointed customers. In addition, by trying to implement as many customer preferences as possible, the consumer packaging portfolio becomes chaotic. This results in sub-optimal situations for Europastry Oldenzaal (EO). These situations mostly occur in the scheduling department and the performance of the consumer packaging lines is not optimal. The scheduling department has a hard time keeping track of all the doughnut and packaging types, which results in a lack of inventory at times. Next to that, if the consumer packaging lines are not designed for standard packaging options, it is difficult to create well-performing packaging lines. Additionally, EO remarks a shift towards more consumer packaging instead of bulk packaging. If this shift towards more consumer packaging is happening, it is important to have a clear portfolio of the packaging that is available. According to Ramos et al. (2011), the retail sector is increasingly demanding a shelf-ready format. The reason for this is in-store

operational efficiency. However, between retailers, the shelf-ready formats differ, which leads to a lot of flexibility for the selling company. Furthermore, there is no clear packaging portfolio available at Europastry at the moment. An overview of possible consumer packaging options is provided in Appendix A, but other types of consumer packaging are also used. In addition, packaging was never the focus of the company, and this resulted in a lack of focus on the packaging (lines). The reason for this is that the origin of Europastry lies in baking bread, pastries, and the like. To be able to sell these products, packaging was needed. So, the easiest packaging was chosen, namely bulk packaging. Over time, more questions and wishes related to packaging came from the customers of EO. However, the packaging of the products always has been and still is a secondary thing that needs to happen to sell the product. Next to that, the changing legislation of the European Union (EU) on packaging also has a great influence on the portfolio of consumer packaging. The changing legislation might result in the fact that certain packaging types will become infeasible or uninteresting to include in the portfolio. Finally, the packaging strategy of Europastry is a pull strategy, which means that the customer determines the packaging type and number of doughnuts in the packaging. Europastry would like to change to a push strategy so that Europastry presents several packaging options from which the customer can choose. This way, it is easier to keep track of all the packaging types. Taking everything just stated into account, the core problem for this thesis is that there is no clear overview of the requirements of consumer packaging. This leads to a portfolio that might not suit the current requirements. Next to that, it is not clear that the consumer packaging options that are offered now are suitable for the future. This leads to chaos, a lot of flexibility needed from the packaging lines and disappointed customers. In the figure below (Figure 1.2), a problem cluster is displayed. In addition to the lack of a portfolio for consumer packaging, it is also not clear whether it is financially feasible to package products in consumer packaging internally or to package them in bulk and repack them in consumer packaging externally. The motivation for this research is to create insights into the requirements of the consumer packaging of EO to determine future improvements (to the packaging portfolio). This way, the preferred packaging strategy could be enabled, reducing chaos and disappointment for customers.

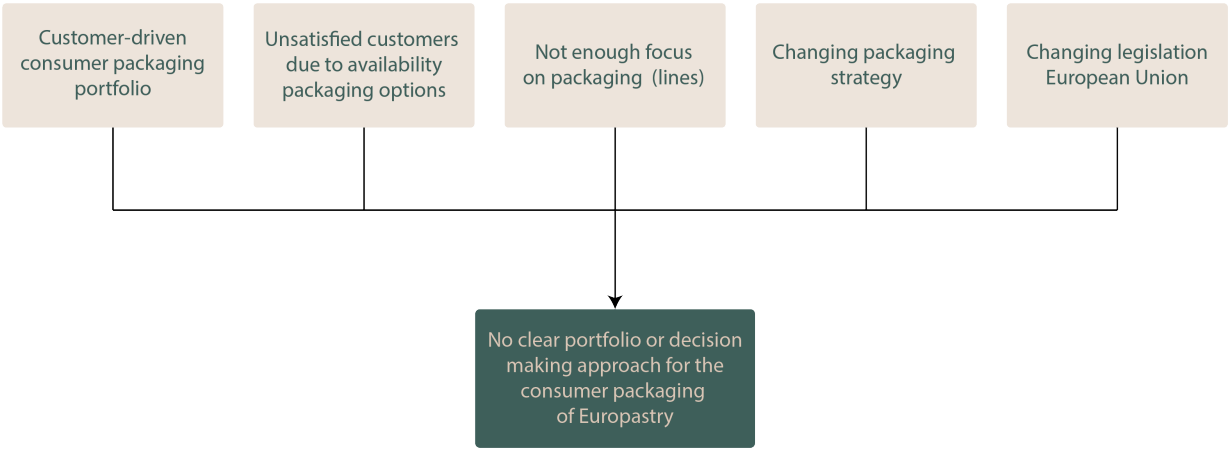

Figure 1.2: Problem cluster

1.3 Scope

The scope of this study will be described in this section. First of all, the packaging included in this study is the consumer packaging for the doughnuts, and therefore, packaging lines 1 and 3. Doughnuts are included because the customers of doughnuts have the most interest in consumer packaging. There is almost no interest in consumer packaging for croissants, so they are out of the scope of this thesis. Popdot customers are interested in consumer packaging, but the production and packaging line started only in 2023, so customers and EO still need to find a stable situation regarding popdots. This makes it less interesting to look at the consumer packaging of the popdots just yet. In the following paragraphs, the use of portfolio management, the tools used to develop the tool, and the tool itself will be described.

First, a portfolio within a company can be seen as the total of all products/packaging/services that a company actively offers on the market at a given point in time. Next to that, portfolio management ensures that the requirements of the customers align with the products/packaging/services (Riesener et al., 2023). However, in many companies, the product or packaging portfolio is often a consequence of historical developments (Nieuwmeijer & Lutters, 2022). Therefore, it can

be outdated, not linked to the current business strategies or not compliant with the customer's wishes. To be able to prevent this, it is necessary to have control of an up-to-date portfolio. An up-to-date and fitting packaging portfolio could help EO make decisions and have a future vision regarding consumer packaging. Furthermore, within a portfolio, there are different products and within those products, there is product variety. Even though product variety can fulfil the customers' requirements, too much product variety leads to negative impacts on production, costs and new product development time (Tolonen et al., 2015). This shows that it is important to strike the right balance between product variety and not just adjusting the product to every need of the customer.

A tool will be designed to create insight into the (future) requirements of the consumer packaging of the doughnuts. This tool will support the decision-making process for future improvements to consumer packaging. The used tool will be one of the tools of the design for Six Sigma in Figure 1.3 (surrounded by the green box). The first term in the box, a quality function deployment (QFD), is a structured approach to defining the needs or requirements of the customer and translating them into process plans to be able to meet the needs (Kiran, 2017). A QFD could be used to quantify the needs/requirements of the customers to be used in the tool. The second and third terms that can be seen in the green box are Design Failure Mode and Effects Analysis (DFMEA) and Process Failure Mode and Effects (PFMEA). These are both forms of the Failure mode and effect analysis, which concerns itself with analysing the failures and their effect. A DFMEA is used during the design process so that potential failures can be taken into account during the design process or product. A PFMEA is used to analyse and maintain the process objectives using a failure mode and effect analysis (Elahi, 2018). The next term in the green box is measurement systems analysis (MSA). A measurement systems analysis determines the system's accuracy to determine whether it is accurate enough to base decisions on it (Saikaew, 2018). The next term in the green box is Design of Experiments (DOE), which is a methodology that can be used for planning and conducting experiments and analysing and interpreting data from those experiments (Antony, 2003). DOE could be used in this study to design experiments to determine the tool's or other subjects' feasibility. Finally, the machine tool capability and process capability (C_p, C_{pk}) are used to statistically measure the capability of the process. It can be used to determine the efficiency of a machine or process (Motorcu & Güllü, 2006). From those tools, QFD is most fitting, as it connects the needs of the customer (or other stakeholder) to the technical requirements of the packaging. This can show whether or not the current packaging fulfils the needs of the customers and helps to provide strategies based on that. These new strategies could potentially affect the costs associated with packaging. Therefore, a cost estimation will be included.

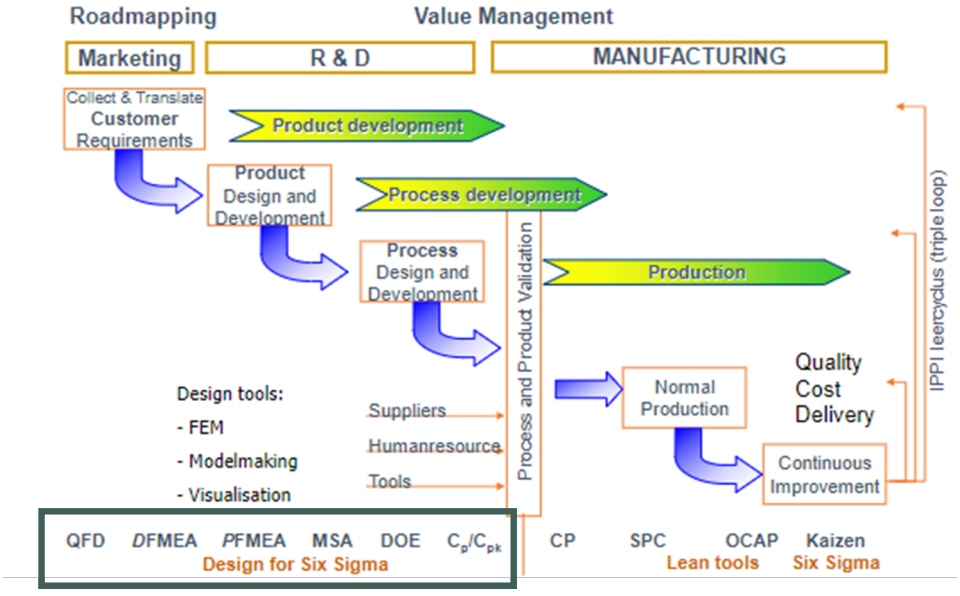

Figure 1.3: Design process approach (ten Klooster, 2020)

So, a QFD and cost estimation will be used to create insights regarding the consumer packaging of lines 1 and 3. A QFD will include the needs of the customers and the laws regarding packaging (sustainability) and relate these to the technical aspects of the packaging. The needs of the customers will be included, as that is in the end the biggest success factor of

the packaging. Next to the needs of the customers, the legislation regarding the packaging will be included, as these have a big influence on the (cost of) packaging in the coming years. An example of these legislations is that *"all packaging (except for lightweight wood, cork, textile, rubber, ceramic, porcelain and wax) will have to be recyclable by fulfilling strict criteria"* (Popp, 2024). So, together, the customers' requirements and the packaging legislation will give a clear overview of what is needed from the packaging. Additionally, the cost estimation will cover the change in costs when comparing the current costs and the potential changed costs. Next to that, the option of packaging the doughnuts in consumer packaging by a third party will be discussed. By including both in the study, a broad overview of requirements of the current consumer packaging is created, which enables decision-making regarding future improvements to the consumer packaging of doughnuts and the plans regarding the consumer packaging lines. The stakeholders of the tool will be the sales/marketing department and management of EO to be able to choose certain packaging and package the doughnuts internally or externally. Portfolio management is often done on a strategic management level, so that is the management level that will be taken into account when developing the tool (Martinsuo, 2013; Riesener et al., 2023).

1.3.1 Research objectives

The main objective of this research is to provide insight into the requirements of Europastry Oldenzaal's consumer packaging to allow decision-making to create an up-to-date portfolio and determine future improvements. Europastry aims to determine whether the current consumer packaging is future-proof. The deliverable of this thesis to the company will be an overview of these requirements and suggested improvements that were found in the QFD and the cost estimation. In addition to these suggested changes, the information, such as the voice of the customer and the cost estimation results will also be included. The research will prepare EO for the future regarding the customer's requirements and the packaging legislation. Next to that, an enhanced understanding of QFD principles will be developed. To be able to perform a QFD, skills like survey design, data collection and analysis will be improved. The contribution to science will be providing an up-to-date literature study of the quality function deployment and cost estimation concerning consumer packaging. Next to that, a case study using QFD to ensure future improvements to consumer packaging will be performed as well, which also contributes to science.

1.4 Research questions

To be able to guide the process and reach the research objectives, the main research question of this study will be:

Can a quality function deployment (QFD) and a cost estimation create insight into the requirements of the consumer packaging of Europastry Oldenzaal to determine future improvements?

1.4.1 Sub-questions

To be able to answer the main research question, the following sub-questions have been determined.

1. What is the current consumer packaging portfolio for the doughnuts and how are the doughnuts packaged?
This question will be answered by analysing the packaging (lines) to discover what packaging is used at the moment and how (often). This will be done by looking into the available data, walk-ins at the packaging lines and interviews with the stakeholders within the company. This question will generate an overview of the current consumer packaging (lines) and the information can be used in the tool at a later point. This question will be answered in Chapter 2.

2. What are the trends and best practices for performing a QFD and cost estimation?
This question will be answered in Chapter 3. First, the QFD and its uses and benefits will be discussed. This will be followed by the different phases and steps of a QFD. Finally, the uses of QFD within sustainability and QFD as an improvement tool will be described. Next to the QFD, the life cycle costs and cost estimation of a product/packaging will be discussed. In this section, the life cycle costs, product price, manufacturing costs and cost estimation methods will be described.

3. What actions can be taken based on the QFD results to improve the consumer packaging?
This question will be answered in multiple chapters, namely Chapters 5 - 8. All parts of the QFD will be discussed in a separate chapter and the QFD phases will be concluded at the end of Chapter 8.

4. What insights does the cost estimation give?
This question will be answered in chapter 9. The cost estimation will be performed among the suggested changes and the insights will be discussed in this chapter as well.

1.5 Outline

The outline of this thesis will be as follows. It will start with an analysis of the current situation to be able to answer the first sub-question in Chapter 2. This analysis describes the current consumer packaging (lines) for the doughnuts. After this analysis, a literature study will be performed in Chapter 3 to gather the information needed regarding a QFD, survey design and cost estimation. After the literature study, the methodology will be discussed in Chapter 4. Afterwards, quality function deployment will be performed to determine the changes that are needed for the consumer packaging (lines) based on customer requirements and legislation of the EU regarding the sustainability of packaging in Chapters 5, 6, 7 and 8. This will be followed by the cost estimation and the comparison to the costs of the current consumer packaging options in Chapter 9. Together, the QFD and cost estimation will enable decision-making for EO regarding the consumer packaging. All the collected requirements will be evaluated in Chapter 10. In Chapter 11, the research question will be answered, a reflection will be done regarding the research activities and used tools and the limitations, recommendations and future research will be described. This thesis will end with the conclusion in Chapter 12.

2 Context analysis

In this chapter, the current situation of customers of EO, products and packaging (lines) will be described to learn more about the current situation. The chapter will start with a description of the customers of EO in Section 2.1, followed by the description and analysis of the products in Section 2.2. When the products are described, the packaging will be discussed in Section 2.3. This chapter will end with Section 2.4 which describes the packaging lines of EO.

2.1 Customers

In 2023, EO sold products to different customers across central Europe (Belgium, the Netherlands, Germany, the UK and Scandinavia). These customers are divided into three categories, namely retail, food service and others. Within the retail categories, supermarkets and convenience stores are placed. Within the food service category, customers like restaurants and catering companies can be found. In the other category, the customers like distribution centres can be found. The division of each customer category can be seen in Figure 2.1. From these categories, the customers within the retail category have the biggest preference for consumer packaging as they can directly sell the products in their story when using consumer packaging. When looking at the sales of EO per customer category over the last few years (2022-2024), the retail customers are responsible for the biggest part of the net sales. The food-service category often sells the products separately in their restaurants, so they do not need consumer packaging to be able to sell the products. However, some food service customers offer products in consumer packaging. The other category mostly consists of distribution centres, etc, so they barely need consumer packaging, as it is not yet an endpoint of the product.

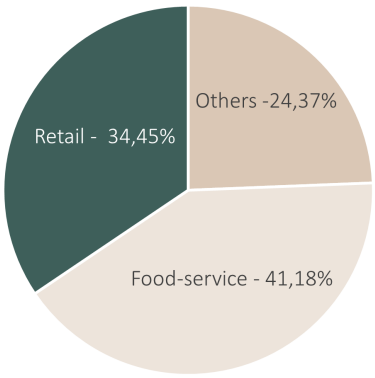

Figure 2.1: Pie chart customer categories

2.2 Products (SKUs)

Figure 2.2 shows the product families of each line. Every type of doughnut is called a dot within EO, so that is the overall product family of all the products produced and packaged at lines 1 and 3. Within the product family, 'dots' are several subfamilies, which can be seen in the figure below (Figure 2.2). Every product subfamily has a variety of dots that differ in filling, dough or coating. For example, the subfamily 'dots' of line 1 consists of doughnuts with no coating, sugar coating, chocolate coating, coating with sprinkles and many more. Line 1 produces and packages the unfilled doughnuts and line 3 produces and packages the filled doughnuts. In 2023, there were 70 different stock keeping units (SKU) for line 1 and 88 for line 3. Each SKU has different packaging but could be similar doughnuts. Next to that, some SKUs are seasonal, so yellow doughnuts are for Easter, or pink doughnuts are for Valentine's. This means that not all SKUs are produced year-round. In addition, some SKUs are within the category "mixboxes". These mixboxes are a combination of several, most often 4, different SKUs that are packaged together in one consumer packaging. Of these subfamilies, the dots, minidots and crodots have the most SKUs for line 1 and for line 3 the filled dots have most of the SKUs. Next to that, these subfamilies are the only ones with consumer packaging.

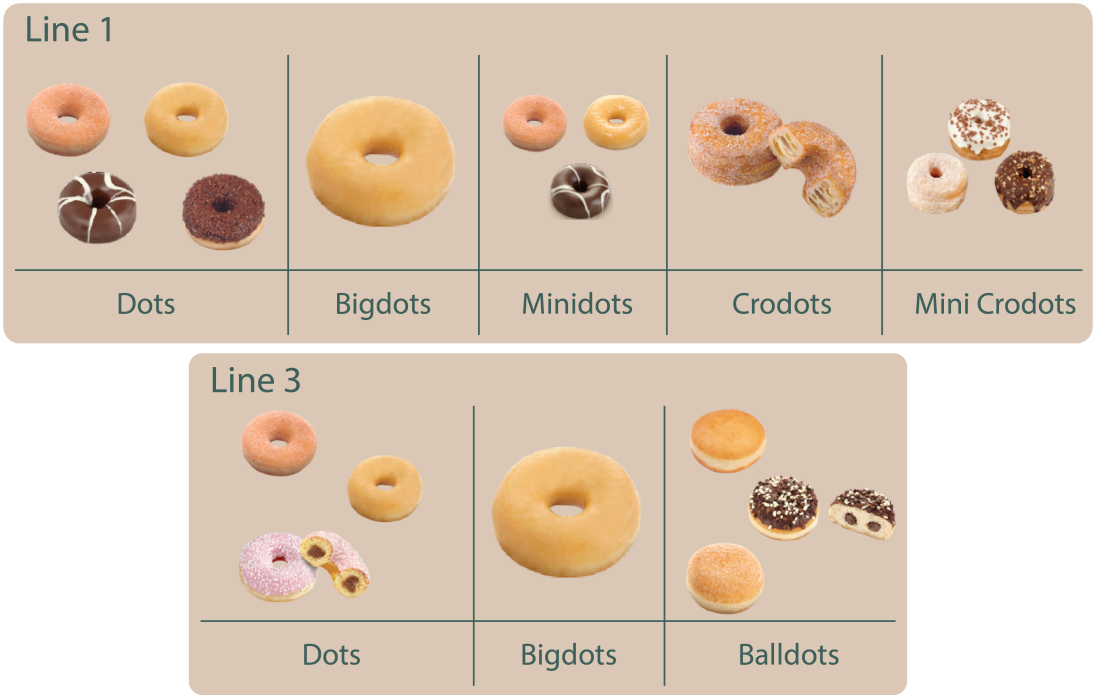

Figure 2.2: Products per line

2.2.1 Guarantee of freshness

In Figure 2.3, the guarantee of freshness for different kinds of doughnuts is displayed. In this figure, there are three different situations, namely open air, partly contact with air and closed off entirely. These guarantees of freshness are determined for room temperature (10-25 °C) with a relative humidity of 60-80% and preserved from air flows. As can be seen in the figure below, there is a difference between the different doughnut types. Coated, filled doughnuts or crodots have a longer guarantee of freshness compared to half-coated, sugar or glazed doughnuts. The main reason that influences the guarantee of freshness is that the doughnuts become stale. When the doughnut has a coating and/or filling, there is more 'protection' for the doughnut. The dough of crodots consists of more butter compared to the normal doughnuts, which limits the staleness as well. For later reference, the doughnuts with lower guarantees of freshness will be type 1 doughnuts (half-coated, sugar and glazed doughnuts) and the others will be type 2 doughnuts (coated, filled or crodots). The doughnuts will be frozen before being packaged and will stay frozen until they arrive at the point of sale. At this point, they get defrosted and then the guarantee of freshness starts.

	Open air (on a plate in the kitchen)	Partly contact with air (blister packaging/cake tin)	Closed off entirely (flowpackaging)
1 day	Half-coated doughnuts Sugar doughnuts Glazed doughnuts		
2 day	Coated doughnuts Filled doughnuts Crodots	Half-coated doughnuts Sugar doughnuts Glazed doughnuts	
3 day		Coated doughnuts Filled doughnuts Crodots	Half-coated doughnuts Sugar doughnuts Glazed doughnuts
4 day			Coated doughnuts Filled doughnuts Crodots

Figure 2.3: Guarantee of freshness

2.3 Packaging

As discussed in Chapter 1, EO produces doughnuts and packages them. EO uses both bulk packaging and consumer packaging. Bulk packaging is used to package a lot of products at once, for either ease of transportation, inventory, or to send to the customer (ten Klooster et al, 2015). This is still the main packaging type of EO and the bulk packaging options can be seen in figure 1.1. Within the bulk packaging of EO, between 9 and 100 products are stored. Within the packaging theory, three packaging terms are used to distinguish different functionalities. These terms are primary, secondary, and tertiary packaging and are explained as follows (ten Klooster et al, 2015). Primary packaging is the packaging that has direct contact with the product and is used as the packaging for sale. The appearance of this packaging is important, as this is the packaging that the customer will see and buy. Additionally, primary packaging also enables easy handling and storage of the product. Secondary packaging is used for the bundling of products, enabling easier handling and distribution. Finally, tertiary packaging enables the bundling of a large number of products for long-distance transport. Consumer packaging, the other packaging option EO offers, belongs to the primary packaging. Consumer packaging is often referred to as a consumer unit. A consumer unit is a unit that the consumer purchases in a store (STAND, 2018). Often, the consumer unit needs a bar code to scan the product. In the next section, the consumer packaging of the doughnuts is discussed in more detail.

2.3.1 Consumer packaging

As can be seen in Figure 1.1, the consumer packaging options for the doughnuts are blister packaging and flowpackaging with or without U-tray. These packaging options store between 1 and 9 doughnuts, depending on the doughnut type. In Figure 2.4, the flow of the packaging within EO can be seen. In the figure below, the three kinds (primary, secondary, and tertiary) of packaging can be seen. First of all, the primary packaging is the consumer packaging of the doughnuts. These primary packaging with doughnuts continue on the packaging line towards the secondary packaging. This packaging type consists of American boxes that package around 20-30 primary packaging per box. Finally, the American boxes (secondary packaging) move towards the palletizer, where multiple secondary packaging is placed on the pallet (tertiary packaging). The doughnuts are transported in their tertiary packaging by truck to the customers.

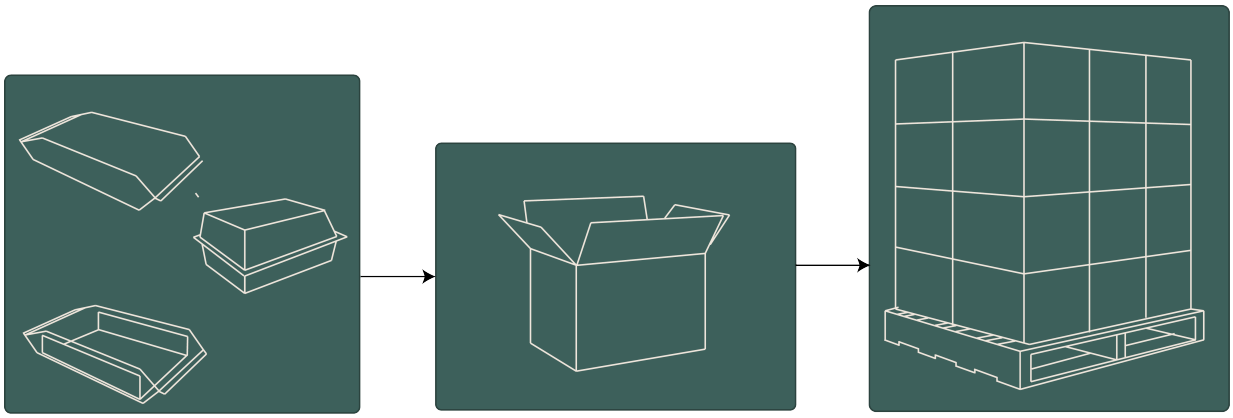

Figure 2.4: Consumer packaging flow

In Figure 1.1 in the previous chapter, an overview is given of the possible packaging types for each line. Each of these packaging is also shown in Figure 2.5 below. In this figure, the packaging types that were used in 2024 for each line/subfamily are displayed. So, for example, the doughnuts of line 1 got packaged in either blister packaging or flowpackaging (with U-tray) in 2023. When there is no line connected to a product family, it means that there is no consumer packaging option for that subfamily. The number of doughnuts in the packaging depends on the subfamily, but overall, it differs between 1 and 9 (mini)doughnuts.

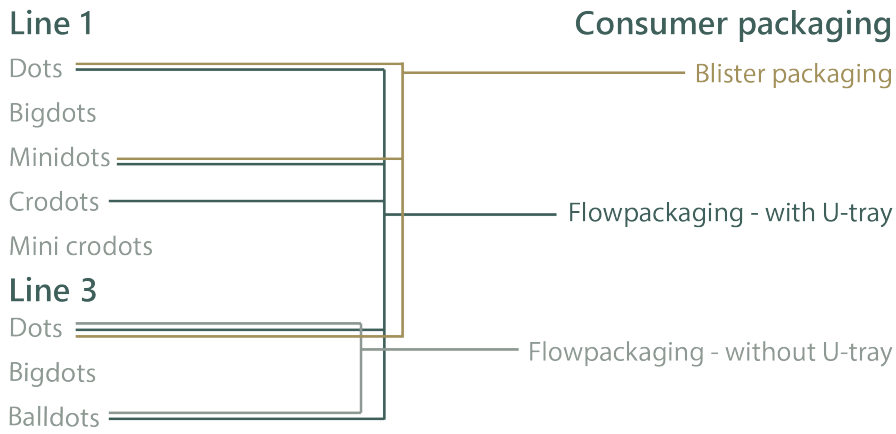

Figure 2.5: Overview doughnuts - consumer packaging

2.4 Packaging lines

The packaging lines, which are the topic of this section, are directly placed after the production lines, so the produced and frozen doughnuts are packaged directly. The complete flow of the doughnuts from start to finish is displayed in Figure 2.6. As displayed, the doughnuts are manufactured in the bakery and afterwards, they go to the freezer. When the doughnuts are frozen, they arrive at the packaging line to get packaged. The doughnuts get packaged in either consumer packaging or bulk packaging and they end up on a pallet, which is transported to the warehouse so that the doughnuts can be added to inventory. If the doughnut is packaged in consumer packaging, all relevant information (ingredient list, best before date, etc.) is mentioned on the label on the secondary packaging. For the mixbox SKUs, the flow is a bit different. First, all the needed SKUs are packaged in bulk at the packaging line and added to the inventory. When all SKUs are produced and packaged in bulk in the warehouse, a shift is scheduled to package all the different types of doughnuts together into one single consumer packaging. This way, the packaging has several different types of doughnuts in one packaging. Most often, there are four different doughnuts in a mixbox and the packaging used is often blister packaging. EO is not able to package mix boxes directly, as only one type of doughnut can be produced at a time. If there is a different packaging type needed or there is not enough capacity, EO sometimes packages the doughnuts in consumer packaging at a third party.

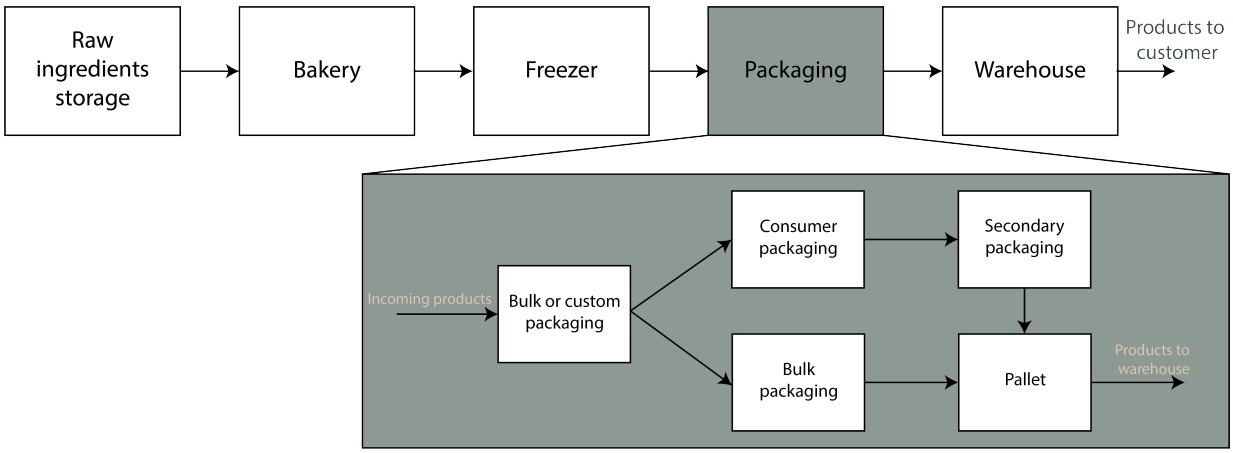

Figure 2.6: Complete flow doughnuts EO, from van der Meer (2024, Chapter 2.5)

The consumer packaging process occurs on two floors for lines 1 and 3. The main reason for this is that on the ground floor, all the 'dirty' parts of the process happen, such as the folding of the carton or palletising. This results in small snippets of carton or wood during the process, which could end up in the product. However, the doughnuts are packaged in their primary packaging (so either consumer or bulk) on the first floor before going downward to be palletised. This way, the doughnuts never come in direct contact with those small wood/carton snippets since they are already packaged in their primary packaging. Below, in figure 2.7, the flow of the consumer packaging lines is displayed, as this is similar for each

packaging line. As can be seen, there are two metal detectors at the beginning and end of the packaging process. This is done to ensure that there is no metal in the products, and these metal detectors are critical control points of the packaging line.

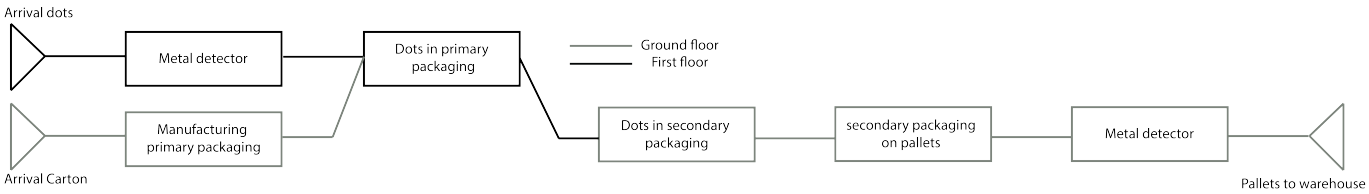

Figure 2.7: Consumer packaging lines flow doughnuts EO, from van der Meer (2024, Chapter 2.7)

2.4.1 Scheduling

In this section, the scheduling and production hours will be described. First of all, the production lines and, therefore, the packaging lines run 24/7. The days are divided into 3 shifts of 8 hours, resulting in 21 shifts a week. During such a shift, 1 - 3 different SKUs are scheduled, these will be produced & packaged consecutively. So, during a week, between 7 and 21 different SKUs can be produced and packaged. To enable the consumer packaging line to switch between packaging types or settings, there is around 15 minutes of changeover time scheduled. In 2023, around 3 shifts per week were scheduled for lines 1 and 3 where doughnuts were packaged in consumer packaging. EO expects that this will increase to around 6 shifts a week in the coming years. During these shifts, different dot-packaging combinations are used, some of these combinations only occur a few times a year. This depends on the requirements of the customers of those specific SKUs. Next to the scheduling of the SKUs, two consecutive cleaning shifts are scheduled each week, so 16 hours of downtime for each line. Next to that, planned maintenance also creates gaps in the schedule.

3 Literature study

3.1 Quality Function Deployment (QFD)

As briefly described in Chapter 1, a QFD is an approach to defining the needs or requirements of the customer and translating them into product/process plans to be able to meet those needs (Kiran, 2017; Kim, 2019). It is a successful tool to combine and encourage combined consideration of marketing and engineering concerns (Aguwa et al., 2012). Next to that, according to Kim (2019), QFD has the unique advantage of understanding that the components of a product should come from the expectations and requirements of the customers to ensure a high-quality level design. The requirements traceability is high, which enables this high-quality design (Burge, 2007). In addition, a QFD is a proactive quality control tool (Mital et al., 2014). Also, a QFD could be used as a design tool, but also as a tool to improve the current product or process (Erdil & Arani, 2018). During the years of use and development of the QFD methodology, the application expanded to wider fields such as design, planning, decision-making, engineering, management, timing, cost, etc. (Lai et al., 2008). According to Kiran (2017), a QFD could be used for product portfolio management, as it defines what a product should need to meet the customer's demands. From that point, the portfolio of a product can be developed further.
According to ISO standard 16355, a QFD is described as *"Quality function deployment (QFD) is a method to ensure customer or stakeholder satisfaction and value with new and existing products by designing, from different levels and different perspectives, the requirements that are most important to the customer or stakeholder"* (ISO, 2021). Additionally, the QFD institute gives the following description: *"QFD is a comprehensive quality system that systematically links the needs of the customer with various business functions and organisational processes, such as marketing, design, quality, production, manufacturing, sales, etc., aligning the entire company toward achieving a common goal"* (Kiran, 2017). Figure 3.1 shows the four phases of the QFD process. These four phases ensure that the user starts with the customer requirements and uses those to design the rest of the product, process, and production requirements. A more detailed description of those four phases is given below.

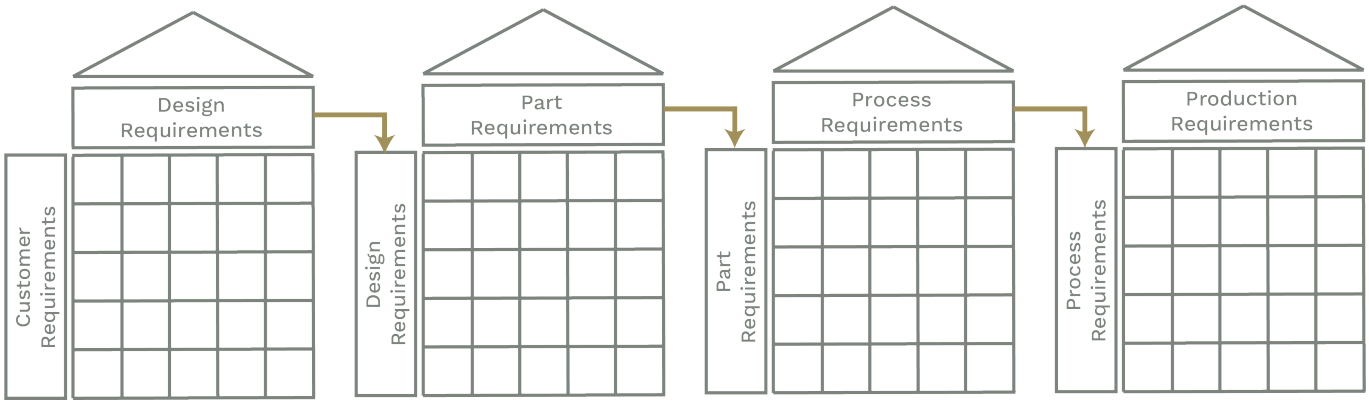

Figure 3.1: Phases of the QFD process, adapted from Erdil & Arani (2018, Chapter 3)

Within the food industry, a QFD road map was developed in the early Nineties, which is displayed in Figure 3.2. As can be seen, the QFD flow for the packaging is similar to the QFD flow in Figure 3.1. The naming of steps differs a bit, but the idea is similar. For food deployment, phases 2 & 3 are combined, but since this study is interested in packaging, this is beyond the scope.

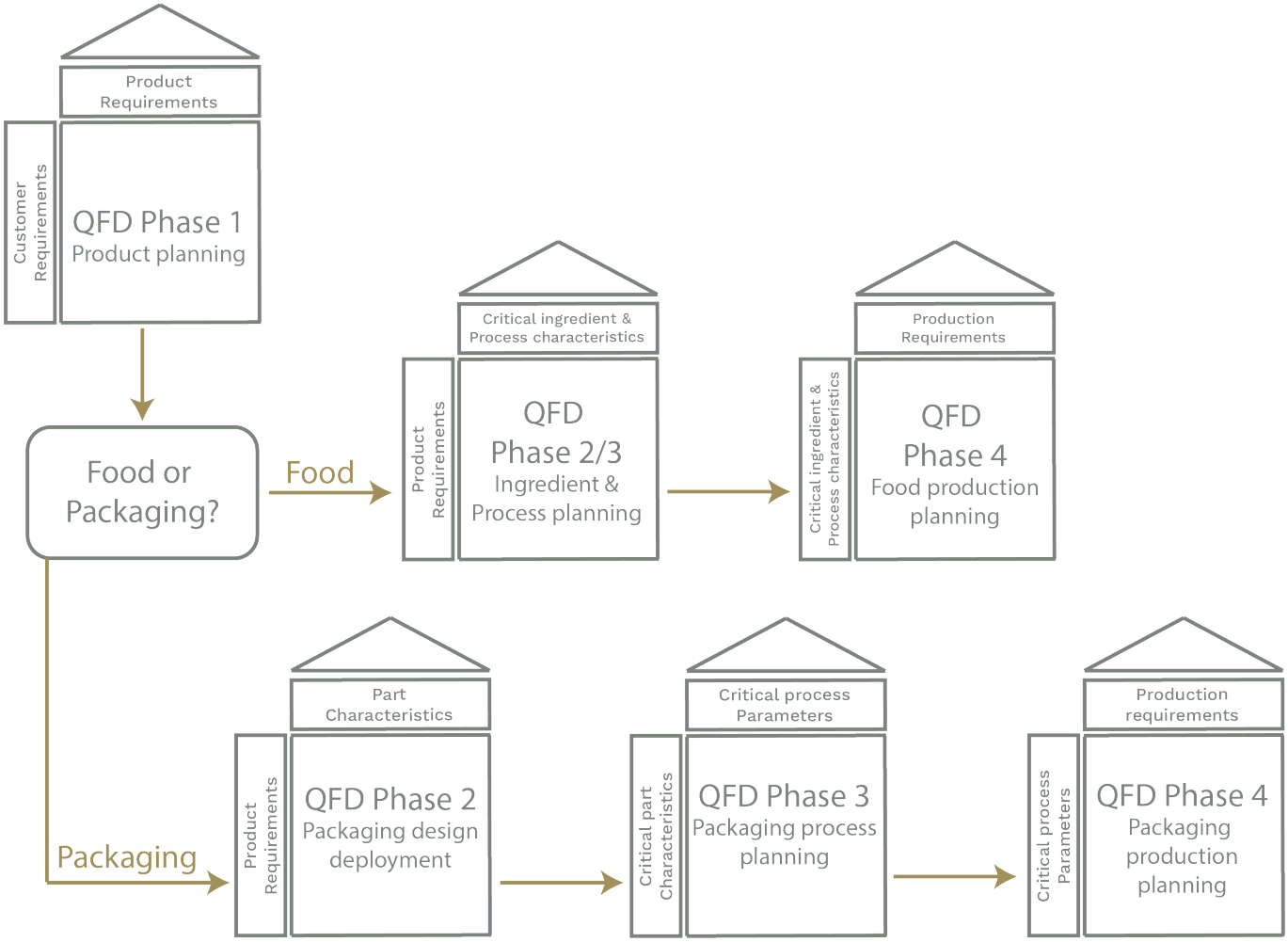

Figure 3.2: A road map for QFD within the food industry, adapted from Benner (2005, Chapter 2.3)

3.1.1 Phases QFD

As can be seen in figure 3.1, a QFD consists of four phases, which will be described in this section. The description will explain the steps to be taken in each phase and the interrelation between these phases.

Phase 1: House of Quality

The first phase, the house of quality, is the most known step of QFD. This phase aims to translate the customer requirements (the WHATs) into the design requirements or technical requirements (the HOWs) (Kim, 2019). Figure 3.3 shows the framework for the first phase of the QFD in more detail. The framework is filled in steps, which are (Erdil & Arani, 2018):

1. Determine the customer requirements (WHAT)
2. Identify technical requirements (HOW)
3. Relationship between the WHAT and the HOW
4. Conduct a competitor assessment
5. Prioritise technical requirements

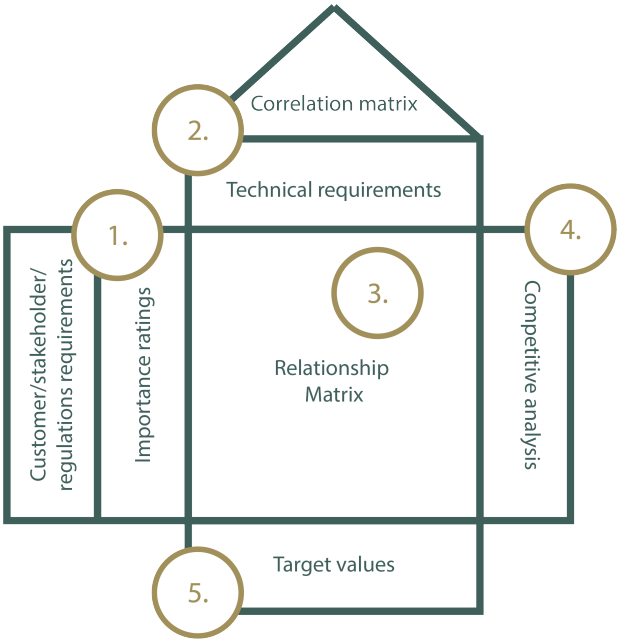

Figure 3.3: Framework phase 1: House of Quality, adapted from Kiran (2017, Chapter 2.3)

Step 1: Determine the customer requirements (WHAT)

The steps will now be discussed in more detail. First, step 1 is to determine the customer requirements (WHAT). These customer requirements are often called the voice of the customer (VOC). According to Aguwa et al. (2012), manufacturing systems can benefit a lot from a detailed VOC analysis. The voice of the customer can be collected in multiple ways, like surveys, customer feedback, customer complaints, and interviews (Kim, 2019). Determining the voice of the customer is often done via a market survey combined with expert opinion (Lai et al., 2008). When collecting customer requirements, they are often vague and ambiguous. However, it does happen that customer requirements are already specified as technical requirements (Burge, 2007). This could lead to duplication and confusion, so customer requirements have to be evaluated first and not implemented directly. Furthermore, if the number of customers/regulation requirements exceeds 30 items, the matrix will have to be divided into smaller modules or subsystems to reduce the number of requirements (Mital et al., 2014; Franceschini, 2001). This could be done by dividing the requirements into levels; primary, secondary, and tertiary (Franceschini, 2001). This way, the requirements are grouped into topics to make the QFD more manageable.

In addition to identifying customer requirements, it is also important to define the importance of each requirement (Erdil & Arani, 2018). This can be done in several ways, most often a 1 - 10 score is used. Determining the level of importance is a subjective assessment, which is directly one of the weaknesses of performing a QFD. This weakness can be overcome by using normalisation or, for example, the Analytic Hierarchy Process (AHP) (Kim, 2019; Tan et al., 2003). An AHP is a multi-criteria decision method which uses paired comparisons between the criteria to identify the most important one. The method uses relationship matrices to calculate the most important requirement (Shapiro & Koissi, 2017). According to Dabous et al. (2024), the integration of AHP into the QFD process can reduce inconsistencies in QFD input, since subjectivity is reduced, and improve the multi-criteria decision-making process (MCDM).

The steps of AHP are as follows (Dabous et al., 2024):

1. Formulation of the aim of work and identification of barriers: Identify the list of barriers related to the study with the assistance of a literature survey, interviews or expert's opinion.
2. Formulation of the pairwise comparison matrix: Constructing the matrix with relative importance a_{ij} between criteria i and j, such as:

$$\begin{array}{c} \\ A \\ B \\ C \end{array} \begin{array}{c} \begin{array}{ccc} A & B & C \end{array} \\ \begin{bmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 2 \\ 1/5 & 1/2 & 1 \end{bmatrix} \end{array}$$

3. Computation of maximum eigenvalues: Determine the eigenvalues λ of each criterion to determine the importance weights of these criteria. This can be done by dividing the relative importance a_{ij} by the sum of all relative importance of the criteria, so: $\lambda_i = \frac{a_{ij}}{\sum a_i}$.
4. Evaluation of the consistency ratio: To ensure the consistency of the pairwise comparisons, the consistency ratio can be calculated by: $CI = \frac{\lambda_i - N}{N-1}$, where λ_i is the maximum eigenvalue and N the number of criteria. An AHP allows for some inconsistency, but the consistency ratio needs to be lower than 0.1. If this is not the case, the pairwise consistency matrix (step 2) needs to be altered to remove the inconsistencies.

Next to determining the importance rating, it is also important to normalise all ratings, so determine the percentage of each customer requirement compared to the other ones (Kim, 2019).

Step 2: Identify technical requirements (HOW)
After identifying the voice of the customer and implementing that in the framework, the technical requirements can be determined. These technical requirements translate the VOC into characteristics expressed in measurable attributes (Erdil & Arani, 2018; Burge, 2007). One technical requirement can fulfil one or more customer needs (Kim, 2019). The technical requirements will be identified by expert knowledge, experience, and research. It is important to make sure that each technical requirement is one variable, and they cannot influence each other. For example, one HOW cannot be that the product has to be 10 x 10 centimetres and have the colour blue. These need to be two different requirements. Next to this, identification of the characteristics and the correlation between these will also be identified in this step. This is important to identify if and which characteristics are positively and negatively correlated (Erdil & Arani, 2018). These negatively correlated requirements might result in a trade-off within the product design later on (Burge, 2007). Early identification and resolution of trade-offs might shorten product development time (Tan et al., 2003). Determining the correlation can be done by using symbols like in Figure 3.4. If there is no correlation, a blank spot will occur in the correlation matrix (Erdil & Arani, 2018).

Figure 3.4: Correlation symbols, adapted from Burge (2007, Appendix A)

Step 3: Relationship between the WHAT and the HOW
The relationship between the customer or regulation requirements and the technical requirement is determined in this third step of the first phase. This will be done in the main body of the house of quality (Kim, 2019). This is often done by using three symbols that represent the relationship as follows (Erdil & Arani, 2018; Kim, 2019):

Table 3.1: Symbols used in relationship matrix

Symbol	Relationship	Score
•	Strong relationship	9
○	Medium relationship	3
△	Weak relationship	1

At least one HOW must have a strong relationship with a WHAT to ensure that every WHAT is represented enough (Erdil & Arani, 2018). Next to that, every HOW should have a relationship, otherwise it is an unnecessary technical requirement (Burge, 2007). This way, it is ensured that every customer requirement translates into one (or more) technical requirements.

This step in the first phase is prone to subjectivity; therefore, it is important to discuss the choices with stakeholders (Kim, 2019).

Step 4: Conduct a competitor assessment
This step aims to determine where the company stands in the market (Kim, 2019). Next to that, it is a nice way to identify areas to concentrate on for the product's design (Tan et al., 2003). In this step, several competitors are listed and evaluated according to the customer requirements. This is often done using the same symbols as in step 3 (Burge, 2007).

Step 5: Prioritise technical requirements
This step consists of determining the target values of each technical requirement (Kim, 2019). This way, the requirements can be prioritised. This is done by multiplying the sums of each requirement by the normalised importance ratings (Erdil & Arani, 2018). So the formula would be:

$$W_{ij} = \sum d_i \times r_{ij} \tag{1}$$

Where W_{ij} is the target value, d_i is the normalised importance rating and r_{ij} is the relationship between the technical requirement and the customer requirement. Afterwards, the target values have to be normalised. This step ensures customer satisfaction if the design targets are met (Burge, 2007). The technical requirements can be sorted based on their target values and the most critical requirements can be selected to tackle first (Kim, 2019).

Phase 2, 3 and 4
The second phase of a QFD is the part deployment, where the technical requirements are translated into (sub)part requirements (Franceschini, 2001). Afterwards, you can take the HOW from phase 2 to the WHAT of phase 3 to determine the important process operations (Hauser & Clausing, 1988). In the last phase, operations become production requirements. Figure 3.5 displays the framework for these phases. The steps of phases 2, 3 and 4 are similar to phase 1, except for the competitor analysis. Additionally, it is not necessary to determine an importance rating, as in each phase, the target values are determined.

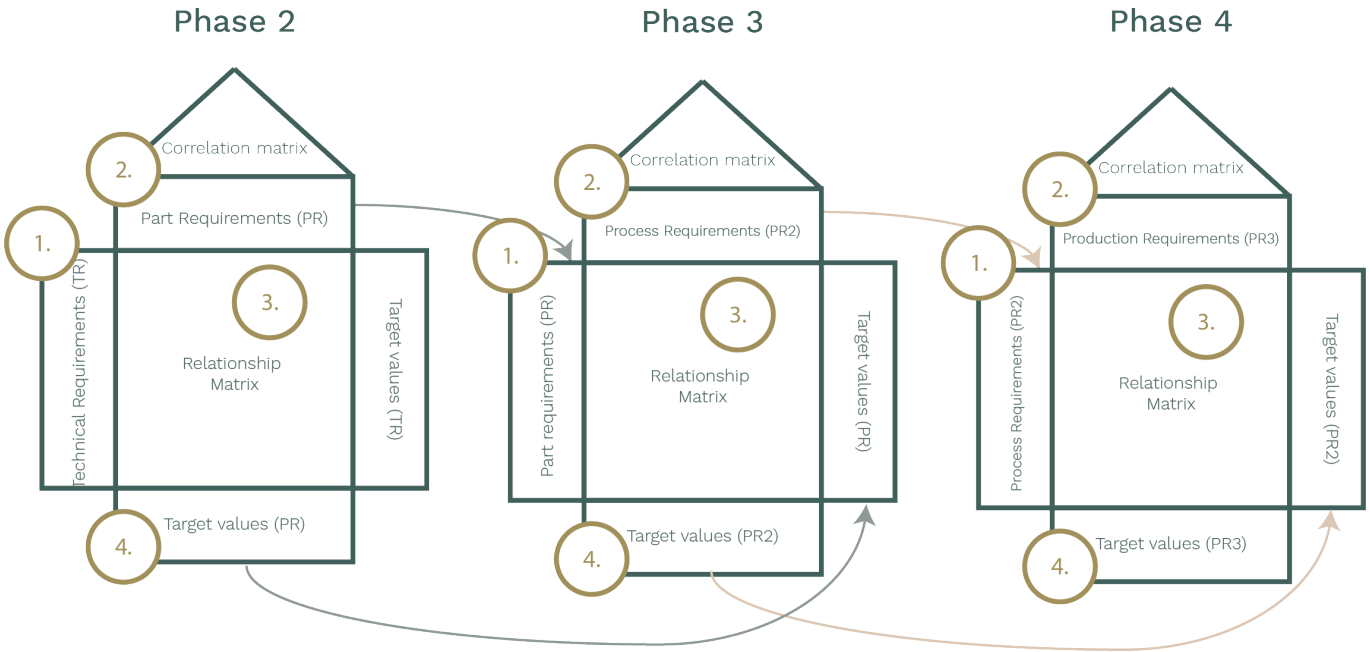

Figure 3.5: Framework phase 2, 3 and 4, adapted from Kiran (2017, Chapter 2.3)

3.1.2 Sustainability in QFD

Sustainability and environmental considerations are becoming more important for the product development process. There are several ways to combine sustainability and a QFD, as the analysis of Puglieri et al. (2020) shows. Different terms are used to show a QFD from a sustainability point of view, such as a Green Quality Function Deployment (GQFD) or Ecological Quality Function Deployment (EQFD). The goal of each of those different environmentally based QFDs is different, some want to assess environmental impacts by including the whole life cycle or combining the QFD with an LCA, and others want to include regulations or environmental parameters as input (Puglieri et al., 2020). The studies that include the regulations/sustainability parameters used matrices for the first phase, such as the ones in Figures 3.6 or 3.7.

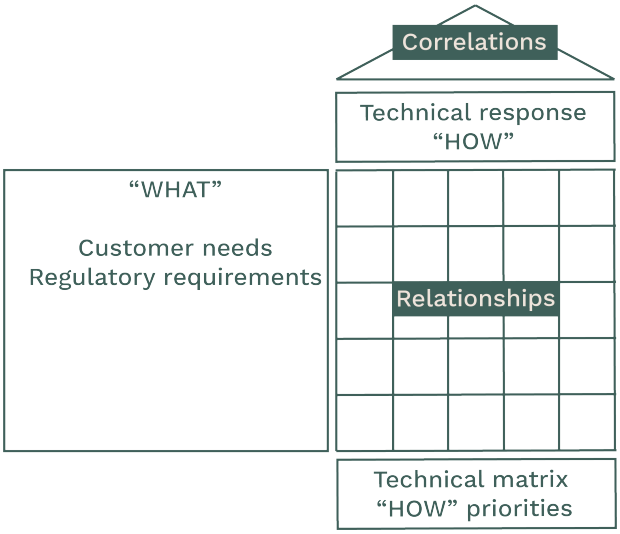

Figure 3.6: Matrix QFD phase 1 with legislation, adapted from Utne (2009, Chapter 2.2)

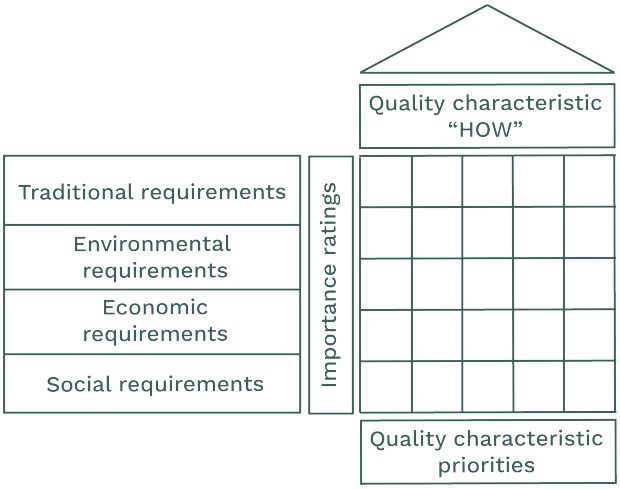

Figure 3.7: Matrix QFD phase 1 for sustainability, adapted from Horan (2022, Chapter 3.1)

3.1.3 QFD as an improvement tool

As mentioned in the first paragraph of Section 3.1, a QFD can also be used as an improvement tool. In the paper of Erdil & Arani (2018), an investigation was carried out to determine to what extent a QFD could be used as an improvement tool. Their paper concluded that it could be used as an improvement tool. Erdil & Arani (2018) found that from 1992 to 2017, around 21% of the QFD implementations were used for improvement instead of design & development. In addition, a framework with a structured approach for QFD as an improvement tool was developed. This framework is displayed in Figure 3.8. The idea behind the framework is to develop a house of quality, the first phase of the QFD, to identify the

technical characteristics that will generate the greatest improvement. With these technical characteristics, an action plan can be developed for preventive or corrective actions. If technical characteristics do not allow for the development of an action plan yet, the user could continue with more QFD phases before developing the action plan (Erdil & Arani, 2018).

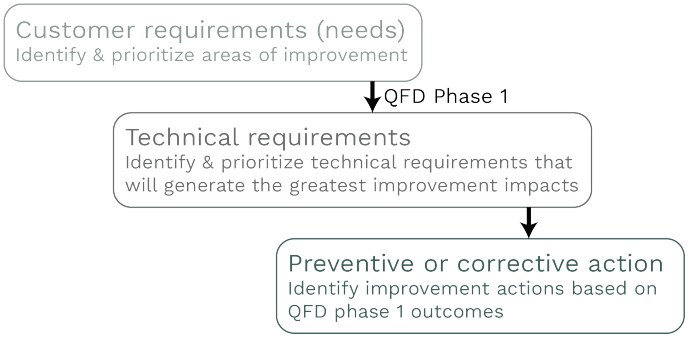

Figure 3.8: Framework for QFD as an improvement tool, adapted from Erdil & Arani (2018, Chapter 3.3)

Paryani et al. (2010) also modified the QFD methodology to improve the hospitality industry. The methodology used in that paper is shown in Figure 3.9. The methodology was mostly adjusted because there is no part deployment in the hospitality industry, so Paryani et al. (2010) used phases 1, 3 and 4 in an adjusted manner to determine how to improve the hospitality industry. Concluding this section, the QFD method is used as an improvement tool quite often, but the traditional QFD method is sometimes adjusted to fulfil the goal.

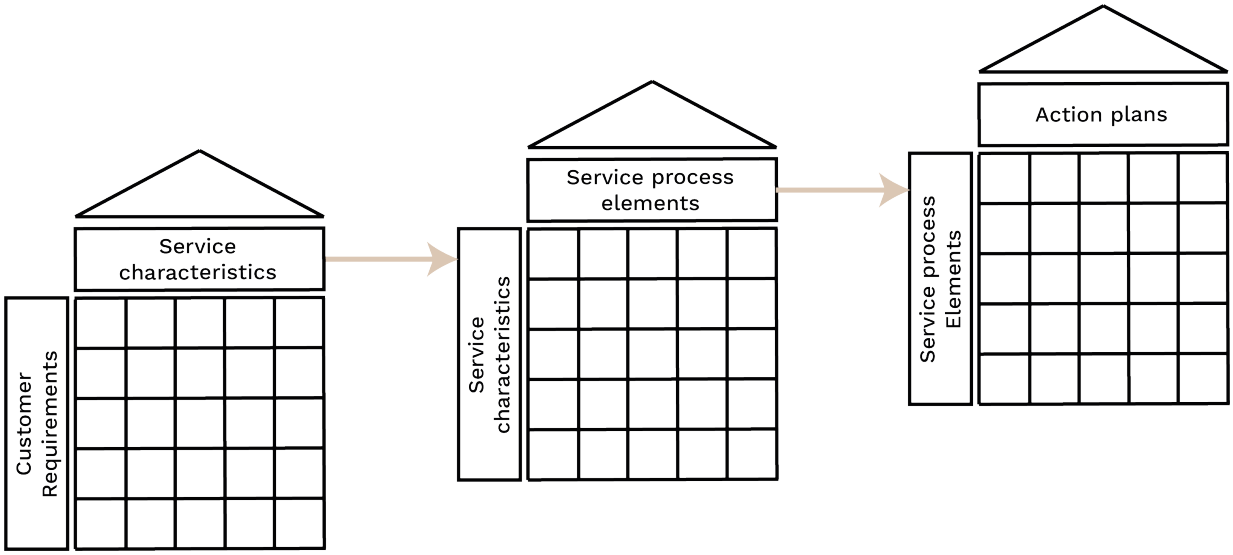

Figure 3.9: QFD process to improve the hospitality industry, adapted from Paryani et al. (2010, Chapter 3)

3.2 Survey design

A survey can be used to collect the customer requirements that are needed for the first phase of the QFD. A survey can be described as a research strategy in which information is collected from a sample taken from a population (de Leeuw et al., 2008). Internet surveys are supposed to be relatively short, to ensure that they actually get finished, around 10-15 minutes (de Leeuw et al., 2008). Since there is no interviewer at a survey, it has to be completely self-explanatory. A big advantage of internet surveys is that it gives flexibility to the respondent, as he/she can complete the survey wherever and whenever. Next to that, it is also less intrusive and more private. A downside of internet surveys is that less attention is paid to the survey compared to interviews or other survey options (de Leeuw et al., 2008). As internet surveys have to be completely self-explanatory, it is even more important to have no ambiguity around the questions asked. That is why closed-questions are more suitable for self-administered surveys (Fowler, 2009). However, it should be taken into account that closed-end questions are sensitive to guiding the questionnaire to specific answers (Lavrakas, 2008). Ambiguity can be limited when

the following things are taken into account (de Leeuw et al., 2008). First, unfamiliar or technical terms should be avoided or explained. When a respondent does not understand a specific term, he/she might just guess an answer, which decreases the reliability of the results. Secondly, abstract nouns & verbs should be avoided. It is important to define the words and phrases to avoid ambiguity. Additionally, adjectives or adverbs should be clearly defined. Next to that, the time frame of a question should be clearly defined. Set time frame boundaries for which the question is asked. Furthermore, assumptions should not be included in the question. This might make it harder for the respondent to answer the question. Finally, it is important to ask one question at a time, otherwise, an influence of both questions might arise.
The process of survey research can be seen in Figure 3.10. The first step is to determine the research objectives. From these objectives, the concepts and population can be defined. When these are specified, the mode of administration can be chosen, such as interviews, online surveys, paper surveys, etc. Afterwards, the questions can be developed for the questionnaire. Next to that, the sampling process can be designed. Both step 4 (questions) and step 5 (sampling) must be revised. This ensures that they are in line with the research objectives. After this, a foundation is laid for the survey and data collection, processing, and analysis can be performed.

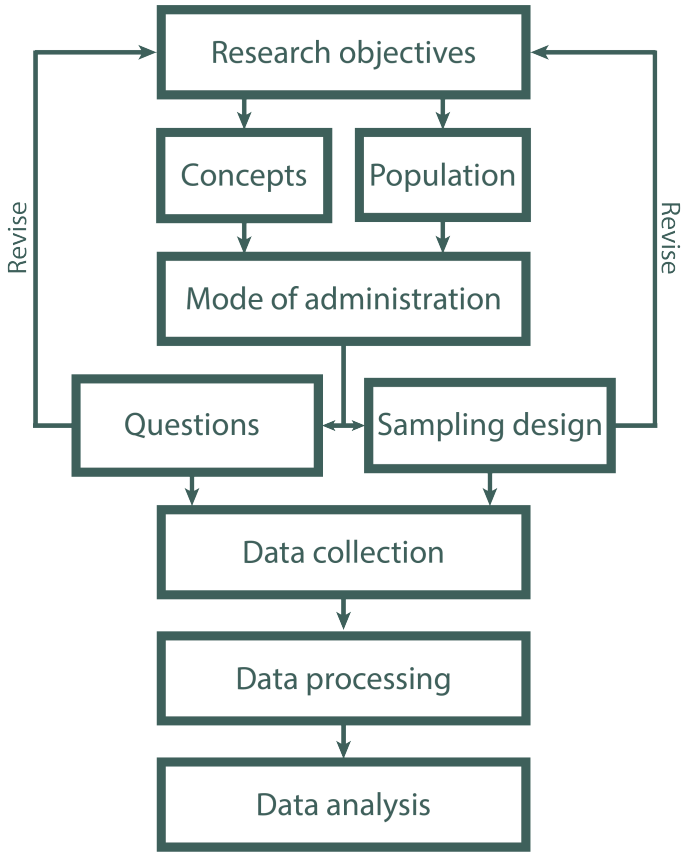

Figure 3.10: Overview of the survey process, adapted from Biemer & Lyberg (2003, Chapter 2.1)

The layout of the questionnaire must reduce the cognitive burden of the respondents and contain a logical flow of questions (Lavrakas, 2008). It is important to try to create the simplest questions and layouts possible in the survey, as that increases the data quality and response rate (Ruel et al., 2016). Next to that, the order of the questions is important as it might influence the answers, especially with follow-up questions. This could be done by grouping the questions with the same topic. Habituation is also an issue related to the question order, as this occurs when respondents are faced with almost similar questions. The questions might be interpreted as similar, so they all get the same answer (Ruel et al., 2016).
Furthermore, the length of the questionnaire is important for several reasons (Lavrakas, 2008). First, the length of a survey might affect the quality of the data. Respondents are getting increasingly tired while filling in a survey, which could decrease the quality of the answers. In addition, when the length of a survey increases, the number of responses decreases. When there are not enough responses, a nonresponse bias might occur.
Finally, there are several guidelines for developing questions, these are as follows (Ruel et al., 2016):

- **Aim for simplicity:** Use simple, clear language that the respondents understand. This reduces the annoyance of the respondents who might be unwilling/unable to correctly answer the questions. Do not make questions too long.
- **Be specific:** Ask direct questions to avoid ambiguity.
- **Avoid double-barrelled questions:** Do not ask two questions at once, this might influence the answers to both questions.
- **Avoid biased and leading questions:** Ask accurate, unbiased questions to avoid manipulation of the answers.
- **Avoid making assumptions:** These assumptions might introduce errors into the responses, which decreases reliability.

3.3 Life cycle cost and cost estimation

Cost estimation can be described as *"Cost estimating is the process of collecting and analysing historical data and applying quantitative models, techniques, tools, and databases in order to predict an estimate of the future cost of an item, product, program or task. Cost estimating is the application of the art and the technology of approximating the probable worth (or cost), extent, or character of something based on information available at the time"* (Mislick & Nussbaum, 2015). Cost estimation can, for example, be used for long-term planning, budgeting and choosing among alternatives (Mislick & Nussbaum, 2015). However, before different cost estimation methods are described, the first topic of this section will be an overview of costs that arise in the life cycle of a product. A more detailed description of product pricing and manufacturing costs will also be given. Finally, different methods for cost estimation will be discussed.

3.3.1 Cost in the whole product life cycle

There are multiple ways to describe the life cycle phases. Some use more detail and therefore have more phases compared to others, but overall there are four life cycle phases: Design, Realisation (production), Use/Service, and Disposal/recycling/retirement. According to Stark (2022), there are five live cycle phases of a product: Ideation, definition, realisation, Use/Service and Disposal/Recycling/Retirement. The life cycle of a product with parallel cycles can be seen in Figure 3.11. In the figure, the life cycle of the product consists of six phases, but the first three phases can be taken together to get the same life cycle phases as described by Stark (2022). The packaging life cycle is comparable to the product life cycle (Oghazi & Olsson, 2015).

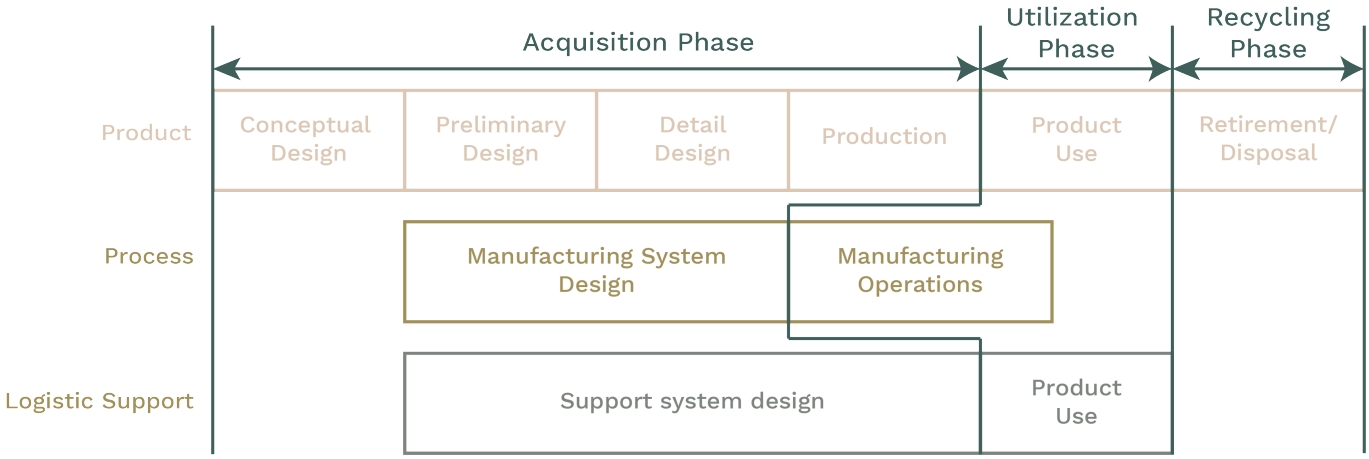

Figure 3.11: Overview of the life cycle of a product, adapted from Asiedu & Gu (2010, Chapter 2)

There are different phases in a product's life cycle, each with different costs. These costs are in the cost breakdown in Figure 3.12. These costs are from the company's point of view. The user or society might have different costs during the life cycle of a product. It is important to note that life cycle phases might overlap each other, so the costs made in each phase might be mixed up a bit as well (Mislick & Nussbaum, 2015).

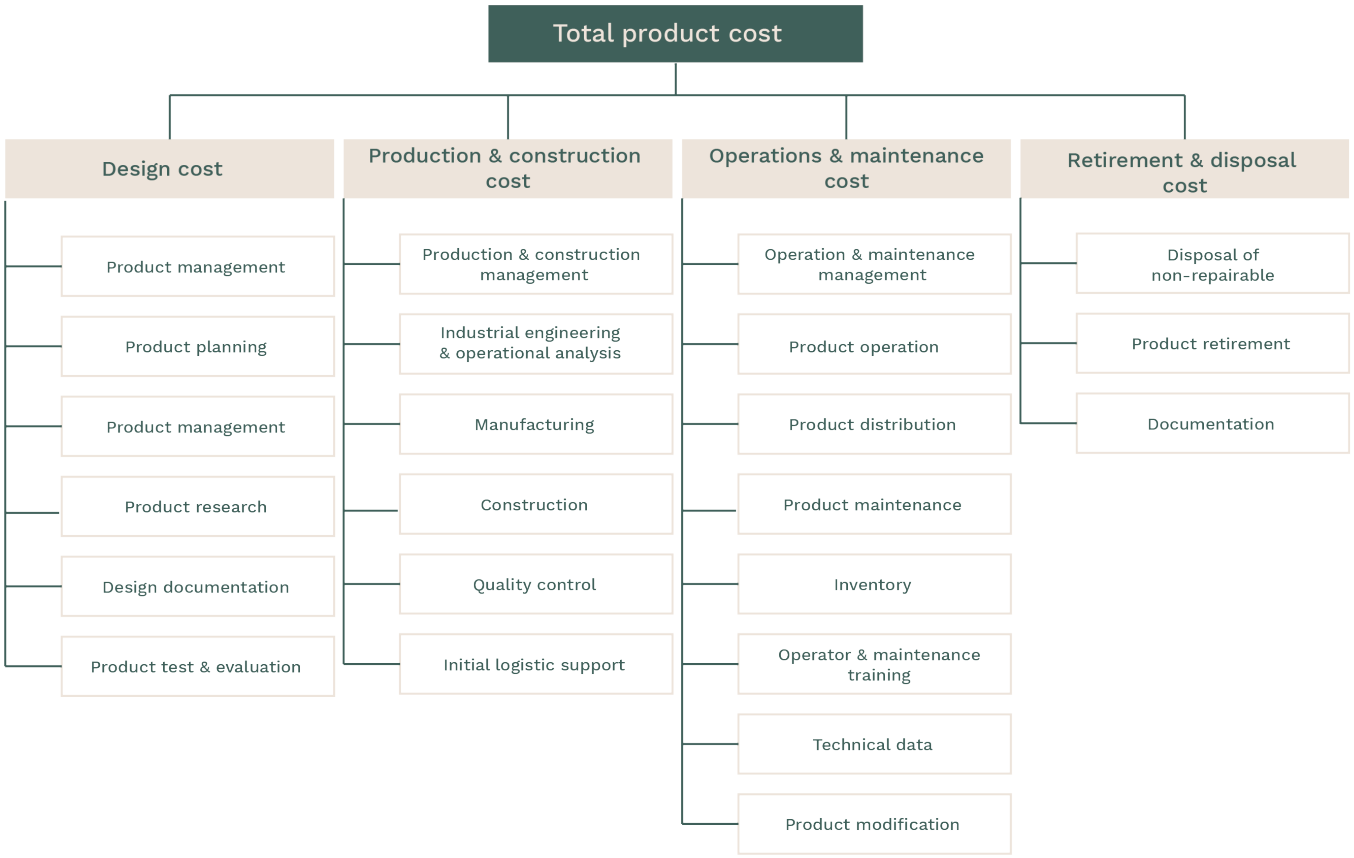

Figure 3.12: Cost breakdown for each phase of the life cycle, adapted from Asiedu & Gu (2010, Chapter 2.1)

3.3.2 Product price

Another way of showing the cost elements of a product is displayed in Figure 3.13. From these elements, often around 30% of the total costs consist of the primary cost (Chuang, 2013). The factory expenses are responsible for around 10% of the total product price, which makes the total manufacturing cost around 40% of the total costs. The percentages of each cost element can be seen in the figure below, however, these are estimates and can, therefore, be different in each situation (Lembersky, 2016).

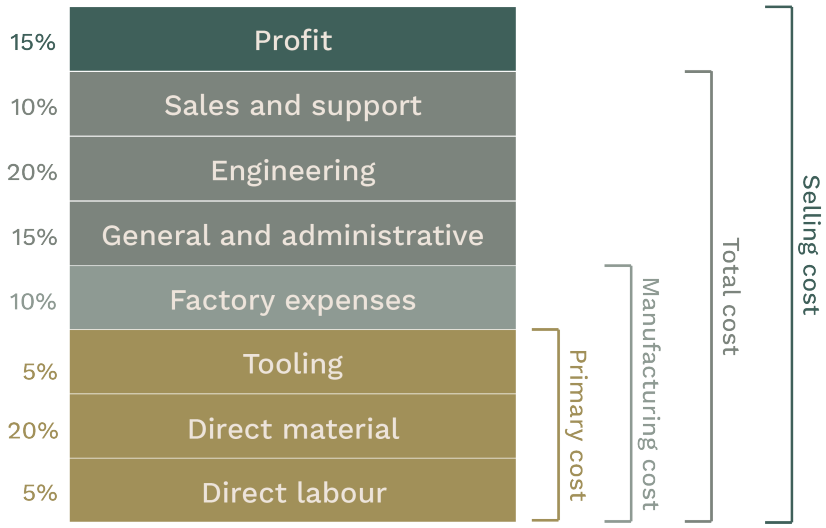

Figure 3.13: Cost elements of a product selling price, adapted from Chuang (2013, Chapter 6.2)

Factory expenses include utilities, maintenance, supplies, etc. It can also be referred to as the indirect cost of manufacturing. These costs can be divided into different categories, such as non-recurring and recurring, fixed and variable, and direct and indirect (Chuang, 2013). In the first category, costs like investment costs can be classified as non-recurring costs, as they are only needed once. However, manufacturing costs are recurring because they occur over and over again. For the second category, 'fixed and variable', the division lies with whether or not a cost depends on the production rate or not. If the cost is not dependent on the production rate, it can be seen as a fixed cost, otherwise, it will be a variable cost. Finally, for the direct and indirect categories, the classification of costs depends on whether a cost is only for a specific task, product line or part or over an entire factory (Chuang, 2013).

3.3.3 Manufacturing costs

Manufacturing costs are part of the cost of the entire life cycle, as shown in the figures above. There are different ways to portray the manufacturing cost. An overview of these different possibilities is displayed in Tables 3.2 & 3.2. As can be seen in the table, there are different layers used to determine the manufacturing costs. Two references (first and last) use fixed and variable costs. The other three references do not use fixed or variable costs, move the costs from the second layer (like labour or components) to the first layer. A lot of the same costs are used by each reference. Below the table, two cost estimations of manufacturing costs are displayed.

Table 3.2: Overview manufacturing cost

	1st layer	2nd layer	3rd layer / details
(Germani et al., 2011)	Machine		Time the machine works on the piece * by the machine cost
	Stock		Stock weight to manufacture the final product * stock unitary cost
	Accessory		Non-operating time of the machine * machine unitary cost
	Machine set up		Set up time
(Chuang, 2013)	Components	Raw Material	
		Tooling	
		Processing	Labour
			Machine
	Assembly	Labour	
		Tooling	
	Overhead	Machine	
		Labour	
(Yamashina & Kubo, 2002)	Fixed	Depreciation cost	
		Labour	Operational & supervisory
		Utilities	
		Plant maintenance	
		Supplies	Office, janitorial, etc
		Plant support	R&D personnel, troubleshooting etc
		Site services	Security, support of plant infrastructure
	Variable	Raw material	
		Waste Treatment	
		Utilities	
(Mandolini et al., 2020)	Material	Net	
		Waste	Scrap/Defected part
	Machine	Operation	Depreciation/Overheads/Maintenance
		Setup	Depreciation/Overheads/Maintenance
		Idle	Depreciation/Overheads/Maintenance
	Labour	Operation	Wage/Overheads
		Setup	Wage/Overheads
		Idle	Wage/Overheads
	Equipment	Initial cost	Material/design/manufacturing
		Maintenance	Routine/unscheduled
	Consumable	Solid/liquid/gas	
	Energy	Machine/labour/equipment	
(Anderson, 2009)	Fixed	Capital depreciation	
		Labour (both operations & supervisory)	
		Utilities	
		Plant maintenance	
		Supplies	
		Plan support	
		Site services (security, etc.)	
	Variable	Raw materials	
		Waste treatment	
		Utilities	

3.3.4 Cost estimation methods

There are different methods available to determine the cost of a product or packaging. Two of these methods will be discussed in this section. First of all, the cost can be determined via a classical cost calculation. The traditional costing systems allocate the costs to a cost centre and afterwards to a cost object (Drury, 2012). The approach is displayed in figure 3.14.

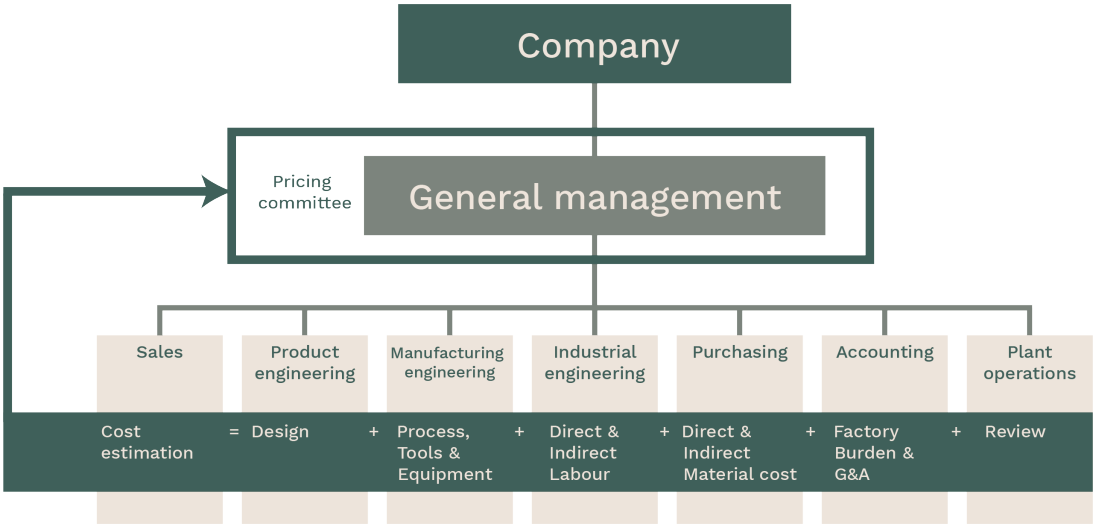

Figure 3.14: Traditional approach for cost estimations, from Lembersky (2016, Chapter 2.2)

In addition, there is the ABC method, the Activity-Based Costing method. This method estimates costs by assigning them to certain activities (Almeida & Cunha, 2017). The idea behind this method is that products use activities, which in turn consume resources. This way, an accurate cost rating of the products can be made (Isai et al., 2014). This is in contrast to the traditional costing system, which allocates cost to a cost centre instead of an activity. An overview of the method, how all costs are translated into the final 'industrial costing', is shown in Figure 3.15. It was introduced as an alternative to traditional accounting techniques (Ozbayrak et al., 2004).

Figure 3.15: Overview of the ABC method, adapted from Almeida & Cunha (2017, Chapter 2.3)

4 Methodology

In Figure 4.1, the methodology and all its steps are displayed. As can be seen, the QFD and cost estimation are the two big blocks of the method, and all the steps of these tools are shown inside. For the QFD, phases 1 and 2 will be performed first in parts 1 (Chapter 5) and 2 (Chapter 6). Afterwards, in part 3 (Chapter 7), a comparison will be made between the most important part requirements found in phase 2 and the current consumer packaging. From this, corrective or preventive changes and actions can be developed. These actions and/or changes will be used in part 4 as input for phase 3 of the QFD to determine the most important changes in the packaging process (Chapter 8). This can then be used for the cost estimation in part 5 (Chapter 9) to determine the cost of the identified actions and changes. After finishing part 5, conclusions and decisions can be made on the future of the current consumer packaging.

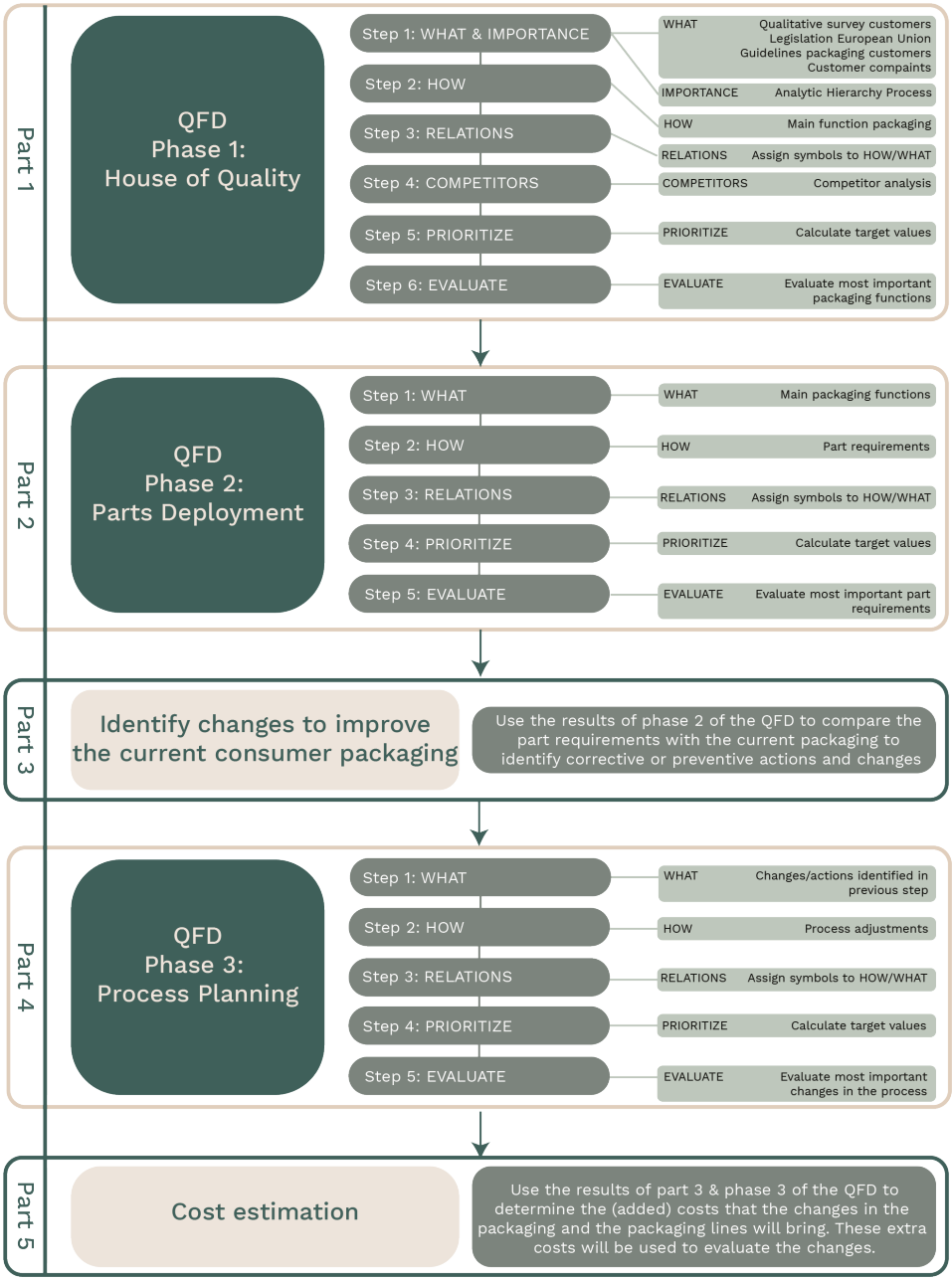

Figure 4.1: Methodology

5 Part 1 - QFD phase 1

In this chapter, the first phase of the QFD, the House of Quality, will be discussed. All steps of the first phase will be described and executed. This section will start with collecting the customer and legislation requirements and continue with identifying the technical requirements. Afterwards, the relationship between both will be determined, which will be done by assigning the symbols that are discussed in Section 3.1.1. The first phase of the QFD will be completed with the competitor analysis, the prioritisation of the technical requirements, and an evaluation. This phase is discussed in parts below and the complete matrix can be seen in Appendix C.

5.1 Step 1.1: Collecting the customer and legislation requirements (WHAT)

In this subsection, the first step, collecting the customer and legislation requirements will be discussed. The subsection will begin with the customer requirements. Within this topic, the survey design and results will be discussed. Afterwards, the legislation requirements will be discussed.

5.1.1 Requirements of the customers

First, the customer's requirements for the doughnut packaging are determined. This is done by sending surveys to EO customers, interviews with account managers, analysing complaints, and looking at the customer guidelines that are present within Europastry. First, the design of the survey will be discussed, followed by the results of the survey. Afterwards, customer complaints and customer guidelines are discussed.

Survey design

To be able to design the survey to collect the customer's requirements, the steps in Figure 3.10 will be followed. The first step is to determine the research objectives. The objective is to collect the customer's requirement for the consumer packaging of the doughnuts of EO. This can be done in several ways, including interviews, surveys, or focus groups. In addition, there are two ways to collect customer data, both qualitative and quantitative. The survey population will be the relevant customers of EO within central Europe. Europastry Oldenzaal sells doughnuts throughout central Europe, including the Netherlands, Belgium, Germany, the United Kingdom, and Scandinavia. Of these customers, the most relevant customers are chosen, which mainly consist of the larger supermarket chains. These customers have the highest interest in consumer packaging. Smaller bakeries are not included during the selection because they sell doughnuts directly on the counter and, therefore, do not need consumer packaging as often. This customer selection resulted in sending the survey to 26 different customers. Due to confidentiality, the names of these companies will not be used. The next step is to determine the mode of administration. After discussion within the company and a review of the possibilities in the literature, an online survey will be developed. The main reason for this is the accessibility of an online survey to get as many responses as possible. In addition, an online survey does not take up much time for customers, which is important to EO. In addition, the survey will be qualitative because the satisfaction of the customer and the wishes are determined. Now that the mode of administration has been determined, the process can continue with developing the questions and designing the sample. First, the questions will be discussed. The questions are a combination of qualitative and quantitative ones. For example, some questions are multiple-choice, so they are quantitative. An example of that is the question: "How many days do you want to offer a guarantee of freshness?". An example of qualitative questions is where the respondents have to fill in the importance of a requirement on a scale or open questions like: "Do you have any additional requirements that were not mentioned yet?". Both an English and Dutch version of the surveys are developed. This way, the customer can choose to fill in the survey with the language of their liking. The questions were developed based on literature research and discussions with several EO account managers. There are 4 sections within the survey: general, general requirements, sustainability requirements, and customisation. In the first section, general questions are asked such as which company, whether they already buy consumer packaging, and if they are satisfied. The first section of the survey ends with question 5, which is displayed in Figure 5.1. If the respondent answers "No" to this question, the survey ends. This is chosen to ensure the validity of the answers of this respondent since he/she does not have any personal gain in answering the questions correctly regarding the requirements of the consumer packaging.

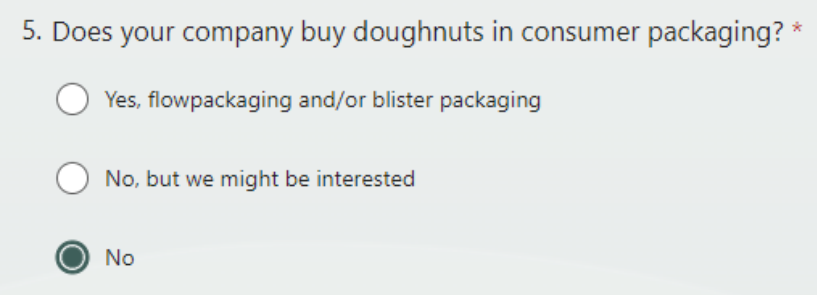

Figure 5.1: Question 5 in the survey

The survey continues with the general requirements, where the respondent needs to answer several questions about general packaging requirements, such as the visibility of the product inside or the length of the guarantee of freshness. Standard requirements, such as protection of the product inside, are included in the survey. The third section contains questions regarding the sustainability of the packaging to determine if the respondent regards that as important for consumer packaging. An example question of this section was to determine the importance of requirements such as recyclability or reusability. The final section of the survey contains questions regarding the customization of the packaging. This section is added to the survey to determine the flexibility that is needed from Europastry or whether it might be possible to use standard packaging. In this section, questions such as the importance of using the design of the company or changing the packaging type were often discussed. Each section ends with an open (optional) question that asks if the respondents missed any requirements or have any other comments. This way, the respondent can always add more information if deemed important. The survey consists of 19 questions and can be finished in around 5 minutes. The complete survey is included in Appendix D. The next steps, as displayed in Figure 3.10, are the data collection, processing and analysis, which will be described in the next paragraph.

Results survey

First of all, all the results of the survey can be seen in Appendix E. Of the 26 customers who were asked to complete the survey, 17 did, which translates into a response rate of 65,38%. Of those 17 customers, 7 completed the survey (so, from Question 5 on). The survey results will be used for the QFD in the following way. All requirements identified in the survey will be included in the QFD. For each requirement, the respondent had to give a numerical value to that requirement either or indicate how important that specific requirement is to the company. The numerical values will be incorporated as a requirement in the QFD. The importance indications of the customers will be used for the importance ratings in the QFD. An average of the responses will be taken to determine the importance of a requirement. This average will be between -2 and 2 since the survey works on a scale from -2 (not important) to 2 (very important). This can be translated to scales 1 - 10 for the QFD importance ratings. For the numerical questions, the importance rating will have to be determined manually in collaboration with the account managers (expert opinion). The importance ratings will be discussed further below in the subsection "Importance ratings". Finally, respondents could add additional requirements in the comment boxes. One company provided its requirements for consumer packaging during a conversation, so this company did not fill in the survey. Still, the requirements that they mentioned are taken into account as well. This results in the complete list of requirements:

- The doughnuts are visible in the packaging.
- The packaging is reclosable.
- The packaging is easy to open.
- The packaging protects the doughnuts.
- The doughnuts can be stored within the packaging.
- The packaging is recyclable.
- The packaging consists of the minimum amount of packaging possible.
- The packaging consists of one type of material.
- The packaging is reusable.
- The design of the company can be used.
- There is a guarantee of freshness of 3 days.
- The packaging can fit either 1, 2, 4, 5, 6 or more normal doughnuts.
- The packaging can fit either 1, 2, 3, 4, 5, 6 or more mini-sized doughnuts.

- The packaging has either the same type of doughnuts or a mix of doughnut types.
- The language on the packaging needs to be similar to the language of the country in which the doughnuts are sold.
- The packaging needs to use less plastic.
- The packaging has to enable scanning the product without having to turn the doughnuts around.

Customer complaints

In addition to the wishes of the customers, complaints can also be used as input to the QFD (Franceschini, 2001). For that, complaints from 2019 until now are analysed. Appendix B displays an overview of these customer complaints. From the complaints, the following requirements were determined. These two requirements are mostly production-related since the flowpackaging is closed at the packaging line and the packaging type, materials, and number of doughnuts also get assembled at the packaging lines.

- Packaging has to be closed correctly (flowpackaging).
- The packaging type, materials, and number of doughnuts must be as agreed upon.

Guidelines packaging

Finally, there are guidelines regarding (consumer) packaging present within Europastry. These guidelines are requirements that EO has to adhere to when selling packaging to those customers. From the analysis of these, the following requirements are chosen:

- The doughnuts have to be protected from outside contamination.
- The packaging has to be free from toxic chemicals and plastics.
- No superfluous materials in primary packaging.
- Primary packaging must feature the disposal logo on the packaging.
- The packaging needs to be at least 30% recyclable.
- There is no unnecessary use of packaging material.
- No use of biodegradable plastics.
- No coloured PET as a packaging material.

5.1.2 Legislation sustainability

In addition to customer wishes and requirements, the EU sustainability legislation might also greatly influence the portfolio management of EO consumer packaging. The legislation relevant to the consumer packaging of doughnuts will be discussed in this section. The main legislation regarding packaging is Directive 94/62/EC (EuropianCommission, 2018). This directive describes all the rules for managing packaging and packaging waste. One of the main targets is the recycling targets for packaging waste, which are shown in Table 5.1. These were initially lower, but the targets increased with the 2022 revision. In addition, packaging weight and volume must be kept to a minimum while still allowing the required level of safety, hygiene and acceptability (EuropianCommission, 2018).

Table 5.1: Recycling targets Directive 94/62/EC

Material	Target % recycling 2025	Target % recycling 2030
All packaging waste	65	70
Plastic	50	55
Wood	25	30
Ferrous metals	70	80
Aluminium	50	60
Glass	70	75
Paper & Cardboard	75	85

The EU has just approved a revision of Directive 94/62/EC. The goal of this revision is to ensure that the packaging section is on track to be climate-neutral by 2050 (EuropianCommission, 2022). The revision of the packaging and packaging waste legislation of the EU has three main objectives. The first objective is to prevent the generation of packaging waste by reducing its quantity, restricting unnecessary packaging, and promoting reusable/refillable packaging solutions. In addition, boosting high-quality recycling by making all packaging on the EU market recyclable. From 2030 onwards, packaging that

is less than 70% recyclable is considered non-recyclable and can therefore not be placed in the market. The third objective is to reduce the need for primary natural resources and create a well-functioning market with secondary raw materials, such as recycled plastics (EuropianCommission, 2022). Next to those three objectives, the EU wants to clear up confusion around bio-based, biodegradable, compostable plastics and which packaging belongs to which recycling bin. Looking at the proposed revision in more detail, the following targets are proposed for recycled content recovered from post-consumer plastic waste, which are shown in Table 5.2. It is important to note that within food packaging, the legislation regarding recycled content in packaging is somewhat more strict compared to others. The reason for this is Regulation 2022/1616 on recycled plastic materials and articles intended to come into contact with foods (EuropianCommission, 2023). This regulation states that all recycled plastic materials and articles have to be manufactured by a suitable technology and contain the necessary documentation, instructions, and labelling (EFSA-approved recycled plastics). The Netherlands has implemented a national program to become circular by 2050. One of the points in the program is to have 25-30% recycled content material or bio-based plastic in plastic (packaging) (Rijksoverheid, 2023). This means that all plastic packaging materials need more recycled content materials in the Netherlands. However, the exact percentage of recycled content material will be announced in 2026. Since the percentage is not known yet and the packaging of EO is used in different countries, the recycled content percentages in the table below will be used.

Table 5.2: Recycled content from post-consumer plastic waste, from (EuropianCommission, 2024)

Type of packaging	Target % recycled content 2030	Target % recycled content 2040
Contact sensitive packaging made from PET	30	50
Contact sensitive packaging made from plastic materials other than PET	10	25
Single-use plastic beverage bottles	30	65
Other packaging	35	65

Next to the recycling targets, the revision proposes the requirement for packaging minimisation by requiring manufacturers to ensure that the packaging is designed in a way that the weight and volume are reduced to the minimum while keeping its function by the 1st of January 2030. Furthermore, packaging will get a recycle score A, B or C. This score represents how recyclable the packaging is, the values of each score are shown in Table 5.3. From 2030 onwards, packaging needs to have at least score C. This score is determined by weighing the criteria per packaging that are stated in Annex II of the Regulation (EU) 2025/40 on the packaging and packaging waste directive (EuropianCommission, 2024). These criteria have parameters like additives, labels, sleeves, colours and ease of dismantling. These criteria make sure that the packaging is designed for recycling. From 2035 onward, the recycled-at-scale assessment is also included. This assessment makes sure that the quantity (weight) of the material is effectively recyclable at bigger scales.

Table 5.3: Recycle scores packaging

Score	Total recyclability (%)
A	≥ 95
B	≥ 80
C	≥ 70
Technically non-recyclable	≤ 70

Additionally, packaging will have to be marked with a label containing the material composition information to make sure that the consumer understands in which bin the packaging should be disposed of. Furthermore, from 01-01-2030 onwards, single-use plastic grouped packaging and single-use plastic packaging for foods and beverages filled and consumed within the premises in the food-service sector are not allowed to be used any more. The revision also proposes that companies that use transport or sales packaging to transport products within the EU will have to ensure that the packaging is reusable within a system for reuse (EuropianCommission, 2024). Even though this is not relevant for the consumer packaging of EO, it is relevant for the secondary and tertiary packaging. As described earlier, the customers of EO are based in Central Europe, which consists, in this case, of the Netherlands, Germany, Belgium, the UK and Scandinavia. Except for the UK, the legislation of the European Union is enforced in all countries. However, the UK has included the packaging directive in their legislation (TheNationalArchives, 2020). The legislation that will be the focus right now are the ones for 2030. Keeping in mind the consumer packaging of the doughnuts, the following requirements can be determined based on the legislation:

- Packaging weight and volume have to be kept to a minimum while still allowing the required level of safety, hygiene and acceptability.
- The plastic parts of the packaging have to contain the minimum recycled recovered content as described in Table 5.2. This requirement does not apply to compostable plastic packaging.
- The packaging has to ensure chemical safety.
- The packaging has to be effectively recyclable for at least 70% (Recycle score C).
- The packaging must have a label containing the material composition information.

Obligatory requirements consumer packaging

Finally, there are obligatory requirements for consumer packaging which have to be taken into account as well. For example, Regulation (EU) No 1169/2011 describes the regulations on the provision of food information to consumers (Parlement, 2011). Even though EO puts all the necessary information on the label on the secondary packaging and the customers put it on the consumer packaging together with a bar code, the requirement 'Label with all required information' will be added to the list. The reason for this is that this mustn't be forgotten in the QFD because it is an obligatory requirement to be able to enter the market. In addition to the obligatory legislation requirements, there are also requirements for food safety. In Regulation (EC) No. 1935/2004, several requirements are listed (EuropianCommission, 2021). The general requirement is that the material in contact with food should not endanger human health, cause a change in the composition of the food, or cause deterioration in the organoleptic characteristics. Next to that, there are requirements on the amount of migration that is allowed per food contact material. However, as EO buys their packaging material from a supplier, this is their responsibility and will, therefore, not be included in the QFD.

5.1.3 List of requirements & importance ratings

To combine all topics discussed above in this section, both the customer requirements and sustainability legislation, the total list of requirements is displayed in the second column of Table 5.4. Some requirements have been bundled as one since they were (almost) similar. The first column shows from which source the requirement came. The abbreviations are as follows:

- S: Survey
- C: Complaints
- G: Guidelines
- L: Legislation

When there are multiple sources, this is also indicated. The third column, 'importance ratings', is determined as follows. The obligatory requirements are stated in bold. These requirements are the ones that are obligatory for legislation. For the first 10 requirements in the table below, the responses to the survey will be used for the importance rating. For the other 15 requirements, multiple EO employees were asked to rate the importance of each requirement. The scale of importance ratings ranges from 1 (not important) to 10 (very important). Next to that, the AHP is used to limit the subjectivity of the importance ratings. The steps of the AHP are discussed in Chapter 3. The result of the AHP is a weight of each requirement that compares them. For this, a comparison matrix was developed and all the requirements were compared with each other. For all general requirements, like "The doughnuts are visible in the packaging" or "The packaging is easy to open" the weight of 1 was given. All important requirements that improve/sustain the safety and quality of the doughnuts like "The guarantee of freshness is 3 days" or "The doughnuts have to be protected from outside contamination" were given a weight of 3. Finally, the requirements that need to be implemented to sell the doughnuts like "The packaging is effectively recyclable for at least 70%" were given a weight of 5. The complete comparison matrix of the AHP is shown in Appendix F. The consistency index of the AHP is much lower than 0,1, so the subjectivity is limited. The importance rating is determined by multiplying the importance rating based on the survey/employees by the weights of the AHP, so:

*Importance rating QFD = importance rating survey/employees * weight AHP*

The requirements 'The packaging is reusable' and 'The packaging is reclosable' have an important rating of 0, as it was not regarded as important by the responses to the survey. Therefore, the requirement will not be included in the House of Quality, as it will not be taken into account with an importance rating of zero. The list of requirements with importance ratings can be seen in Table 5.4.

Table 5.4: WHAT - House of quality + Importance ratings

Source	Requirement	Importance rating
S	The doughnuts are visible in the packaging.	4
S	The packaging is reclosable.	0
S	The packaging is easy to open.	2
S	The packaging protects the doughnuts (mechanical damage).	10
S	The doughnuts can be stored within the packaging.	2
S, G, L	**The packaging is effectively recyclable for at least 70%.**	10
S, G, L	**The packaging consists of the minimum amount of packaging possible.**	10
S	The packaging consists of one type of material.	1
S	The packaging is reusable.	0
S	The design of the company can be used.	2
S	There is a guarantee of freshness of 3 days.	8
S	The packaging can fit either 2, 4, 5, 6 or more normal doughnuts.	3
S	The packaging can fit either 2, 3, 4, 5, 6 or more mini-sized doughnuts.	3
S	The packaging has either the same type of doughnuts or a mix of doughnut types.	3
S	The language on the packaging needs to be adaptable.	3
S	The packaging needs to use less plastic.	2
S	The packaging has to enable scanning of the product without having to turn the doughnuts around.	2
C	Packaging has to be closed correctly.	3
C	The packaging type, materials and number of doughnuts must be as agreed upon.	4
G	The doughnuts have to be protected from outside contamination.	10
G, L	**The packaging has to be free from toxic chemicals and plastics.**	10
G, L	**Primary packaging must feature the disposal logo and material composition information on the packaging.**	10
G	No use of biodegradable plastics.	2
G	No coloured PET as a packaging material.	3
L	**The plastic packaging parts must contain the right amount of recycled content from post-consumer plastic waste.**	10
L	**Label with all required information.**	10

5.2 Step 1.2: Identify technical requirements (HOW)

For the technical requirements (HOW), the main functions of packaging will be used. This choice is made because it is important to identify the important packaging functions to take these into account when determining whether current consumer packaging is future-proof. The traditional packaging functions are protection, communication, containment and convenience. These packaging functions were determined in the 1980s, and since then, more functionalities have been determined (Lydekaityte & Tambo, 2020). The first function, protection, is to protect the product from outside factors and to preserve the quality of the product. The second function, communication, concerns the identification of the product and the brand to capture the consumers' attention and to advertise. Containment of the product is the third function of packaging. Finally, the convenience function takes into account the ease of use during the life cycle, so handling during the life cycle, but also ease of use for the consumers. The containment function is often overlooked, even though it can be considered one of the most essential functions most of the time. It can be seen as a prerequisite for the packaging instead of a function (ten Klooster et al, 2015). On the other hand, protection of the product inside the packaging is often seen as the most important. The convenience functionality takes into account the practicality and the user-friendliness of the packaging. Finally, the communication category enables the transfer of information and marketing to all stakeholders in the supply chain. This can include all the legally required information, as well as bar codes (Bauer et al., 2022).
An overview of different sources that discuss packaging functionality is displayed in Tables 5.5 and 5.6. As can be seen, a lot of sources use the main functions or a sub-function of those. However, some sources add functionalities to the packaging, such as machinability or sustainability, or use different names for the functionalities. Syed (2018) divided the functions into primary, secondary, and tertiary functions, as can be seen in the table. This distinction between functions is made because of the importance of the functions. Next to that, within a category, the functions influence each other (Syed, 2018). Yu-Che & Chu-Yin (2019) used the packaging functions as technical requirements for the House of Quality to determine the important functions for the design of cosmetic packaging. Hemavathi & Siddaramaiah (2018); Marsh & Bugusu (2007); Coles et al. (2003) looked specifically at functionalities of food packaging. Sadeghi et al. (2022) looks at packaging functions from a 'packaging 4.0' point of view. The "packaging 4.0" concept is an integration of industry-4.0 elements in packaging science, such as intelligent devices.

Table 5.5: Packaging functions

	Functions	Sub-functions/Explanation
(Lydekaityte & Tambo, 2020)	Containment	Embodying, Encompassing
	Protection	Preservation, barrier protection, tamper resistance and mechanical protection
	Communication	Identification, information, attention & display, decision-making, brand identification and advertising
	Convenience	Display, Handling (supply chain & consumers), opening, utilisation, disposal
(ten Klooster et al, 2015)	Containment	
	Facilitate transport	Stackable, seizable, manageable
	Protect the contents	From outside influences and internal changes
	Inform the users	Throughout the life cycle
	Enable use & disposal	
(Paine & Paine, 2012)	Containment	
	Protection & preservation	From mechanical damage, deterioration by the climate(s)
	Communication	Throughout the life cycle (legal requirements, marketing)
	Machinability	Good performance in filling and closing operations
	Convenience & use	Throughout the whole life cycle
(Youssef & El-Sayed, 2018)	Containment	
	Protection & preservation	
	Convenience	
	Marketing & Communication	
(Syed, 2018)	Primary functions	Protection & Storage, loading & Transport, convenience
	Secondary functions	Sales and promotion, service & guarantee
	Tertiary functions	Security, recycle
(Lindh et al., 2016)	Protect, preserve, conserve	
	Facility handling	convenience, creating utility, machinability
	Communication	Informational value, marketing, brand identity
	Contain	
(Tiekstra et al., 2021)	Containment	
	Protection & preservation	
	Convenience	
	Marketing & Communication	
	Sustainability	No contamination of the environment, no waste resources in the manufacturing process
		Facilitating access for people with a handicap, biodegradable
		Reusable, recyclable or returnable, avoidance of waste
	Economy	Low price, good value, no excessive increase of the product price
(Konstantoglou et al., 2020)	Physical protection	External factors like shock vibration, temperature
	Consumer health protection	Against bacterial contamination or spoilage
	Unitisation of foods	To facilitate their movement through the supply chain
	Provision of information	Concerning use, consumption, storage and recycling
(Yu-Che & Chu-Yin, 2019)	Protection	Protect the quality of goods from damage and maintain their value
	Transportation	Transport, storage, delivery
	Commodity	Promotional feature
	Mass production	To reduce costs
	Informational	
	Beautification	Stimulate consumer's desire to buy product
	Display-ability	Make purchase more convenient
	Convenience	Convenience of use
	Handling	Environmentally friendly packaging
(Hemavathi & Siddaramaiah, 2018)	Product containment	Holding food in a form suitable for transport or handling
	Protection & preservation	Retard deterioration, extend shelf life, maintain/increase quality
	Convenience	Handling, distribution, stacking, display, sales
	Communication & marketing	Inform consumers & design attractive packaging

Table 5.6: Packaging functions (continued)

	Functions	Sub-functions/Explanation
(Marsh & Bugusu, 2007)	Protection/preservation	extend shelf life, maintain food safety
	Containment	
	Food waste reduction	
	Marketing & Information	
	Traceability	Follow the movement of a food through specified stage(s)
	Convenience	Ease of access, handling, disposal, product visibility
	Tamper indication	So it is clear when the packaging has been opened
(Coles et al., 2003)	Containment	
	Protection	Prevention of mechanical damage
	Preservation	Prevention or inhibition of chemical, biochemical or microbiological changes
	Information about the product	
	Convenience	For packaging handlers and users throughout the chain
	Presentation	Material type, shape, size, colour
	Brand communication	
	Promotion	
	Economy	Efficiency in distribution, production, storage
	Environmental responsibility	In manufacture, use, reuse or recycling
(Sadeghi et al., 2022)	Convenience	Smart factory, Additive manufacturing, Autonomous robot
	Protection	Freshness information, sensor, active packaging, shelf life
	Communication	E-commerce, intelligent packaging, consumer behaviour, logistics
	Circular economy	Sustainability, recycling, closes loop system, waste management

Looking at important packaging functions regarding food packaging, the protection function is especially important, as food might perish if not correctly packaged. This packaging function also greatly influences food waste (Hemavathi & Siddaramaiah, 2018). The goal of the QFD, and therefore the house of quality as well, is to determine whether the current consumer packaging is future-proof for both customer satisfaction and sustainability legislation. Taking into account the packaging functions in Table 5.5, the functions and sub-functions in Table 5.7 are chosen as HOW of the house of quality. As can be seen, the four traditional packaging functions have been chosen, as well as the sustainability function. The reason for choosing an additional function (sustainability) is due to the fact that the scope of this research is the sustainability legislation, and therefore, it makes sense to include sustainability as a packaging function in the QFD. Next to the functions, sub-functions have been chosen. These specific sub-functions are chosen because they are relevant to the scope of the study. Finally, per subfunction, a short description is given.

Table 5.7: Packaging Functions - HOW in house of quality

Function	Subfunction	Description
Protection	Preservation	Delay deterioration and maintain the quality of the doughnuts
	Mechanical protection	Prevention of mechanical damage
Communication	Presentation	The looks of the packaging; material type, shape, size, colour
	Identification (brand)	Show the brand of the product on the packaging
	Information	Concerning use, consumption, storage and recycling
	Advertising	Capture the consumers' attention
Containment	Embodying	Holding the doughnuts in the packaging
Convenience	Handling (consumers)	Ease of handling/transport from the point of sale to the end destination
	Opening (consumers)	Ease of opening
	Utilisation (consumers)	Ease of use (storage)
	Disposal (consumers)	Ease of disposal
Sustainability	Reusable, recyclable or returnable	How the packaging can be disposed
	Avoidance of waste	To avoid or minimize food waste when possible

5.2.1 Correlation matrix

Next to determining which packaging functions will be the HOW in phase 1, it is important to determine the correlation between the HOW. This way, potential trade-offs between the HOWs can be identified at an early stage. The correlation matrix is displayed in Figure 5.2. As can be seen, most packaging functions do not have any correlation. There are a few that positively correlate with each other, like preservation and embodying. Others have a negative correlation, like preservation and opening (customers) or utilisation (customers). The function 'information' especially has a lot of positive correlations with other packaging functions.

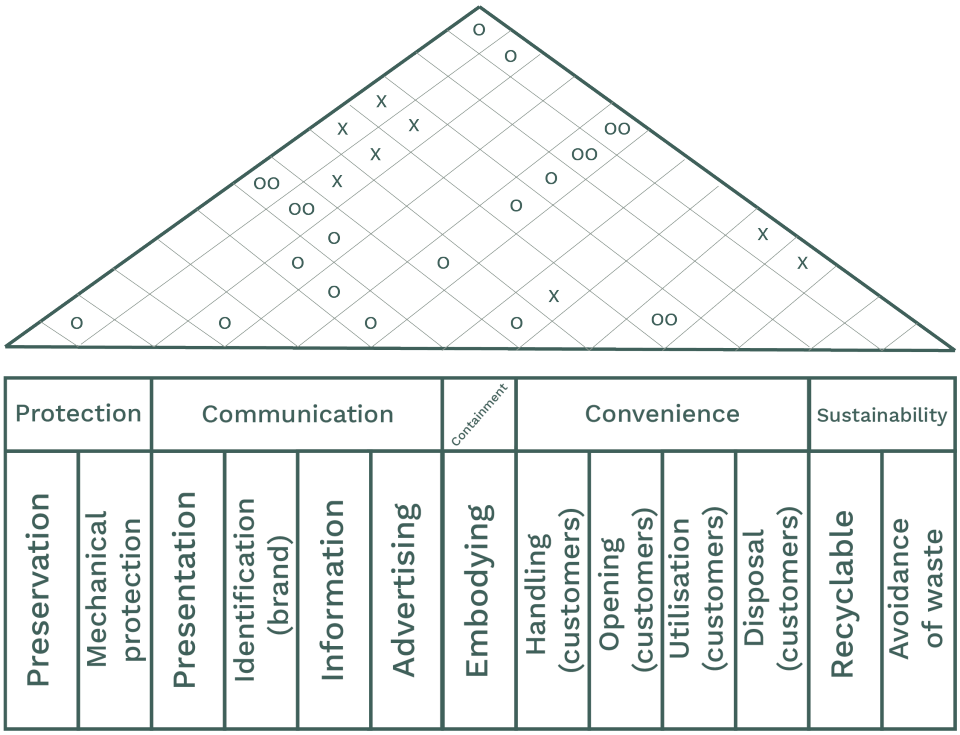

Figure 5.2: Correlation matrix - HOW

5.3 Step 1.3: Relationship between WHAT and HOW

The matrix can be found in Figure 5.3. As can be seen, the relationships between WHAT and HOW are denoted by the symbols from Table 3.1. The values 1, 3, and 9 are used to determine the target values at a later point. These values are chosen to be able to accentuate the relationship, especially the strong relationships. To limit subjectivity, the relationships have been discussed with employees of EO. The obligatory requirements for legislation are shown with a green background. Every requirement has at least one strong relationship with one of the packaging functions. Next to that, all packaging functions have multiple relationships each, so each HOW can be seen as an added value to the matrix. As can be seen, especially the packaging functions 'embodying', 'presentation', 'recyclable' and 'Avoidance of waste' have a lot of strong relationships with the requirements. Meanwhile, the functions 'mechanical protection', 'handling (consumers)', 'opening (consumers)', 'utilisation (consumers)', 'disposal (consumers)' and 'avoidance of waste' only have one strong relationship each. Looking at the requirements, the requirement 'There is a guarantee of freshness of three days' has four strong relationships. Some other requirements have three strong relationships, like 'the language on the packaging needs to be adaptable'. Nevertheless, most requirements have one or two strong relationships with the packaging functions.

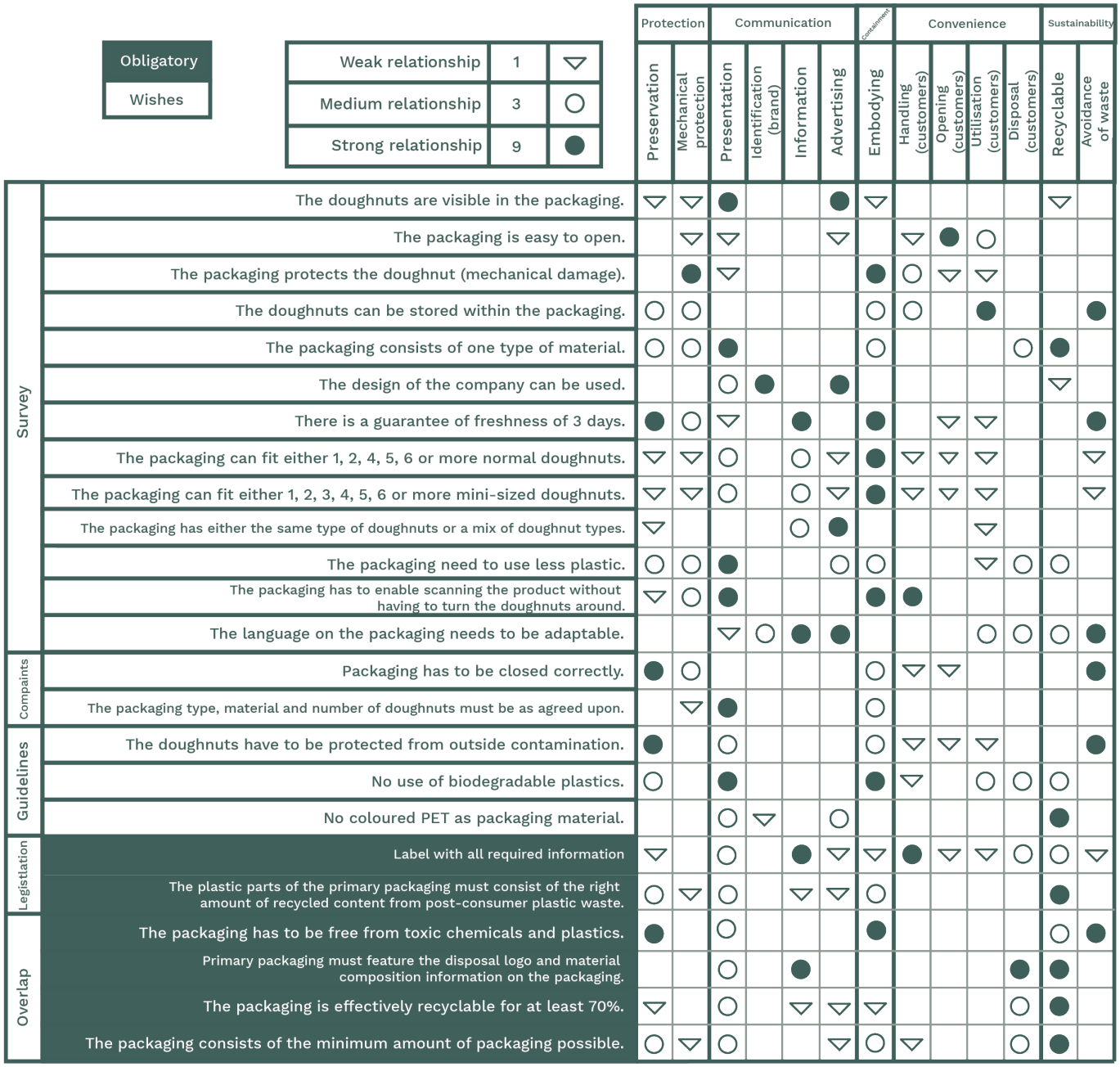

Figure 5.3: Relationship matrix - QFD phase 1

5.4 Step 1.4: Conduct a competitor assessment

The competitor assessment will consist of two parts. As the scope of the study, and therefore the QFD, is the consumer packaging of doughnuts, the competitor assessment will have to look at the competitors of EO from both a doughnut point of view and a consumer packaging point of view. From the survey results, it could be concluded that some customers buy doughnuts in bulk and afterwards repackage them into consumer packaging. These consumer packaging are therefore a 'competitor' of the consumer packaging offered by EO. Of the 17 responses to the survey, 7 customers do not buy doughnuts in EO consumer packaging but repackage the doughnuts themselves in consumer packaging. The information about the consumer packaging was (mostly) available for four of these customers. The consumer packaging of those four customers will be used in the competitor assessment. In addition to packaging competitors, the doughnut competitors of EO are also taken into account. The overview of the competitor assessment can be seen in Figure 5.4. As can be seen in the figure, the consumer packaging types of EO (blister packaging and flowpackaging (with or without U-tray) are also scored to be able to compare those to the packaging of the competitors.

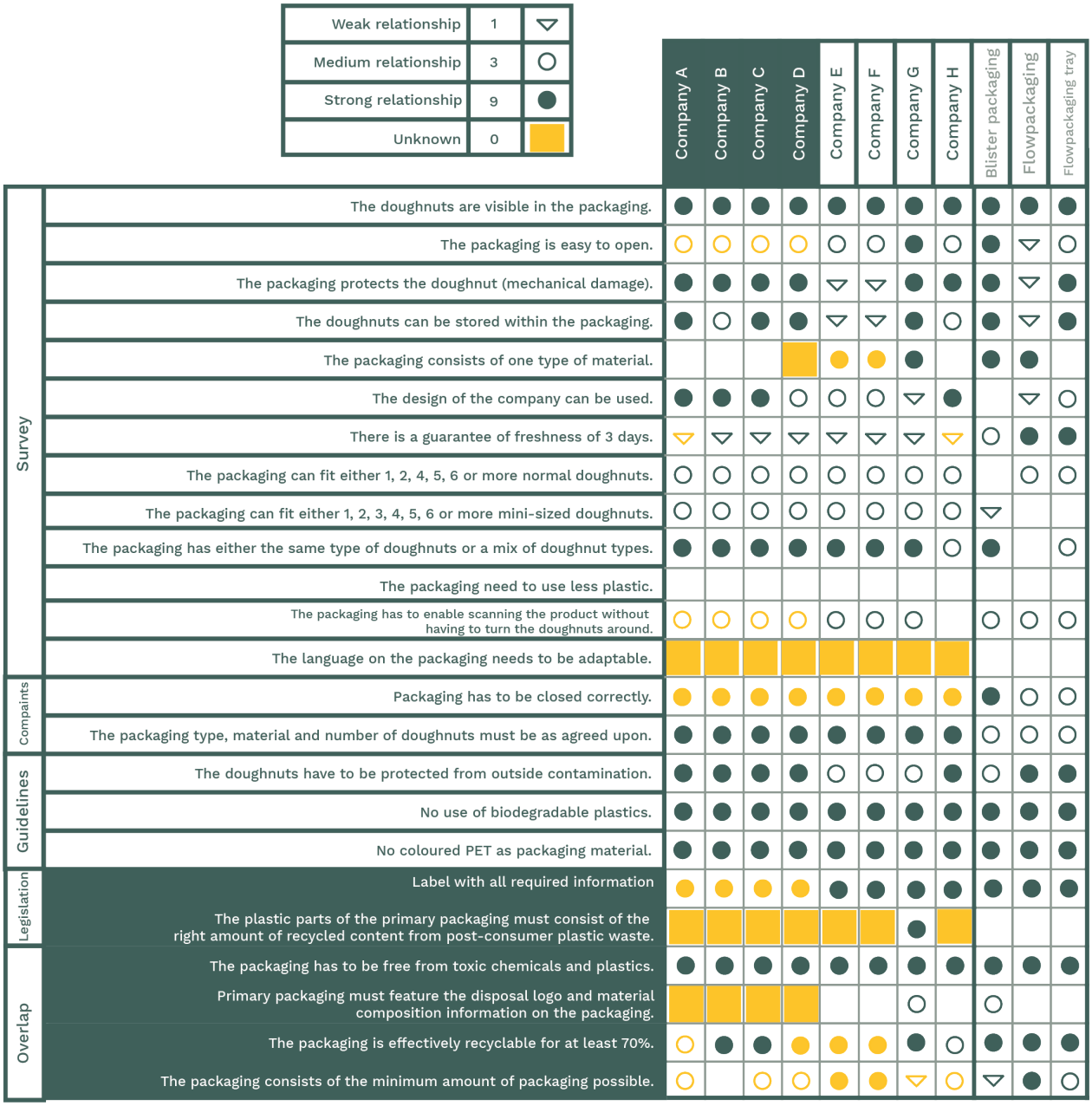

Figure 5.4: Competitor assessment

Companies A, B, C and D are doughnut competitors and the others (E to H) are packaging competitors. A weak relationship shows that the requirement is somewhat implemented in the packaging, a medium relationship has a bit more implementation of the requirement and a strong relationship shows that the requirement is fully implemented in the packaging. Not all information was available, so for some requirements assumptions needed to be made, these assumptions are shown in yellow. An example is that it was not clear for companies A, B, C, D, E, F and G if the packaging needed to be turned around to be able to scan the product. However, the shape of the packaging could enable scanning without turning the packaging around, so the assumption is made that it could be possible. For company H, it is not necessary to scan the product, as this requirement does not apply to this company. Next to that, the yellow blocks represent information that was not present at all, so no assumption could be made. It is, for example, not known if the packaging of companies A, D, E and F adhere to the requirement 'The plastic parts of the primary packaging must consist of the right amount of recycled content from post-consumer plastic waste.'. Additionally, some requirements need additional information on how they are scored. The requirement easy to open is scored based on the force that is needed to open the packaging without damaging the doughnuts. For example, the blister packaging is very easy to open, but to open the flowpackaging without U-tray some force is needed and it is easy to damage the doughnuts in the process. The requirement concerning the usage of one

type of material, assumptions are made for some of the competitors because it cannot be said with certainty that these packaging do not consist of multilayer materials. For the competitors without any symbol, it is clear that multiple materials are used for their packaging. Finally, the recyclability of the packaging (requirement: The packaging is effectively recyclable for at least 70%) is determined based on assumptions and the available information. There is a table available where the criteria are listed on which the recycle score will be assessed. However, the EU has not yet decided how the score will be calculated. Some competitors have their technical data sheets available on their websites. On these pages, the recyclability of the packaging was most often described. However, the assumption for all these scores is that the packaging is disposed of correctly (especially when the packaging consists of multiple materials). Next to that, these scores are without the labels on the packaging. These labels are often added later by the retailer that wants to sell the doughnuts. To treat all the competitors equally, the choice has been made not to take the added labels into account. Some competitors do not have any influence on what kind of label gets put on their packaging. What is interesting to note is that, when specified, the doughnuts had a guarantee of freshness of 1 - 2 days, compared to the required three days from the survey results. Next to that, all packaging types have high product visibility. When comparing the packaging of the competitor to the ones of EO, there is often not much difference. The reason for this might be that the packaging does not differ much from the EO packaging or they both score similarly on that specific requirement. The EO packaging types score better on the guarantee of freshness than the competitor packaging types. Furthermore, it might not be completely fair to compare the competitor packaging types with the EO packaging types because all information is available for the EO packaging types, while the competitor does not reveal all information. For that reason, this comparison can only be used as an indication of how the EO packaging types lie in the market. With this relationship matrix, the target values of each company can be determined using formula 2. The target values of the EO packaging types have also been calculated. These can be seen in Table 5.8.

$$W_{ij} = \sum d_i \times r_{ij} \tag{2}$$

Where W_{ij} is the target value, d_i is the normalised importance rating and r_{ij} is the relationship between the competitor and the customer requirement. If a strong relationship could be given for every requirement, the target value would be 9,0. This is then the maximum target value that could be reached. None of the competitors, as well as the EO packaging types, reached a 9,0. The top three competitors are Company G, Company C and Company D. These companies outperform the others at certain requirements, like 'The packaging protects the doughnut' or 'The doughnuts have to be protected from outside contamination'. The flowpackaging with U-tray of EO scores just below the top 3 of Companies G, C and D, but the blister packaging and flowpackaging without U-tray do not perform as well. The consumer packaging of these top three competitors could be used to look into different consumer packaging options to add to the portfolio of EO.

Table 5.8: Target Values Packaging Competitors (sorted high to low)

Competitor/packaging	Target Value
Company G	6,06
Company C	5,71
Company D	5,61
Flowpackaging with U-tray	5,57
Company B	5,38
Company A	5,24
Flowpackaging without U-tray	5,23
Blister packaging	5,16
Company H	4,95
Company E	4,93
Company F	4,93

5.5 Step 1.5: Prioritise & evaluate technical requirements

The target values displayed in Table 5.9 have been calculated for each packaging function (HOW). The packaging functions are sorted by the target value. These target values are calculated using the same formula as the target values of the competitor analysis, but with the technical requirements instead of the competitor. As can be seen, the packaging functions "Embodying", "Recyclable", "Presentation", "Preservation" and "Avoidance of waste" have the highest target values. This is partly because these functions can be seen as the most important functions of food packaging or because the legislation

requires those functions to be in focus. However, following that logic, it is interesting to see that the sub-function "mechanical protection" or "information" does not have a high target value. Furthermore, the packaging function "Avoidance of waste" is not enforced by legislation, but it does have six strong relationships with the requirements. The reason for this might be that this function could be seen as a combination of the function preservation and protection because both of these functions directly influence the avoidance of food waste. As those functions can be seen as important packaging functions, it might be the reason for the high target value of the function 'avoidance of waste'. Another way of looking at it is that the requirements (and therefore the packaging) have a lot of influence on the avoidance of food waste because the packaging can keep the food preserved, protected and stored. This could decrease the amount of food waste. When looking at the lowest target values, the convenience sub-functions (opening, utilisation and disposal) have very low target values, although disposal and handling are slightly higher compared to the rest. The reason for this is that the packaging function convenience might be seen as the least important function because it does not directly protect the product or the quality of the product. The packaging function with the lowest target value is "Identification (brand)". The reason for this might be that the customers and account managers of EO did not really think this was an important requirement for the consumer packaging of doughnuts, which also can be justified when looking at the importance ratings. Taking the correlation matrix (Figure 5.2) into account when looking at the target values, it is interesting to see that the top five of the packaging functions do not (negatively) correlate with each other. This means that there might be no trade-offs at a later stage of the QFD. Concluding this section, the most important packaging functions are "Embodying", "Recyclable", "Presentation", "Preservation" and "Avoidance of waste". As the target values of the packaging functions will be used in the next phase, the importance of these five sub-functions will be taken into account during the development of the part requirements in phase II.

Table 5.9: Target Values Packaging functions (sorted high to low)

HOW	Target Value	Norm. Target Value (%)
Embodying	3,87	14,68
Recyclable	3,80	14,41
Presentation	3,16	11,96
Preservation	3,11	11,78
Avoidance of Waste	2,68	10,14
Information	2,57	9,73
Disposal (customers)	1,61	6,09
Mechanical Protection	1,42	5,37
Handling (customers)	1,39	5,28
Advertising	1,35	5,10
Utilisation (customers)	0,69	2,63
Opening (customers)	0,51	1,94
Identification (brand)	0,24	0,89

6 Part 2: QFD - Phase 2

In this chapter, the second phase of the QFD will be described. This will start with determining the WHAT and HOW of this phase and will continue with the relationship matrix between the WHAT and the HOW. Based on this matrix, the target values of each HOW can be determined and evaluated. From the target values, the most important part requirement can be determined, which can help with the comparison between the QFD results of phase 2 and the current consumer packaging. More about this comparison can be found in Chapter 7. In Appendix G, the complete matrix is shown for this phase.

6.1 Step 2.1 & 2.2: WHAT and HOW of phase 2

The second phase of the QFD (Parts deployment) starts with taking the HOW from phase 1 and using those as the WHAT of phase 2. This results in the packaging functions of phase 1 (displayed in Table 5.7) are given as the WHATs of phase 2. The technical requirements need to be translated to part requirements of consumer packaging (the HOWs). Each part requirement will have a numerical value assigned, if applicable. This is done to ensure later comparison to the current consumer packaging. The part requirements are displayed in Table 6.1. As can be seen in the first column of the table, each requirement is assigned an 'O' or a 'W'. The **'O'** requirements are obligatory to be able to enter the market. All **'W'** requirements are wishes from the customers based on the survey, complaints or customer guidelines. They are, therefore, important to take into account but not obligatory to follow before entering the market.

Table 6.1: HOWs - QFD phase 2

O/W	Part requirement	Numerical value / details
W	Moisture permeability	Maximum of 1,49% (type 1) or 1,99% (type 2) of the total doughnut weight.
W	Impact resistant	Doughnuts are protected against smashing and tearing in a shopping bag.
O	Chemical safety	No mitigation of chemical materials or fluids from the packaging into the doughnuts.
W	Protection from outside contamination	Protection against physical, chemical, biological and allergenic contamination.
W	Size packaging - Number of doughnuts	1,2,4,5,6 or more normal doughnuts & 1,2,3,4,5,6 or more mini doughnuts in a packaging.
W	Size packaging - Type of doughnuts	Same type of doughnuts in a packaging or a mixbox.
W	Doughnuts storage	The doughnuts can be stored in the packaging.
W	Easy to open/access	Opening does not need much force and the doughnuts are not damaged.
O	Disposal logo & material composition	The correct disposal logo and material composition information should be on the packaging. This can differ per destination country.
O	Recyclable materials	The packaging is for at least 70% recyclable (recycle score C or higher).
O	Recycled content	The materials used (if plastics) have to be for the correct amount made from recycled content (Table 5.2).
O	Minimum amount of material	The minimum amount of material used in the packaging while keeping in mind the other requirements and functionalities of the packaging.
W	No coloured PET and partly transparent	The packaging has to be (partly) transparent and no use of coloured PET.
W	No biodegradable plastics	No use of biodegradable plastics.
O	Placement of the label	There has to be space of at least 70 cm^2 for the placement of the label with the among others the bar code, material composition, disposal logo, best before date and ingredient list.
O	Required information present	The obligatory information like best before date and ingredient list are present.
W	Design of the customer	The design of the customer of EO can be used in the packaging.
W	Adaptable language	The language has to be adaptable for each country that the doughnuts get sold in.
W	Sustainable choice of material	The packaging needs to use sustainable materials.
W	Sustainable perception to customers	The packaging needs a sustainable perception.
W	Packaging has to be closed correctly	During the packaging process the packaging needs to be sealed correctly.
W	The packaging, material and number of doughnuts have to be as agreed	During the packaging process, the correct packaging, number of doughnuts and packaging material is used.

These part requirements are chosen based on the packaging requirement identified from the survey and sustainability legislation. The packaging requirements with an importance rating of 0 or 1 are not taken into account. The reason for this is that these requirements are not important enough to use in phase 2. The first part requirement 'moisture permeability' is developed to ensure the guarantee of freshness for three days. As already discussed in Chapter 2, the doughnuts are frozen before the packaging and will stay frozen until the point of sale. In the freezer, the doughnuts will stay fresh, but the packaging will have to ensure that the doughnuts will keep their quality. An example of quality loss is when the doughnuts

get freezer burn. This can be prevented by packaging if evaporation cannot take place (Zaritzky, 2010). Next to that, the material of the packaging also needs to be able to withstand low temperatures. However, since all consumer packaging is packaged in secondary packaging (American boxes), the deterioration of the doughnuts should be limited in the freezer. When the doughnuts are sold, they will defrost in the packaging. When the doughnuts are defrosted, they will end up on the shelves. For the doughnuts it is important that enough moisture can leave the packaging, otherwise, condensation will form on the packaging and the doughnuts will start 'sweating' and the doughnuts become soggy. This means that the packaging will need to release enough moisture to prevent the doughnuts from becoming soggy, but not too much to prevent the doughnuts from becoming stale. To be able to determine the moisture permeability needed for a guarantee of freshness of three days, tests are performed by the quality assessment team of EO. For these tests, four doughnuts from five different SKUs were chosen, so 20 doughnuts in total. The doughnuts are displayed in Figure 6.1.

Figure 6.1: Doughnuts for moisture loss test

The first, fourth and fifth doughnuts (counted from above) belong with the type 1 doughnuts with a shorter guarantee of freshness. The second and third doughnuts in the figure belong to the type 2 doughnuts. The doughnuts were in the open air in a room with a temperature of around 19,5 °C, around 60% relative humidity and preserved from air flows. This means that the type 1 doughnuts have a guarantee of freshness of 24 hours and the type 2 doughnuts have a guarantee of 48 hours, according to the Europastry standards. Each doughnut was weighed every 24 hours for five days. The doughnuts were still frozen at the first weighing moment. The results of the tests can be seen in Table 6.2. The type 1 doughnut loses on average 1,49% moisture of their total weight in 24 hours and the type 2 doughnut loses on average 1,99% moisture of their total weight. This means that the packaging around the doughnut has to make sure that some moisture leaves to avoid the doughnut from getting soggy, but a maximum of 1,49% (type 1) or 1,99% (type 2) of the doughnut weight. Even though the minidots were not included in the test, the assumption has been made that these can lose the same percentage of moisture compared to the normal-sized doughnuts. The reason for this is that minidots have the same guarantee of freshness compared to normal-sized doughnuts.

Table 6.2: Results moisture loss tests

Type doughnut	Measurement	Result
Type 1 doughnut (24u)	Moisture loss shelf life (grams)	0,77
	Moisture loss shelf life (%)	1,49
Type 2 doughnut (48u)	Moisture loss shelf life (grams)	1,63
	Moisture loss shelf life (%)	1,99

Next to the moisture permeability, packaging can have an oxygen barrier as well. However, as indicated by the quality assessment team of EO, oxygen does not have any effect on the guarantee of freshness of the doughnuts. Therefore, the oxygen permeability is not included in the part requirements. Furthermore, the guarantee of freshness is also influenced by microbiological effects. However, doughnuts become stale before the doughnuts get mouldy, so this is negligible regarding the packaging requirements. Some requirements have been specified in more detail together with EO, like 'Impact resistant' or 'easy to open/access'. The details of these requirements are chosen because this is what the consumer packaging will need to be able to guarantee consumer/customer satisfaction. For the requirement 'Placement of the label', it is important to note that the font on the label has to be at least 1.2 millimetres high (FoodDrinkEurope, 2022). This translates to a

font size of 7 for most standard font types like Arial. With all necessary information on the label with the correct font size and the necessary icons regarding material and disposal, the label will need an area of at least 70 cm^2. The requirement from one of the survey respondents 'less plastic' has been translated into two requirements, namely 'Sustainable choice of material' and 'Sustainable perception to customers'. This is done in consultation with account managers of EO because the problem is not really the use of plastic, but more that plastic has a bad image as a packaging material and it might not be sustainable. However, as some plastics (especially mono-material plastics) can be recyclable and using another material might not be beneficial, these two requirements have been developed. This way, it is taken into account that a sustainable material is used and the bad image of the plastic packaging material is kept in mind as well.

6.2 Step 2.3: Relationship matrix

In the previous section, the WHAT and HOW were described. Now that these are known, the relationship matrix can be developed. This matrix can be seen in Figure 6.2. Here, the HOWs with a green background are the obligatory requirements and the others are the wishes of customers. Similar to phase 1, the values 1, 3, and 9 are used to determine the target values at a later point. As can be seen in the figure below, the packaging function 'Avoidance of waste' has most strong relationships compared to the other packaging functions (WHATs). This is followed by 'recyclable' (six strong relationships), 'advertising' (five strong relationships), 'preservation' (four strong relationships), 'presentation' (four strong relationships) and 'embodying' (four strong relationships). Looking at the packaging requirements (HOWs), 'Moisture permeability', 'Impact resistance', 'Chemical safety', 'Disposal logo and material composition' and 'Adaptable language' are the requirements with the most strong relationships (each has three). The other requirements have one or two strong relationships. However, the requirement "Place for ingredient list, bar code, material & disposal information' has 4 medium relationships and 6 weak relationships. This shows that this requirement does have a lot of influence on the packaging functions, just not very strong ones. It can be concluded that each HOW has at least one strong relationship with a WHAT, so they are well represented.

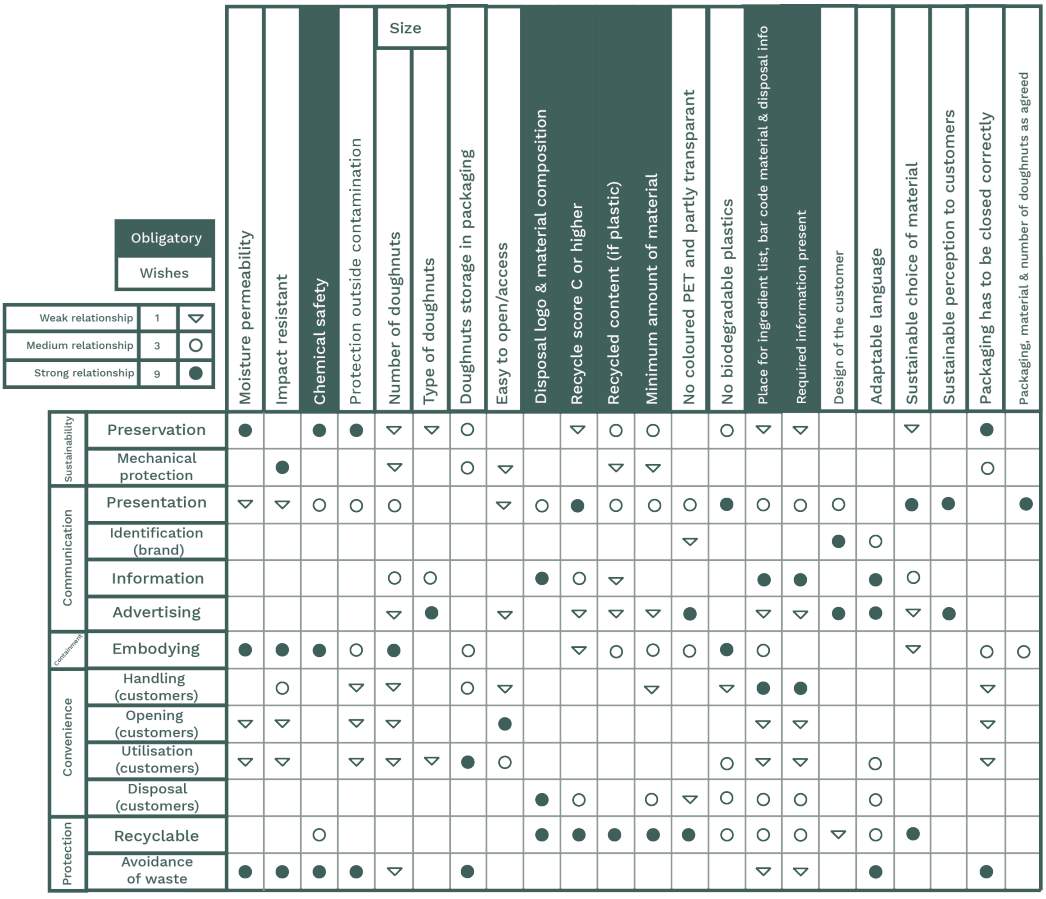

Figure 6.2: Relationship matrix - QFD phase 2

6.3 Step 2.4: Prioritise and evaluate part requirements

In this section, the part requirements will be prioritised and evaluated based on their target value. The target values are again determined using formula 2 from previous phase, where W_{ij} is the target value of the part requirements (WHAT), d_i is the normalised target value of the packaging functions (HOW) and r_{ij} is the relationship between the packaging function and the part requirement. In Table 6.3 the packaging requirements with the target values are sorted from high to low. The boldly stated requirements are obligatory for legislation. As can be seen, the food safety, guarantee of freshness (moisture permeability) and protection of the doughnuts have a relatively high target value. Next to that, the obligatory requirements from legislation like recycle score C or higher also score relatively high. Also in the list of high target values is the requirement 'No biodegradable plastics'. This is remarkable since this is not an obligatory or 'must-have' packaging requirement. The reason for this high target value is that this requirement has quite a lot of medium or strong relationships with the packaging functions. Continuing down the table, there are more obligatory requirements like 'place for ingredient list, bar code, material & disposal information', 'minimum amount of material' or 'recycled content'. Some non-obligatory requirements are between the obligatory requirements. An example of this is 'No biodegradable plastics', as said above, but also 'Sustainable choice of material' or 'Adaptable language'. These two might also have quite high target values because the sustainable choice of material concerns the recyclability of the packaging and the adaptable language might help consumers use and dispose of the packaging correctly. Since the packaging function 'recyclable' has a high target value and these two requirements have a medium or strong relationship with this packaging function, the high target value might be explained. If the target values were equally divided over all requirements, each requirement would have a target value of 4,55%. Looking at the requirements this way, all requirements above 'Size - number of doughnuts' have a target value higher than the average. All requirements below that target value of 4,55% might be less interesting to include since they have low target values.

Table 6.3: Target Values Packaging requirements (sorted high to low)

HOW	Target Value	Norm. Target Value (%)
Chemical safety	4,09	7,32
No biodegradable plastics	3,50	6,27
Moisture permeability	3,46	6,20
Recycle score C of higher	3,16	5,67
Disposal logo & material composition	3,08	5,52
Place for ingredient list, bar code, material & disposal information	3,08	5,52
Impact resistance	3,04	5,45
Sustainable choice of material	2,98	5,34
Adaptable language	2,97	5,32
Protection of outside contamination	2,87	5,15
Minimum amount of material	2,79	5,00
Packaging has to be closed correctly	2,67	4,79
Recycled content	2,65	4,75
Required information present	2,64	4,73
No coloured PET and (partly) transparent	2,63	4,71
Size - number of doughnuts	2,39	4,29
Doughnuts can be stored in the packaging	2,26	4,06
Sustainable perception to customers	1,54	2,75
Packaging, material & number of doughnuts as agreed	1,52	2,72
Design of the customer	1,04	1,87
Size - Type of doughnuts	0,89	1,60
Easy to open/access	0,53	0,95

7 Part 3: Comparison results QFD phase 2 & current consumer packaging

This chapter will compare the results of phase 2 of the QFD with those of the current consumer packaging. The HOWs of QFD phase 2 show what part requirements are needed to comply with customer satisfaction and sustainability legislation. These part requirements can be compared to the current packaging characteristics to determine how much the current consumer packaging complies with the customer's satisfaction and sustainability legislation. This will be done by making a matrix like the other QFD matrices with the part requirements as WHAT and the part characteristics as HOW. The relationship matrix can be made to determine which characteristics need updating and which characteristics are still sufficient. Figure 7.1 displays an overview of the comparison matrix. The target values can be calculated to see how the packaging characteristics score in terms of the requirements. The packaging characteristics with a high target value show that they are important and successful, while the characteristics with low values show that they do not bring much added value and/or might not be incorporated enough. Next to that, each part requirement must be represented by one packaging characteristic with a strong relationship. This shows that each requirement is sufficiently incorporated into the packaging. These relationships will be described in section 7.2. This matrix will be evaluated to determine how the current consumer packaging is performing with regard to the packaging requirements from the QFD in Section 7.3. Finally, the changes and actions are identified in Section 7.4. First, the current consumer packaging characteristics will be discussed in Section 7.1.

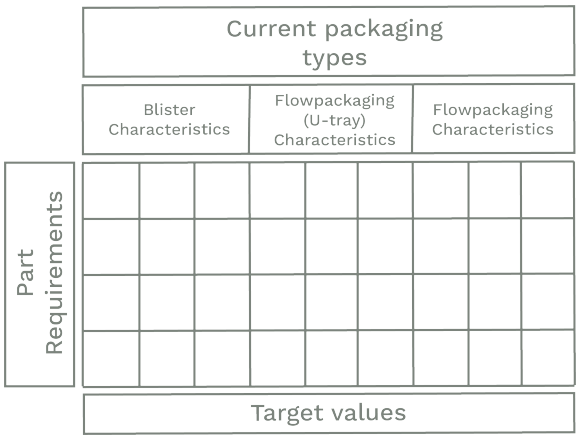

Figure 7.1: Relationship matrix - Comparison Packaging - QFD

7.1 WHAT and HOW comparison QFD

Just like the previous QFD phases, the WHAT of this comparison matrix will be the HOW of the previous phase. In this case, the part requirements can be found in Table 6.1. The HOWs of this matrix, the packaging characteristics of the current packaging types, will be discussed now. As described in Chapter 2, there are three types of consumer packaging for doughnuts for EO at the moment, the blister packaging, the flowpackaging with U-tray and the flowpackaging without the U-tray. The packaging characteristics of each packaging type can be seen in Tables 7.4, 7.5 and 7.6. The packaging characteristics are based on the requirements, so for example for the requirement 'impact resistance', the packaging characteristic 'strength packaging' is included. This way, there can be a clear comparison between the current packaging and the requirements. The first characteristic, moisture permeability, has been determined for each packaging type separately. This was done to check that the guarantee of freshness is indeed two days for the blister packaging and three days for the flowpackaging (with or without U-tray). First, the moisture permeability of the blister packaging, which consists of 2 mm APET, will be determined. The water vapour permeability of 2 mm PET is 0,25 gr/day/m^2 (Eco-Ease, n.d.). The permeability of the blister is determined as displayed in equation 3, where MM is the maximum moisture loss through the packaging, $P_{material}$ is the moisture loss through the material of the blister packaging, P_{gap} the moisture loss through the gap of the blister packaging and SL is the shelf life of the doughnuts.

$$MM = (P_{material} + P_{gap}) * SL \tag{3}$$

The $P_{material}$ will be determined using formula 4 where P is the permeability of the packaging (gram/m^2/day), S is the surface of the packaging (m^2) and SL is the shelf life (days) (ten Klooster et al, 2015). The P_{gap} will be determined using

the formula 5. Where D is the diffusion coefficient (m^2/s)), L is the length of the gap in meters, ΔP is the vapour pressure difference across the gap, R is the universal gas constant (8,314$J/mol.K$), T is the absolute temperature in Kelvin and A the area of the gap in squared meters.

$$P_{material} = \frac{P}{\frac{1}{S}} \tag{4}$$

$$P_{gap} = \frac{D}{L} * \frac{\Delta P}{RT} * A \tag{5}$$

In table 7.1, the moisture loss through both the material and the gap are displayed. The sum of these times the shelf life is displayed in the column 'Moisture loss 2 days (gr)' and 'Moisture loss 3 days (gr)'. The doughnuts have a guarantee of freshness for two or three days in blister packaging, depending on the doughnut type. The first column shows the amount of minidots that are packaged within the packaging. With this, the percentage of moisture one minidot can lose can be determined, which is displayed in the last column. So, for example, a minidot in a blister packaging of four can lose 0,14-0,24% or 0,21 - 0,36% of moisture in their shelf life of two (type 1 doughnut) or three (type 2 doughnut) days. As can be seen in the table, the values have been determined for two different temperatures. The reason for this is that temperature influences the permeability of plastics. A rule of thumb is to estimate a 30-50% change for every 5°C in temperature (Massey, 2002). The official permeability tests are performed in a situation where the room temperature is 23°C. The moisture loss tests were performed with a room temperature of 19°C. In other situations, the room temperature might be even higher. For this reason, a range is displayed in the table instead of a fixed value. The lower value represents the permeability and moisture loss in a situation with 19°C and the higher value in a situation with 28°C. As can be seen, the percentage of moisture that one doughnut can lose in a blister packaging is lower than 1,49% (type 1) or 1,99% (type 2) which is the acceptable moisture loss to ensure freshness. This is especially the case for the lower values (19°C). A conclusion might then be drawn that the shelf life of 2 or 3 days could be extended. However, as already said, the temperature might have a lot of influence on the moisture loss. If EO wants to ensure that the doughnuts still have a guarantee of freshness when the point of sale has a higher room temperature, the allowed moisture loss and the calculated moisture loss are closer to each other. Furthermore, the difference in moisture loss might be explained by the fact that the doughnuts start sweating in the blister packaging. This suggests that the doughnuts do lose moisture, but it cannot leave the blister packaging. The quality team of EO encounters condensation taking place in the blister packaging after a while. Next to that, the permeability of a plastic can also be influenced by the relative humidity. Taking into account the fluctuating permeability rates of the blister packaging and the fact that there is condensation in the packaging, the doughnut might lose more moisture than calculated and displayed in the table below. These factors might then lead to a shelf life of two days instead of longer.

Table 7.1: Maximum moisture loss blister packaging

Packaging size	4		9	
Temperature (°C)	19	28	19	28
$P_{material}$	0,010	0,021	0,016	0,034
P_{gap}	0,264	0,461	0,335	0,586
Moisture loss 2 days (gr)	0,547	0,963	0,703	1,241
Moisture loss 3 days (gr)	0,820	1,445	1,054	1,861
Doughnuts 2 days (%)	0,14	0,24	0,03	0,06
Doughnuts 3 days (%)	0,21	0,36	0,05	0,09

Secondly, the permeability of the flowpackaging will be determined. The foil of the flowpackaging consists of 30 μm BOPP and according to the material specifications, the material has a water vapour permeability of 5,0 g/m^2/d for a thickness of 30 μm BOPP and 23 °C. The U-tray can be different for specific packaging. It consists of a carton board with either an Eagle Barrier or an HDPE film laminate. The U-tray does not have any influence on the moisture permeability. For this reason, the moisture permeability of both packaging types is similar and the maximum moisture loss of the doughnuts can be determined. Since the flowpackaging does not have a gap in the packaging, the permeability can be determined using only equation 4. As already described, the permeability P = 5,0 gr/m^2/day. The results are displayed in Table 7.2. The table has similar columns as Table 7.1 above, except for the P_{gap}. These percentages of moisture loss per doughnut differ per packaging size because the surface per doughnut type is different. For the flowpackaging for one doughnut, there is a

lot of packaging for that one doughnut, whereas the amount of packaging is 'shared' among 2, 4 or 6 doughnuts in the other packaging sizes. The biggest moisture loss per doughnut is in the flowpackaging with one doughnut. At 28 degrees Celsius, the moisture loss is similar to the acceptable moisture loss from the tests. However, for the lower temperatures, it is lower than the 1,49% or 1,99% of allowed moisture loss for the type 1 and type 2 doughnuts, respectively. This might again be partly explained by the changing permeability with different temperatures and relative humidities. Another explanation might be that the calculations assumed that there are no gaps in the flowpackaging. However, there might be small gaps in the seal of the flowpackaging, which can influence the food quality and shelf life of the doughnut (Ilhan, 2023). If there are small gaps in the seal of the flowpackaging, it might create an extra option for moisture to escape the packaging. The permeability of the packaging types can be concluded by saying that the calculated moisture loss through the packaging is lower than the acceptable moisture loss from the tests of EO (Section 6.1). However, this can be explained and therefore the shelf life of the doughnuts as determined by EO could be plausible.

Table 7.2: Maximum moisture loss flowpackaging

Packaging size	1		2		4		6	
Temperature (°C)	19	28	19	28	19	28	19	28
$P_{material}$	0,116	0,249	0,206	0,442	0,359	0,770	0,512	1,097
Moisture loss 3 days (gr)	0,349	0,748	0,618	1,325	1,077	2,309	1,536	3,292
Moisture loss 4 days (gr)	0,466	0,998	0,8246	1,767	1,436	3,078	2,048	4,389
Doughnuts 3 days (%)	0,70	1,50	0,31	0,66	0,13	0,29	0,09	0,18
Doughnuts 4 days (%)	0,93	2,00	0,41	0,88	0,18	0,38	0,11	0,24

One requirement that needs to be explained is the requirement 'recyclable'. As mentioned in Chapter 5, the recyclability of a packaging will be determined based on specified criteria. These criteria include the use of a label on the packaging, as these "can affect the efficiency of the sorting process. Material from which the label is made and type of glue or adhesive also affect the quality of the secondary raw material." (EuropianCommission, 2024). EO does not directly have an influence on the label, since a label will always be attached to the packaging by the customers of EO. The recyclability of the packaging will depend on the label. If paper labels are glued to the plastic packaging, it is harder to recycle because the label first has to be removed. If labels are used that can be washed off by water, the recyclability of the plastic is not a problem. However, as EO does not attach the labels to the consumer packaging, it is not fair to take the labels into account for the recyclability score. Therefore, the recyclability of the packaging after the attachment of the labels is out of scope for all packaging types. The recyclability might decrease when the customers of EO put labels on the packaging, but it is up to the customers to find a sustainable solution regarding the recyclability of the packaging with labels on it. However, it is still important that EO offers consumer packaging with high recyclability scores, to enable good recyclability of the packaging. Next to that, EO can offer a selection of options for labels that would not directly decrease the recyclability of the packaging. For all the other criteria are displayed below in Table 7.3 and their relation to the characteristics of the current packaging. As can be seen, the packaging types (without labels) score well on most criteria which will likely result in high recycle scores.

Table 7.3: Recycle criteria and their relation to the current packaging

Criteria	**Blister**	**Flowpackaging**	**Flowpackaging U-tray**
Additives	No	No	No
Labels	Out of scope	Out of scope	Out of scope
Sleeves	No	No	No
Closures/small components	No	Seals	Seals
Adhesives	No	No	No
Colours	No	No	No
Material composition	Mono-material	Mono-material	BOPP & carton board
Barriers/Coatings	No	No	No
Inks/printing	No	Print on foil	Print on foil
Product residues/ease of emptying	Easy	Harder	Easy
Ease of dismantling	Easy	Easy	Easy

The details of other current packaging characteristics can be found in the tables below. These characteristics were determined by consulting the technical information of the packaging (suppliers) or together with employees of EO. Some characteristics,

like 'packaging is closed correctly', are more with regard to the packaging process of that packaging. The characteristic 'Size' incorporates the 'number of doughnuts' and 'type of doughnuts' requirements. The characteristic 'sustainable choice of material' for the flowpackaging with U-tray is not really fulfilled. The reason for this is that there are two types of materials used in the packaging. If these would be disposed of together, the materials cannot be recycled. This is also not communicated to the consumer. Next to that, it is difficult to customise the blister packaging. Additionally, since there is no text on the packaging, the requirement 'adaptable language' might not be applicable to this packaging type.

Table 7.4: HOW comparison matrix - packaging characteristics (Blister)

Packaging type	Characteristic	Numerical value / details
Blister packaging	Moisture permeability	0,250 gr/m^2/day
	Strength packaging	Packaging protects the doughnuts sufficiently in a shopping bag.
	Chemical safety	Conform to legislation food safety
	Protection outside contamination	Still contact with the outside world because of a split in the packaging
		Split is max. 1 mm
	Size	4 or 9 mini doughnuts
		Both normal and mixboxes
	Storage of doughnuts	Yes, but contact with the outside world
	Easy opening	Can be opened with limited force and without damaging the doughnuts
	Disposal logo & material composition	No disposal information present, material composition on primary packaging
	Recyclable	Recycle score C or higher (without label)
	Recycled content	No, virgin APET material
	Minimum amount of material	Not fully, convenience for packaging results in added material.
	Colour packaging	Fully transparent
	Biodegradable plastics	No biodegradable plastics
	Required information present	All necessary information is available on the secondary packaging.
	Placement of the label	Yes, enough space
	Customisation	Only on label (that is added by the customer)
	Adaptable language	No
	Sustainable choice of material	Yes, recyclable plastics
	Sustainable perception to customers	Not really, use of plastics. Recyclability is not communicated to customers
	Packaging is closed correctly	Yes
	Packaging, material and number of doughnuts	Not always

Table 7.5: HOW comparison matrix - packaging characteristics (Flowpackaging (without U-tray))

Packaging type	Characteristic	Numerical value / details
Flowpackaging	Moisture permeability	5 gr/m^2/day
(without U-tray)	Strength packaging	The doughnuts can be crushed in the packaging in a shopping bag.
	Chemical safety	Conform to legislation food safety
	Protection outside contamination	Not possible, packaging is completely closed.
	Size	1, 2, 4 or 6 normal doughnuts
		Only one type of doughnut in a packaging
	Storage of doughnuts	Possible, but contact with the outside world and not very convenient.
	Easy opening	Needs some force to open the seal and change of damaging the doughnuts during opening or getting them out of the packaging.
	Disposal logo & material composition	No information present
	Recyclable	Recycle score C or higher (without label)
	Recycled content	No, virgin BOPP material
	Minimum amount of material	Yes
	Colour packaging	Fully transparent
	Biodegradable plastics	No biodegradable plastics
	Required information present	All necessary information is available on the secondary packaging.
	Placement of the label	Yes, enough space
	Customisation	Only on label (that is added by the customer)
	Adaptable language	No
	Sustainable choice of material	Yes, recyclable plastics
	Sustainable perception to customers	Not really, use of plastics. Recyclability is not communicated to customers.
	Packaging is closed correctly	Most of the time
	Packaging, material and number of doughnuts	Not always

Table 7.6: HOW comparison matrix - packaging characteristics (Flowpackaging (with U-tray))

Packaging type	Characteristic	Numerical value / details
Flowpackaging (with U-tray)	Moisture permeability	5 gr/m^2/day
	Strength packaging	Packaging protects the doughnuts sufficiently in a shopping bag.
	Chemical safety	Conform to legislation food safety
	Protection outside contamination	Not possible, packaging is completely closed.
	Size	2, 4 or 6 normal doughnuts
		Only one type of doughnut in a packaging
	Storage of doughnuts	Yes, but contact with the outside world
	Easy opening	Needs some force to open the seal, but limited chance of damage to doughnuts.
	Disposal logo & material composition	No information present
	Recyclable	Recycle score C or higher (without label)
	Recycled content	No, virgin BOPP material, virgin trays
	Minimum amount of material	No, the tray is 'additional material'.
	Colour packaging	Almost fully transparent (tray blocks the visibility from below)
	Biodegradable plastics	No biodegradable plastics
	Required information present	All necessary information is available on the secondary packaging.
	Placement of the label	Yes, enough space
	Customisation	Only on the label (that is added by the customer)
	Adaptable language	No
	Sustainable choice of material	Not really, two types of materials in the packaging
	Sustainable perception to customers	Not really, use of plastics and bleached (laminated) carton.
		Recyclability is not communicated to customers
	Packaging is closed correctly	Most of the time
	Packaging, material and number of doughnuts	Not always

7.2 Relationship matrix

The relationship matrices of each packaging type are displayed in Figures 7.2, 7.3 and 7.4. As can be seen, the relationships, weak, medium and strong, are used again. Next to that, the yellow box indicates no relationship at all. Furthermore, the obligatory requirements are again shown with a green background (legislation). Each comparison matrix will be discussed in this section separately. The evaluation of the current consumer packaging with regard to the packaging requirements from the QFD will be discussed in the next section (Section 7.3).

7.2.1 Blister packaging

The first matrix of this section will be focused on blister packaging. As can be seen, there are 6 yellow boxes in the matrix (Figure 7.2). This shows that several requirements do not have a relationship with the current packaging characteristics and are therefore under-represented. If the packaging would fit the packaging requirements from the QFD perfectly, every requirement (the WHATs) would have at least one strong relationship with a packaging characteristic. In the case of the blister packaging, 12 requirements out of 22 have a strong relationship with the characteristics. Four requirements have a medium relationship with the characteristics and 2 requirements have a weak relationship. All in all, 10 requirements are not completely represented in the matrix. For example, moisture permeability does not have a strong relationship. The reason for this is that the doughnuts in the blister packaging do not have a guarantee of freshness of three days but two days for type 1 doughnuts. For the requirements that do not have any relationship with the characteristics at all, the number of doughnuts is an example. Only the minidots are packaged in a blister with 4 or 9 units. The doughnuts or crodots do not get packaged in blister packaging. Therefore, the 'number of doughnuts' and 'number of crodots' characteristics do not have a relationship with the requirement 'number of doughnuts'. As can be seen in Table 7.4, the packaging has a split in the packaging, which results in incomplete protection from outside contamination. Other packaging characteristics also do not completely fulfil the requirements, which leads to a weak or strong relationship in the matrix.

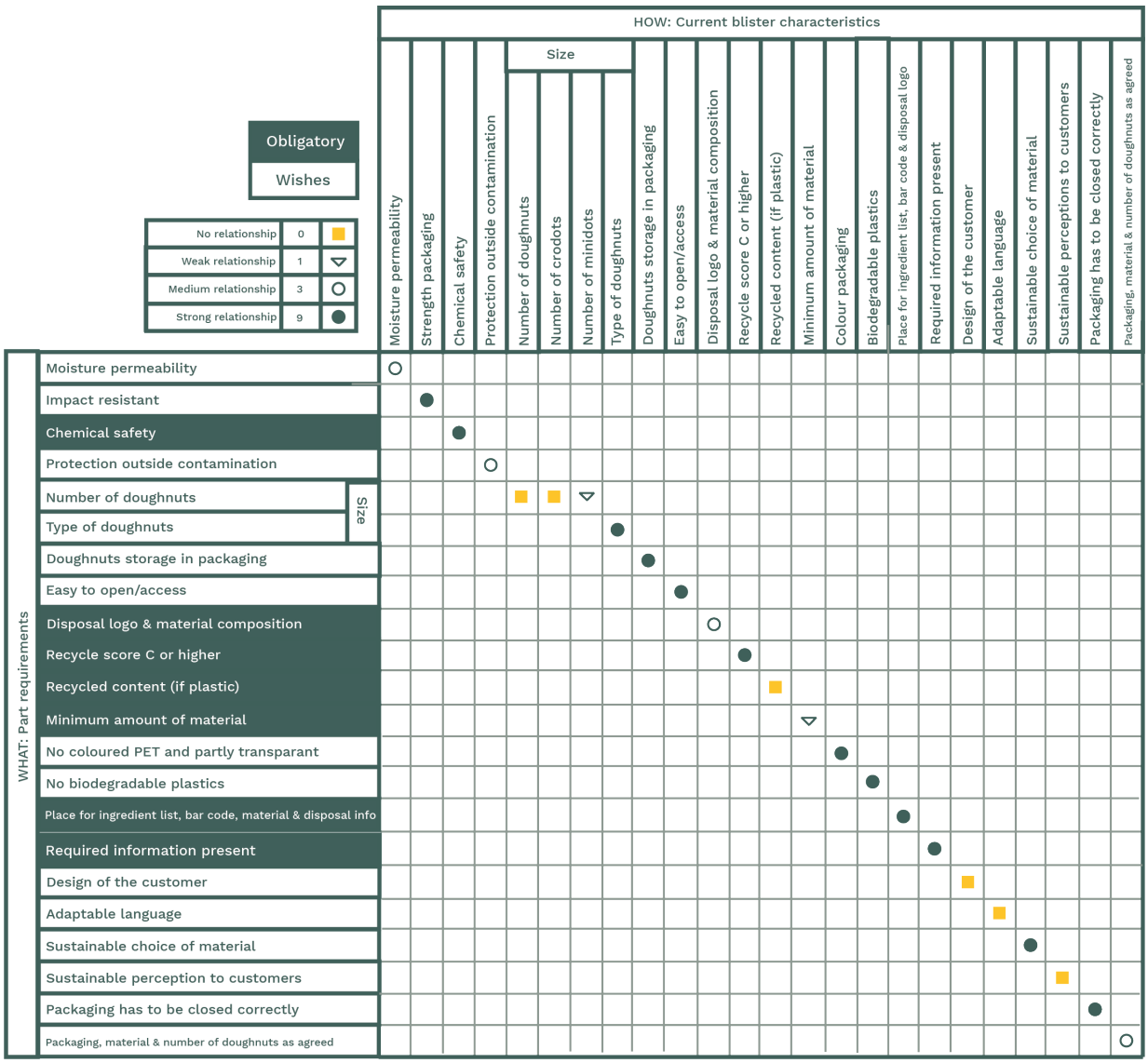

Figure 7.2: Relationship matrix - Comparison Blister packaging

7.2.2 Flowpackaging without U-tray

The next matrix is the one that compares the packaging requirements with the characteristics of the flowpackaging without U-tray (Figure 7.3). As can be seen in the figure below, there are 10 requirements well represented (strong relationships), 9 requirements are insufficiently represented (weak or medium relationship) and 3 requirements are not represented by the characteristics at all. Again, the characteristics regarding the number of doughnuts have no relationship with the requirement 'number of doughnuts'. However, compared to the blister packaging, the flowpackaging without U-tray does package doughnuts, but no minidots or crodots. Furthermore, the packaging characteristics of this packaging type, which are described in detail in Table 7.5, do not always fully fulfil the packaging requirements. An example of this is the requirement 'Impact resistant' since the doughnuts can be crushed in the packaging when it is placed in a shopping bag. Furthermore, there is only one type of doughnut possible in the flowpackaging. EO does not work with mixboxes (different types of doughnuts in the packaging) in flowpackaging.

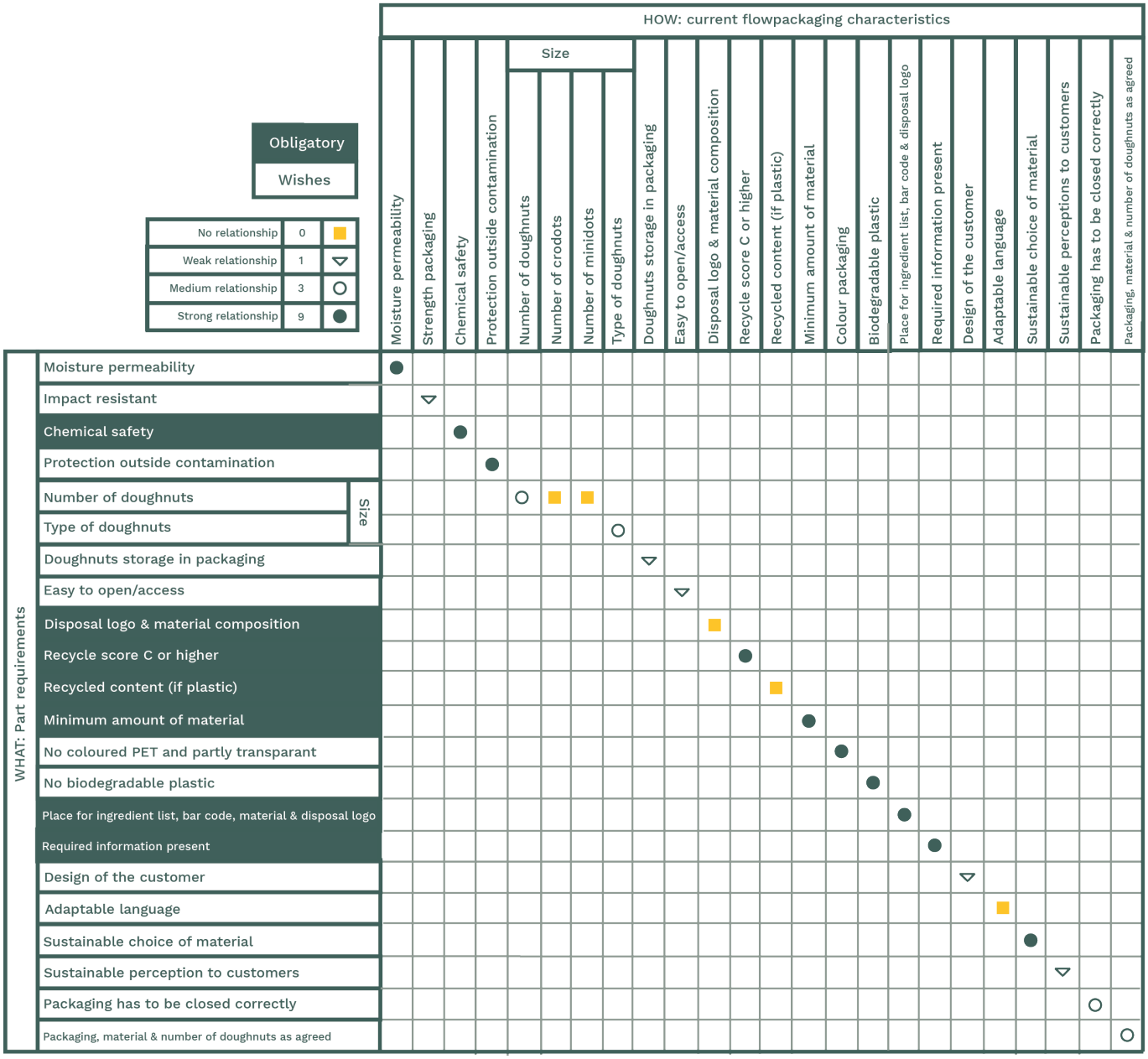

Figure 7.3: Relationship matrix - Comparison Flowpackaging (without U-tray)

7.2.3 Flowpackaging with U-tray

The final matrix of this section is the matrix of the flowpackaging with U-tray. This matrix has 10 requirements with a strong relationship to the packaging characteristics. This means that 12 requirements are not or insufficiently represented in the current flowpackaging. However, from those 12 requirements, only three requirements do not have any relationship at all. This is partly due to the fact that the flowpackaging with U-tray does package both the crodots and doughnuts. Furthermore, the type of doughnuts is only similar types of doughnuts in the flowpackaging, as already mentioned above. In Table 7.6 the packaging characteristics are described in more detail. This table can be used to understand the relationships of the matrix below.

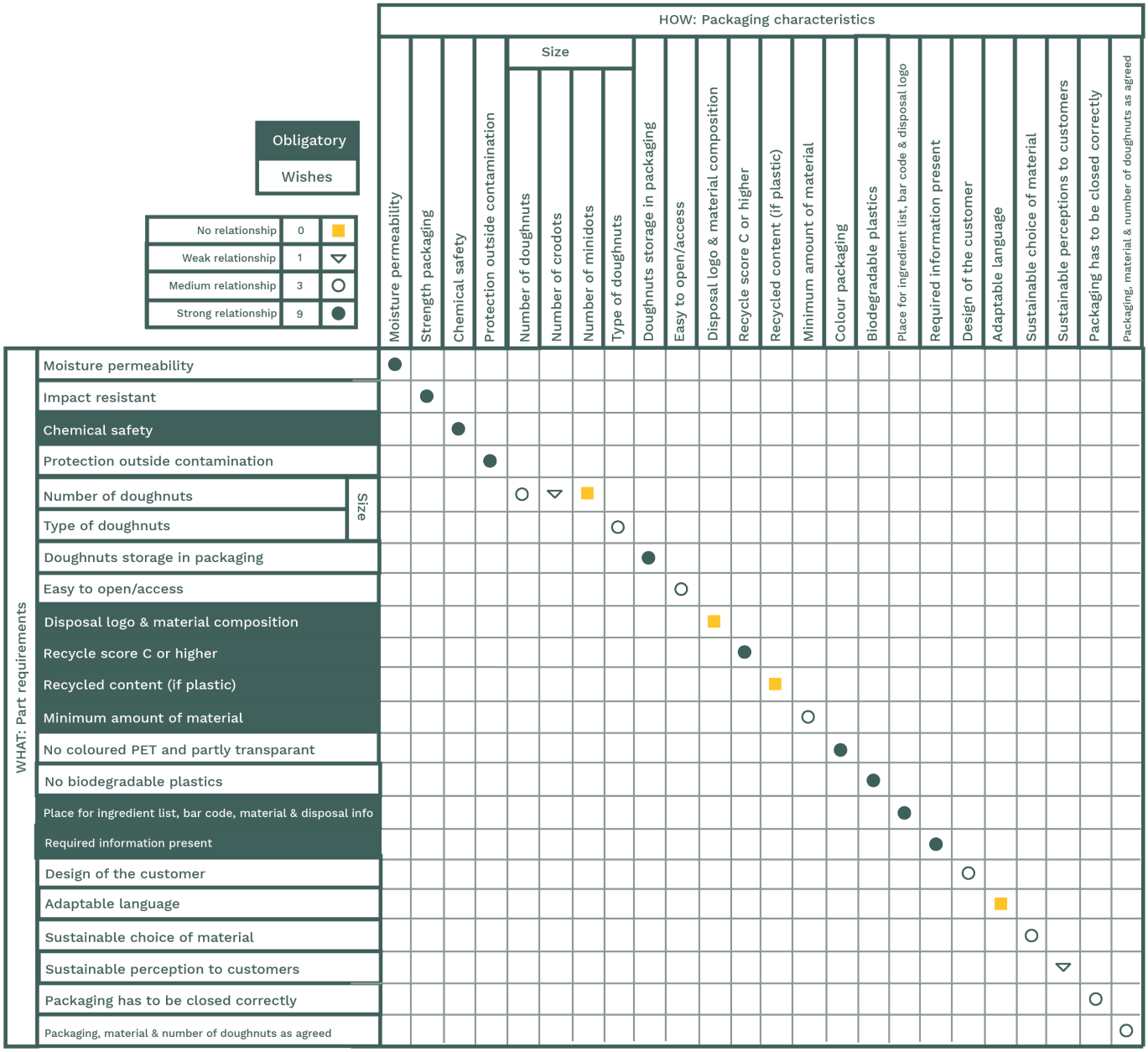

Figure 7.4: Relationship matrix - Comparison Flowpackaging (with U-tray)

7.3 Evaluate current consumer packaging

If the current consumer packaging options score perfectly (so all requirements have a strong relationship with packaging characteristics), the sum of the target values of the characteristics would be 9,77. The sum of the target values of the current consumer packaging is displayed at the bottom in Table 7.7. The column 'Blister' is for the blister packaging, the column 'FP' is for the flowpackaging without U-tray and the 'FP Tray' is the flowpackaging with U-tray. The final column shows the maximum target value for this characteristic. The packaging characteristics in bold represent the obligatory requirements. For example, for the characteristic 'moisture permeability', the maximum value would be 0,56. As can be seen in the table, the flowpackaging with U-tray performs best of the three packaging options. The flowpackaging without U-tray performs worst. However, all three target values lie quite close to each other. The reason for the better performance of the flowpackaging with U-tray might be that there are only three requirements with no relationship at all, compared to the 4 requirements for the flowpackaging without U-tray and 5 requirements for the blister packaging. Next to this, the flowpackaging with U-tray has a strong relationship with the requirements in the top 5 (Table 6.3). The blister packaging and the flowpackaging without U-tray do not have strong relationships with all of these requirements. Next to the sum of

the target value, the separate target value for each HOW can also be seen in the table below. Looking at all these target values and the differences between the packaging types, it can be seen that all the packaging types score similar on some of them, like 'chemical safety' or 'recyclable'. Other characteristics, like 'Size (doughnuts)' are different for each packaging type. It is important to note that some packaging types might never reach the maximum value because a packaging type might not be able to fulfil a specific requirement. For example, the requirement 'customisation' cannot be fulfilled by the blister packaging, as there is not much to customise on the packaging. This will be taken into account when determining the changes and actions for the packaging types. Furthermore, the packaging types score not always well on the obligatory requirements, like disposal logo & material composition or recycled content. Other obligatory requirements like chemical safety and recyclability do have strong relationships with all packaging types. In the next section below, the packaging characteristics are described separately to determine potential changes and/or actions to improve them.

Table 7.7: Target values per packaging characteristic

Packaging characteristic	Blister	FP	FP Tray	Maximum value possible
Moisture permeability	0,19	0,56	0,56	**0,56**
Strength packaging	0,49	0,05	0,49	**0,49**
Chemical safety	0,66	0,66	0,66	**0,66**
Protection outside contamination	0,15	0,46	0,46	**0,46**
Size (doughnuts)	0	0,13	0,13	**0,39**
Size (crodots)	0	0	0,04	**0,39**
Size (minidots)	0,04	0	0	**0,39**
Normal & mixboxes	0,14	0,05	0,05	**0,14**
Storage of doughnuts	0,37	0,04	0,37	**0,37**
Easy opening	0,09	0,01	0,03	**0,09**
Disposal logo & material composition	0,17	0	0	**0,50**
Recyclable	0,51	0,51	0,51	**0,51**
Recycled content	0	0	0	**0,43**
Minimum amount of material	0,05	0,45	0,15	**0,45**
Colour packaging	0,42	0,42	0,42	**0,42**
No biodegradable plastic	0,56	0,56	0,56	**0,56**
Required information present	0,43	0,43	0,43	**0,43**
Placement of the label	0,50	0,50	0,50	**0,50**
Customisation	0	0,02	0,06	**0,17**
Adaptable language	0	0	0	**0,48**
Sustainable choice of material	0,48	0,48	0,16	**0,48**
Sustainable perception to customers	0	0,03	0,03	**0,25**
Packaging is closed correctly	0,43	0,14	0,14	**0,43**
Packaging, material and number of doughnuts	0,08	0,08	0,08	**0,24**
SUM	**5,76**	**5,59**	**5,82**	**9,77**

7.4 Identify the changes and actions

In this section, the changes and actions will be identified. This will be done for each packaging requirement separately below. For each requirement, the packaging characteristics will be discussed and how/if they could change to completely fulfil the requirements.

7.4.1 Moisture permeability

The moisture permeability is not sufficient for the blister packaging, as it has a guarantee of freshness of two days instead of three for type 1 doughnuts. The moisture permeability could be improved by changing the packaging design of the blister packaging (surface area), the material or the thickness of the material. Something else that can be taken into account is the condensation in the packaging when the doughnuts are defrosted. The moisture permeability for the flowpackaging (with or without U-tray) is sufficient to fulfil the requirement.

7.4.2 Impact resistant

The blister packaging and the flowpackaging with U-tray are sufficient for this requirement. The flowpackaging without U-tray does not have enough strength to avoid crushing the doughnuts in a shopping bag. The main reason for this is that the packaging fully consists of flexible material. If the flowpackaging without U-tray would have a tray or another fixed part in the packaging, it would fulfil the requirement.

7.4.3 Chemical safety

All the packaging types ensure chemical safety.

7.4.4 Protection outside contamination

Both the flowpackaging types have full protection from outside contamination because the packaging gets sealed. The blister packaging, however, does not completely protect from outside contamination, as there is a small split in the packaging. If the blister packaging were completely closed, the packaging would be sufficient for this requirement. An option could be to seal the blister packaging, but this could make it very hard to open. One of the benefits of blister packaging is that the consumer can open and close the packaging very easily. If the blister packaging were closed, the convenience of this packaging type would decrease. Another factor that will have to be taken into account when closing the blister packaging completely is moisture permeability. The doughnut will have to be able to lose some moisture in the packaging when defrosting and avoid 'sweating'. If the blister packaging is completely closed, the doughnut might not be able to do this. Finally, there is a very small gap, so there is a small chance that any contamination will actually occur. Therefore, it might not be interesting to look into closing the blister packaging completely and accepting that there is no strong relationship with this requirement. Next to that, a big part of the life cycle of a doughnut will be spent in secondary packaging, which limits the contamination from outside even more.

7.4.5 Number of doughnuts

This requirement takes into account all types of doughnuts. From the survey, the requirement resulted in that there is space for 1, 2, 4, 5, 6 or more normal-sized doughnuts (doughnuts and crodots) and 1, 2, 3, 4, 5, 6 or more mini-sized doughnuts (minidots). As can be seen in Appendix A, the blister packaging can fit either 4 or 9 minidots. The flowpackaging without U-tray can fit 1, 2, 4 or 6 normal doughnuts and the flowpackaging with U-tray can fit 2, 4 or 6 normal doughnuts or 2 crodots. So, when looking at all the consumer packaging types together, the requirement is roughly fulfilled. However, when taking into account the packaging types separately, the requirement is not sufficiently fulfilled on its own. If, for example, the blister packaging is removed from the portfolio, the minidots are not packaged in consumer packaging any more. To make sure that the requirement is fulfilled, more doughnut numbers should be packaged, potentially divided over different packaging types. It would be best if every packaging type would have all doughnut types and numbers to give many options, but this does require a lot of flexibility of EO.

7.4.6 Type of doughnuts

The blister packaging is, at the moment, the only option for mixboxes. The flowpackaging with or without U-tray does not have the mixbox option. If lines 1 and 3 were adjusted to the line, it would be easier to package mixboxes there. The packaging itself (flowpackaging with or without U-tray) could have different types of doughnuts. Line 1 does not have to make too many adjustments, but all the doughnut types will have to be put in a tray manually or in the right order to make sure that the different types of doughnuts get packaged together. This should, however, not need a big adjustment, as employees place the doughnuts in the tray anyway. For line 3, the order of the doughnuts has to be correct before entering the flowpackaging machine because line 3 is completely automated from that point. As the conveyor belt before the flowpackaging machine is quite short, this could end up being a challenge if no adjustment is made to the conveyor belt. Next to that, all the different doughnut types will have to be taken from inventory and placed along the packaging line, which could be tight in space as well at line 3.

7.4.7 Doughnuts storage in packaging

This requirement has a strong relationship with the blister packaging and the flowpackaging with U-tray. These packaging types enable storage in the packaging. The flowpackaging without U-tray does not really enable storage in the packaging. It is possible, but it is a bit harder to put them back in the packaging and the chance that the coating or sugar on top of the doughnut would spread out is quite big. A change for the flowpackaging without U-tray would be to add the tray or some other shape to enable the doughnuts to be easily placed back in the packaging. When the packaging is opened and the doughnuts are stored in the packaging, the guarantee of freshness might decrease because the doughnuts are in contact with (more) open air.

7.4.8 Easy to open/access

The blister packaging has a strong relationship with this requirement. The reason for this is that it is easy to open/access and remove the doughnuts from the packaging. The flowpackaging with U-tray has a medium relationship because there is some force needed to open the seal. However, there is a limited chance that the doughnuts get damaged in the process. Since the seal has an important role in this packaging type, like protection from outside contamination and moisture permeability, it might be difficult to change something to facilitate easy opening of the packaging. The flowpackaging without U-tray only has a weak relationship with this requirement. The reason for this is that it is easy to open/access, but it is not easy to remove the doughnuts from the packaging. For this, it might be necessary to get a pair of scissors to cut the packaging open to easily remove the doughnuts from the packaging. The suggested change for the flowpackaging without U-tray for this requirement is similar to the previous one, adding a tray or another fixed shape to enable the doughnuts to be removed from the packaging.

7.4.9 Disposal logo & material composition

The disposal information/logo is not present on all packaging types. The blister packaging does have the material composition on the packaging, but both flowpackaging types do not have that. Since this information, both the disposal and material, have to be presented in different ways across Europe, it might not be useful to place that on the packaging at Europastry. It might be better to include the necessary information on the secondary packaging, similar to the ingredients and best-before date. This way, the customers of EO can place the correct logos and information on the label.

7.4.10 Recycle score c or higher

All packaging types are completely recyclable. However, when the labels are added to the packaging, the percentage of recyclability will decrease. Nevertheless, looking at the criteria from the recycle score, all packaging types will likely still be at least 70% recyclable and will, therefore, receive at least a recycle score C.

7.4.11 Recycled content

None of the packaging types have recycled content. For the blister packaging, the percentage of recycled content in the packaging material needs to be at least 30%, as the blister is made of PET. The use of recycled PET in the material does not influence the moisture permeability (Dombre et al., 2014). For the flowpackaging, there needs to be 10% recycled content in the BOPP. In 2018, around 95% of the accepted recycling processes for food safety were for PET, only the remaining 5% for PP or HDPE. For more recycling processes to add to this list, the European Food Safety Authority (EFSA) needs to approve them, which is a slow process (Geueke et al., 2018). Since then, some more recycling processes for PP have been added, but the focus on PET recycling remains (Väre, 2024). Due to the limited knowledge about food-grade recycling of PP (BOPP), there is not much knowledge about the barrier properties of this recycled PP. Next to that, since only 10% of the material needs to consist of recycled content, the barrier properties should not have too much influence. However, the potential change in barrier properties of recycled content BOPP should be taken into account by EO when changing the foil for the flowpackaging. Another option could be to look into the possibility of packaging in PET foil since there is more food contact acceptable recycled PET at the moment. However, PET foil might not be fully suitable for EO in terms of usability with the current packaging machines (seal ability), sufficient barrier properties or insufficient transparency. Next to that, it is not clear what will happen regarding the number of accepted recycling processes for the food safety of PP. If

every company in the EU moves towards PET foil instead of PP foil, there will also be limited recycled PET in the market. It is important to look into how the market of recycled content plastic materials for food packaging changes and what the best foil would be for the flowpackaging.

7.4.12 Minimum amount of material

Both the blister packaging and the flowpackaging with U-tray have a medium relationship with this requirement. The reason for this is that the convenience or protection of the doughnuts results in an increase in packaging material. The flowpackaging without U-tray has the minimum amount of material. It is hard to directly suggest changes to improve this requirement because it has a lot of correlation with other requirements, such as impact resistance or convenience. It might be possible to change the surface area or thickness of the packaging for blister packaging and to reduce the amount of material for the flowpackaging with U-tray. However, when doing this, the trade-offs with different requirements/packaging functions should be taken into account.

7.4.13 Colour packaging

All packaging types have a strong relationship with this requirement since the packaging is (partly) transparent and does not use coloured PET.

7.4.14 Biodegradable plastics

None of the packaging types use biodegradable plastics.

7.4.15 Place for ingredient list, bar code & disposal logo

All information needed and the space for the label are present for all packaging types. This is the case when taking into account that the disposal and material information will be on the secondary packaging, as described above.

7.4.16 Required information present

All required information, like the ingredient list and best-before date, is present on the secondary packaging of the doughnuts.

7.4.17 Design of the customer

The blister packaging does not have any relationship with this requirement. The reason for this is that there is no option to customise this packaging type. The flowpackaging without U-tray has a weak relationship with this requirement. The reason for this is that the foil of the flowpackaging is printable. The facilities to easily customize the foil are not at the packaging lines. The flowpackaging with U-tray has a medium relationship because you can also print a logo or something else on the tray next to the foil. However, this is also not facilitated at the packaging lines. If the foil of the flowpackaging changes to partly recycled content material, it needs to be checked if that foil is still printable. Facilitating this option can be done in two ways, namely buying the foil printed or installing a printer before the flowpackaging machine at line 1. The foil can be printed and bought at the current supplier. The other option is printing the foil at the packaging line before it is used to package the doughnuts. The goal of this adjustment is to enable customisation of the consumer packaging. By allowing print on the foil, the customers can choose their logo, colour or text and if text is used, it can be in the language of the destination country. When buying this foil printed from the supplier, there is less flexibility because EO already needs to finalise the design before ordering the printed foil. Next to that, there will be a lot of inventory from different designs/customers, which might not be used that often and could lead to waste. When installing a printer before the flowpackaging, the foil could be printed just before the doughnuts are packaged. The downside of this option is that it is an extra step in the process and especially when this step is down, the doughnuts cannot be packaged. This could lead to a waste of doughnuts. The advantage of this option is that the foil can be printed at the beginning of the process, which results in less inventory of different types of foil. The design needs to be ready just before the start of that shift with less waste of unnecessary foil. Both options would require more flexibility from EO. Regardless of the choice to enable printing on the foil, there also needs to be a confirmation that printing on recycled content material is possible. The printing of the tray is kind of similar to the printing of the foil since the trays can also be bought already printed or EO needs to

do that themselves. This means that the choice is similar to printed foil. It is important to take into account that ink or printing on the packaging is one of the criteria on which the packaging will be scored to determine the recycle score EuropianCommission (2024). Therefore, it is important to limit the amount of ink or printing on the packaging.

7.4.18 Adaptable language

There is no relationship with any of the packaging types for this requirement. The reason for this is that there is often no text on the packaging. If there is text on the packaging, it is in English. There is therefore no option to change the language. This, similar to the previous requirement, could be solved by customizing the trays or foil of the flowpackaging, but this requires a lot of flexibility. The labels that are placed on the packaging with the ingredient list and bar code, etc., can of course be in different languages, but this is the responsibility of the customers of EO.

7.4.19 Sustainable choice of material

This requirement is fully fulfilled by the blister packaging and flowpackaging without U-tray. Both packaging types consist of mono-material and there are no additives. However, if the foil of the flowpackaging is printed to enable the design of the customers, this requirement will be fulfilled less. The method of printing on the foil can also make the recyclability more difficult, so that needs to be taken into account as well. The flowpackaging with U-tray has a medium relationship. As already explained above, the reason for this is that the complete packaging consists of two material types. This could be increased to a strong relationship if the packaging would consist of one material for both the foil and the tray. Another option is to clearly indicate to the consumer that both parts of the packaging will have to be thrown away separately. This would not fix the fact that the packaging has two different materials, but it might result in the disposal of those two materials separately.

7.4.20 Sustainable perception to the customers

None of the packaging types have a strong relationship with this requirement. The reason for this is that plastics have a bad image regarding sustainability from the customer's perspective (Horsthuis et al., 2024). Therefore, the blister packaging has no relationship with this requirement. The flowpackaging with U-tray has a weak relationship with this requirement because it also uses carton. However, the carton is bleached and loses the sustainable look. This requirement is hard to fulfil completely because the use of plastic packaging material makes the most sense with regard to full recyclability and other characteristics. If the use of plastic is reduced in food packaging, this could lead to more food waste (Brouwer et al., 2020). Another option might be the use of carton/folding box/paperboard, but using one of these materials as a packaging material for a doughnut will require some kind of laminate to ensure that the carton does not take in all the oil and moisture from the doughnut. This laminate results in lower recyclability of the packaging. Next to that, a carton packaging would need some kind of screen to ensure the transparency/product display requirement. The flowpackaging with U-tray can use non-bleached carton, which is more sustainable. This carton will still need some kind of laminate to ensure that the moisture from the doughnut does not get in the carton. This could still be an HDPE laminate similar to the current trays. The only difference is that the carton does not get bleached. Next to that, the plastics that are used could be made from recycled content (which is already a requirement) and the packaging could state somewhere that the packaging is recyclable. This way, plastics could still be used.

7.4.21 Packaging has to be closed correctly

This requirement is for the packaging process. This is not a problem for the blister packaging, but the flowpackaging does not always get sealed correctly. The result of this is that the packaging is not closed correctly and the guarantee of freshness and the protection of the doughnuts decreases. It is important to make sure that the flowpackaging gets sealed correctly. At the moment, the shift leader takes 4 samples each hour in a shift and checks the doughnuts on weight and shape and if the packaging is correct. Samples could be taken more frequently to make sure that the machines work sufficiently. Another option is looking into a vision system at the end of the consumer packaging line before the consumer packaging ends up in secondary packaging. A vision system could check whether the flowpackaging is correctly sealed.

7.4.22 Packaging, material & number of doughnuts as agreed

This is a requirement for the packaging process as well. It sometimes happens that the packaging, material or number of doughnuts that customers receive are not as agreed. An example of this is the blister packaging with three or five minidots instead of four. Since the blister packaging is filled with doughnuts by employees, the main reason for this is human error. Similar to previous requirements, samples could be taken more frequently to ensure that this requirement is fulfilled. Again, another option could be a vision system at the end of the consumer packaging line.

7.5 Suggested changes and actions

The list of requirements above suggests different options for improving the packaging to fulfil the requirements of the customers or legislation. These suggestions are summarised in Table 7.8. The requirements are numbered for later use.

Table 7.8: Suggested changes/actions - summary

	Requirement	Suggested changes/actions	C/P	Blister	FP	FP Tray
1	Moisture permeability	Change material, thickness material or surface area	C	X		
2	Impact resistant	Add tray or fixed part to packaging	C		X	
3	**Chemical safety**	-				
4	Protection outside contamination	-				
5	Number of doughnuts	Enable more/different doughnut numbers	C	X	X	X
6	Type of doughnut	Enable mixboxes	C		X	X
7	Doughnut storage in packaging	Add tray or fixed part to packaging	C		X	
8	Easy to open/access	Add tray or fixed part to packaging	C		X	
9	**Disposal logo & Material composition**	Present necessary information on secondary packaging	P	X	X	X
10	**Recycle score C**	-				
11	**Recycled content**	Change to recycled content material	P	X	X	X
12	**Minimum amount of material**	Change surface area / reduce thickness material	P	X		X
13	Colour	-				
14	**Place for ingredient list, bar code, material & disposal information**	-				
15	**Required information present**	-				
16	Design of the customer	Enable printing on foil or trays, Customisation is really possible for blister packaging	C	 X	X	X
17	Adaptable language	Enable printing different languages on trays or foils No language on blister packaging	C	 X	X	X
18	Sustainable choice of material	Change to mono-material/indicate separate disposal Lower environmental footprint of the packaging	C			X
19	Sustainable perception to customers	Use unbleached trays and recycled content plastics Advertise on packaging with recycled content material	C C	X X	X X	X X
20	Packaging has to be closed correctly	Samples / vision system	C		X	X
21	Packaging, material & number of doughnuts	Samples / vision system	C	X	X	X

In this table, the requirements and suggestions are displayed and for which packaging type the suggestion is applicable. The column 'C/P' indicates whether this is a corrective (C) or preventive (P) change. The column 'Blister' is for the blister packaging, the column 'FP' is for the flowpackaging without U-tray and the 'FP Tray' is the flowpackaging with U-tray. As can be seen in the table, most changes/actions are corrective. Some of the suggestions in the table below correlate with each other, either positively or negatively. For example, the requirements 'doughnut storage in packaging' and 'easy to open/access' both have the same suggestion. So, if that suggestion is implemented, both requirements will be fulfilled for that packaging type. However, the requirement 'minimum amount of material' will be less adhered to, as the suggestion of those two requirements is to add material to the packaging. Next to that, it might also influence the recycling score. Therefore, it is important to take these correlations into account. As can be seen in Table 7.8 below, only 6 requirements out of the 21 do not have any suggested changes or actions for any of the packaging types. Next to that, some requirements need changes for all packaging types. An example of this is the requirement 'number of doughnuts' since all packaging types together have to enable all the different packaging sizes. Another example is the requirement 'Recycled content' since all packaging types make use of virgin materials. The blister packaging has 8 different changes out of the 21 requirements, the flowpackaging without U-tray has 13 different changes and the flowpackaging with U-tray has 12 different changes. Below,

the packaging types will be discussed separately to determine what changes can be made and how that would influence the sum of the target values.

Blister packaging

For the blister packaging, there are several changes to ensure a better relationship with the packaging requirements. The suggested changes are again shown below in Table 7.9. In the first column, the change is displayed. The second column shows the requirements that will be more fulfilled by the change. The numbers represent the numbered requirements from Table 7.8. The changes displayed in italics are obligatory requirements (legislation). The third, fourth and fifth columns are shown what the change has influenced. For example, to make sure the requirement 'change material, thickness material or surface area' gets implemented, the packaging needs to change. If that change is implemented, it will help requirements 1 and 13. The change 'enable more/different doughnut numbers' influences all three categories. The reason for this is that the number of doughnuts has to fit in the packaging, the packaging process needs to be adjusted and the portfolio needs to be adjusted. As already mentioned shortly above, some packaging types will not be able to reach the maximum target value of 9,77 due to the fact that the packaging cannot fulfil every requirement. For the blister packaging, this is the case for the requirements 'customisation', 'adaptable language' and 'sustainable perception to customers'. It is quite hard to customise blister packaging since it is standard packaging with not many options to change colour or text. Next to that, there is no text on the packaging, so there is also no language to adapt to the destination country. Finally, even if the packaging advertises recycled content material, there is still a realistic chance that the packaging will never have a completely sustainable perception to customers (Horsthuis et al., 2024). If these are taken into account, the maximum value that a blister packaging can get is a target value of 8,91 instead of 9,77.

Table 7.9: Suggested changes/actions - blister

Change/action	Requirements	Influence on		
		Packaging	Process	Portfolio
Change material, thickness material or surface area	1, 13	X		
Enable more/different doughnut numbers	5	X	X	X
Present necessary information on secondary packaging	9		X	
Change to recycled content material	11	X		
Advertise recycled content material on packaging	19	X		
Samples/vision system	20, 21		X	

As EO buys the blister packaging as consumer packaging, EO does not directly have a lot of influence on the surface area, material or material thickness. It is easiest to search for another type of blister that fits better for the current packaging requirements that are described above (Table 6.1). If EO can find a blister packaging that has a moisture permeability to enable the right amount of moisture loss, uses recycled content material and uses the minimum required material, a lot of requirements would get a strong relationship. If these packaging changes, together with more samples or a vision system in the packaging process, the relationship matrix would look like Figure 7.5. With these changes, the sum of the target value increases from 5,76 to 7,48. However, it might be difficult to find a blister that fits all the requirements to increase the target value to 7,48, especially for the same price per packaging. In case it is not possible to find that blister type that has all the requirements, it is important to look at the changes that are needed for the top 5 requirements, such as moisture permeability. Finally, the only suggested change/action that influences the portfolio is the change 'enable more/different doughnut numbers'. EO could look into the possibility of packaging more doughnut types and numbers in blister packaging, for example, the crodots. If this gets incorporated into the packaging portfolio, the packaging process will also have to enable this. In the matrix below, there is both a medium and strong relationship for the requirement 'number of doughnuts'. This is done because the portfolio overall has to incorporate more doughnut types and numbers. If more doughnut numbers/types are incorporated in the portfolio for blister packaging, the target value of this packaging type would increase even more, to 7,82 or 8,60 (medium or strong relationships). This means that if the blister packaging packages all doughnut types to get a strong relationship for each doughnut type, the maximum target value of the blister packaging is almost reached. The only requirement that needs to be improved to get to the maximum value is 'protection from outside contamination'.

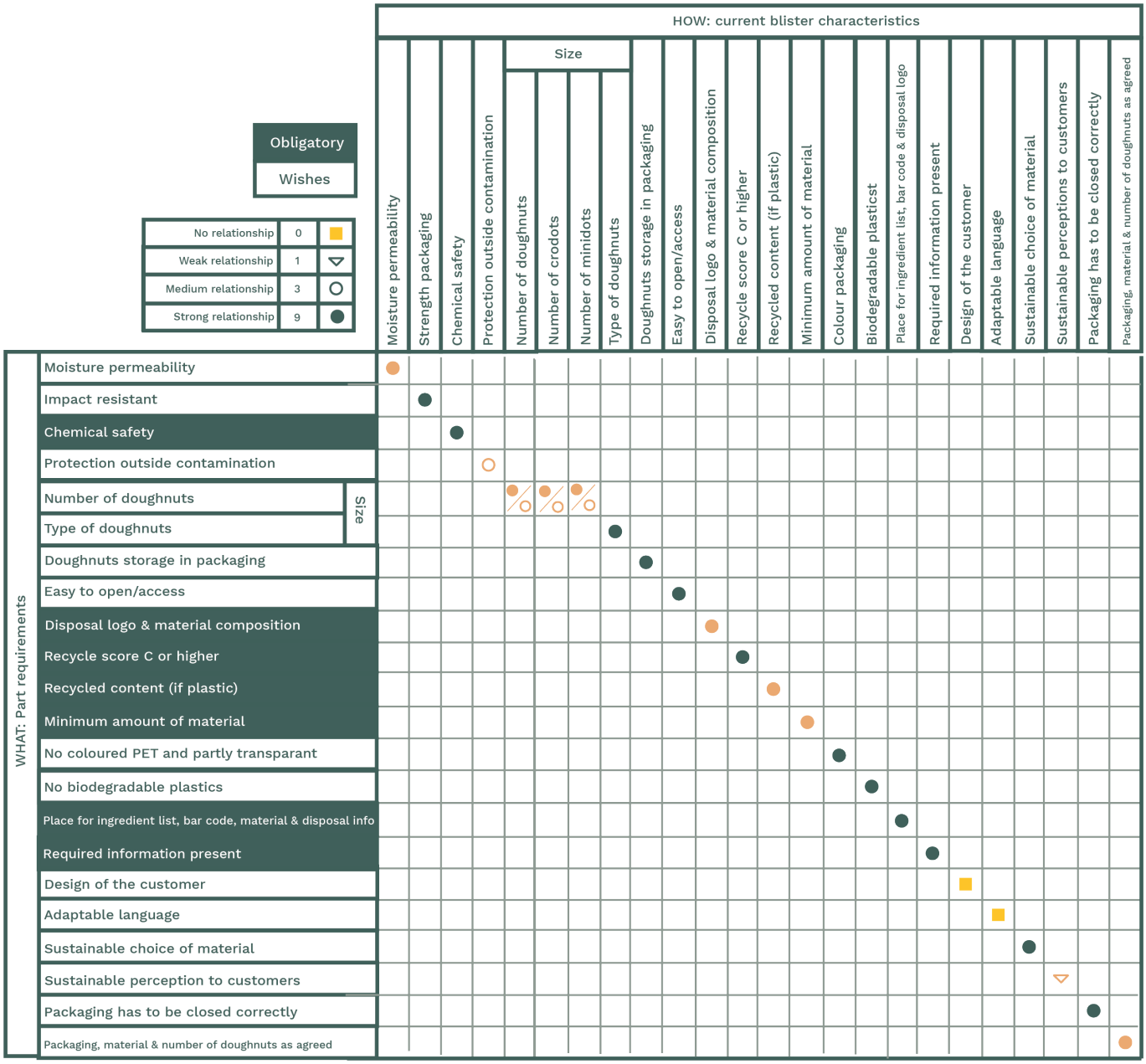

Figure 7.5: Relationship matrix - Blister packaging with suggested changes

Flowpackaging without U-tray

The suggested changes for the flowpackaging without U-tray are displayed in Table 7.10. Again, the obligatory changes are displayed in italics. Similar to the blister packaging, this packaging type cannot fulfil all requirements completely to reach the maximum target value of 9,77. The maximum target value for this packaging type is 9,55. The reason for this is that the requirements 'sustainable perception to customers' and 'easy to open/access' cannot be completely fulfilled. The reason for this is that plastics have a bad image regarding sustainability and the seal makes opening the packaging more difficult. As can be seen in the table, the suggestion 'Add tray or fixed part to packaging' is used for three different requirements. The difficult thing with the change is that the packaging ends up similar to the flowpackaging with U-tray. If that is the case, it might be more interesting to remove this packaging type from the portfolio. Another option is to add another part to the packaging so that it differs from the flowpackaging with U-tray.

Table 7.10: Suggested changes/actions - flowpackaging without U-tray

Change/action	Requirements	Influence on		
		Packaging	Process	Portfolio
Add tray or fixed part to packaging	2, 7, 8	X	X	
Enable more/different doughnut numbers	5	X	X	X
Enable mixboxes	6		X	X
Present necessary information on secondary packaging	9		X	
Change to recycled content material	11	X	X	
Enable printing on the foil	16		X	
Enable printing different languages on the foil	16		X	
Advertise recycled content material on packaging	19	X		
Samples/vision system	20, 21		X	

At other locations of Europastry, the packaging displayed in Figure 7.6 is used. This could be an option to improve this packaging type. It could also be an easy option since the knowledge to package this is already present within the company. It is important to note that if the addition to the packaging is the box shown below, there will be two types of material in the packaging. In this case, it is important to indicate separate disposal of the paper and plastic parts to encourage easier sorting and recycling.

Figure 7.6: Packaging at different locations of Europastry

Next to that, the only other changes specifically for the packaging are to use recycled content material and advertise it on the packaging. As already mentioned in the recycled content section above, there is not much known yet about using recycled content material in BOPP. Slowly, more possibilities arrive to recycle PP for food packaging, but this needs to be taken into account when changing to recycled content foil for the flowpackaging. Changes for the process include different numbers/types of doughnuts, enabling mixboxes, presenting necessary information on secondary packaging, enabling printing on the foil (in different languages) and taking samples to ensure that the packaging is correct. These changes will be discussed separately. First, the number/types of doughnuts would mean that the minidots or crodots would also have the possibility of being packaged in a flowpackaging without U-tray. This is a difficult option, as that is not possible at packaging line 1 at the moment. If EO wants to package the minidots or crodots in flowpackaging without U-tray, a flowpackaging machine has to be implemented at line 1, similar to the one on line 3. Next to the doughnut type, the number of doughnuts that get packaged in a flowpackaging without U-tray at the moment is 1, 2, 4 or 6. If this packaging type wants to have a strong relationship with the requirement, the uneven number 5 also has to be incorporated. This could be a challenge because the doughnuts will have to be packaged 2 at the top and 3 at the bottom. This might be a bit difficult to package correctly and ensure that there is no extra space so that the doughnuts could move in the packaging. If the tray or fixed part of Figure 7.6 were incorporated, it might be easier to package five doughnuts. The next change to the process is to enable mixboxes. This could be implemented, but adjustments might be made to line 3 to do this efficiently. Next to that, the change 'present necessary information on secondary packaging' will have an influence on the label that is on the secondary packaging. Next to the ingredients and best-before date, the disposal and material information need to be included. The next two changes for the process can be combined into enabling printing (in different languages) on the foil. Another method

would be buying the foil already printed. However, this might not be cost-efficient and EO will have a lot of different types of foil if they buy it already printed. Therefore, it might be more interesting to enable printing at the packaging lines since this would reduce foil inventory and mistakes are less easily made. For this change, the recyclability needs to be taken into account. If there is a lot of ink in the foil, the recyclability of the foil might decrease. Finally, the last process change is to take more samples during the packaging process. This could limit the number of packaging that are not closed correctly and the correct number of doughnuts in the packaging. So, all in all, the packaging would need some kind of tray or fixed part and use recycled content material to get better relationships with the requirements. Next to that, the process will have to be adjusted to enable printed foil and mixboxes. If all these things are implemented, the relationship matrix of the flowpackaging without U-tray would look like the one displayed in Figure 7.7.

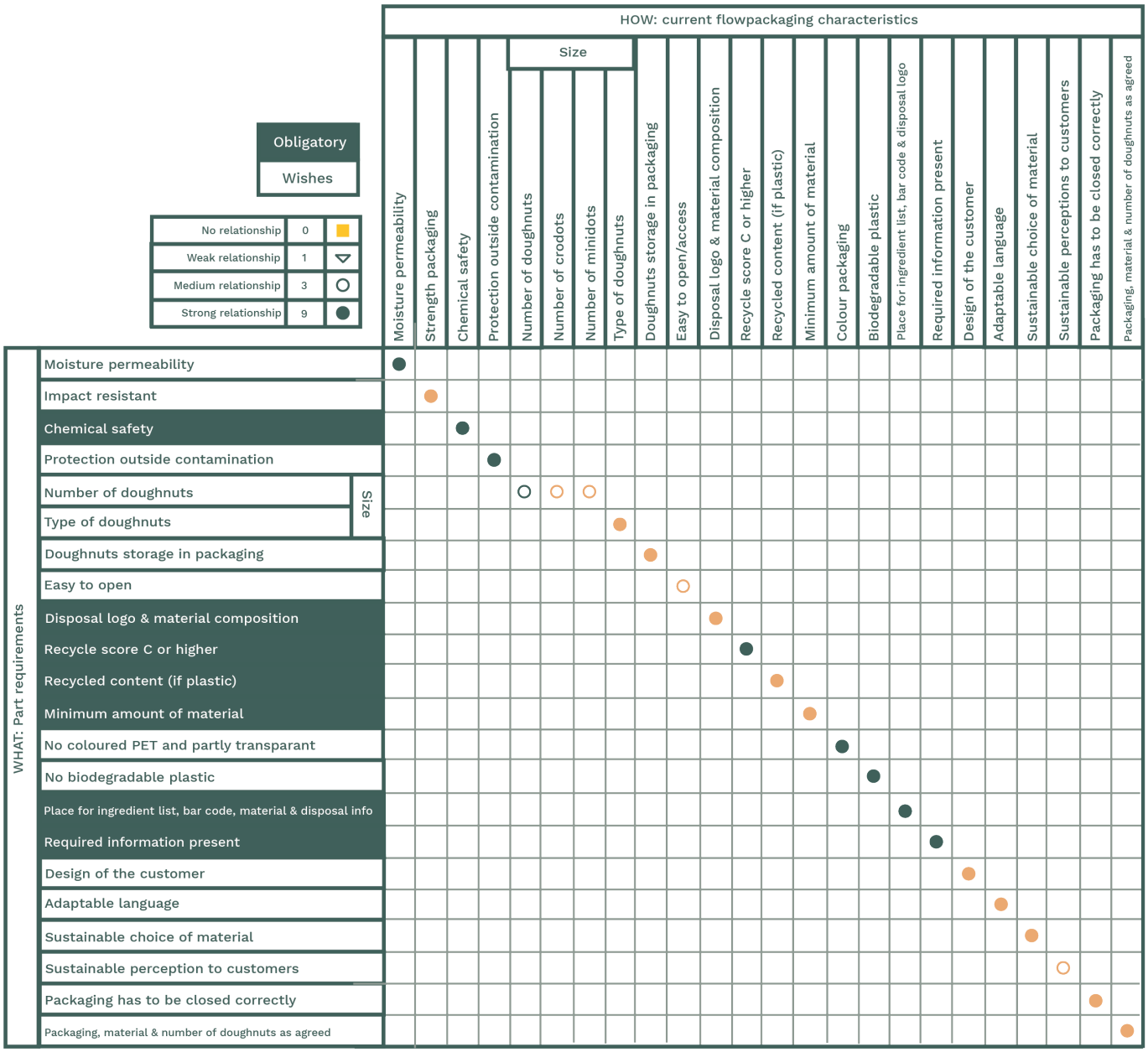

Figure 7.7: Relationship matrix - Flowpackaging without U-tray with suggested changes

With these changes, the target value would increase from 5,59 to 8,52. If minidots and crodots can also get packaged in this packaging type, the target value would increase to 8,78. The packaging does not get the maximum target value possible (9,55) because the number of doughnuts, crodots and minidots have a medium relationship. If the packaging of Figure 7.6 is chosen, the fixed part or tray might help package uneven numbers in this packaging type. This will, in turn, help increase the relationships with the other requirements. This way, the maximum target value for this packaging type might be reached.

Flowpackaging with U-tray

The final packaging type that will be discussed in this section is the flowpackaging with U-tray. This packaging type got the highest target value of all three packaging types of 5,88. The suggested changes and/or actions for the flowpackaging with U-tray are shown in Table 7.11. Similar to the previous two tables, the obligatory changes are displayed in italics. The maximum possible target value of this packaging type is similar to the flowpackaging without U-tray, namely 9,55. If the changes from the table above are implemented, the relationship matrix changes to the one in Figure 7.8. The target value would increase from 5,88 to 8,52. If the number of doughnuts, crodots and minidots would have a medium relationship each, the target value would increase to 8,78. The first change action is to enable more/different doughnut numbers for this packaging type. This change influences the packaging, process and portfolio. To enable this, the shape of the packaging might have to change in some cases. The doughnuts and crodots are already packaged in this packaging, but the minidots are not. The minidots might be able to be packaged in this packaging at line 1 with minimal adjustments to the packaging line. The shape of the packaging might have to change as minidots are smaller. Similar to the change for the flowpackaging without U-tray, it might be hard to package doughnuts in uneven numbers. It would be a bit easier compared to the flowpackaging without U-tray, but the machines will have to make 'triangle' shapes in the packaging like 1 on top and 2 below or 2 on top and 3 below to package 3 or 5 doughnuts. That might cause space in the packaging, which might result in the doughnuts moving in the packaging. This could cause damage to the doughnuts. If the doughnuts could be placed in the trays standing, it would be easier to package uneven numbers. However, the current setup of both lines does not facilitate this option.

Table 7.11: Suggested changes/actions - flowpackaging with U-tray

Change/action	Requirements	Influence on		
		Packaging	Process	Portfolio
Enable more/different doughnut numbers	5	X	X	X
Enable mixboxes	6		X	X
Present necessary information on secondary packaging	9		X	
Change to recycled content material	11	X	X	
Change surface area/thickness material	12	X	X	
Enable printing on the foil and tray	16		X	
Enable printing different languages on the foil and tray	17		X	
Change to one material/indicate separate disposal	18	X	X	
Use unbleached trays and recycled plastics	19	X		
Advertise recycled content material on packaging	19	X		
Samples/vision system	20, 21		X	

To create mixboxes (the second suggested change) with this packaging type, the lines would have to be adjusted. The next suggested change is to present the necessary information regarding disposal and material on the secondary packaging. The fourth suggested change is changing to recycled content material instead of virgin material. Similar to the flowpackaging without U-tray, EO needs to look into the possibilities and material properties of recycled content BOPP. The next suggestion is to change the surface area or thickness of the material to decrease the amount of material used. The U-tray especially might be a bit thinner, as it has a thickness of 6 - 8 mm at the moment. However, it might be difficult to get a strong relationship with this requirement for this packaging type, as there will always be a trade-off between the protection & convenience of the packaging versus the amount of material. The fourth and fifth suggested changes concern the printing on the foil and tray. This change is quite similar to the one described for the flowpackaging without U-tray. At the moment, the trays get bought with prints so that EO does not have to do that themselves. If, however, this would be incorporated in the packaging line, the U-trays will have to be printed before they are folded. This would extend the packaging process with an extra step. The next suggested change is changing to one type of material or to indicate separate disposal. This would ensure that the packaging can be recycled correctly. If the paper-based tray is changed into a tray made of PP, the packaging would have a less sustainable perception to customers. The separate disposal indication could also do the job, but then, EO leaves the choice to the consumers of the doughnuts. A tray made of PP could also not be customisable since it is not possible to print on a PP tray.

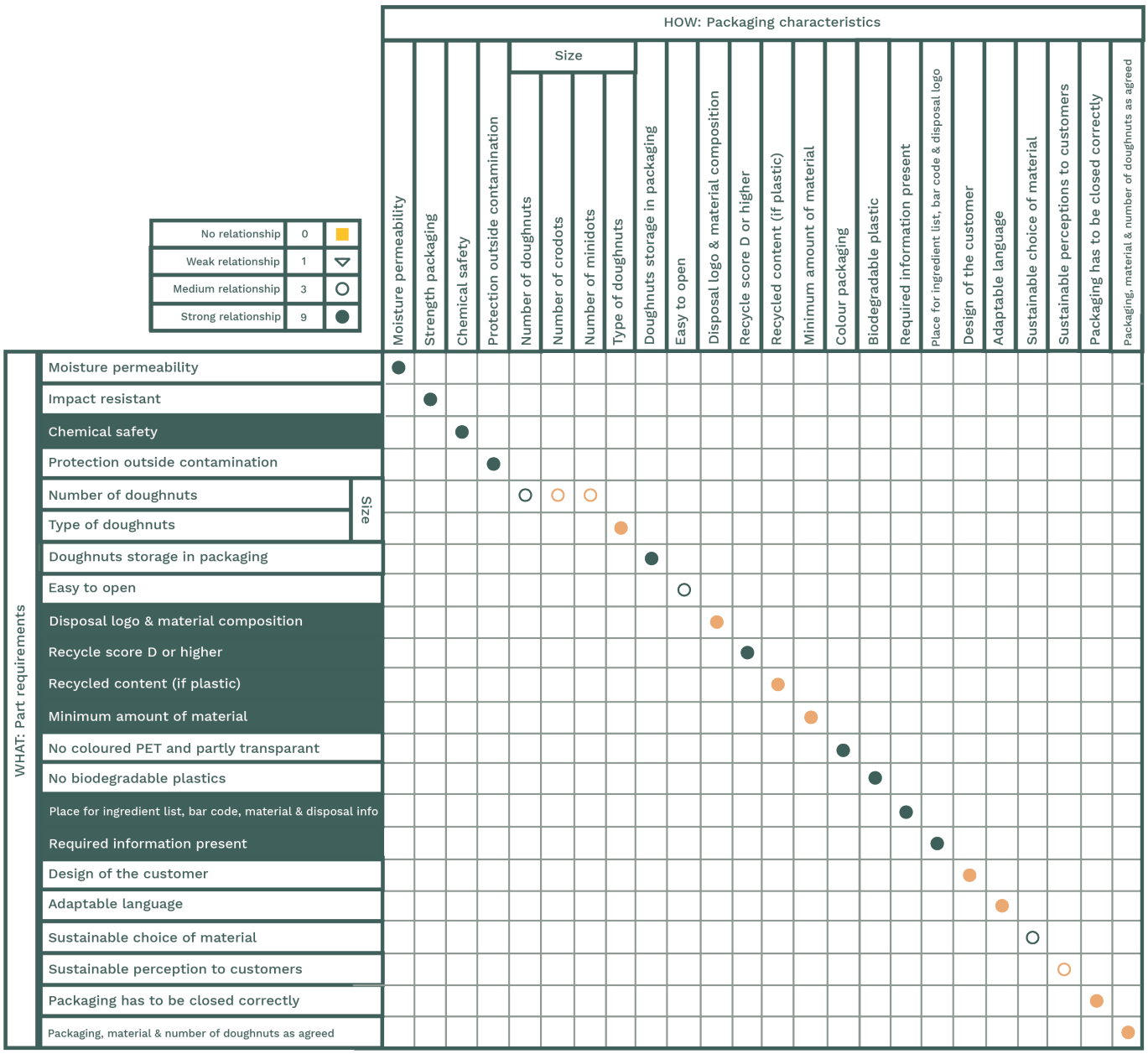

Figure 7.8: Relationship matrix - Flowpackaging with U-tray with suggested changes

Looking at the change in the sum of the target value, EO would benefit more from a PP tray compared to the sustainable perception and customizability. For that reason, the suggestion will be to change to one type of material. Next to that, the minimum amount of material might also benefit from this change, as the weight of PP is much lower compared to the carton. The moisture permeability of the packaging overall might change when a PP tray is used. Even though the current tray does not (fully) 'accept' the moisture from the doughnut due to the laminate, when switching to a PP tray, small droplets of moisture might appear on the plastic. Furthermore, the flowpackaging machine at line 3 might not be able to use PP trays instead of carton, but this will be discussed in more detail in the next chapter. Another thing to take into account is that when EO changes the foil to PET foil (or something else) to ensure the recycled content material, the tray needs to change to PET as well. The seventh and eighth suggested changes are the last changes that influence the packaging. These suggested changes include the use of unbleached trays and recycled plastics and advertising the recycled content material on the packaging to improve the sustainable perception to the customers. The recycled plastics are already described above and the unbleached trays could be purchased instead of the bleached trays. The last two suggested changes are similar to the last two of the flowpackaging without U-tray, that more samples could be taken to ensure that the packaging is closed correctly and the correct number of doughnuts is inside the packaging.

7.5.1 Conclusion suggested changes

Looking at the packaging types, the blister packaging could increase to a target value of 7,48 (7,82 or 8,60 with more doughnut types), the flowpackaging without U-tray could increase to a target value of 8,58 (8,83 with more doughnut types) and the flowpackaging with U-tray could increase to a target value of 8,30 (8,58 with more doughnut types). This means that the flowpackaging with U-tray still performs best when the extra doughnut types are not taken into account. The reason that the target values with more doughnut types are included in brackets/separately is that this is a requirement that has to be met using all packaging types. If all consumer packaging types would stay in production and together they package all the doughnut types and numbers, the portfolio would be sufficient as the customers can choose the doughnut types and numbers. However, a customer of EO could want the minidots specifically in a flowpackaging with U-tray, so it might be beneficial to 'mix and match' the doughnuts types, number of doughnuts and packaging type. This does require a lot of flexibility from EO. Even if all the doughnut types are included in the sums of the target value, none of the packaging types have a perfect score of 10,25. The reason for this, as already discussed for each packaging type separately, is that even though the changes increase the sum of the target value, the packaging types might not perfectly fit the wishes of the customers. For example, it is quite hard to use plastics to get a very sustainable perception for the customers that buy the doughnuts in the store. For this, a different packaging type might be more interesting. However, with the changes, both the flowpackaging types have a medium or strong relationship with all requirements. The blister packaging has three requirements without a relationship. This is mostly because the blister packaging is not really customizable and does not have a sustainable perception. The obligatory requirements of the legislation are all adhered to with the suggested changes. To finalize this chapter, Table 7.12 shows the changes per packaging type that are discussed in this chapter. In the final column, the details of each change are specified. The changes displayed in bold are obligatory to adhere to legislation.

Table 7.12: Final suggested changes/actions

Packaging type	Change/action	Details
Blister packaging	**Change material, thickness material or surface area**	To have a guarantee of freshness of three days **To minimize amount of material used**
	Present necessary information on secondary packaging	**Material composition and disposal information**
	Change to recycled content material	**To adhere to legislation**
	Enable more/different doughnut numbers	Package (un)filled doughnuts, crodots and minidots in blister packaging In multiple numbers
	Advertise recycled content material on packaging	To increase the sustainable perception to customers
	Samples/vision system	To ensure that the packaging is closed and consists of the correct material and number of doughnuts
Flowpackaging	**Present necessary information on secondary packaging**	**Material composition and disposal information**
	Change to recycled content material	**To adhere to legislation**
	Add tray or fixed part to packaging	For mechanical protection Storing doughnuts in the packaging To open the packaging easily
	Enable more/different doughnut numbers	Package (un)filled doughnuts, crodots and minidots in flowpackaging In multiple numbers
	Enable mixboxes	To package different types of doughnuts in flowpackaging
	Enable printing on the foil in different languages	To enable customization and local languages
	Advertise recycled content material on packaging	To increase the sustainable perception to customers
	Samples/vision system	To ensure that the packaging is closed and consists of the correct material and number of doughnuts
Flowpackaging (U-tray)	**Present necessary information on secondary packaging**	**Material composition and disposal information**
	Change to recycled content material	**To adhere to legislation**
	Change surface area/thickness material	**To minimize material used**
	Enable more/different doughnut numbers	Package (un)filled doughnuts, crodots and minidots in flowpackaging In multiple numbers
	Enable mixboxes	To package different types of doughnuts in flowpackaging
	Enable printing on the foil in different languages	To enable customization and local languages
	Change to one material	To have a sustainable choice of material
	Advertise recycled content material on packaging	To increase the sustainable perception to customers
	Samples/vision system	To ensure that the packaging is closed and consists of the correct material and number of doughnuts

8 Part 4: QFD - Phase 3

In this chapter, part 4 of the methodology: QFD - phase 3, will be described. Phase 3 of the QFD consists of the process planning. Figure 8.1 shows the matrix for this phase. As can be seen, the WHATs will be the process changes for each packaging type and the HOWs will be packaging lines 1, 3 and both lines and/or general processes. For the flowpackaging without U-tray and the blister packaging, the matrix is blurred for lines 1 or 3. The reason for this is that the packaging type is not possible/used at those lines at the moment. However, they are blurred instead of removed because enabling those packaging types at the lines might be interesting. In this chapter, the first section will describe the WHAT and HOW in more detail. Section 8.2 describes the relationship between the WHAT and HOW and Section 8.3 will evaluate the process changes at lines 1 and 3 based on the target values. The complete matrix can be found in Appendix H.

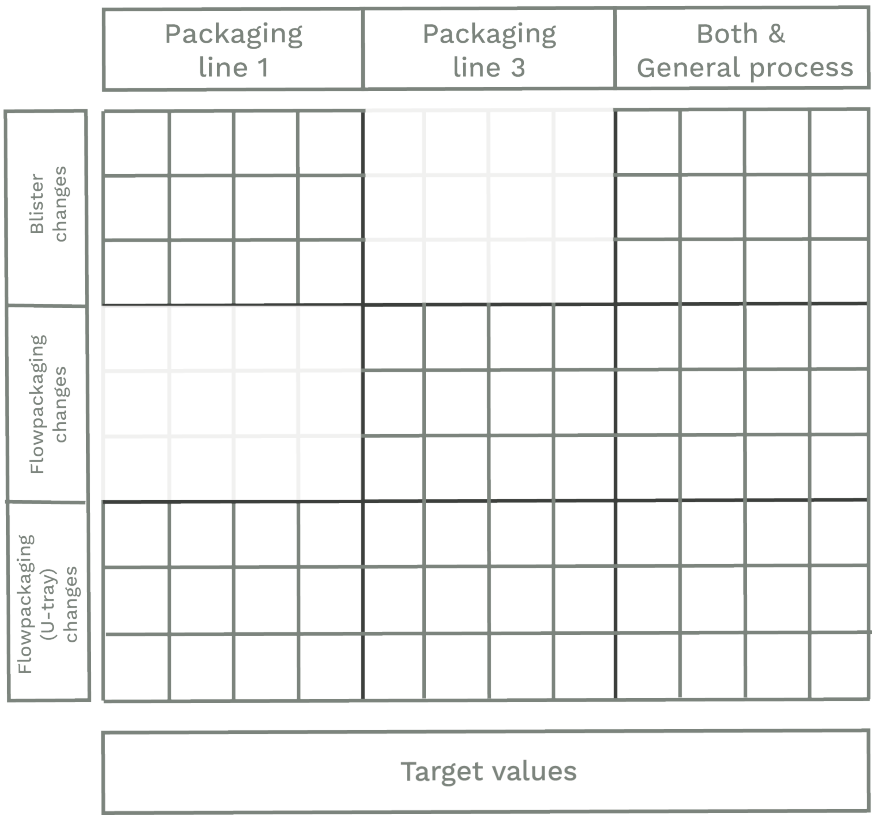

Figure 8.1: Matrix Phase 3 - process planning

8.1 Step 3.1 & 3.2: WHAT and HOW

In this section, the WHAT and the HOW of this phase will be discussed. The WHAT of this phase will be the identified changes in the previous chapter that influence the packaging process. These changes are shown per packaging type in Table 8.1. The changes displayed in italics are obligatory. The changes are based on Table 7.12, looking at both the direct process changes and the changes in the process due to a change in the packaging. For example, the flowpackaging without U-tray has the change 'add tray or fixed part to the packaging'. This results in an extra process step where this tray or fixed part is included in the packaging. Another example is 'advertise recycled content material on packaging'. This could be incorporated into the process by placing a sticker or printing it on the foil of the packaging. However, when a sticker is added to the packaging, the recyclability of the packaging might decrease, as there is an added layer and glue on the packaging. Similar to adding extra ink on the foil of the flowpackaging. This will counteract the sustainability of the packaging, while recycled content should mostly be beneficial for the environment. Next to that, adding a sticker to every blister packaging is very much work. Next to that, advertising recycled content on the packaging might be more beneficial for the customers of EO. Therefore, it might be best to make this the responsibility of the customers. This way, the customers of EO can decide for themselves if they want to implement it and how. Therefore, it will not be added to the matrix for this phase and is not in the table below. In the column 'target value' the target value is displayed for this change. This target value

is determined by the (sum of the) target value of the requirement(s) that would be fixed by that change. For example, the change 'Close packaging completely' for the blister packaging has a target value of 6,48. This is the sum of the target values of the requirements 'Moisture permeability' and 'Protection from outside contamination'. In the last column, the normalised target value over all changes is displayed.

Table 8.1: WHAT QFD Phase 3

Packaging type	Change	Target value	Norm. target value
Blister packaging	Enable more different types of doughnut	2,39	0,04
	Enable more numbers of doughnuts	2,39	0,04
	Present necessary information on secondary packaging	3,08	0,05
	Samples/Vision system	4,195	0,07
Flowpackaging without U-tray	Incorporate tray/fixed part to packaging	5,83	0,10
	Enable more different types of doughnut	2,39	0,04
	Enable more numbers of doughnuts	2,39	0,04
	Enable mixboxes	0,89	0,01
	Present necessary information on secondary packaging	3,08	0,05
	Change to recycled content material	2,65	0,04
	Enable printing on the foil	1,04	0,02
	Enable printing different languages on the foil	2,97	0,05
	Samples/Vision system	4,19	0,07
Flowpackaging with U-tray	Enable more different types of doughnut	2,39	0,04
	Enable more numbers of doughnuts	2,39	0,04
	Enable mixboxes	0,89	0,01
	Present necessary information on secondary packaging	3,08	0,05
	Change to recycled content material	2,65	0,04
	Change surface area/thickness material tray	2,79	0,05
	Enable printing on the foil	1,04	0,02
	Enable printing different languages on the foil	2,97	0,05
	Samples/Vision system	4,19	0,07

The HOW of this phase is displayed in Table 8.2. These are determined based on the necessary adjustments to the packaging lines to incorporate all changes (WHATs). As displayed in Figure 8.1, there are three categories, namely, line 1, line 3 and both/general. Each adjustment will be discussed below the table.

Table 8.2: HOW QFD Phase 3

Packaging line	Adjustment to the packaging process
Line 1	Add SKUs to the schedule
	Incorporate processes to package in flowpackaging without U-tray
	Enable mixboxes at the packaging line in flowpackaging with and without U-tray
	Change to recycled content material (plastics)
Line 3	Add SKUs to the schedule
	Adjust the packaging line to fixed part/tray for flowpackaging without U-tray
	Enable mixboxes at the packaging line
	Change to recycled content material (plastics)
	Adjust processes on change in material/thickness trays
Both lines/general	Enable printed foil in the packaging process
	Extra employee/vision system to take samples
	Adjust labels on secondary packaging

8.1.1 Packaging line 1

In this subsection, the adjustments to packaging line 1 will be discussed in more detail.

Add SKUs to the schedule

This adjustment enables multiple changes from the previous chapter. EO could add SKUs to be able to:

- Package more minidot numbers in blister packaging
- Package more crodot and unfilled doughnut numbers in flowpackaging with U-tray

- Package crodots and unfilled doughnuts in blister packaging
- Package mixboxes with crodots, minidots and unfilled doughnuts in flowpackaging without U-tray
- Package mixboxes with crodots, minidots and unfilled doughnuts in flowpackaging with U-tray
- Package mixboxes with crodots and minidots in blister packaging

These SKUs will enlarge the portfolio quite a lot. It might not be necessary to add SKUs to incorporate all these bullet points. This change to the packaging line is closely connected to the similar change on line 3 since these two changes together need to enable more doughnut numbers, types and mixboxes. The changes that more SKUs will have on the packaging line are not that much as almost everything at line 1 is done by manual labour, which also has a lot of flexibility. If the crodots or unfilled doughnuts need to be packaged in blisters, maybe new blister types will have to be bought. However, this does not change much in the packaging line itself. To package mixboxes, some changes might be necessary, but this is discussed below.

Incorporate processes to package in flowpackaging without U-tray
At the moment, it is not possible at line 1 to package crodots, minidots or unfilled doughnuts in flowpackaging without U-tray. How this can be incorporated into the packaging process depends on the changes made to the flowpackaging without U-tray. If the tray/fixed part that is added to the packaging is similar to the one in Figure 7.6, the changes to the process could be taken from other production locations of Europastry. To be able to incorporate this adjustment into the packaging line, the tray/fixed part should first be determined. However, since the consumer packaging at line 1 is packaged almost completely by hand, this packaging type could be added to the packaging options of line 1 quite easily. It might be necessary to schedule more employees to enable the extra process step(s). Some employees will need to fold the tray in the right position and afterwards, the doughnuts will need to be placed in that tray. The steps are comparable to the ones of the current flowpackaging with U-tray, there are around 10 employees needed. Another option is to look into cobots (collaborative robots). Robots can help increase productivity in the food industry. According to the results of the simulation of the packaging lines of van der Meer (2024), cobots could help EO with packaging the doughnuts. Within the food industry, robots are most often used within the packaging department. Additionally, robots can increase food safety and hygiene levels (Duong et al., 2020). Finally, cobots can collaborate well with employees. This could give EO the option to reduce the number of employees at the line since they can be difficult to find. Since cobots have a high variation in settings, it also enables flexibility in tasks (van der Meer, 2024).

Enable mixboxes at the packaging line in flowpackaging with and without U-tray
This change does not need a major adjustment to the packaging line, since the trays are already packaged by hand. The only change will be that the different types of doughnuts will have to be taken from the warehouse to be packaged. An employee needs to take one doughnut from each doughnut type and place them together in a tray. This tray will then get a foil and be sealed just like flowpackaging with one type of doughnut. The only change is that the doughnuts do not arrive directly from the production lines, but from the inventory. It is important to make sure that samples are taken to ensure that there is limited human error and each doughnut type is in the packaging once.

Change to recycled content material (plastics)
The changes on the line for this suggested change depend on the mechanical properties of the new material with recycled content. If it is still BOPP foil, not many changes might be necessary, but the sealing process might need to be re-optimized. If the foil changes in material type, the sealing properties of this material have to be acceptable for the flowpackaging machine on line 1. If the properties do work for the flowpackaging machine on line 1, the settings might have to be adjusted, but that might be the only change. Next to the change in settings, the fact that the foil consists of recycled content material will be the responsibility of the supplier.

8.1.2 Packaging line 3

In this subsection, the adjustments to packaging line 3 will be discussed in more detail.

Add SKUs to the schedule
This adjustment enables multiple changes from the previous chapter. EO could add SKUs to be able to:

- Package filled doughnuts in blister packaging
- Package more filled doughnuts numbers in flowpackaging with U-tray
- Package more filled doughnut numbers in flowpackaging without U-tray
- Package mixboxes with filled doughnuts in flowpackaging without U-tray
- Package mixboxes with filled doughnuts in flowpackaging with U-tray
- Package mixboxes with filled doughnuts in blister packaging

As already said above, this change and the same change on line 1 could be combined. However, this change could need adjustments on the packaging line as follows. If the filled doughnuts get packaged in blister packaging, this will need to be done at the bulk packaging line part of line 3. This part of the packaging line does not need any adjustments, as the only change is that the employees do not package the doughnuts in bulk but in blister packaging. When the doughnuts are in the blister packaging, they can continue to the rest of the packaging line to get packaged into secondary packaging (American boxes). If more filled doughnuts get packaged in flowpackaging with U-tray, this will need to be the uneven numbers. The uneven numbers cannot really be packaged in the current U-trays, because the doughnuts can start moving within the packaging. An option is to not include this and keep the packaging as it is, or maybe look into placing the doughnuts standing in the U-tray. This is, however, not possible at the moment. If more filled doughnut numbers get packaged in flowpackaging without U-tray, this depends on the changes to the packaging itself. This will be described in more detail in the next HOW. The last three bullet points concern the mixboxes with different types of filled doughnuts on line 3. How this can be implemented at packaging line 3 will be discussed below.

Adjust the packaging line to fixed part/tray flowpackaging without U-tray
How this adjustment will look in reality really depends on the fixed part or tray that will be added to the flowpackaging. If the part from Figure 7.6 will be added, EO can look at different plants of Europastry for inspiration. At the moment, the U-trays are arriving at the consumer packaging line by a universal feeder. This feeder only accepts flat products. If the box/tray from Figure 7.6 is used, this feeder might need to be replaced by something else. Another option is that this box/tray is folded in the consumer packaging process, so after it arrives at the consumer packaging line and before the doughnuts are placed in them. However, this would also mean an adjustment to the packaging line. This could be done if the conveyor line before the flowpackaging machine were extended. This way, employees or maybe cobots could fold the box/tray and place the doughnuts in there. Afterwards, the box/tray with the doughnuts can go through the flowpackaging machine to finish the flowpackaging. Instead of these two options, EO could, as mentioned before, also use the knowledge from other Europastry sites to enable this packaging type.

Enable mixboxes at the packaging line
Mixboxes at line 3 could quite easily be included for the blister packaging. This does not differ from the same type of filled doughnuts in the blister packaging, only the different types need to be taken from inventory. Packaging mixboxes in the flowpackaging with or without U-tray might be a bit more challenging. The different types of doughnuts need to arrive at the start of the flowpackaging machine in the right order to be packaged correctly in a flowpackaging. It will probably be easiest to manually place the doughnuts from the inventory boxes in the correct order at the conveyor belt before the flowpackaging machine. The only problem is that the conveyor belt is too short to be able to do this efficiently with more than 2 employees. If EO wants to incorporate this option of packaging mixboxes in flowpackaging, it might be easier to extend the conveyor belt before the flowpackaging machine so that there is more space to correctly place the filled doughnuts in the right order by employees.

Change to recycled content material (plastics)
This change is quite similar to the one from line 1. However, as the machine on line 3 is different to the one on line 1, the settings of the machine might differ a bit from the one on line 1. Still, the mechanical properties of the foil need to be inspected to set the machine up correctly. Again, the fact that the foil consists of recycled content material will be the responsibility of the supplier.

Adjust processes on change in material/thickness trays
This change depends on how the trays are adjusted. If EO chooses to for the (unbleached) carton trays, but maybe with a decreased thickness, the folding of the trays has to be adjusted accordingly. The settings of that part of the packaging line

will have to be changed so that the trays are folded correctly. Furthermore, the flowpack machine of line 3 will have to be adjusted to the new dimensions of the tray. If EO chooses PP trays, these will have to be bought and incorporated at the line. Unfortunately, the flowpack machine of line 3 cannot work with the PP trays. The reason for this is that the part of the machine that makes sure that the trays are part of the packaging can only work with flat products. This means that if the choice is made for a PP tray, this part of the packaging line will have to be changed in a way that the PP trays can be incorporated.

8.1.3 Both lines & general processes

In this subsection, the adjustments to both lines or general packaging processes will be discussed in more detail.

Enable printed foil in the packaging process
The first adjustment for both packaging lines 1 & 3 is to make sure that the foil of the flowpackaging is printed. As already discussed in the previous chapter, this can be done in two ways, namely, buying the foil printed or installing a printer before the flowpackaging machines. Both options have benefits and downsides. In the next chapter (Chapter 9), the costs for each adjustment will be determined. Maybe this will make the choice between the two easier.

Samples/vision system
To make sure that more samples are taken to ensure the correct packaging of the correct number of doughnuts, an extra employee could be placed at the packaging line. This employee could check both lines 1 and 3 during a shift since the employee has enough time to do both. Instead of an extra employee, the shift leader of those lines could also take more samples, but he/she needs to have enough time to do that. Another option could be, as already mentioned earlier, installing vision systems at the end of the consumer packaging line before the secondary packaging. This vision system could check if the seal of the flowpackaging is correct, if there are the right number of doughnuts in the packaging, etc. This vision system could also for example check whether the doughnuts have the right diameter or that the doughnuts are coated correctly. This way, fewer 'faulty' doughnuts and consumer packaging will be sent to the customers.

Adjust labels on secondary packaging
The labels on the secondary packaging will have to be adjusted to add information about the material of the packaging and the disposal. This will be a one-time change to the standard labels per packaging type.

8.2 Step 3.3: Relationship matrix

Now that the WHAT and HOW are determined in the previous section, the relationship matrix can be developed. The matrix is displayed in Figure 8.2. For this matrix, the relationships are displayed by a circle and there are no differences in the strength of the relationship. The reason for this is that if a certain change is implemented, a specific adjustment for the packaging line is necessary. For example, if more number of doughnuts are enabled for the blister packaging, packaging lines 1 and 3 both need to schedule more SKUs for doughnuts in blister packaging. As can be seen in the figure, each packaging change (WHAT) has a relationship with a process adjustment (HOW), so EO can implement all packaging changes when preferred. Some packaging changes have two or more relationships. For example, enabling mixboxes for the flowpackaging without U-tray has four relationships. When this change gets implemented, both packaging lines need to add SKUs to the schedule and make an adjustment to the packaging line. So, for each line, two things need to happen before the mixboxes with flowpackaging without U-tray are possible. However, it is also possible that one of the two lines implements mixboxes and the other line does not implement the adjustments. This is also the case for enabling mixboxes for the flowpackaging with U-tray.

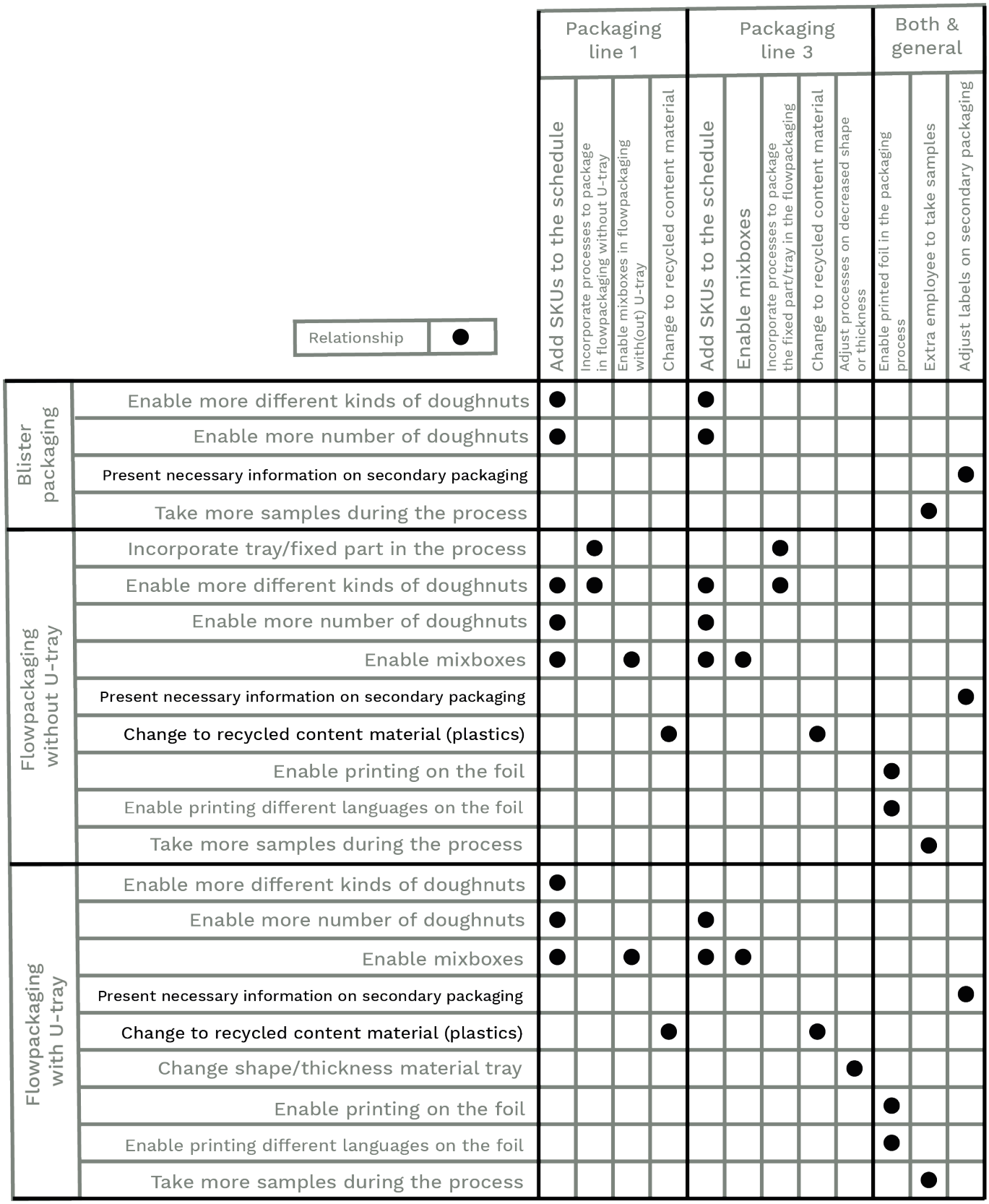

Figure 8.2: Matrix Phase 3

8.3 Step 3.4: Evaluation

The (normalised) target values of the process changes are displayed in Table 8.3, these are sorted from high to low. The process change with the highest target value is to add SKUs to the schedule at line 1. The reason for this is that this process change has a relationship with 8 different packaging changes. Even though those packaging changes are not the most important ones, they still add up. The second process change in the table is to add SKUs to the schedule at line 3. The reason that this one has a lower target value compared to the one from line 1 is that the flowpackaging with U-tray cannot easily package uneven numbers, so this process change does not have a relationship with the packaging change 'enable more types of doughnuts' for the flowpackaging with U-tray. The third one is to add an extra employee to take samples. This change only has three relationships (one for each packaging type), but the target value of this packaging change is high. What is interesting to note is that the obligatory process changes are to adjust the labels on the secondary packaging for the material composition and disposal logo and to change the settings/processes of both lines to recycled content material. These three process changes did not end up at the top of this table. The reason for this might be that the process changes are specifically made for the obligatory packaging change. Therefore, there are no relationships with other packaging changes. Even though the target values of the obligatory packaging changes are quite high, they still only 'solve' one packaging change.

Table 8.3: Target Values process changes (sorted high to low)

HOW	Target Value	Norm. Target Value (%)
Add SKUs to the schedule (line 1)	0,27	0,17
Add SKUs to the schedule (line 3)	0,23	0,15
Samples/vision system	0,21	0,13
Adjust labels on secondary packaging (both)	0,15	0,10
Incorporate processes to package in flowpackaging without U-tray (line 1)	0,14	0,09
Adjust the packaging line to fixed part/tray flowpackaging without U-tray (line 3)	0,14	0,09
Enable printed foil in the packaging process (both)	0,13	0,09
Change to recycled content material (line 1)	0,09	0,06
Change to recycled content material (line 3)	0,09	0,06
Adjust processes on change in material/thickness trays	0,05	0,03
Enable mixboxes at the packaging line in flowpackaging with and without U-tray (line 1)	0,03	0,02
Enable mixboxes at the packaging line in flowpackaging with and without U-tray	0,03	0,02

8.4 Conclusion QFD phases

Now that all the QFD phases (parts 1 - 4 of the methodology (Ch. 4)) have been performed, a conclusion can be drawn. The conclusion will start at phase 1 and continue chronologically. The start of phase 1 of the QFD was collecting data regarding the customers and legislation requirements. These requirements were the WHAT of phase 1. The HOW of phase 1 were the main and relevant packaging functions. These WHAT and HOW were put in a relationship matrix to see how they relate to each other. The most important packaging functions were embodying, recyclable, presentation, preservation and avoidance of waste. In this phase, a competitor assessment was performed as well. Competitors from both the doughnuts and the consumer packaging of doughnuts were tested on the customer and legislation requirements. This competitor matrix concluded that the packaging with U-tray performed better than most competitors, but the other two packaging types performed a bit less than some companies. From phase 1, the most important packaging functions were determined and it could be seen how the packaging types lie in the market. The next phase was phase 2: parts deployment. In this phase, the packaging requirements could be determined. The WHAT of this phase were the HOW of the previous phase, so the packaging functions. The HOW of this phase were the part requirements. Within these part requirements, the distinction was made on which requirements were obligatory or not. The legislation requirements were obligatory to adhere to since that determines whether a packaging type can enter the market or not. From this phase, the most important part requirements could be determined. The most important part requirements from this phase were:

- Chemical safety
- No biodegradable plastics
- Moisture permeability
- Recycle score C or higher
- Disposal logo & material composition

What mostly could be concluded from this phase and the target values of the part requirements was that the requirements regarding convenience were at the bottom of the list with the lowest target values. It was interesting to note that not all obligatory requirements ended up in the top 5 of the part requirements based on the target values. After phase 2, it was time to compare the results of phase 2 to the current consumer packaging of EO. The comparison between these two was made by putting the part requirements on one side of the matrix and the packaging characteristics on the other side. This way, a relationship matrix could be made and the sum of the target values could show how the packaging type scores. The maximum target value that could be reached was 9,77 and all packaging types scored between 5,59 and 5,82. However, for each packaging type, it was not realistic to reach the maximum target value. The reason for this was for example that it is really difficult to customise a blister packaging. Therefore, this packaging type will never have a strong relationship with the requirement. Nevertheless, changes were identified to increase the target value of the packaging types. These suggested changes are displayed in Table 8.4.

Table 8.4: Final suggested changes/actions

Packaging type	Change/action	Details
Blister packaging	**Change material, thickness material or surface area**	To have a guarantee of freshness of three days **To minimize amount of material used**
	Present necessary information on secondary packaging	**Material composition and disposal information**
	Change to recycled content material	**To adhere to legislation**
	Enable more/different doughnut numbers	Package (un)filled doughnuts, crodots and minidots in blister packaging In multiple numbers
	Advertise recycled content material on packaging	To increase the sustainable perception to customers
	Samples/Vision system	To ensure that the packaging is closed and consists of the correct material and number of doughnuts
Flowpackaging	**Present necessary information on secondary packaging**	**Material composition and disposal information**
	Change to recycled content material	**To adhere to legislation**
	Add tray or fixed part to packaging	For mechanical protection Storing doughnuts in the packaging To open the packaging easily
	Enable more/different doughnut numbers	Package (un)filled doughnuts, crodots and minidots in blister packaging In multiple numbers
	Enable mixboxes	To package different types of doughnuts in flowpackaging
	Enable printing on the foil in different languages	To enable customization and local languages
	Advertise recycled content material on packaging	To increase the sustainable perception to customers
	Samples/Vision system	To ensure that the packaging is closed and consists of the correct material and number of doughnuts
Flowpackaging (U-tray)	**Present necessary information on secondary packaging**	**Material composition and disposal information**
	Change to recycled content material	**To adhere to legislation**
	Change surface area/thickness material	**To minimize material used**
	Enable more/different doughnut numbers	Package (un)filled doughnuts, crodots and minidots in blister packaging In multiple numbers
	Enable mixboxes	To package different types of doughnuts in flowpackaging
	Enable printing on the foil in different languages	To enable customization and local languages
	Change to one material	To have a sustainable choice of material
	Advertise recycled content material on packaging	To increase the sustainable perception to customers
	Samples/Vision system	To ensure that the packaging is closed and consists of the correct material and number of doughnuts

The last phase of the QFD was phase 3 in this chapter. In this phase, the suggested changes to the packaging were translated into adjustments to the packaging line to enable these changes. The WHAT of this phase were the packaging changes and the HOW of this phase were the process adjustments to the packaging lines 1 & 3. In this phase, the process adjustments were described in more detail and the relationship matrix and the corresponding target values showed that mostly adding SKUs to the schedule on both lines and scheduling an extra employee to take samples to ensure the correct packaging of doughnuts were the most important process adjustments. Next to the most important requirements, packaging functions, packaging characteristics, packaging changes and process adjustments of all phases, it is also important to take into account the obligatory requirements to adhere to legislation. To ensure this, the following figure (Figure 8.3 creates an overview of the obligatory packaging requirements, packaging changes and process adjustments. Next to the obligatory requirements and changes, this figure also shows the most important packaging requirements, packaging changes and process adjustments

to conclude the QFD of this study. In the following chapter (Ch. 9), a cost estimation will be made with different scenarios to determine the added cost.

		Obligatory	Top 5
Phase 1: House of quality	Packaging functions	• Not applicable	• Embodying • Recyclable • Presentation • Preservation • Avoidance of waste
Phase 2: Parts deployment	Packaging requirements	• Chemical safety • Recycle score C or higher • Disposal logo and material composition • Place for obligatory information • Minimum amount of material used • Recycled content material (plastics)	• No biodegradable plastics • Moisture permeability • Impact resistance • Sustainable choice of material • Adaptable language
Comparison	Obligatory packaging changes		
Phase 3: Parts deployment	Process planning	• Change to recycled content material • Adjust labels on secondary packaging	• Add SKUs to the schedule (line 1) • Add SKUs to the schedule (line 3) • Samples/vision system (both lines) • Incorporate processes to package in flowpackaging without U-tray (line 1) • Adjust the packaging line to fixed part/tray flowpackaging without U-tray (line 3)

	Blister	Flowpackaging	Flowpackaging tray
Change material, thickness or shape	X		X
Present necessary information on secondary packaging	X	X	X
Change to recycled content material (plastics)	X	X	X

Figure 8.3: Obligatory and top 5 requirements of each phase

9 Part 5: Cost estimation

In this chapter, the current manufacturing costs and the suggested changes to the packaging and packaging lines will be discussed in terms of the costs that they might bring. The current costs, and therefore the comparison between the current costs and the added costs as well, are confidential. For this reason, parts of this chapter, including the current manufacturing costs, are moved to Appendix I. Due to unavailable data regarding the current manufacturing costs, not all packaging types (and their doughnut numbers) for both lines are stated in the Appendix. In Section 9.1 different scenarios will be discussed. These scenarios will be evaluated based on the costs in Section 9.2.

9.1 Scenarios

In this section, different scenarios will be discussed. These 4 scenarios are based on incorporating the changes for each packaging type (scenarios 1, 2 and 3) or only packaging at EO in bulk and having a third party package all consumer packaging (scenario 4). In Appendix I, a comparison between the added costs and the current cost will be made.

9.1.1 Scenario 1: Changes blister

The first scenario will be to implement the changes to the blister. These changes will be discussed separately below. Afterwards, this scenario will be concluded.

Change (to recycled content) material, thickness material or surface area of the packaging
This change is combined to ensure two requirements will be fulfilled. The first requirement is an obligatory one, namely, to change to recycled content material. As the current blister packaging material is PET, the recycled content target is 30% of the packaging weight. The second requirement relevant to this change is moisture permeability (guarantee of freshness). This can be done by looking into a different type of material, changing the thickness of the material so more moisture can leave the packaging or changing the surface area of the packaging. This change might increase the material costs of the packaging only. The packaging line(s) do not have to change anything, so there are no added costs other than the packaging material costs. So, especially recycled content material might increase the price of the packaging material. However, as this is an obligatory requirement, there is not much to be done about this price increase. By choosing another material, the thickness of the material or the surface area of the packaging, the price does not immediately have to increase, as EO can choose this different packaging type themselves. It is hard to say what the price of recycled content material will be in the coming years. Suppliers could ask for higher prices because it is an obligatory thing to do, no matter the costs. However, since everyone will change to recycled content material, that might also drive the price down. An example of almost similar blister packaging made from 100% recycled PET costs around €0,18 (papstar, 2025). Since this example packaging is made from 100% recycled PET, the costs might differ with a packaging type with lower recycled material content. However, this could be an indication of the price change.

Present necessary information on secondary packaging (material composition and disposal logo)
This change does not bring any added costs. A one-time cost might be considered when taking into account the administration that will have to be done when implementing this change. However, since it is a small change by adding some more information to the secondary packaging, the administration cost should be limited too.

Enable more/different doughnut numbers
No direct extra costs are made when enabling more or different doughnut numbers in consumer packaging. One thing that will need to be taken into account is that different sizes might be necessary for the blister packaging. These do not directly cost much more, but more sizes will result in more inventory. This might lead to more capital in inventory. More or different numbers will not affect the packaging lines and therefore there won't be any added costs for manufacturing.

Advertise recycled content on packaging
As discussed in Section 8.1, it might be best to let the customers of EO determine if and how they want to advertise the recycled content material on the packaging. This also has the benefit that it does not bring any added costs for EO.

Samples/Vision system
This change will result in fewer faulty packaged doughnuts. One employee can check the doughnuts on both lines 1 and 3. It might be beneficial to schedule consumer packaging on those two lines at the same time since that will result in one employee checking both lines. The extra costs of this change will be the salary of one employee for that one shift. There are around 160 shifts of consumer packaging each year (15% of all shifts). These can be divided over both lines. If EO schedules them together as much as possible, the number of shifts that need an employee to take samples of both lines could decrease to around 80. However, it might not always be possible to schedule them together, so a more realistic number might be 100 shifts where an extra employee is needed. Taking the minimum wage of the Netherlands in 2025 and that a shift is 8 hours, this would cost €112,48 per shift (Rijksoverheid, 2025). This would cost €11.248 for the 100 shifts in a year. The other option could be installing a vision system at the end of the consumer packaging lines. A vision system with a robot to remove the faulty packaging would cost around €300.000 for each line (van der Meer, 2024). The extra employee will be an ongoing cost and the vision system will be an investment cost. Even though the vision system might increase utility costs like electricity, depreciation and maintenance costs somewhat, it will also decrease the number of unsatisfied customers. This will, in turn, potentially save EO money due to the fact that they do not have to resend certain products due to faulty packaging. Next to that, a vision system can check all packaging instead of the employee who can only take random samples of the packaging every so often.

To conclude this scenario, there are a few changes that will add costs. The first one is a different blister packaging type in terms of recycled content material and a better moisture permeability for this situation. This will increase the costs of the packaging itself. Changing to recycled content material is obligatory, so these added costs will have to be made anyway. Changing the packaging for better moisture permeability is not obligatory, but it is beneficial and EO might take that also into account when looking for new blister-type packaging. By offering more/different doughnut numbers, the inventory of the different packaging sizes might increase. If, however, a specific packaging size is not wanted any more, the inventory becomes redundant and that is a waste of money and material. The third change is that samples should be taken more frequently. This would cost around €1124,80 per year or an investment cost of around €300.000 with increased manufacturing costs per packaging line. The only obligatory change is to change to recycled content material, which might increase the material costs for the packaging.

9.1.2 Scenario 2: Changes flowpackaging without U-tray

Similar to scenario 1, all suggested changes and their conclusion will be discussed below.

Present necessary information on secondary packaging (material composition and disposal logo)
Similar to this suggested change for the blister packaging, it does not bring any added costs.

Change (to recycled content) material
This is an obligatory change that has to be implemented. The added costs that might occur are, similar to the blister packaging, higher material costs for the packaging. This might be caused by higher costs because of the recycling and added processes to create the correct BOPP foil. Another reason might be that EO changes from BOPP foil to PET foil because recycled PET already has more EFSA-approved recycling methods for food safety. Similar to the blister packaging, it is not yet completely clear what will happen with the material price of the packaging. The recycled content PET foil will probably have a different price compared to the BOPP foil since it is a different material with recycled content. The recycled content food-grade BOPP foil is not yet on the market, so it is not clear how much this will cost. Next to the material costs, it needs to be taken into account that the current flowpackaging machines can correctly seal this new material. This could be done by tweaking the machine settings, for example, the sealing heat or speed. If this is not the case, another flowpackaging machine needs to be chosen. However, this becomes very costly quite quickly, so it is best to find a material that fits the current machines.

Add a tray or fixed part to the packaging
This change will cause two added costs, namely the material costs for the tray/fixed part and the extra process step(s). For now, the assumption has been made to use the tray from figure 7.6, to make the cost estimation more tangible. First,

the material costs for this tray would be around €0,05. The extra process step(s) might need to be implemented in both lines 1 and 3. The implementation at line 1 will be discussed at the next change. As discussed above, adjustments might be necessary at line 3 to enable a different type of tray. The costs for this adjustment will of course depend on what the adjustment will look like. By replacing the feeder at the beginning of the packaging line, the added costs might be around €80.000. If the conveyor belt is extended and cobots are installed to fold and fill the boxes/trays, the added costs can be determined as follows. The extended conveyor belt will cost around €30.000. Next to that, potentially suitable cobots will cost around €20.000 each (van der Meer, 2024). The number of cobots will need to be determined in more detail, but around 12 cobots could be an indication for now (van der Meer, 2024). Next to that, implementation, transport costs and moving costs of the current consumer packaging line will have to be taken into account. The implementation and transport costs will be assumed to be around €50.000 (€20.000 conveyor belt + €30.000 cobot). The moving costs and re-implementation costs of the current consumer packaging line will be assumed to be around €30.000. If 12 cobots are needed, the total costs would be around €270.000. The manufacturing costs might increase due to the depreciation of the tooling, utilities (energy) and maintenance. Another option is to schedule employees to do the folding and filling of the boxes/trays. Assuming this takes as many employees as the flowpackaging with U-tray needs, this would end up being around 10 employees. Taking the minimum wage from earlier, this would result in €1124,80 per shift. Assuming that around 5% of all shifts are for flowpackaging without U-tray, this would result in around €62.000 each year.

Incorporate processes to package at line 1

As discussed in the previous chapter, the processes can probably be incorporated into the process by scheduling more employees or installing cobots. As the changes might be similar to the ones of line 3 that are just described above, the added costs are similar as well. This means that installing, transporting, moving and adjusting the packaging line to cobots will cost around €320.000. Scheduling employees to carry out the tasks will cost around €1124,80 per shift, resulting in around €62.000 each year.

Enable more/different doughnut numbers

This change is similar to the one from the blister packaging. However, the flowpackaging machine needs to be able to package the new doughnut numbers. This might lead to changes which can incur costs. Next to that, the packaging will use the same foil, so no extra inventory of different sizes is necessary. There might be different sizes of boxes/trays, which might increase the inventory costs.

Enable mixboxes

To be able to offer mixboxes in flowpackaging without U-tray, some adjustments have to be implemented at packaging line 3. This adjustment is similar to the one to enable packaging the box/tray from the flowpackaging without U-tray. So, the first one is the extension of the conveyor belt before the flowpackaging machine. For this, the whole flowpackaging machine and the conveyor belt after the machine will need to move. So, next to the costs for an extra conveyor belt, installation and moving costs also need to be taken into account. This would be around €80.000. The second adjustment is that the order of the doughnuts will have to be correct before entering the flowpackaging machine. This could be done by employees or cobots. As already mentioned, assuming 12 cobots or employees, this would cost €270.000 for the implementation of the cobots or €62.000 for the employees each year. For line 1, no extra adjustments (next to the adjustment from the change 'Incorporate processes to package at line 1') need to be made to package mixboxes in this packaging type. Finally, the manufacturing costs of the mixboxes will be higher compared to the 'normal' flowpackaging. The reason for this is that the doughnuts are first packaged in bulk packaging and afterwards repacked into mixboxes. This means around twice the manufacturing costs compared to 'normal' flowpackaging.

Enable printing on foil in different languages

As mentioned before, two steps could be taken to enable printed foil in different languages. The first option is to buy the foil already printed. This is already done in some cases. The material cost of the printed foil does not differ from the unprinted foil. The added cost would mostly be increased inventory cost. Suppose that, for example, EO has 10 different customers who buy doughnuts in consumer packaging. In that case, there will be 10 different foils, one for each customer. There might be even more foils needed if those customers sell doughnuts in different countries. In that case, the number of foils might increase to 15. These 15 different foils for those 10 customers need to be stored in the raw material warehouse.

However, instead of having a certain amount of similar foil in inventory, this amount of inventory will contain different types of foil. All in all, enabling different prints (foils) for customers might increase the number of rolls of foil in the inventory. This will take space and there is capital in this inventory. If a customer does not need this specific foil any more, this might result in a waste of inventory. Next to that, there might be more setup time because the foil might need to change between shifts if the doughnuts are destined for different customers. However, this could be limited by the planning department by scheduling the doughnuts for the same customer together. This option would limit the needed flexibility from EO, as they can buy the rolls of foil printed. The other option is to print the foil inline before using it in the flowpacker machine. This would result in an extra step in the process and more flexibility needed from EO. The benefit of this option is that there are fewer different types of inventory needed, which might save costs. There is already a small printer installed at both lines 1 & 3. However, even though this printer might be quick enough to print something on all the packaging, it can only be 53 mm wide and 300 mm long. This results in a small part of the packaging that could be printed. If this might be enough to customise the flowpackaging, there would be no extra costs. If this is not the case, the printer might need to be exchanged with another to enable a bigger printing area. Changing the printer results in an investment cost of around €15.000, which includes the implementation as well. Next to this, the maintenance costs might increase as well, as this printer will be used more frequently. Furthermore, there is ink needed to print on the foil, which will also have costs. The choice to be made if this change gets implemented is between added inventory and setup costs or an investment cost of around €15.000 and more manufacturing costs.

Advertise recycled content on packaging
Similarly to the blister packaging, as discussed in Section 8.1, it might be best to let the customers of EO determine if and how they want to advertise the recycled content material on the packaging. This also has the benefit that it does not bring any added costs for EO.

Samples/Vision system
This change is similar to the blister packaging; the total costs for this change would be €11.248 each year to schedule an employee to take more samples or €300.000 per line to install a vision system.

Similar to the changes from the blister packaging, the only obligatory cost that will have to be made is the potential increase in material costs due to the recycled content material. Next to that, installing cobots (investment of €620.000 in total for both lines) or scheduling more employees (€124.000/year in total for both lines) could enable multiple changes namely 'Add a tray or fixed part to the packaging', 'Incorporate processes to package at line 1' and 'Enable mixboxes'. Next to those costs, there is an additional investment cost of around €80.000 needed for the conveyor belt of line 3. Finally, the change 'Enable printing on the foil in different languages' needs an increased inventory and setup cost or a potential investment cost of around €15.000 for a new printer and increases depreciation costs.

9.1.3 Scenario 3: Changes flowpackaging with U-tray

The changes and their potential extra costs will be discussed below.

Present necessary information on secondary packaging (material composition and disposal logo)
Similar to this suggested change for the blister packaging and flowpackaging without U-tray, it does not bring any added costs.

Change (to recycled content) material
This is an obligatory change that has to be implemented. The added costs that might occur are, similar to the flowpackaging without U-tray, higher material costs for the packaging.

Change surface area/thickness material or change to one material
This change is a combination of minimizing the material (changing surface area/thickness material) and changing to one material (for a more sustainable choice). This change does not directly have different costs. The cost for the trays when there is less material might potentially even lower the material costs. On the other hand, if a different supplier is needed, the material costs might rise. In both cases, the material costs per tray do not have to differ much. If the choice is made to

change to a PP tray instead of a paperboard tray, the material cost might also differ. If EO chooses to change the BOPP foil to PET foil due to the recycled content part, the tray will have to be made from PET as well. Next to that, packaging line 3 will have to be adjusted to facilitate the PP/PET trays instead of the paperboard trays. In this case, the added costs will be much higher. This might, however, be possible if this is combined with the implementation of cobots from the changes of the flowpackaging without U-tray. This will still result in an investment cost of around €350.000 (cobots + conveyor belt). Therefore, it might be more interesting to look at the possibility of minimizing the material of the paperboard trays. If the paperboard trays will be used, separate disposal should be stated on the packaging. In this case, the added costs might be negligible because the material costs might be slightly higher or even lower and the separate disposal indication does not cost much as well since this might be solved by adding some text or figure on the tray.

Enable more/different doughnut numbers
This change is similar to the one from the flowpackaging without U-tray. For this packaging type, packaging uneven numbers of doughnuts might be a challenge. This is, as mentioned earlier, not possible at the moment at line 3. To enable this, the trays need to be folded differently and another flowpacker machine needs to be installed. This will be a very high investment. Next to that, it would be a shame for the current flowpacker machine, since that one was installed not too long ago. Taking this into account, it might not be that interesting to look into packaging the doughnuts standing. It might be more interesting to focus on offering uneven doughnut numbers in the flowpackaging without U-tray. If this is the case, no additional costs will be made.

Enable mixboxes
To be able to offer mixboxes in flowpackaging with U-tray, the same adjustments to consumer packaging line 3 have to be made as for the flowpackaging without U-tray. This means an extended conveyor belt and employees or cobots.

Enable printing on foil and trays in different languages
Similar to this change for the flowpackaging without U-tray, the foil can be bought printed or the printer in the packaging lines will have to print the foil. Next to that, the trays cannot be printed at the moment. For this, it might be easiest to buy them printed, even though it might increase the inventory and setup cost. The reason for this is that the current packaging line does not facilitate printing on the trays.

Advertise recycled content on packaging
This change is similar to the blister packaging and flowpackaging without U-tray, so no added costs.

Samples/Vision system
This change is similar to the blister packaging; the total costs for this change would be €11.248 labour costs or €300.000 for a vision system.

Concluding this scenario, two changes are obligatory, namely the recycled content material and the minimizing material changes. These changes might bring some material costs. Next to that, no extra costs are made. The other changes need extra costs when they are implemented. However, some costs could be combined for all packaging types and multiple changes. More about combining the costs will be described in the conclusion of this chapter.

9.1.4 Scenario 4: Package consumer packaging at third party

Another option is to stop packaging the doughnuts in consumer packaging at EO and to outsource this. This way, all doughnuts get packaged in bulk at the production location in Oldenzaal and they get sent to a third party. Reasons to outsource manufacturing operations include achieving more production flexibility, expanding capacity, focusing on core competencies, improving product quality and potentially reducing costs (I.Bardhan et al., 2006; Kumari et al., 2015). Additionally, it reduces the investments in plant facilities, inventory and employees. Another reason to outsource certain manufacturing processes is to be able to react to the variability of demand, reduce risk and use outside expertise (Bengtsson & Dabhilkar, 2006). Looking at the manufacturing costs in Chapter 3, outsourcing might decrease some of them, such as utilities or plant maintenance. Nevertheless, the third party need to be paid, so there does not have to be a cost

reduction. According to Bengtsson & Dabhilkar (2006), using outsourcing for manufacturing can be successful when using it in combination with in-house manufacturing and to use it to further develop the in-house processes. The long-term benefits, however, are not conclusive (Bengtsson & Dabhilkar, 2006; Strange & Magnani, 2017). On the other hand, a more recent article shows that there might be benefits of outsourcing on the firm performance, but with two findings (Karna et al., 2022). The first finding was that the benefits for firm performance are higher when the firm outsources non-core activities. The second finding is that outsourcing manufacturing activities does not have any added performance benefit compared to the outsourcing of services. Next to the potential benefits of outsourcing manufacturing processes, there are also downsides. One of those is that the company no longer have the opportunity to develop its own knowledge and expertise within that field. The longer a company outsources processes, it will never grow in expertise for these processes (Bengtsson & Dabhilkar, 2006). Next to that, there is increased dependency and vulnerability when manufacturing processes are not in-house. Furthermore, it is important that a company makes appropriate decisions regarding outsourcing its processes and interacts with multiple third parties to negotiate the price and terms and conditions (Kumari et al., 2015). If this is not the case, the third party might take advantage of the situation by raising the prices or not offering the quality needed. Quality management is, therefore also very important when outsourcing manufacturing processes. According to Akbari (2024), there are potential risks when making the decision to outsource. These risks include loss of control, poor vendor performance or potential emergence of competitors. Losing control over the process or product is a risk which could lead to financial or reputational harm. Poor vendor performance can lead to insufficient quality of the product or losses. Finally, the emergence of competitors can occur when the chosen third party starts offering the services themselves or takes clients.

Taking the potential benefits or downside into account, EO might consider hiring a third party to consumer package their doughnuts. The benefits of this might be that the company can focus on the bakery part of the production line and fully automate or optimise their bulk packaging lines. Next to that, it is hard for EO to find enough employees. This problem might also be (partly) solved. Furthermore, more flexibility in the type of consumer packaging can be offered. This way, EO can react to different preferences from customers. Next to the preferences of the customer, EO does not have to focus on changing packaging legislation. The downside might be that no knowledge regarding consumer packaging will be within the company. If EO wants to package the doughnuts in consumer packaging again at a later stage, it will need to start all over. Another downside is that there were already quite some investments regarding the consumer packaging lines over the last decade. Moving the consumer packaging to a third party means that these investments become redundant. Furthermore, there will be double packaging costs by first packaging the doughnuts in bulk and afterwards repacking those same doughnuts in consumer packaging by a third party. Finally, since sustainability within companies is increasingly important, it might be considered a waste that EO first packages all the doughnuts in bulk packaging, transports them to a third party, unpacks the doughnuts, repackages them again in consumer packaging and transports them back to the warehouse of EO. This can be seen as an unnecessary use of resources, materials and emissions. As already mentioned in Chapter 2, the doughnuts get packaged in consumer packaging by a third party when the packaging type is not available or the capacity is not sufficient. EO could consider using this third party to outsource all their consumer packaging. Another option might be that EO packages everything in bulk and another plant of Europastry repackages the doughnut into consumer packaging. If the latter option is chosen, the knowledge stays within the company, but the benefits of outsourcing might still be there. However, some downsides will still be there as well, such as double packaging costs and waste of resources, materials and emissions. It might still be interesting enough to look into that option instead of outsourcing to a third party.

As already mentioned, if EO starts consumer packaging the doughnuts at a third party, double packaging costs will be made. First, to package the doughnuts at EO in bulk and afterwards to consumer package them at a third party. Next to that, there will be transportation costs to transport them first to the third party and then back to the warehouse of EO. Even though packaging in bulk is less expensive compared to packaging in consumer packaging, there is a big chance that consumer packaging at a third party will be more expensive for EO. However, the extra costs might be limited while increasing the flexibility by a lot. Next to that, EO can focus on producing frozen bakery products, which is their core business.

9.2 Evaluation scenarios

The costs of the scenarios described above will be evaluated in this section. To start, the costs due to the suggested changes are summarised in Table 9.1. In this table, the change is displayed in the first column. The second column shows which packaging type is relevant (FP stands for flowpackaging without U-tray and FP tray stands for flowpackaging with U-tray).

The third column will be the type of cost and the fourth the amount. The fifth and sixth columns represent line 1 ('1') and line 3 ('3'). The final column shows the total cost of both lines. As can be seen, some changes do not have costs yet, but instead 't.b.d.' (to be determined). The reason for this is that it is not clear what the costs will exactly be. The changes stated in italics are obligatory and therefore these costs will be obligatory.

Table 9.1: Summary costs scenario 1 - 3

Change	Packaging	Type of cost	Amount	1	3	Total cost (both lines)
Recycled content material	All	material cost	t.b.d.	x	x	t.b.d.
Necessary information on secondary packaging	All	-	-	-	-	-
Enable more/different doughnut numbers	Blister & FP	Inventory	t.b.d.	x	x	t.b.d.
	FP tray	-	-	-	-	-
Advertise recycled content material	All	-	-	-	-	-
Samples/Vision system	All	Labour cost *or* Vision system	€11248 €300.000	x x	x x	€11248/year €600.000
Add tray or fixed part to the packaging	FP	Material cost	€0,05	x	x	t.b.d.
		Conveyor belt Labour cost *or* Cobots *or* Feeder trays	€80.000 €62.000 €270.000 €80.000		x x x x	€80.000 €62.000/year €270.000 €80.000
Incorporate processes to package at line 1	FP	Labour cost *or* Cobots	€62.000 €270.000	x x		€62.000/year €270.000
Enable mixboxes	FP & FP tray	Conveyor belt Labour cost *or* Cobots	€80.000 €62.000 €270.000	 x x	x x x	€80.000 €124.000/year €540.000
Enable printing on foil in different languages	FP & FP tray	Inventory Printer	t.b.d. €15.000	x x	x x	t.b.d. €30.000
Change surface area/thickness material or change to one material	FP Tray	Material Cobots (if PP tray)	t.b.d. €270.000	x	x x	t.b.d. €270.000

Furthermore, there are multiple choices shown in the table. For example, the choice between labour costs or a vision system for the change 'Samples/Vision system'. This is done to indicate that the choices have different costs. Additionally, multiple changes have the choice between labour costs or installing cobots. If the choice for cobots is made, there might be an increase in manufacturing costs due to the increasing utilities and maintenance costs. This is, however, not represented in the table. The manufacturing costs are discussed in the appendix. The potential moving and implementation costs are taken into account separately for each change. If all those changes (for the vision system, cobots, conveyor belt, change of printer) are combined and one company supplies all these things, the implementation costs could decrease. This could be the case because if one company offers everything, they also can combine the implementation, which might save time. Next to that, the transport costs might also decrease, as this can be combined. Furthermore, the change 'Enable more/different packaging numbers' has costs for the blister and flowpackaging without U-tray, but not for the flowpackaging with U-tray. The reason for this is that the flowpackaging with U-tray already packages all the number of doughnuts that is possible, as uneven numbers are hard. For this reason, it is more interesting to divide the uneven numbers over the other two consumer packaging types. This way, no unnecessary and difficult changes will have to be made to the packaging or packaging line. Another thing to note is that the labour costs are based on the current percentage of shifts that package in consumer packaging. If this percentage increases in the future, the labour costs will increase as well. Finally, as can be seen in the table, some adjustments (and therefore investments) are needed if the changes are implemented. Despite the potential investments or increased costs, the adjustments might also result in benefits. Logically, the biggest benefit is adhering to the legislation by implementing the changes stated in italics in the table above. Next to that, by implementing other changes like enabling more/different doughnut numbers or mixboxes, EO might get more customers. If the flowpackaging without U-tray gets a box or tray, it can protect and handle the doughnuts better, which results in higher consumer satisfaction. By taking more samples or installing a vision system, the success rate of the packaging lines will increase, which will result in fewer complaints. In the next chapter, the QFD and cost estimation will be evaluated further and the costs and potential

benefits to adhere to customer satisfaction and legislation will be discussed as well.

10 Evaluation consumer and legislation requirements

In this chapter, the packaging requirements will be evaluated on how they went through all the parts of the methodology. All parts of the methodology (all QFD phases + cost estimation) will be evaluated per requirement separately. This way, the requirement can be discussed and if it might be worth the changes and added costs compared to the improvement of the packaging. Below, in Section 10.1, all the requirements of the first phase are discussed and their flow through all parts of the methodology. The evaluation of each requirement and the overall QFD will be concluded in Section 10.2

10.1 Evaluation of requirements

In this section, the requirements will be evaluated. The requirements 'The packaging is reclosable.', 'The packaging consists of one type of material.' and 'The packaging has to enable scanning the product without having to turn the doughnuts around.' are not included, as they were only in part 1. The reason that those requirements were left out of the rest of the parts of the methodology is that they were not deemed important enough by customers or employees. For each requirement below, a figure shows the flow through all parts of the methodology.

The guarantee of freshness is three days

The first requirement that will be discussed is 'The guarantee of freshness is three days.' The flow of this requirement through all parts of the methodology is displayed in Figure 10.1. As can be seen, the requirement started in phase 1 (customer requirement) as 'The guarantee of freshness is three days.' and continued in part 2 (packaging requirement) and 3.a (packaging characteristic) as 'Moisture permeability'. The change that was identified was to change the material, thickness material or surface area of the blister packaging. This might result in added material costs for the blister packaging. For this requirement, there were no process adjustments identified. If this change could be implemented, the sum of the target values of the blister packaging would increase from 5,76 to 6,13. This is an increase of 6%.

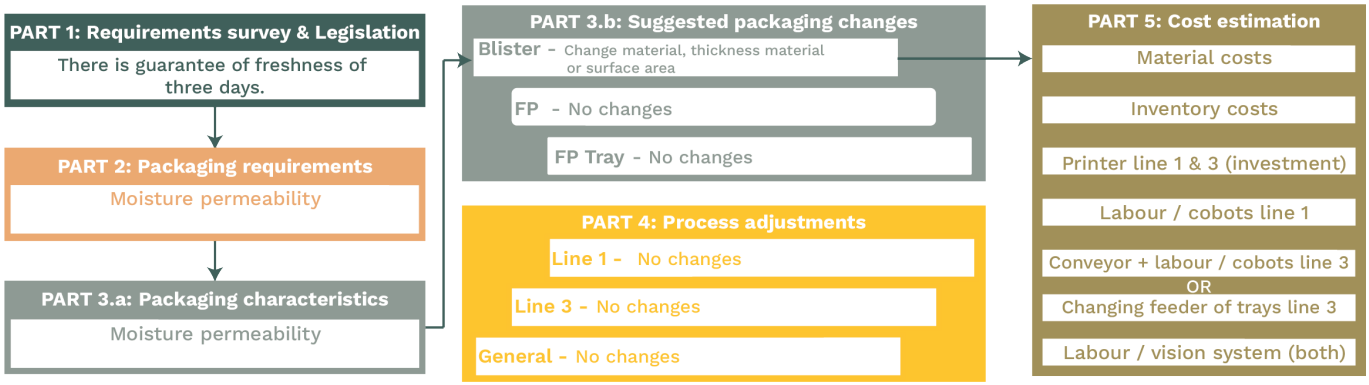

Figure 10.1: Flow requirement: The guarantee of freshness is three days

The packaging protects the doughnuts (mechanical damage)

The flow of this requirement can be seen in 10.2. The second requirement changes from impact resistant to strength packaging throughout the first three parts. Afterwards, the change of adding a tray or fixed part to the flowpackaging without U-tray was determined. This would need two process adjustments for both lines 1 and 3. Next to that, the material cost of the packaging will increase by around €0,05. The adjustments for both lines in total would cost around €124.000/year + an investment of €80.000 or an investment of €350.000. Implementing this change for this requirement would increase the sum of the target values of the flowpackaging without U-tray from 5,59 to 6,02, which is an increase of 7%.

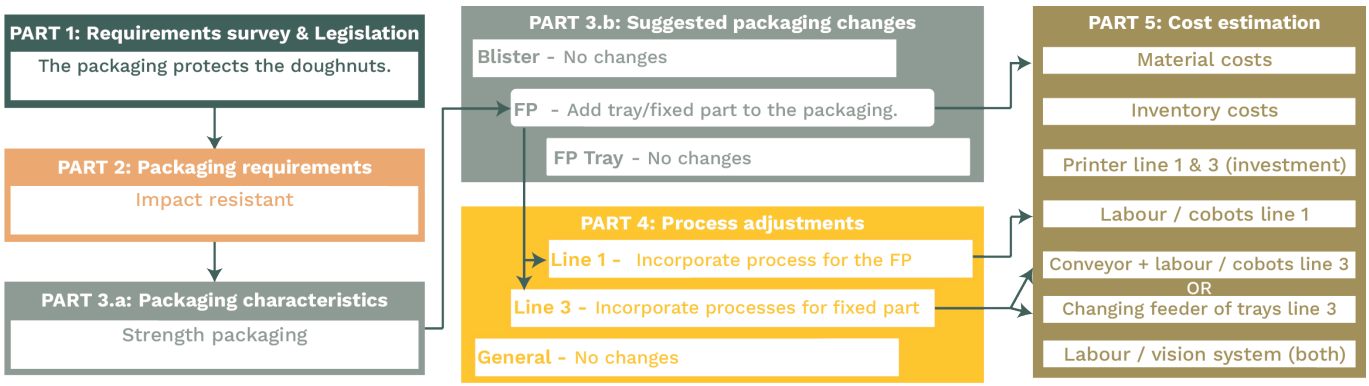

Figure 10.2: Flow requirement: The packaging protects the doughnuts (mechanical damage)

The packaging has to be free from toxic chemicals and plastics

This is an obligatory requirement. As can be seen in Figure 10.3, this requirement was used in parts 1, 2 and 3.a. However, no change or adjustment was needed since this is fulfilled by the supplier, so this requirement ended in part 3.a. For all packaging types, the maximum target value was reached.

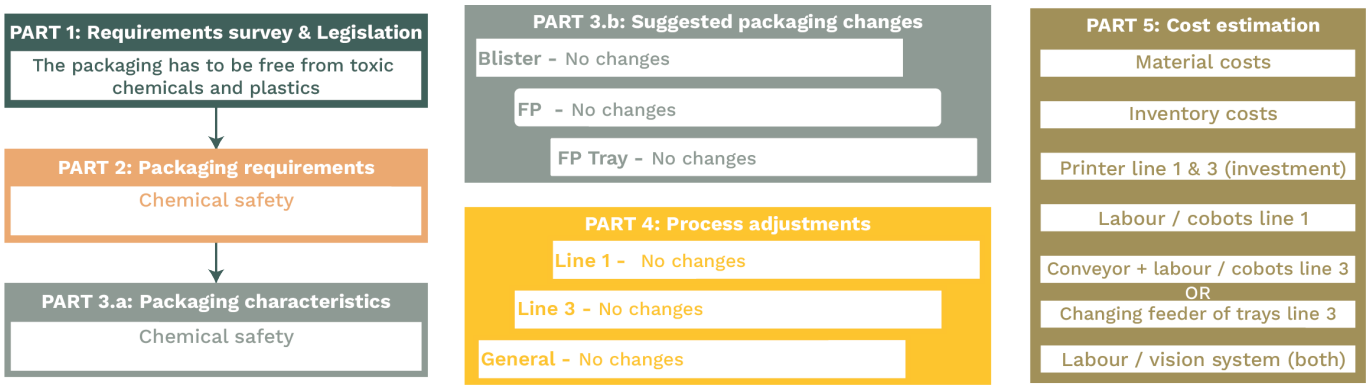

Figure 10.3: Flow requirement: The packaging has to be free from toxic chemicals and plastics

The doughnuts have to be protected from outside contamination

Similar to the previous requirement, this requirement also does not continue to part 3.b and further. This was done even though the blister packaging does not have a strong relationship with this requirement. The reason for this is that the outside contamination for the blister packaging is limited and otherwise the whole packaging design of a blister packaging had to be changed. Figure 10.4 shows the flow for this requirement.

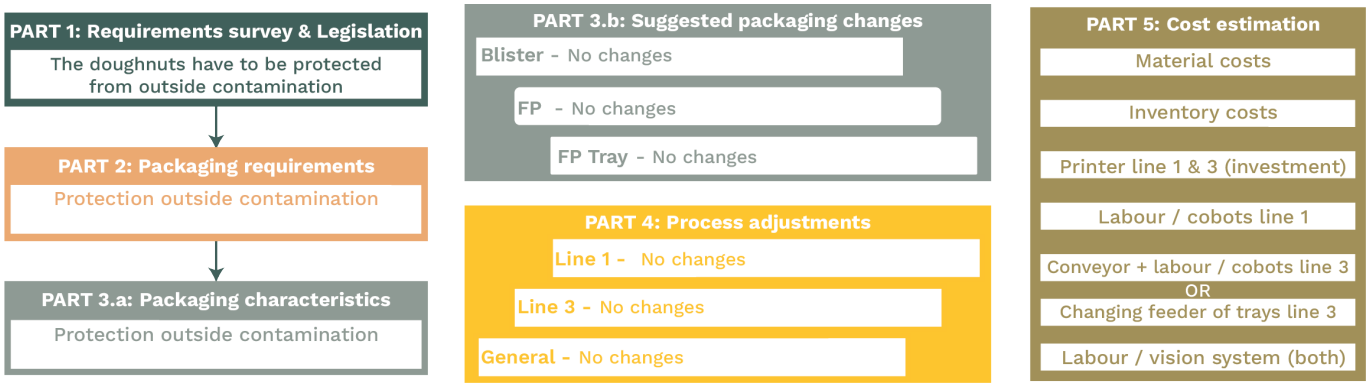

Figure 10.4: Flow requirement: The doughnuts have to be protected from outside contamination

The packaging can fit either 1, 2, 3, 4, 5, 6 or more mini-sized doughnuts & The packaging can fit either 1, 2, 4, 5, 6 or more normal sized doughnuts

Figure 10.5 shows the flow for two requirements: The packaging can fit either 1, 2, 3, 4, 5, 6 or more mini-sized doughnuts & The packaging can fit either 1, 2, 4, 5, 6 or more normal sized doughnuts. These two requirements are merged for part 2. Afterwards, there are three packaging characteristics for part 3.a. For all packaging types, the same suggested change is made, which results in adding SKUs to the schedule for both lines 1 & 3 and more inventory costs for the packaging material. Furthermore, there are no added costs for adding SKUs to the schedule. If these changes are implemented, the sum of target values will be increased for each packaging type as follows. For the blister, an increase of 6% when the requirement has a medium relationship with the characteristics and an increase of 16% with a strong relationship. For the flowpackaging without U-tray, the increase in the sum of target value is 4% for medium relationships and 16% for strong relationships. The increase in the sum of target value of the flowpackaging with U-tray is 4%. For these changes, an increase in inventory costs might be likely.

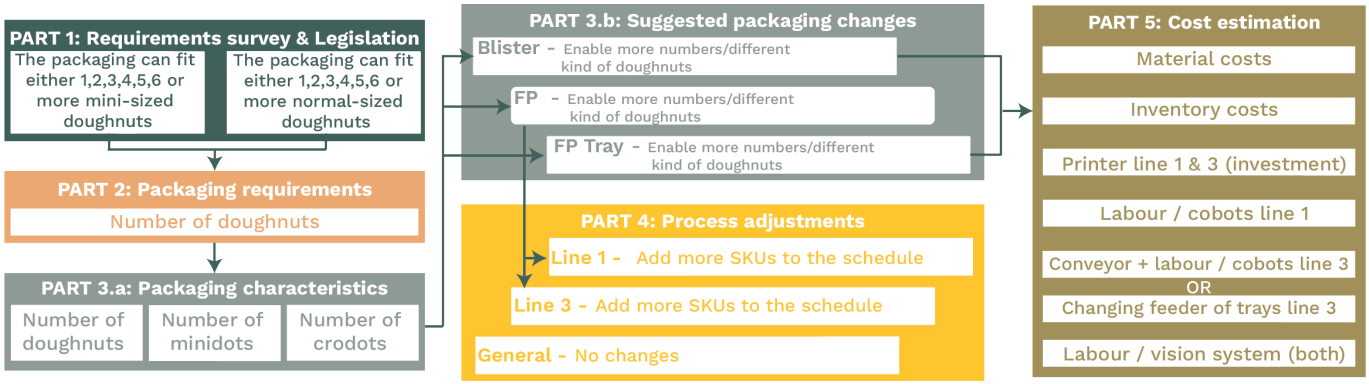

Figure 10.5: Flow requirement: The packaging can fit either 1, 2, 3, 4, 5, 6 or more mini-sized doughnuts & The packaging can fit either 1, 2, 4, 5, 6 or more normal-sized doughnuts

The packaging has either the same type of doughnuts or a mix of doughnut types

This requirement and its steps through the parts of the methodology can be seen in Figure 10.6. As can be seen, both flowpackaging types need a change to fulfil this requirement. For this, there is a line adjustment needed for both lines 1 & 3, which will need an investment or labour costs. If these two changes for the flowpackaging types are implemented, there is an increase in the sum of target values of 2% for both packaging types.

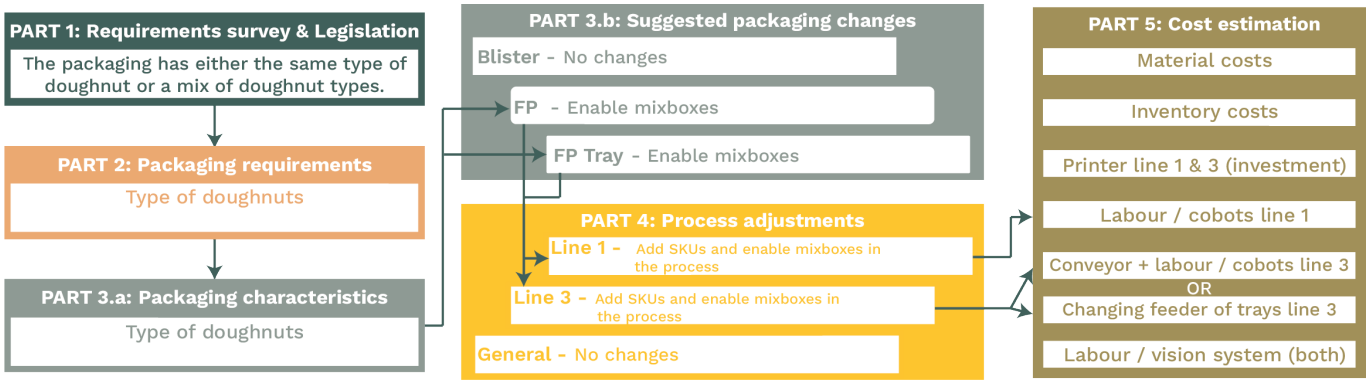

Figure 10.6: Flow requirement: The packaging has either the same type of doughnuts or a mix of doughnut types

The doughnuts can be stored within the packaging

This requirement was part of every part of the methodology. Figure 10.7 shows the flow of this requirement. As can be seen, the flowpackaging without U-tray needs a change, which also needs a line adjustment for both packaging lines. The added costs which might be incurred are material costs and an investment for both packaging lines or more labour costs. If this change is implemented, it would mean an increase in the sum of target value of 5%.

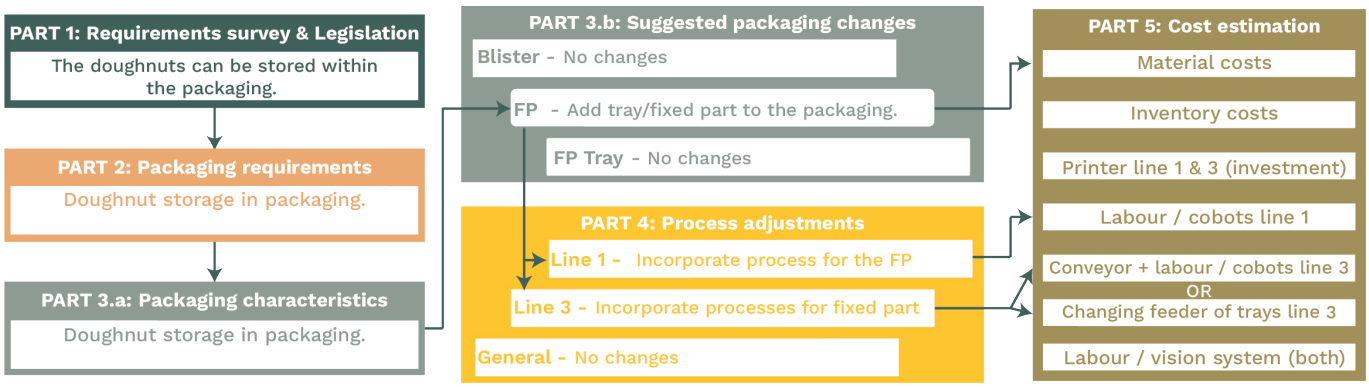

Figure 10.7: Flow requirement: The doughnuts can be stored within the packaging

The packaging is easy to open

This requirement needs the same change to the flowpackaging without U-tray as the previous requirement. This means that the added costs are similar as well. However, since the target value of this requirement is much lower compared to the previous requirement, the increase of the sum of target value is 1%. Figure 10.8 shows the flow for this requirement.

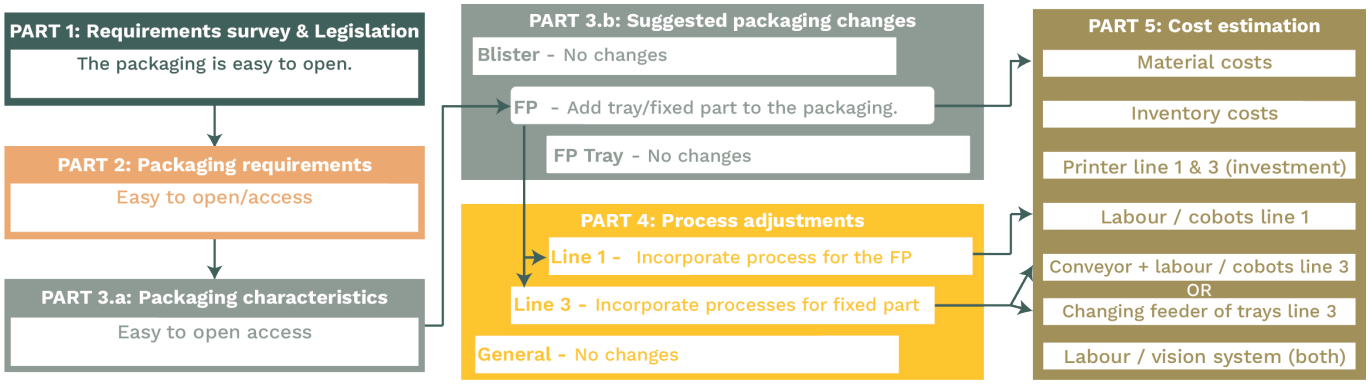

Figure 10.8: Flow requirement: The packaging is easy to open

Primary packaging must feature the disposal logo and material composition information on the packaging

This is an obligatory requirement and its flow through all parts of the methodology is displayed in Figure 10.9. The change for all packaging types is a relatively simple one, as the labels on the secondary packaging need to be adjusted. This way, all the required information is presented on the secondary packaging. This will not have any added costs for the packaging or packaging lines. This requirement will result in an increase of the sum of target value of 5% for the blister packaging and 8% for both flowpackaging types. There is a difference between the blister and flowpackaging because the material composition information is already on the blister packaging.

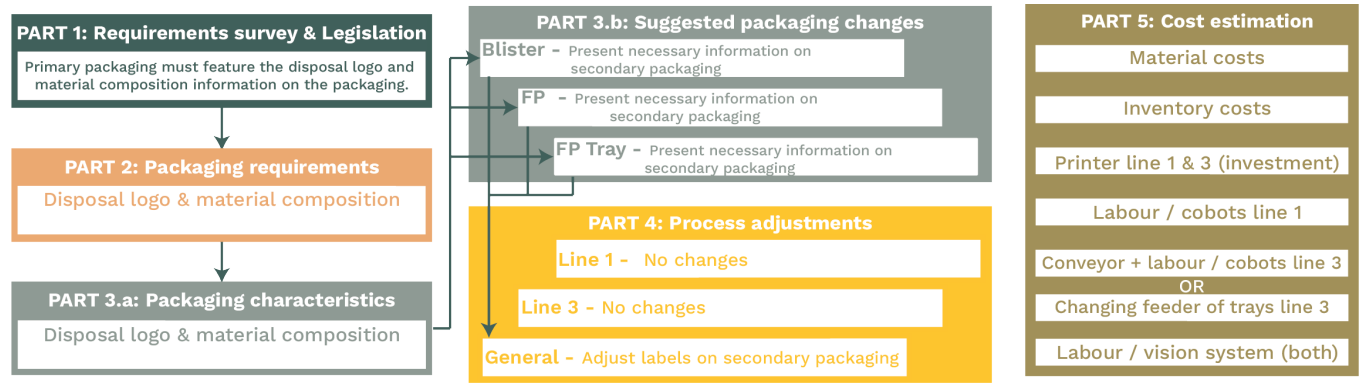

Figure 10.9: Flow requirement: Primary packaging must feature the disposal logo and material composition information on the packaging

The packaging is effectively recyclable for at least 70%

This obligatory requirement was used in parts 1, 2 and 3.a. However, no change or adjustment was needed, so this requirement ended in part 3.a. For all packaging types, the maximum target value was reached. Figure 10.10 shows the flow for this requirement.

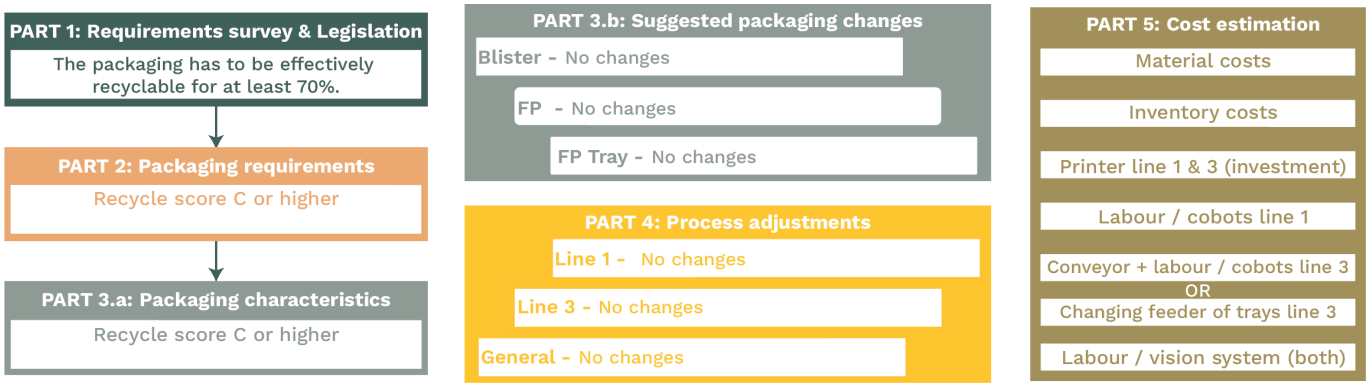

Figure 10.10: Flow requirement: The packaging is effectively recyclable for at least 70%

The plastic parts of the primary packaging must consist of the right amount of recycled content from post-consumer plastic waste

This is an obligatory requirement. As can be seen in the figure below (Figure 10.11), all packaging types need to change to recycled content material. This might result in an adjustment for lines 1 & 3 for the flowpackaging (settings sealing machine). The requirement might have added material costs. The increase for the sum of target value of 7% for all packaging types.

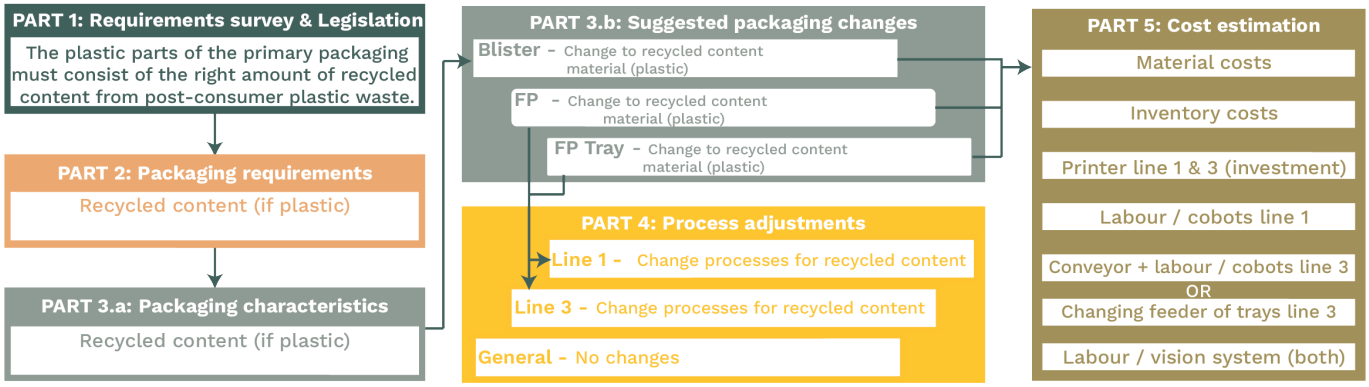

Figure 10.11: Flow requirement: The plastic parts of the primary packaging must consist of the right amount of recycled content from post-consumer plastic waste

The packaging consists of the minimum amount of packaging possible

This obligatory requirement needs two changes, for the blister packaging and the flowpackaging with U-tray. This requirement is displayed in Figure 10.12. For the flowpackaging with U-tray, a line adjustment might be necessary, which will lead to added costs. In addition to that, there might be more material costs. However, EO can choose the new packaging and their suppliers, so they might have an influence on the material costs. For the blister packaging, there is an increase of 6% and for the flowpackaging an increase of 5%. The flow through all parts of the methodology can be seen in the figure below.

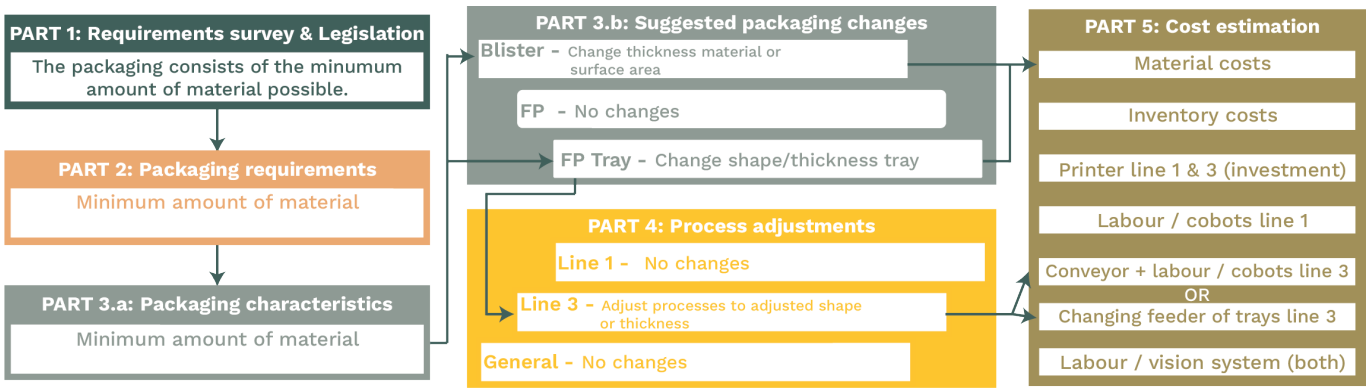

Figure 10.12: Flow requirement: The packaging consists of the minimum amount of material possible

No coloured PET as packaging material & The doughnuts are visible in the packaging

This requirement was used in parts 1, 2 and 3.a. However, no change or adjustment was needed, so this requirement ended in part 3.a. For all packaging types, the maximum target value was reached. Figure 10.13 shows the flow for this requirement.

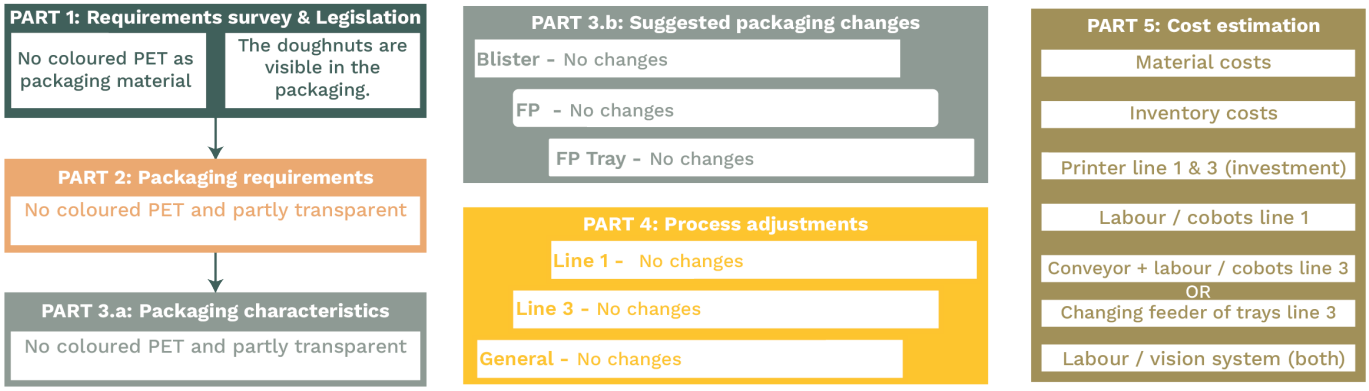

Figure 10.13: Flow requirement: The packaging is effectively recyclable for at least 70% of its weight

No use of biodegradable plastics

Figure 10.14 shows the flow for this requirement. This requirement was used in parts 1, 2 and 3.a. However, no change or adjustment was needed, so this requirement ended in part 3.a. For all packaging types, the maximum target value was reached.

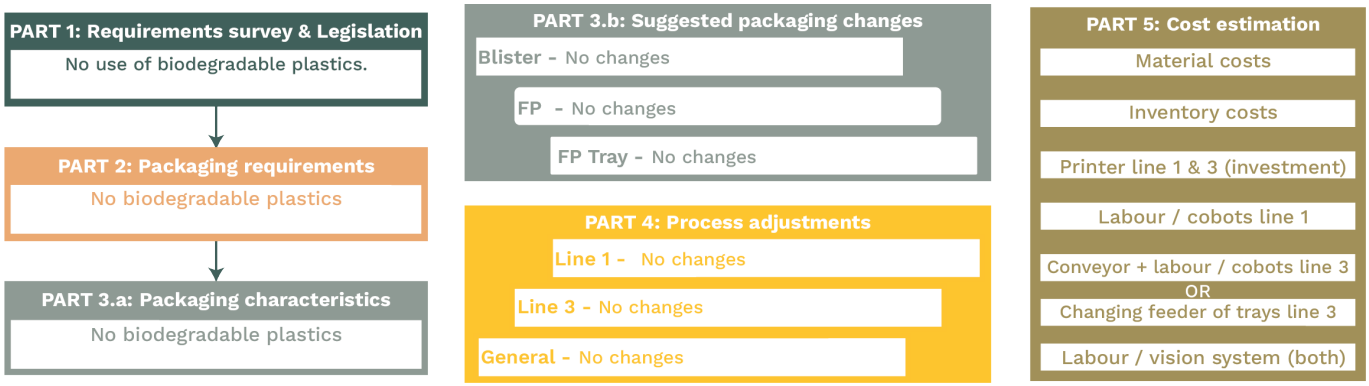

Figure 10.14: Flow requirement: No use of biodegradable plastics

Label with all required information

The flow of this obligatory requirement can be seen in Figure 10.15. As can be seen, the requirement from part 1 translates into two requirements for part 2 and two packaging characteristics for part 3. There are no changes identified since all information is present with the changes to the requirement regarding the disposal logo included. The space for a label on the packaging is there as well. The maximum target value was reached for these requirements.

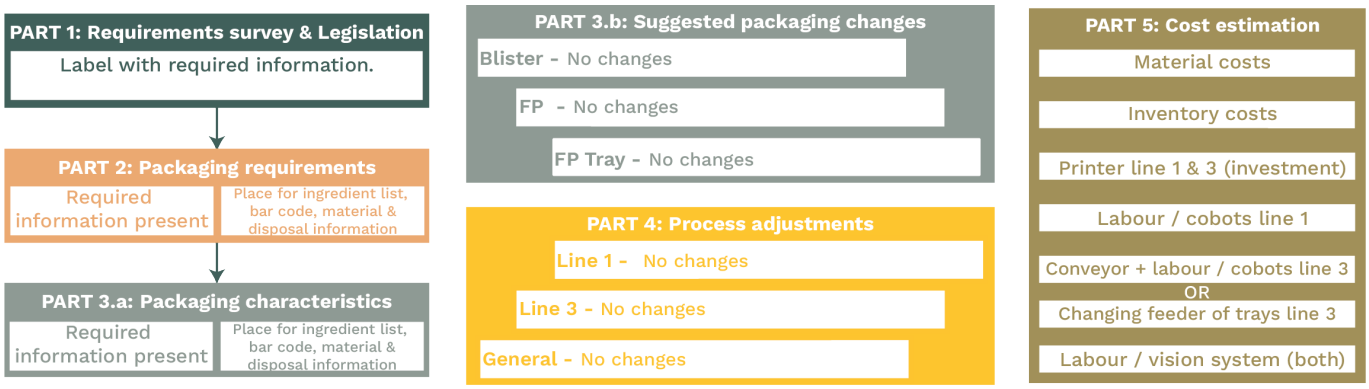

Figure 10.15: Flow requirement: Label with all required information

The design of the company can be used

This requirement and its flow can be seen in Figure 10.16. As can be seen, both flowpackaging types will need a change to enable printing on the foil. This way, the packaging can be customised. This needs an adjustment for both lines if the current printer is not suitable for this change. This could result in an investment to buy new printers for both lines. Another option is to buy the foil with different prints. If this is implemented, the increase for the sum of target value would be 3% for the flowpackaging without U-tray and 2% for the flowpackaging with U-tray.

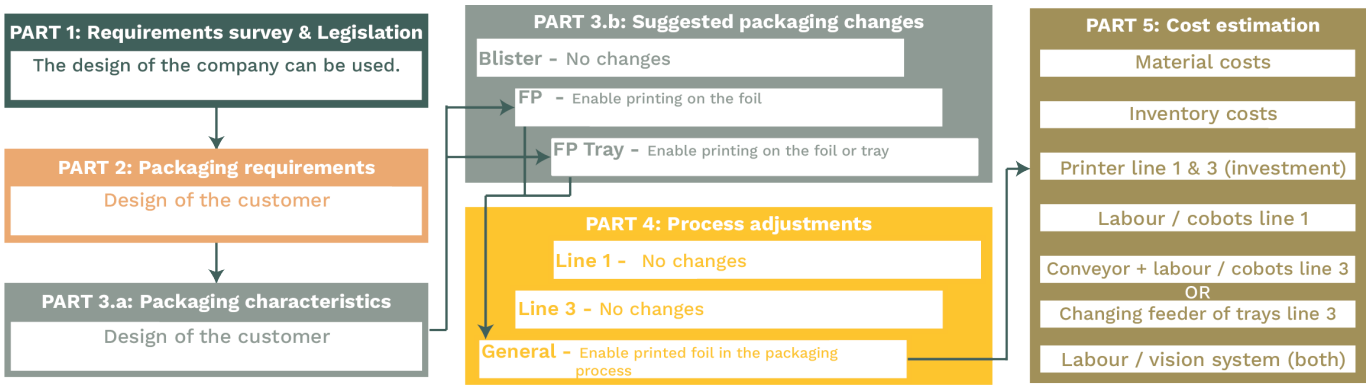

Figure 10.16: Flow requirement: The design of the company can be used

The language on the packaging needs to be adaptable

This requirement has the same suggested changes as the previous requirement and therefore the same line adjustment and costs. The increase for the sum of target value would be 8% for both packaging types. Figure 10.17 shows the flow for this requirement.

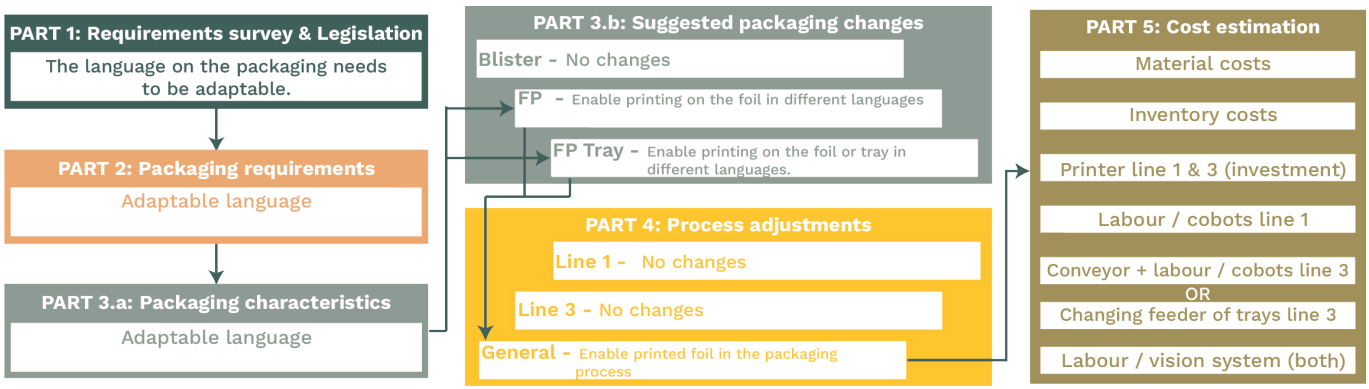

Figure 10.17: Flow requirement: The language on the packaging needs to be adaptable

The packaging needs to use less plastic

This requirement from part 1 is translated into two requirements and two characteristics for parts 2 and 3, respectively. This is displayed in Figure 10.18. This requirement resulted in a change for all packaging types. However, only the flowpackaging with U-tray might need a line adjustment if the PP tray is chosen. If this is the case, there will be added costs. If this requirement is implemented, an increase of 0,5% for the blister packaging, 1% for the flowpackaging without U-tray and 6% for the flowpackaging with U-tray would occur.

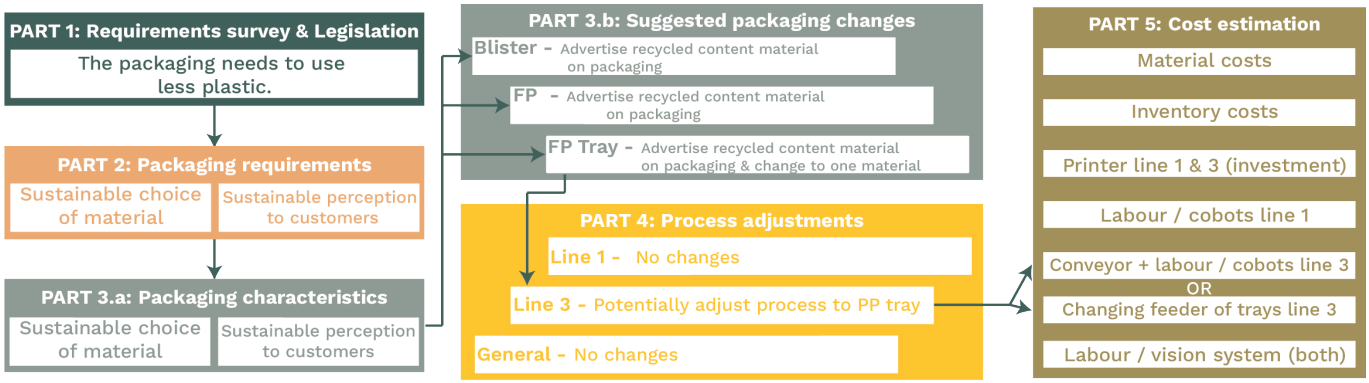

Figure 10.18: Flow requirement: The packaging needs to use less plastic

The packaging has to be closed correctly

This requirement was made based on complaints that the packaging was not closed correctly. The flow of this requirement can be seen in Figure 10.19. As can be seen, both flowpackaging types need a change; more samples are taken during the process. This can be enabled by scheduling an employee to take samples more frequently or by implementing a vision system at the end of the packaging line. If this change is implemented, the increase for both flowpackaging types would be 5%.

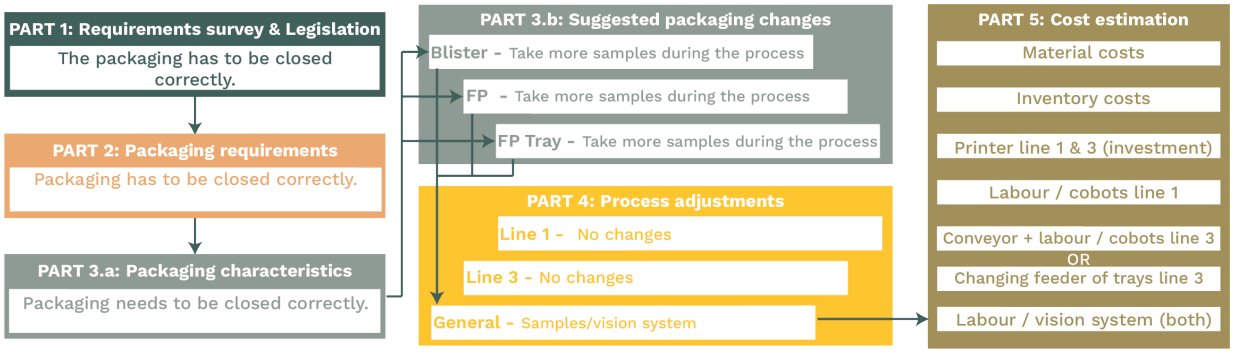

Figure 10.19: Flow requirement: The packaging has to be closed correctly

The packaging type, material and number of doughnuts must be as agreed

This requirement has similar changes compared to the previous one. The only difference is that now all packaging types need this change. All packaging types would have an increase of 3% if this change is implemented. Figure 10.20 shows the flow for this requirement.

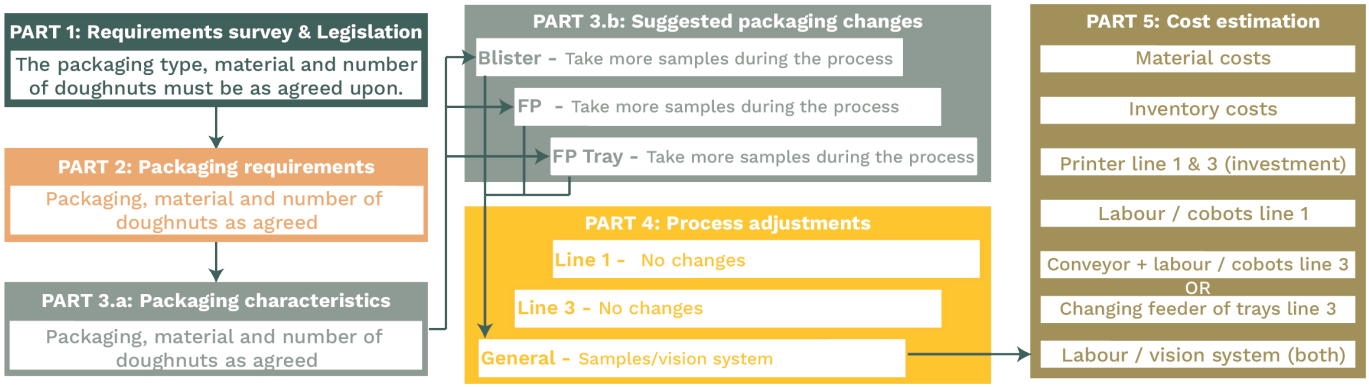

Figure 10.20: Flow requirement: The packaging type, material and number of doughnuts must be as agreed

10.2 Conclusion evaluation of requirements

Looking at all the requirements above, some costs could be combined to increase the sum of target value for that packaging type even more. If, for example, cobots are installed at lines 1 & 3, a total improvement of 15% is reached for the flowpackaging without U-tray. However, some requirements on their own might not be worth the costs to implement them. An example of this is enabling mixboxes for both flowpackaging types. However, this requirement can be part of the 15% improvement with the combination of costs. Another example of a requirement that might not be worth the hassle is to enable the usage of the design of the customer. When looking at the initial scores of the packaging types in Chapter 7, the scores reached between 5,59 and 5,82 out of 9,77. Even though the total score of 9,77 might be a bit unrealistic to reach, there is still quite a big gap between the actual scores and the highest score. If the obligatory requirements are taken into account, the scores increase to between 6,51 and 7,05. Still, it could also be an option to look into different consumer packaging that suits the (future) requirements better. The downside of this is that, when EO starts doing this, the company might have to change its consumer packaging every few years to keep up with future requirements and wishes. This asks for a lot of flexibility and investments. If the packaging lines have to be adjusted often, this is a waste of money. However, following that logic, the consumer packaging portfolio can never be changed any more. So, it is important to look critically at the current consumer packaging. If another type of consumer packaging fits the current requirements better, that packaging type could be considered. Nevertheless, EO should be cautious and not change the packaging type too often. An example of consumer packaging for other bakery products is displayed in Figure 10.21.

Figure 10.21: Example packaging

This packaging type is used at Albert Heijn, which is a supermarket with among others cakes and other bakery products. Since retail customers are mostly interested in consumer packaging, this might be an interesting example to look into (with some potential changes to accommodate the packaging of doughnuts). This packaging type consists of a PP tray at the bottom and a transparent PET tray at the top. At the moment, this packaging does not allow for doughnuts to fit in the packaging, but with some adjustments in width and height, it might be possible. If, with some assumptions, the comparison matrix from part 3 is used for this packaging type, it would get a score of 7,28. Even though it is not the total score of 9,77, it is already higher compared to the scores of the current packaging types. The matrix can be seen in Figure 10.22 and will be explained below.

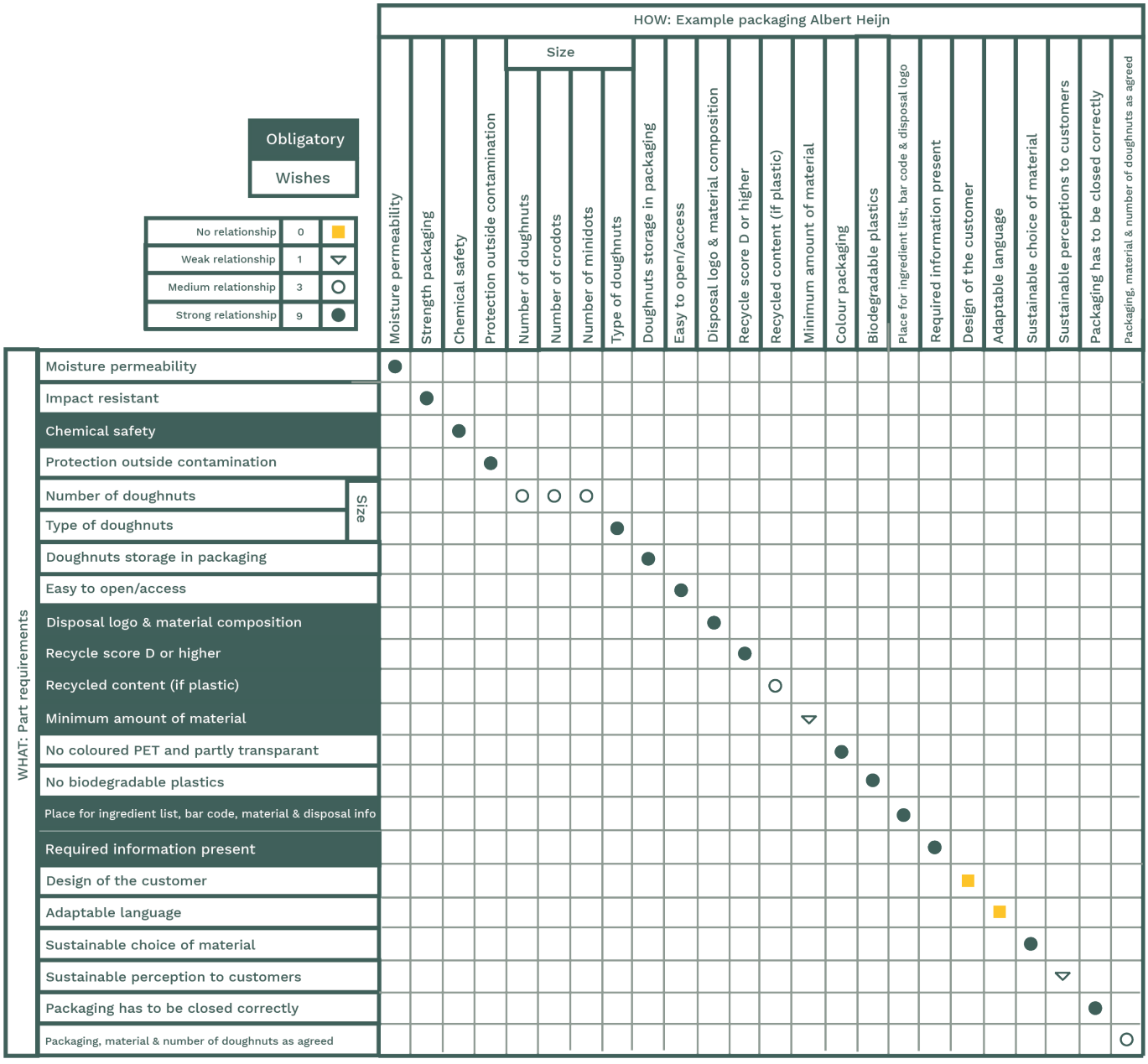

Figure 10.22: Comparison matrix example packaging Albert Heijn

The relationship between the requirements and the (assumed) packaging characteristics will be explained per requirement:

- **Moisture permeability**: The cakes in the current packaging had a guarantee of freshness of 7 days. Of course, the cakes could have different acceptable moisture and/or oxygen levels, but the assumption is made that the doughnuts will have a guarantee of freshness of 3 days.
- **Impact resistant**: The packaging protects the doughnuts against smashing and tearing in a shopping bag.

- **Chemical safety**: The packaging is assumed to be chemically safe, as it is sold in supermarkets.
- **Protection from outside contamination**: Even though the packaging is not completely sealed, there is a click system that clicks the top at the bottom of the packaging. Next to that, there is barely any space between the two packaging parts. For these reasons, the relationship between the requirement and the characteristic is strong.
- **Number of doughnuts**: This relationship is chosen based on the possibility of using this packaging at the packaging lines of EO. This could be the case for all doughnut types from lines 1 & 3. However, since uneven numbers are not possible to package in this packaging, the relationship is a medium one.
- **Type of doughnuts**: Similar to the previous requirement, this relationship is chosen based on what would be theoretically possible. As both types of doughnuts (normal and mixboxes) could be possible at both packaging lines, the requirement has a strong relationship with the requirement.
- **Doughnut storage in the packaging**: The doughnuts can easily be stored in the packaging.
- **Easy to open/access**: There is not much force needed to open this packaging type. After opening it, it is very easy to access the doughnuts.
- **Disposal logo & material composition**: The material composition is shown on the packaging itself. The disposal logo is incorporated on the label of the packaging.
- **Recycle score C or higher**: The assumption has been made that the packaging is effectively recyclable for at least 70%. This might not fully be the case in reality, since there is a paper label on the packaging which might decrease the recyclability of the packaging. However, as already mentioned in Chapter 7, the recyclability of the packaging after the attachment of a label is out of scope for this study. The reason for this is that it is not the responsibility of EO to attach the labels to the packaging.
- **Recycled content (if plastics)**: This requirement has a medium relationship with the packaging characteristic. The reason for this is that the assumption has been made that the PP tray does not contain any recycled content, as there are limited EFSA-approved options for food-grade PP. However, there are more options for PET materials and according to Albert Heijn, 58,6% of their PET packaging consists of recycled PET (AlbertHeijn, 2023). For these reasons, the assumption has been made that the PET tray does consist of recycled content material.
- **Minimum amount of material**: To ensure higher convenience, the packaging might have more material than necessary. Therefore, this requirement has a weak relationship, just as the blister packaging of EO.
- **No coloured PET and partly transparent**: The packaging fulfils this requirement.
- **No biodegradable plastics**: No biodegradable plastics are used in this packaging.
- **Place for ingredient list, bar code, material & disposal information**: There is enough space on the packaging for a label.
- **Required information present**: All required information is present.
- **Design of the customers**: This requirement does not have a relationship with this packaging because there is no customisation possible.
- **Adaptable language**: There is no relationship for this requirement because there is no text on the packaging.
- **Sustainable choice of material**: It is assumed that the packaging material is recyclable. The packaging consists of two different kinds of plastic. However, these can be disposed of in the same bin, so that should not be a problem.
- **Sustainable perception to customers**: Since the packaging consists fully of plastic, it does not really have a sustainable perception.
- **Packaging has to be closed correctly & Packaging material and number of doughnuts as agreed**: These two requirements both have similar relationships as the blister packaging of EO. The reason for this is that it is not known how these requirements would score for this. However, since the production process would probably be similar to the blister packaging of EO, these scores are used for these requirements.

So, this example packaging scores better (with the adjustment in size to package doughnuts) compared to the current consumer packaging of EO. However, for this example packaging, there are still improvements to be found. This specific packaging is used as an example of how EO could improve or add to its packaging portfolio. Another packaging that will be used as an example is the packaging displayed in Figure 10.23. This packaging is used to sell doughnuts at the supermarket Dirk van den Broek. This packaging packages two doughnuts in a transparent plastic foil. The packaging is closed by the label. Similar to the previous example packaging, this packaging type will be scored as well. The score of this packaging is 6,19, which is higher than all the consumer packaging types of EO. The score is lower compared to the packaging of the Albert Heijn.

Figure 10.23: Example packaging

The score will be justified per requirement below. Afterwards, the relationship matrix can be seen in Figure 10.24.

- **Moisture permeability**: The guarantee of freshness of the doughnuts in the store is 1 day. Therefore, the relationship that is given is a weak one.
- **Impact resistant**: This relationship is weak because it is easy to smash the doughnuts.
- **Chemical safety**: The packaging is assumed to be chemically safe, as it is sold in supermarkets.
- **Protection from outside contamination**: Since the packaging is closed by a label, there is still limited airflow possible. Therefore, a medium relationship is given for the requirement.
- **Number of doughnuts**: This relationship is chosen based on the possibility of using this packaging at the packaging lines of EO. This could be the case for all doughnut types from lines 1 & 3.
- **Type of doughnuts**: Similar to the previous requirement, this relationship is chosen based on what would be theoretically possible. As both types of doughnuts (normal and mixboxes) could be possible at both packaging lines, the requirement has a strong relationship with the requirement.
- **Doughnut storage in the packaging**: This requirement has a weak relationship, as it is not easy to store the doughnuts in the packaging.
- **Easy to open/access**: There is not much force needed to open this packaging type. However, after opening it, it is not that easy to access the doughnuts without smearing the coating.
- **Disposal logo & material composition**: Both the material composition and disposal logo are not displayed on the packaging.
- **Recycle score C or higher**: The assumption has been made that the packaging is effectively recyclable for at least 70%. This might not fully be the case in reality, since there is a paper label on the packaging which might decrease the recyclability of the packaging. However, as already mentioned in Chapter 7, the recyclability of the packaging after the attachment of a label is out of scope for this study. The reason for this is that it is not the responsibility of EO to attach the labels to the packaging.
- **Recycled content (if plastics)**: Since the packaging material is not known, the assumption is made that no recycled content material is present.
- **Minimum amount of material**: This packaging type has used the minimum amount of material.
- **No coloured PET and partly transparent**: The packaging fulfils this requirement.
- **No biodegradable plastics**: No biodegradable plastics are used in this packaging.
- **Place for ingredient list, bar code, material & disposal information**: There is enough space on the packaging for a label.
- **Required information present**: All required information is present.
- **Design of the customers**: This requirement does not have a relationship with this packaging because there is no customisation possible.
- **Adaptable language**: There is no relationship for this requirement because there is no text on the packaging.
- **Sustainable choice of material**: It is assumed that the packaging material is recyclable.
- **Sustainable perception to customers**: Since the packaging consists fully of plastic, it does not really have a sustainable perception.

- **Packaging has to be closed correctly & Packaging material and number of doughnuts as agreed**: These two requirements both have similar relationships as the blister packaging of EO. The reason for this is that it is not known how these requirements would score for this. However, since the production process would probably be similar to the blister packaging of EO, these scores are used for these requirements.

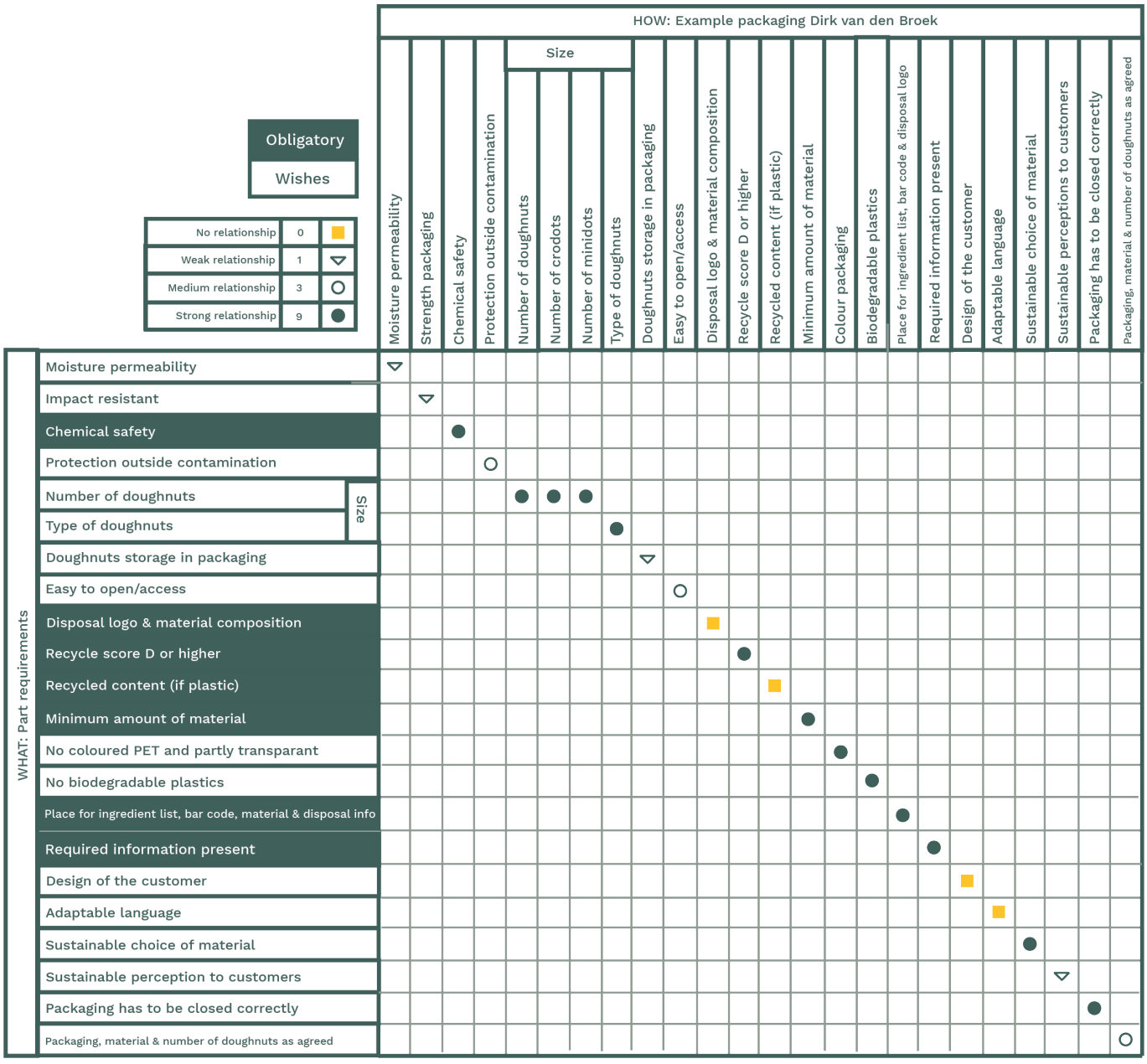

Figure 10.24: Comparison matrix example packaging Dirk

So, two examples are given to show how the QFD could be used to test other packaging types. These two packaging examples score higher than the current consumer packaging. However, there is still some improvement possible for these example packaging. EO could use the QFD to test other or new consumer packaging to see how it scores compared to the current consumer packaging. This way, the portfolio could be updated. Concluding this chapter and looking at this whole chapter and evaluation, there are quite a few changes needed to improve the current consumer packaging of EO. These changes are mostly quite small, but some need bigger process adjustments which will bring some added costs. Next to that, some requirements might not deserve the change and/or added costs since it is not important. It might also be interesting for EO to look at different packaging types that would better fit the requirements.

11 Discussion

This chapter includes a discussion of this study. In the first section, the research questions will be answered. A reflection on the research activities and the tools used will be given in Section 11.2. Afterwards, in Section 11.3, the limitations of this study will be discussed. This chapter will continue with the recommendations (Section 11.4) and finish with future research (Section 11.5).

11.1 Answers to the research questions

In this section, the research questions will be answered. First, this study aimed to give insights into the (future) requirements of the consumer packaging of EO. To be able to do this, a QFD and cost estimation were chosen as tools. This resulted in the following main research question:

Can a quality function deployment and a cost estimation create insight into the requirements of the consumer packaging of Europastry Oldenzaal to determine future improvements?

Next to this main research question, four sub-questions were chosen. These sub-questions will be answered first, and afterwards, the main research question will be answered.

1. What is the current consumer packaging portfolio for the doughnuts and how are the doughnuts packaged?
To answer this question, the current packaging (lines) were analysed. The products, their customers, their packaging and their packaging lines are described in Chapter 2. The analysis was performed by a data analysis of the available data, walk-ins at the packaging lines and interviews with the stakeholders within the company. A concise answer to this question is that there are 8 different subfamilies of the doughnut produced at lines 1 & 3 of EO. Of these 8 subfamilies, 4 have consumer packaging options at the moment. These consumer packaging can be blister packaging or flowpackaging with or without U-tray. Around 15% of the doughnuts are packaged in consumer packaging at the moment and EO expects that this percentage will increase. The packaging lines are placed directly after the freezer, so the doughnuts are produced, frozen and directly packaged. Afterwards, the doughnuts go to the warehouse. Finally, around 35% of all the customers are within the retail category, these customers are the focus of this study. The reason for this is they have the most interest in consumer packaging because, in that way, they do not have to repackage the doughnuts themselves any more.

2. What are the trends and best practices for performing a QFD and cost estimation?
In Chapter 3, the trends and best practices for performing a QFD and cost estimation have been explored. For the QFD, the focus within the literature study was on how a QFD could be used as an improvement tool next to an approach to translate requirements into product and process plans. Next to that, QFD models within the food industry and for sustainability purposes are described as well. For the cost estimation, a description is given for the costs in a life cycle and a product price. The manufacturing costs are explored in more detail. Finally, several methods for cost estimations are discussed.

3. What actions can be taken based on the QFD results to improve the consumer packaging?
To answer this question, all QFD phases will be described. In the first phase of the QFD, the voice of the customer and legislation was determined. This was done by sending a survey to the relevant customers of EO and a thorough investigation of all relevant legislation. The requirements from customers and legislation were quantified by the relationship matrix of part 1. These requirements were filtered and translated into part requirements of the consumer packaging of doughnuts in part 2. The obligatory and top 5 part requirements are:

- Obligatory
  - Chemical safety
  - Recycle score C or higher
  - Disposal logo & material composition
  - Place for label with obligatory information
  - Minimum amount of material used
  - Recycled content material (plastics)

- Top 5
  - No biodegradable plastics
  - Moisture permeability
  - Impact resistance
  - Sustainable choice of material
  - Adaptable language

In part 3, these part requirements were compared with the current packaging characteristics. Since the part requirements were quantified in importance during the first two parts of the methodology, a score could be given to the current consumer packaging in part 3. The current consumer packaging scored between 5,59 and 5,82 out of 9,77. However, it is very hard for the current packaging types to reach the total score of 9,77 due to the fact that it is just not possible to fulfil some requirements. An example of this is that it is not possible to customise blister packaging, as it is bought by EO and therefore not much customisation can be done. Still, to improve the score of the current packaging, changes were identified. The changes were identified for the requirements that were not completely fulfilled by the characteristics where this was possible. The changes can be seen in Table 11.1. The requirements and changes displayed in italics are obligatory, as they have to be implemented to adhere to legislation.

Table 11.1: Suggested changes for each packaging type

Packaging type	**Requirement**	**Change**
Blister packaging	Number of doughnuts/crodots/minidots	Enable more different types of doughnut
	Number of doughnuts/crodots/minidots	Enable more numbers of doughnuts
	Required information present	*Present necessary information on secondary packaging*
	Packaging has to be closed correctly Packaging, material & number of doughnuts as agreed	Samples/Vision system
Flowpackaging without U-tray	Strength packaging Doughnut storage in packaging Easy to open/access	Incorporate tray/fixed part in the process
	Number of doughnuts/crodots/minidots	Enable more different types of doughnut
	Number of doughnuts/crodots/minidots	Enable more numbers of doughnuts
	Type of doughnuts	Enable mixboxes
	Required information present	*Present necessary information on secondary packaging*
	Recycled content material	*Change to recycled content material*
	Design of the customer	Enable printing on the foil
	Adaptable language	Enable printing different languages on the foil
	Packaging has to be closed correctly Packaging, material & number of doughnuts as agreed	Samples/Vision system
Flowpackaging with U-tray	Number of doughnuts/crodots/minidots	Enable more different types of doughnut
	Number of doughnuts/crodots/minidots	Enable more numbers of doughnuts
	Type of doughnuts	Enable mixboxes
	Required information present	*Present necessary information on secondary packaging*
	Recycled content material	*Change to recycled content material*
	Minimize amount of material	*Change surface area/thickness material tray*
	Design of the customer	Enable printing on the foil
	Adaptable language	Enable printing different languages on the foil
	Packaging has to be closed correctly Packaging, material & number of doughnuts as agreed	Samples/Vision system

In part 4, the necessary packaging process adjustments were identified to facilitate the changes to the packaging. Not all packaging changes needed a process adjustment. These process adjustments, and their packaging change, are displayed in Table 11.2. Again, the changes and adjustments displayed in italics are obligatory.

Table 11.2: Suggested changes for each packaging type

Packaging	Packaging change	Process adjustment	Line 1	Line 3
Blister	Enable more different types of doughnuts Enable more number of doughnuts	Add SKUs to the schedule	x	x
	Present necessary information on secondary packaging	Adjust labels on secondary packaging	x	x
	Samples/Vision system	Extra employee/vision system to take samples	x	x
FP	Incorporate tray/fixed part to the packaging	Incorporate/Adjust processes to package in flowpackaging without U-tray	x	x
	Enable more different types of doughnuts Enable more number of doughnuts	Add SKUs to the schedule	x x	x
	Enable mixboxes	Add SKUs to the schedule Enable mixboxes at the packaging line for flowpackaging	x x	x x
	Present necessary information on secondary packaging	Adjust labels on secondary packaging	x	x
	Change to recycled content material	(Potentially) Adjust processes	x	x
	Enable printing on the foil Enable printing in different languages	Enable printed foil in the packaging process	x	x
	Samples/Vision system	Extra employee/vision system to take samples	x	x
FP Tray	Enable more different types of doughnuts Enable more number of doughnuts	Add SKUs to the schedule	x x	x
	Enable mixboxes	Add SKUs to the schedule Enable mixboxes at the packaging line for flowpackaging	x x	x x
	Present necessary information on secondary packaging	Adjust labels on secondary packaging	x	x
	Change to recycled content material	(Potentially) Adjust processes	x	x
	Minimize amount of material	(Potentially) Adjust processes	x	x
	Enable printing on the foil Enable printing in different languages	Enable printed foil in the packaging process	x	x
	Samples/Vision system	Extra employee/vision system to take samples	x	x

4. What insights does the cost estimation give?

In Chapter 9, the suggested changes to the packaging and packaging line were discussed in terms of their added (manufacturing) costs. Next to the changes, the possibility of packaging the doughnuts in consumer packaging is also included in this chapter. However, due to a lack of data, this scenario could only be theoretically described instead of a calculation to determine the feasibility of this scenario. In the corresponding appendix (Appendix I), the confidential parts of the cost estimation were described. In this appendix, more detailed calculations regarding the potential new manufacturing costs for some of the packaging types are described. The chapter and its appendix conclude that there are some added costs and investments needed if all changes are implemented. However, the obligatory requirements do not directly have that much added cost. The change to recycled content material might have added material costs, but it is not clear yet what this increase in material costs might be. The summary of all potential added costs can be seen in Figure 11.1. As can be seen in the figure, some suggested changes are stated twice. The reason for this is that these suggested changes have two types of added costs. On the right-hand side of the figure, the packaging type that is influenced is stated.

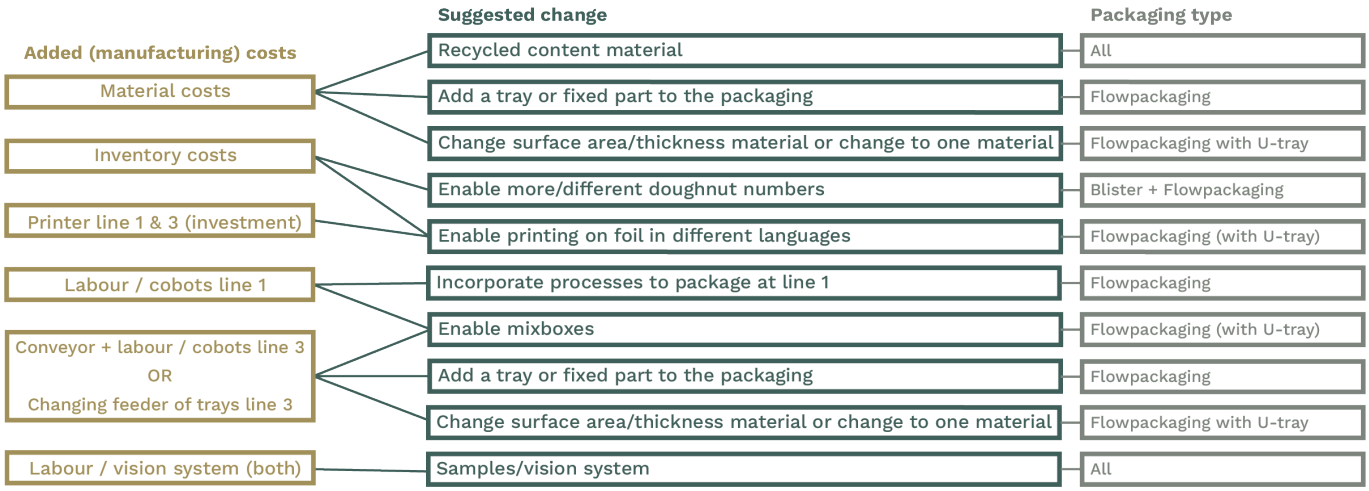

Figure 11.1: Summary of potential added (manufacturing) costs

Now that all the sub-questions have been answered, the main research question can be answered as well. In short, a quality function deployment and cost estimation can create insight into the requirements of the consumer packaging of Europastry Oldenzaal. By collecting all the requirements in part 1 of the methodology and quantifying those in part 2, a clear overview

was given of all the requirements. The third part of the methodology compared and evaluated how the current consumer packaging performs with regard to the collected list of requirements. Afterwards, changes were identified for the current packaging types to perform better. For all the changes, potential process adjustments were identified as well. Finally, the potential added costs were determined. These packaging changes, process adjustments and added (manufacturing) costs are all summarised above in Tables 11.1, 11.2 and Figure 11.1. The main research question can be divided into multiple parts. The first part is the requirements of the consumer packaging, the second part is the comparison between those requirements and the consumer packaging to determine the performance and the third part of the question is to determine the future improvements. So, in conclusion, EO can use the identified requirements from customers and legislation as an up-to-date list of requirements. Next to that, EO can use the comparison between those requirements and the characteristics of the current packaging as a review of the performance of the current packaging types. The suggested packaging changes and process adjustments can help to improve the current packaging or as examples of how the packaging types could be improved. Finally, the QFD that is developed can help test other consumer packaging to see how it scores based on the target values, as already done with two example packaging in Chapter 10. This way, the QFD can help with updating the consumer packaging portfolio.

11.2 Reflection on the research activities and used tools

In this section, a reflection will be done on the research activities and the tools used. The reflection will include whether or not the activities and tools helped in achieving the main objective of this study. The main objective of this research is to provide insight into Europastry Oldenzaal's consumer packaging to allow decision-making to create an up-to-date portfolio and determine future improvements. The main research question stated above is derivative of the main objective.
The research activities for this study were a context analysis, a literature study and an investigation into the legislation regarding packaging and packaging waste. In the context analysis, the context around the core problem and the core problem itself were investigated and described in Chapter 2. This was useful for the study because the context surrounding the core problem could be understood better before moving forward. The literature study included the quality function deployment, the survey design and life cycle cost and cost estimation. For the QFD, the main goals and all phases and their steps are described. Next to that, the use of QFD in the food/packaging industry and for legislation of sustainability were investigated. This QFD section in Chapter 3 ensured a thorough understanding of the QFD. It became clear that for the QFD, a survey would be needed to determine the requirements of the customers. That is why the next section in the literature study concerns the design of a survey and its steps. Finally, the life cycle costs and cost estimation finalised the literature study. In this section, the costs of a whole life cycle were investigated to make sure that all the costs could be taken into account in Chapter 9, if applicable. Additionally, some cost estimation methods were included to get an overview. Next to the context analysis and the literature study, an investigation into the legislation for packaging and packaging waste was performed. This investigation resulted in an overview of the relevant requirements for consumer packaging for now and in the future. Since these requirements are obligatory to enter the market, it was important to include these in the study. All the research activities helped achieve the main objective because it gave the background needed to understand the problem better, the tools that were used during the study and it ensured that the obligatory legislation requirements were taken into account.
Next to the research activities, the tools that were used were the QFD, a survey and a cost estimation. As can be seen in the methodology described in Chapter 4, three out of the five parts consist of a QFD phase. The survey was part of the first phase of the QFD in part 1 of the methodology. Finally, the fifth part of the methodology was the cost estimation. All parts of the methodology will be discussed now and reflected upon. The first part of the methodology was the first phase of a QFD, the voice of the customer. The goal of this phase is to translate customer requirements into technical requirements. The requirements in this study consisted of customer and legislation requirements. The customer requirements were collected via the survey and the account managers of EO. The legislation requirements were determined based on various directives of the EU. These requirements were put in a relationship matrix with the relevant packaging functions to determine how the requirements relate to the packaging function. Looking back at this first part of the methodology, it helped achieve the objective of this study by collecting all requirements of the consumer packaging. However, a distinction could have been made between the important and less important requirements. This was done by looking at the importance ratings, but it was a bit limited. This way, a lot of different requirements ended up in the first relationship matrix of the QFD. On the one hand, this might be a good representation of the diversity of the requirements based on all the different customers of EO.

Nevertheless, some requirements might only be represented by one customer and might therefore not be that important to take into account. An example of this is the requirement 'Adaptable language'. One customer commented this as an extra requirement in the survey. Since this requirement influences a lot of different packaging functions, it became a requirement with quite some influence. Still, the importance of requirements and the relationship matrix was discussed with multiple employees with EO to make sure that it made sense. Next to the potential distinction between requirements, the sample of the customers that received the survey could have been bigger or encouraged more to fill in the survey. This way, there would have been more data from the customers to work with. Finally, the correlation matrix that was developed in this phase was not really used in the rest of the study. Only during part 3 of the methodology, the identification of the changes, some correlations between the packaging requirements were mentioned. However, the correlations between the packaging functions were not used. This might show that, in this case, the correlation matrix was not that useful. After the first phase of the QFD, the second phase was part of part 2 of the methodology. The goal of the second phase of the QFD was to translate the part requirements from the previous phase. So, this part of the methodology helped achieve the research objective by creating a set of packaging requirements with importance ratings. This second phase of the QFD, even though it helped create the set of packaging requirements for the rest of the study, might not have been fully necessary. The results from the survey and the legislation were already formulated as technical requirements in a lot of the cases. If this is the case, duplication of requirements can occur, as described by (Burge, 2007). This might have been the case for some requirements, as a lot of the requirements of phase I of the QFD are (almost) similar to the packaging requirements of phase II of the QFD. Still, the important packaging functions were determined at the end of phase 1 of the QFD and phase 2 of the QFD made sure that all customer and legislation requirements were measurable. The third part of the methodology was the comparison between the packaging requirements and the current packaging. This part showed that the current packaging scored around 58% out of the total score of 100%. This means that there could be some improvements and these were also identified in this part. Reflecting on the comparison and the identification of the changes, it is important to note that the identified changes to improve consumer packaging are potentially not the only options. A more detailed investigation could be performed with more stakeholders to reflect on the changes suggested in this study and if there might be more interesting/efficient/easier/cheaper options that also achieve the goal. However, the suggested changes can be seen as a start of this investigation. The fourth part of the methodology took into account the potential process adjustments to facilitate the packaging changes. This helped achieve the future improvements part of the research objective because an overview of the potential process adjustments was created. The potential process adjustments that are described in Chapter 8 are a good start of ways to improve the packaging, but there could of course be more possibilities that were not described. Finally, part 5 of the methodology was a cost estimation of the packaging changes and process adjustments. This also helped with the future improvements part of the research objective because with the cost estimation, a well-founded choice could be made regarding the feasibility and worthiness of a packaging change or process adjustment. Unfortunately, not much financial data was available, and this resulted in a limited cost estimation of the new manufacturing costs of the consumer packaging. Next to that, no cost estimation method was used to determine the new manufacturing costs. However, this also was not that relevant or suitable to use because there were relatively small changes to an already existing manufacturing system. This also already had its already existing cost method.

All in all, the tools used were the QFD, survey and cost estimation. The QFD was the main tool that was used. Looking back, the QFD was a suitable tool to achieve the research objective because it helped collect all the necessary requirements and translate them into packaging requirements. These could then be compared to the current packaging and changes could be identified. As described earlier in the literature study, Erdil & Arani (2018) already described how a QFD could be used as an improvement tool. This fact could be confirmed in this study, as there are multiple improvements found for consumer packaging. The advantage of using a QFD to find improvements is that the traceability of the requirements is very high. It is very easy to keep track of all the requirements and their potential improvements this way. Even though the methodology of this study was not completely similar to the developed framework of Erdil & Arani (2018), the same idea was followed. However, the methodology of this study also included the second and third phases of the QFD instead of only the first one. The survey was a suitable way to collect the customer requirements because it was low-key for the customers to respond while still being able to get input from the customers. Even though the sample of customers could have been somewhat bigger, the response rate was quite high (around 65%). This could show that an internet survey was the right choice in this case because it does give the respondent relatively much freedom in how and when the survey gets answered. As de Leeuw et al. (2008) describes in their article, an internet survey should be short to encourage the respondents to answer the survey, which was the case for this survey. Finally, the cost estimation was a suitable addition to ensure that the

costs could be an indication of how interesting or feasible a packaging change or process adjustment would be.

11.3 Limitations

In this section, the limitations of this study will be described. The first limitation is the subjectivity of the QFD phases. Even though all phases and conclusions were discussed with employees from EO and an AHP was used for the first phase, a QFD should be performed by a multi-disciplinary team. Since this was not the case, it could be that there is still some subjectivity in the results from the QFD. Additionally, the QFD started with the collection of the customer and legislation requirements for consumer packaging. The customer requirements were collected by an internet survey that was sent to 26 different customers of EO that were divided over all countries to which EO sells their doughnuts. There was a 65,38% response rate from the survey and it gave an overview of the requirements that are important to the customers of central Europe. However, as described in the literature study, an internet survey can be limited, due to the fact that the respondent and interviewer cannot have an open conversation about the topic at hand. Therefore, the results of the survey might be limited to what was asked in the survey without many additional requirements or comments. Even though the question for additional comments or requirements was asked multiple times in the survey, it is still a list of questions instead of a conversation. Furthermore, the sample of customers could be increased, the response rate could be higher or a combination of both to increase the number of responses. This will create a better overview of the current wishes of the customers. Nevertheless, the survey and its sample of customers that were used now are a good start to the collection of the customer requirements. Finally, as mentioned earlier, there was limited financial data available. For this reason, only the blister packaging with 6 minidots for line 1 and the flowpackaging (with U-tray) with 4 doughnuts for line 3. All the other doughnut - packaging - packaging line combinations could not be included. Even though the added manufacturing costs could be determined per doughnut type, a complete overview of all the packaging types could not be made. Next to that, the financial feasibility of scenario 4 for the cost estimation could not be determined. Even if the financial information from a third party was available, the comparison between that information and the manufacturing costs of the doughnuts could not have been made. For this reason, only the theoretical benefits and downsides of packaging at a third party are discussed.

11.4 Recommendations

The first recommendation that will be described in this section is to evaluate the packaging changes and process adjustments and their benefit to the packaging. By evaluating those and maybe researching them in more detail, some changes can be implemented. As mentioned, several requirements, and therefore their changes, are obligatory, so it is important to at least take these into account. Furthermore, this study did not look into the doughnut types that do not have consumer packaging, such as the BigDots or MiniCrodots. It could be interesting to look for consumer packaging for these doughnut types and test them in the same way as the blister and flowpackaging have been tested. The QFD could be reused for other doughnut or packaging types as well. Next to that, the QFD could also be reused with other customer or legislation requirements. For example, the sample of customers for the survey was now focussed on central Europe, but it might also be interesting to collect customer requirements within other parts of the world where Europastry sells doughnuts. Finally, it might be interesting to look at the results of the survey in more detail. For example, out of the 17 respondents to the survey, 6 customers already buy doughnuts in consumer packaging and only 1 indicated potential interest. Even though 7 out of the 17 is a much higher percentage (around 41%) than the current consumer packaging rate of 15%, this can likely be explained by the fact that a specific sample is chosen and the customers that already buy consumer packaging are more likely to actually fill in the survey. The reason why it might be interesting to look into this in more detail is that only 1 of the 17 respondents indicated potential interest. Even though EO has the idea that more customers want consumer packaging, this is not fully represented in the results of the survey. A reason for this might also be that the customers do not want consumer packaging from the current portfolio, but it might be interesting to find out why only one respondent indicated potential interest.

11.5 Future research

Multiple topics could be explored for future research. The first topic for future research is to look into the possibility of enlarging the survey sample. More relevant customers could be reached and a more complete list of requirements could be determined. Another option is to encourage the customers more to fill in the survey or to work with interviews instead of surveys. The survey sample could also be changed to the south of Europe or other continents, to see if the requirements change much. This is interesting to see because then Europastry can determine different types of packaging for different countries. There is already some difference between packaging types for each location of Europastry, but maybe a division can be made between the relevant packaging types for that market. Another topic is to collect all the necessary financial data to complete the cost estimation. This way, all doughnut - packaging - packaging line combinations could be included in the cost estimation. If the relevant financial data is available, the feasibility of packaging at a third party could also be determined.

12 Conclusion

This study was conducted to create insights into the requirements of the consumer packaging of Europastry Oldenzaal. Europastry Oldenzaal is part of the multinational company Europastry, which specialises in frozen bakery products. There are multiple reasons that lead to this study, among others that consumer packaging is becoming more important to customers of EO. Another reason is that the legislation regarding packaging and packaging waste is changing. The scope of this study was the consumer packaging of the doughnuts with a focus on the retail customers of EO. These doughnuts are produced and packaged at lines 1 & 3 at EO.

First, a context analysis was done to further understand the problem at hand and its context. Afterwards, a literature study was performed to create a theoretical basis for this study and its tools and methods. From there, the methodology could be developed. There were five parts in the methodology, where the first, second and fourth parts consisted of QFD phases. Part three consisted of the comparison between the QFD results of part two and the current consumer packaging. The fifth part consisted of a cost estimation. These will be shortly described below. First, the QFD tool was used to translate the collected customer and legislation requirements into packaging requirements in parts one and two of the methodology. The result of these two parts was an up-to-date list of requirements and how these could be translated to packaging requirements. Afterwards, in part three, these packaging requirements were compared to the characteristics of the current packaging. The result of this comparison was an overview of how the current consumer packaging scores on the requirements. From this comparison, changes can be identified to improve the current packaging. For these packaging changes, process adjustments were identified when applicable in part four. In part five, for both the packaging changes and process adjustments, a cost estimation has been performed.

Combining all the information from both the QFD and the cost estimation, EO can learn more about the current (and future) requirements, how these are implemented in the current consumer packaging at this moment and how the consumer packaging could be improved. Another option is to look into different packaging types to add to the portfolio of EO instead of or in addition to the current consumer packaging. All in all, with the information collected in this study, more insight can be created into the requirements of the consumer packaging of the doughnuts of Europastry Oldenzaal. Therefore, the research objective has been achieved.

References

Aguwa, C., Monplaisir, L., & Turgut, O. (2012). Voice of the customer: Customer satisfaction ratio based analysis. *Expert Systems with Applications*, *39*(11), 10112-10119. Retrieved from https://www.sciencedirect.com/science/article/pii/S0957417412003156 doi: https://doi.org/10.1016/j.eswa.2012.02.071

Akbari, M. (2024). *The road to outsourcing 4.0*. Palgrave Macmillan.

AlbertHeijn. (2023). *Circulair. beter verpakken.* Retrieved from https://duurzaamheidsverslag.ah.nl/2023/beter-verpakken

Almeida, A., & Cunha, J. (2017). The implementation of an activity-based costing (abc) system in a manufacturing company. *Procedia Manufacturing*, *13*, 932-939. Retrieved from https://www.sciencedirect.com/science/article/pii/S2351978917307990 doi: 10.1016/j.promfg.2017.09.162

Anderson, J. (2009). Determining manufacturing cost. *Aiche CEP*. Retrieved from https://my.che.utah.edu/~ring/Design%20I/Articles/CostEstn.pdf

Antony, J. (2003). *Design of experiments for engineers and scientists*. Elsevier.

Asiedu, Y., & Gu, P. (2010). Product life cycle cost analysis: State of the art review. *International Journal of Production Research*, *36*(4), 883-908. Retrieved from https://www.scribd.com/document/415701893/asiedu1998 doi: https://doi.org/10.1080/002075498193444

Bauer, A., Leppik, K., Galic, K., Anestopoulos, I., Panayiotidis, M., Agriopoulou, S., ... Krauter, V. (2022). Cereal and confectionary packaging: Background, application and shelf-life extension. *Foods*, *11*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8909407/pdf/foods-11-00697.pdf doi: .https://doi.org/10.3390/foods11050697

Bengtsson, L., & Dabhilkar, M. (2006). Manufacturing outsourcing and its effect on plant performance—lessons for kibs outsourcing. *Journal of Evolutionary Economics*, *19*, 231-257. Retrieved from https://link.springer.com/article/10.1007/s00191-008-0129-1# doi: 10.1007/s00191-008-0129-1

Benner, M. (2005). The chain information model: A systematic approach for food product development. *Wageningen University*. Retrieved from https://edepot.wur.nl/121698

Biemer, P., & Lyberg, L. (2003). *Introduction to survey quality*. John Wiley and Sons.

Brouwer, M., van Velzen, E. U. T., Ragaert, K., & ten Klooster, R. (2020). Technical limits in circularity for plastic packages. *Sustainability*, *12*(23). Retrieved from https://www.mdpi.com/2071-1050/12/23/10021 doi: oi:10.3390/su122310021

Burge, S. (2007). A functional approach to quality function deployment (putting the function back into quality function deployment). *Systems Engineering*.

Chuang, K. (2013). *Product manufacturing and cost estimating using cad/cae* (1st ed.). Elsevier.

Coles, R., McDowell, D., & Kirwan, M. J. (2003). *Food packaging technology* (1st ed.). Blackwell Publishing.

Consumentenbond. (2024). *Stroomprijs per kwh.* Retrieved from https://www.consumentenbond.nl/energie-vergelijken/kwh-prijs#:~:text=Kilowattuur%20(kWh),-De%20prijs%20van&text=In%20augustus%202022%20was%20het,van%20een%201%2Djarig%20contract.

Dabous, S. A., Ayoub, M., Alsharqawi, M., & Hosny, F. (2024). An integrated model for selecting bridge structural systems using quality function deployment and analytic hierarchy process. *Journal of infrastructure intelligence and resilience*, *3*(2). Retrieved from https://www.sciencedirect.com/science/article/pii/S277299152400015X

de Leeuw, E., Hox, J., & Dillman, D. (2008). *International handbook of survey methodology*. European Association of Methodology.

Dombre, C., Marais, S., Chappey, C., Lixon-Buquet, C., & Chalier, P. (2014). The behaviour of wine aroma compounds related to structure and barrier properties of virgin, recycled and active pet membranes. *Journal of membrane science*, *463*, 215-225. Retrieved from https://www.sciencedirect.com/science/article/pii/S037673881400252X?ref=pdf_download&fr=RR-2&rr=8d825073a9fb1cc6 doi: https://doi.org/10.1016/j.memsci.2014.03.066

Drury, C. (2012). *Management and cost accounting* (8th ed.). Cengage Learning.

Duong, L. N., Al-Fadhli, M., Jagtap, S., Bader, F., Martindale, W., Swainson, M., & Paoli, A. (2020). A review of robotics and autonomous systems in the food industry: From the supply chains perspective. *Trends in Food Science and Technology*, *106*, 355-364. Retrieved from https://www.sciencedirect.com/science/article/pii/S0924224420306518 doi: https://doi.org/10.1016/j.tifs.2020.10.028

Eco-Ease. (n.d.). *Pet technical handbook.* Retrieved from https://ecoease.co.uk/wp-content/uploads/2018/09/PET-Technical-Handbook-1.pdf

Elahi, B. (2018). *Safety risk management for medical devices.* Academic Press.

Erdil, N., & Arani, O. (2018). Quality function deployment: More than a design tool. *International Journal of Quality and Service Sciences*, *11*(1). Retrieved from https://www.researchgate.net/publication/328716319_Quality_function_deployment_more_than_a_design_tool doi: DOI:10.1108/IJQSS-02-2018-0008

EuropianCommission. (2018). *Consolidated text: European parliament and council directive 94/62/ec of 20 december 1994 on packaging and packaging waste.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01994L0062-20180704

EuropianCommission. (2021). *Regulation (ec) no 1935/2004 of the european parliament and of the council of 27 october 2004 on materials and articles intended to come into contact with food and repealing directives 80/590/eec and 89/109/eec.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02004R1935-20210327

EuropianCommission. (2022). *European green deal: Putting an end to wasteful packaging, boosting reuse and recycling.* Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7155

EuropianCommission. (2023). *Recycled plastic packaging in contact with food, summary of: Regulation (eu) 2022/1616 on recycled plastic materials and articles intended to come into contact with foods.* Retrieved from https://eur-lex.europa.eu/EN/legal-content/summary/recycled-plastic-packaging-in-contact-with-food.html

EuropianCommission. (2024). *Revision of the packaging and packaging waste directive.* Retrieved from https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/745707/EPRS_BRI(2023)745707_EN.pdf

FoodDrinkEurope. (2022). *Fooddrinkeurope - guidelines on legibility of labelling.* Retrieved from https://www.fooddrinkeurope.eu/wp-content/uploads/2022/10/06672-Guidelines-on-Legibility-of-Labelling_45.pdf

Fowler, F. J. (2009). *Survey research methods* (4th ed.). SAGE Publications.

Franceschini, F. (2001). *Advanced quality function deployment* (1st ed.). St. Lucie Press.

Germani, M., Mandolini, M., & Cicconi, P. (2011). Manufacturing cost estimation during early phases of machine design. *Proceedings of the 18th International Conference on Engineering Design (ICED 11)*, 198-209. Retrieved from https://www.designsociety.org/publication/30592/MANUFACTURING+COST+ESTIMATION+DURING+EARLY+PHASES+OF+MACHINE+DESIGN

Geueke, B., Grah, K., & Munchke, J. (2018). Food packaging in the circular economy: Overview of chemical safety aspects for commonly used materials. *Journal of Cleaner Production*, *193*, 491-505. Retrieved from https://www.sciencedirect.com/science/article/pii/S0959652618313325?via%3Dihub doi: https://doi.org/10.1016/j.jclepro.2018.05.005

Hauser, J. R., & Clausing, D. (1988). The house of quality. *Harvard business review*. Retrieved from https://blogs.ubc.ca/nvdteamb/files/2013/10/7-The-House-of-Quality.pdf

Hemavathi, A., & Siddaramaiah, H. (2018). Food packaging: Polymers as packaging materials in food supply chains. *Encyclopedia of Polymer Applications*, *1*. Retrieved from https://www.researchgate.net/profile/A-Hemavathi-2/publication/367982013_Food_Packaging_Polymers_as_Packaging_Materials_in_Food_Supply_Chains/links/63dbb85bc465a873a27c4323/Food-Packaging-Polymers-as-Packaging-Materials-in-Food-Supply-Chains.pdf doi: https://doi.org/10.1201/9781351019422-140000032

Horan, L. (2022). The dynamic changes of customer requirements for sustainable design over time in quality function deployment. *Production and manufacturing Research*, *10*(1), 42-61. Retrieved from https://www.tandfonline.com/doi/full/10.1080/21693277.2022.2039316?scroll=top&needAccess=true doi: https://doi.org/10.1080/21693277.2022.2039316

Horsthuis, E., Groenen, F., Toxopeus, M., & Lutters, E. (2024). Closing the perception-reality gap for sustainable fresh food plastic packaging. *Procedia CIRP*, *122*, 647-652. Retrieved from https://www.sciencedirect.com/science/article/pii/S2212827124001264 doi: https://doi.org/10.1016/j.procir.2024.02.019

I.Bardhan, Whitaker, J., & Mithas, S. (2006). Information technology, production process outsourcing, and manufacturing plant performance. *Journal of Management Information Systems*, *23*(2), 13–40. Retrieved from https://doi.org/10.2753/MIS0742-1222230202 doi: 10.2753/MIS0742-1222230202

Ilhan, I. (2023). *Understanding seal integrity: Sealing and closing of flexible packaging* (Doctoral dissertation). doi: 10.3990/1.9789036555814

Indeed. (2025). *Salaris voor storingsmonteur (m/v) in nederland.* Retrieved from https://nl.indeed.com/career/storingsmonteur/salaries

Isai, V., Radu, R. I., & Ionescu, C. (2014). A study on the abc approach in cost management practice. *International conference "Risk in Contemporary Economy"*, *15*.

ISO. (2021). Application of statistical and related methods to new technology and product development process — part 1: General principles and perspectives of quality function deployment (qfd). *International Organization for Standardization*. Retrieved from https://cdn.standards.iteh.ai/samples/74103/81cbd7a8cfb143ffaeb4988c9da217e8/ISO-16355-1-2021.pdf

Karna, S. L. N. A., Kalubandi, S., & Edacherian, S. (2022). Performance implications of outsourcing: A meta-analysis. *Journal of Business Research*, *139*, 1303-1316. Retrieved from https://www.sciencedirect.com/science/article/pii/S0148296321007918 doi: https://doi.org/10.1016/j.jbusres.2021.10.061

Kim, J. (2019). Designing quality on flexible packaging systems using qfd-ahp. *Michigan State University*.

Kiran, D. R. (2017). *Total quality management*. Butterworth-Heinemann.

Konstantoglou, A., Folinas, D., & Fotiadis, T. (2020). Exploring the multi-function nature of packaging in the food industry. *Logistics*, *4*(3). Retrieved from https://www.mdpi.com/2305-6290/4/3/21 doi: https://doi.org/10.3390/logistics4030021

Kumari, S., Mishra, A. S. A., & Garza-Reyes, J. (2015). A multi-agent architecture for outsourcing smes manufacturing supply chain. *Robotics and Computer-Integrated Manufacturing*, *36*, 36-44. Retrieved from https://www.sciencedirect.com/science/article/pii/S0736584515000071 doi: https://doi.org/10.1016/j.rcim.2014.12.009

Lai, X., Xie, M., Tan, K., & Yang, B. (2008). Ranking of customer requirements in a competitive environment. *Computers and industrial Engineering*, *54*, 202-214. Retrieved from https://www.sciencedirect.com/science/article/pii/S0360835207001672 doi: https://doi.org/10.1016/j.cie.2007.06.042

Lavrakas, P. (2008). *Encyclopedia of survey research methods*. SAGE Publications.

Lembersky, M. (2016). *Realistic cost estimating for manufacturing* (3rd ed.). Society of Manufacturing Engineers (SME).

Lindh, H., Williams, H., Olsson, A., & Wikstrom, F. (2016). Elucidating the indirect contributions of packaging to sustainable development: A terminology of packaging functions and features. *Packaging Technology and Science*, *29*, 225-246. Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1002/pts.2197 doi: https://doi.org/10.1002/pts.2197

Lydekaityte, J., & Tambo, T. (2020). Smart packaging: definitions, models and packaging as an intermediator between digital and physical product management. *The international review of retail, distribution and consumer research*, *30*(4). Retrieved from https://www-tandfonline-com.ezproxy2.utwente.nl/doi/full/10.1080/09593969.2020.1724555 doi: https://doi.org/10.1080/09593969.2020.1724555

Mandolini, M., Campi, F., Favi, C., Germani, M., & Raffaeli, R. (2020). A framework for analytical cost estimation of mechanical components based on manufacturing knowledge representation. *International journal of advanced manufacturing technology*, *107*, 1131–1151. Retrieved from https://link.springer.com/article/10.1007/s00170-020-05068-5 doi: https://doi.org/10.1007/s00170-020-05068-5

Marsh, K., & Bugusu, B. (2007). Food packaging—roles, materials, and environmental issues. *Journal of Food Science*, *72*(3). Retrieved from https://www.researchgate.net/profile/Kenneth-Marsh-3/publication/5850700_Food_PackagingRoles_Materials_and_Environmental_Issues/links/5a046cf8a6fdcc1c2f6062e0/Food-PackagingRoles-Materials-and-Environmental-Issues.pdf doi: https://doi.org/10.1111/j.1750-3841.2007.00301.x

Martinsuo, M. (2013). Project portfolio management in practice and in context. *International Journal of Project Management*, *31*(6), 794-803. Retrieved from https://www.sciencedirect.com/science/article/pii/S026378631200155X?via%3Dihub doi: https://doi.org/10.1016/j.ijproman.2012.10.013

Massey, L. K. (2002). *Permeability properties of plastics and elastomers* (2nd ed.). William Andrew Inc.

Mislick, G. K., & Nussbaum, D. (2015). *Cost estimation: method and tools* (1st ed.). Wiley.

Mital, A., Desai, A., Subramanian, A., & Mital, A. (2014). *4 - design review: Designing to ensure quality* (2nd ed.). Elsevier.

Motorcu, A. R., & Güllü, A. (2006). Statistical process control in machining, a case study for machine tool capability and process capability. *Materials & Design*, *27*, 364-372. Retrieved from https://www.sciencedirect.com/science/article/pii/S0261306904002997 doi: https://doi.org/10.1016/j.matdes.2004.11.003

Nieuwmeijer, L., & Lutters, E. (2022). Where variants and familiarity meet: portfolio management in companies that design and produce. *Procedia CIRP*, *109*, 502-507. Retrieved from https://www.sciencedirect.com/science/article/pii/S221282712200734X#cebibsec1 doi: https://doi.org/10.1016/j.procir.2022.05.285

Oghazi, V. S. P., & Olsson, A. (2015). An improved supplier driven packaging design and developmentmethod for supply chain efficiency. *Packaging technology and Science*, *29*, 161-173. Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1002/pts.2194 doi: https://doi.org/10.1002/pts.2194

Ozbayrak, M., Akgun, M., & Turker, A. (2004). Activity-based cost estimation in a push/pull advanced manufacturing system. *International Journal of Production Economics*, *87*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0925527303000677 doi: doi:10.1016/S0925-5273(03)00067-7

Paine, F., & Paine, H. (2012). *A handbook of food packaging* (2nd ed.). Springer Science and Business Media.

papstar. (2025). *Saladebakken met deksels, r-pet ovaal 750 ml 6,2 cm x 14,4 cm x 17,5 cm transparant*. Retrieved from https://www.papstar-shop.nl/saladebakken-met-deksels-r-pet-ovaal-750-ml-6-2-cm-x-14-4-cm-x-17-5-cm-transpa-88050.htm

Parlement, E. (2011). *Regulation (eu) no 1169/2011 of the european parliament and of the council*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R1169

Paryani, K., Masoudi, A., & Cudney, E. (2010). Qfd application in the hospitality industry: A hotel case study. *Quality management journal*, *17*(1). Retrieved from https://www.tandfonline.com/doi/abs/10.1080/10686967.2010.11918258 doi: https://doi.org/10.1080/10686967.2010.11918258

Popp, D. (2024). *New eu rules to reduce, reuse and recycle packaging*. Retrieved from https://www.europarl.europa.eu/news/en/press-room/20240419IPR20589/new-eu-rules-to-reduce-reuse-and-recycle-packaging#:~:text=To%20reduce%20unnecessary%20packaging%2C%20a,banned%20from%201%20January%202030.

Puglieri, F., Ometto, A. R., Salvador, R., Barros, M., Piekaski, C. M., Rodirgues, I. M., & Netto, O. D. (2020). An environmental and operational analysis of quality function deployment-based methods. *Sustainability*, *12*(8). Retrieved from https://www.mdpi.com/2071-1050/12/8/3486 doi: https://doi.org/10.3390/su12083486

Qiwei, H., Boylan, J., Huijing, C., & Labib, A. (2018). Or in spare parts management: A review. *European Journal of Operational Research*, *266*, 395 - 414. Retrieved from https://www.sciencedirect.com/science/article/pii/S0377221717307014 doi: https://doi.org/10.1016/j.ejor.2017.07.058

Ramos, A., Ribeiro, J. P., & Lopes, M. (2011). In-house outsourcing of packaging activities. *Business Sustainability 2.0*, *2*, 183-187. Retrieved from https://core.ac.uk/download/pdf/570970059.pdf#page=206

Riesener, M., Kuhn, M., Boßmann, C., & Schuh, G. (2023). Concept for the portfolio management of industrial solution providers in machinery and plant engineering. *Procedia CIRP*, *119*, 1152 - 1157. Retrieved from https://www.sciencedirect.com/science/article/pii/S2212827123006078 doi: https://doi.org/10.1016/j.procir.2023.03.156

Rijksoverheid. (2023). *Regelgeving voor circulaire plastics*. Retrieved from https://www.nederlandcirculairin2050.nl/nationaal-programma-circulaire-economie/regelgeving-voor-circulaire-plastics#:~:text=De%20nationale%20circulaire%20plastics%20norm,%25%20%2D%2030%25%20in%202030.

Rijksoverheid. (2025). *Bedragen minimumloon 2025*. Retrieved from https://www.rijksoverheid.nl/onderwerpen/minimumloon/bedragen-minimumloon/bedragen-minimumloon-2025

Ruel, E., III, W. E. W., & Gillespie, B. J. (2016). *The practice of survey research: Theory and applications*. SAGE Publications.

Sadeghi, K., Kim, J., & Seo, J. (2022). Packaging 4.0: The threshold of an intelligent approach. *Institute of Food Technologists*, *21*(3), 2075-3029. Retrieved from https://ift.onlinelibrary.wiley.com/doi/epdf/10.1111/1541-4337.12932 doi: https://doi.org/10.1111/1541-4337.12932

Saikaew, C. (2018). An implementation of measurement system analysis for assessment of machine and part variations in turning operation. *Measurement*, *118*, 246-252. Retrieved from https://www.sciencedirect.com/science/article/pii/S0263224118300095 doi: https://doi.org/10.1016/j.measurement.2018.01.008

Shapiro, A. F., & Koissi, M. (2017). Fuzzy logic modifications of the analytic hierarchy process. *Insurance: Mathematics and Economics*, *75*, 189-202. Retrieved from https://www.mindtools.com/a7y139c/the-analytic-hierarchy-process-ahp doi: https://doi.org/10.1016/j.insmatheco.2017.05.003

STAND. (2018). *170 requirements for design of consumer unit (cu)*. Retrieved from https://stand.no/en/articles/170-requirements-for-design-of-consumer-unit-cu/#:~:text=Consumer\%20Unit\%20(CU)\%20is\%20the,a\%20tray\%20on\%20the\%20shelf

Stark, J. (2022). *Product lifecycle management (volume 1)* (5th ed.). Springer Nature Switzerland.

Strange, R., & Magnani, G. (2017). The performance consequences of manufacturing outsourcing: Review and recommendations for future research. *Advances in International Management*, *30*, 217-244. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/s1571-502720170000030009/full/html doi: doi:10.1108/S1571-502720170000030009

Syed, Q. A. (2018). Fmcg packaging model: Characteristics and relationship between packaging functions. *Tallinn University of Technology*. Retrieved from https://digikogu.taltech.ee/et/Download/a5f53b61-9f04-4761-89d6-6c3c8f4d2bef/Esmatarbekaupadepakendamisemudelomadustejafu.pdf

Tan, K., Xie, M., & Goh, T. N. (2003). *Advanced qfd applications*. Quality Press.

ten Klooster, R. (2020). *Packaging design and management - introduction*. University of Twente.

ten Klooster et al, R. (2015). *Zakboek verpakkingen* (2nd ed.). Plato product consultants.

TheNationalArchives. (2020). *European parliament and council directive 94/62/ec*. Retrieved from https://www.legislation.gov.uk/eudr/1994/62/contents

Thiede, S. (2024). *Lecture 3: Production performance*. University of Twente.

Tiekstra, S., Dopico-Parada, A., Koivula, H., Lahti, J., & Buntinx, M. (2021). Holistic approach to a successful market implementation of active and intelligent food packaging. *Foods*, *10*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7923791/pdf/foods-10-00465.pdf doi: .https://doi.org/10.3390/foods10020465

Tolonen, A., Shahmarichatghieh, M., Harkonen, J., & Haapasalo, H. (2015). Product portfolio management – targets and key performance indicators for product portfolio renewal over life cycle. *International Journal of Production Economics*, *170*, 468 - 477. Retrieved from https://www.sciencedirect.com/science/article/pii/S0925527315002017

UniversalRobots. (2022). *Cobots and electricity use: one less thing to worry about.* Retrieved from https://www.universal-robots.com/blog/cobots-and-electricity-use-one-less-thing-to-worry-about/

Utne, I. B. (2009). Improving the environmental performance of the fishing fleet by use of quality function deployment (qfd). *Journal of Cleaner Production*, *17*(8), 724-731. Retrieved from https://www.sciencedirect.com/science/article/pii/S0959652608002837 doi: https://doi.org/10.1016/j.jclepro.2008.11.005

van der Meer, W. (2024). Increasing the capacity of the consumer packaging lines of europastry oldenzaal. *University of Twente*. Retrieved from https://purl.utwente.nl/essays/98893

Väre, E. (2024). Barriers to the circularity of single-use plastic food packaging in the european union. *Tampere University*. Retrieved from https://trepo.tuni.fi/bitstream/handle/10024/159060/VareEmma.pdf?sequence=2

Yamashina, H., & Kubo, T. (2002). Manufacturing cost deployment. *International Journal of Production Research*, *40*(16), 4077-4091. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/00207540210157178 doi: https://doi.org/10.1080/00207540210157178

Youssef, A., & El-Sayed, S. (2018). Bionanocomposites materials for food packaging applications: Concepts and future outlook. *Carbohydrate Polymers*, *193*(1), 19-27. Retrieved from https://www.sciencedirect.com/science/article/pii/S0144861718303485 doi: https://doi.org/10.1016/j.carbpol.2018.03.088

Yu-Che, H., & Chu-Yin, T. (2019). Research for qfd applied to education of cosmetics package design. *International Conference on Digital Technology in Education*, *3*. Retrieved from https://dl.acm.org/doi/pdf/10.1145/3369199.3369208 doi: https://doi.org/10.1145/3369199.3369208

Zaritzky, N. (2010). 20 - chemical and physical deterioration of frozen foods. *Chemical Deterioration and Physical Instability of Food and Beverages*, 561-607. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/B9781845694951500204 doi: https://doi.org/10.1533/9781845699260.3.561