Appendix

Inventory drivers in a pharmaceutical supply chain

A framework for optimized inventory management derived from an analytical approach

CONTENT

Appendix A- Survey questionnaire and survey analysis

1. The survey questionnaire

1.1. Introductory notes

The following text is the content of the e-mail sent internally to the selected population for the study.

Dear *PharmaNordic* employee,

I am a student assistant in the Supply Chain Analytics department and I am about to finalise my MSc within Management Engineering at the Technical University of Denmark (DTU).

In my Thesis I am investigating which factors have a greater impact on finished goods inventory levels, specifically in the pharmaceutical industry. Furthermore, I am investigating which inventory management and control policies pharmaceutical companies should aim for with regards to finished goods.

I am contacting you, in the hope that you will help me with your business acumen, to fill in the gaps derived from the data analysis I have done so far. The aim of the following survey is to create a holistic data foundation which will be used to benchmark current practices within inventory management in *PharmaNordic* with industry standards.

The questions relate to *finished goods* inventory management: identification of current practices in *PharmaNordic* as well as questions relating to specific contextual factors impacting inventory levels at affiliates. The data in this survey will be compared with analytical findings obtained through data analysis techniques.

The survey can be accessed following the link below, which leads to a google-form:

https://goo.gl/forms/8Utc2vEx39u1wfcY2

It will take approx. 10 min to complete the survey. **The survey is completely anonymous and will be used for internal research purposes only**.

If in doubt, please feel free to contact me: clva@pharmanordic.com (+45 50207299) or mkpm@pharmanordic.com.

I would really appreciate it if you could fill in this survey before 12th of May 2017 EOD. Please feel free to forward to who you might find this relevant for.

In advance, thank you very much for your time.

Best regards,

Clara Masvidal Andreu
Thesis Student
Supply Chain Analytics

1.2. Survey scope and structure

Presentation of the survey study to the respondents:

Most inventory management research is performed in heavy manufacturing industries, such as the automobile or airplane manufacturing industries. Furthermore, quantitative methods such as operations research and advanced mathematical models and simulation techniques that determine the optimal inventory allocation have received increasing attention in the past recent years. However, there is a lack of a more holistic and multidisciplinary approach in managing inventories in pharmaceutical supply chains with regards to finished goods and the delivery chain. This research contributes with novel insights by extensively examining inventory drivers in other industries and selecting the relevant ones for the pharmaceutical industry, proposing a theoretical framework which is useful for practitioners and relevant to the academia.

The quantitative survey follows an inductive approach and allows obtaining consistent data input about parameters impacting inventory levels at the affiliates of the case study company.
The survey consists of five sections, as shown in Table 1 below.

Each section aims at investigating different aspects within inventory management at the case study firm.

Table 1. Distribution of questions among sections in the survey study

Survey Section	No. of questions	Distribution
Practical Information	3	6%
Identifying the main issues within inventory management in the case study company	2 (Multiple statements)	11%
Specific issue: *overstocking* and *stock-outs*	7	13%
Identifying inventory drivers	35	62%
Final remarks	6	7%
Total	**53**	**100%**

The estimated time to complete the survey is 10 minutes.

1.3. Survey questionnaire: Hypothesis and questions

Dear respondent,

The questions in this survey relate to finished goods inventory management: identification of current practices in the company as well as questions relating to specific contextual factors impacting inventory levels at affiliates. The data in this survey will be compared with analytical findings obtained through data analysis techniques.
The scope is on finished goods stocks (7-items) for insulin products.
The survey is completely anonymous and will be used for internal research purposes only. If in doubt, please do not hesitate to contact: clva@pharmanordic.com.
Thank you very much for taking the time to answer this survey.

Section 1: Practical Information

This section is used as documentation on practical information about you and your role within the firm. Knowing your role and position will enable a more comprehensive examination of the answers provided. However, as some of the information requested in this survey can be considered sensitive you can choose to answer anonymously.

Question	Answer Type	Purpose of the question
1. Have you, or are you currently involved in any inventory management process within *PharmaNordic*?	- Yes - No, I am not eligible for this survey	Determine if the respondent is eligible for the survey and ensure that the respondent has enough valuable input to the study.
2. Would you like to be anonymous or can we publish your name? * Hint: If you're fully anonymous, no name or obvious references will figure in publications. If you choose to be public, your name may be published in supporting the research.	Multiple-choice: - Fully anonymous - Public	To clear the disclosure question right from the start as this might be a major concern for the respondent taking the survey.
3. What is your role and position within the firm? * Hint: E.g. Production planner. 7-items FlexP.	Text type	To examine the role of the respondent; is he/she directly responsible for managing inventories?

Section 2: Identifying the main issues within inventory management in the case study company

The following section intends to determine what are the perceived key issues with regards to inventory management and control in *PharmaNordic*.

Question	Answer Type	Purpose of the question
4. Overall, how would you rate *PharmaNordic*'s ability to manage and control inventory levels at affiliates?	Likert scale from 1 to 5 1: Very poor 5: Highly advanced	Situate the respondents to the subject that will be discussed and determine the respondents' perception on whether this is an important topic or not.
5. To which degree do you agree with the following statements? *5.1.* We have the right ERP systems and planning processes in place. These allow us to do an informed assessment on inventory needs at the affiliates. *5.2.* We have the right visibility on what the affiliates have in stock. *5.3.* The sales forecast is accurate enough (the –forecast name used internally in the case study company- sales are usually also realized sales). *5.4.* We have too many stock-outs at the affiliates. *5.5.* We expedite too often in order not to have stock-outs. *5.6.* Lead Times are usually longer than what the order LT policy establishes. (Delivery Plant-Delivery System)	Likert scale 1 to 5 1: Completely disagree 2: Disagree 3: Neutral (neither agree or disagree) 4: Agree 5: Completely agree	To determine what are the **key issues** with regards to inventory management and control identified by experts within the case company.

The questions in this section arise from an exhaustive examination of the case study company internal documentation and interviews conducted among Supply Chain specialists. The hypotheses that led to the formulation of the questions are the following:

H1. One of the issues faced by the case study company is an incomplete integration of the ERP systems used between the headquarters and the affiliates where products are stocked.

H2. PharmaNordic faces a challenge when it comes to stock visibility at affiliates. MRP affiliates provide automatic updates on the stock levels, but in non-MRP affiliates, the stock levels are not visible from central HQ functions.

*H3.*Sales forecast accuracy is one of the main issues planners for planning replenishment orders and safety stock levels.

*H4.*and *H5.*The Product Supply department within *PharmaNordic* is a very conservative organization (expediting in an urgent manner is allowed in order not to have stock-outs). Management's focus is on having the right service levels.

H6. In line with the previous hypothesis, Lead Times are usually longer than what the policy establishes.

Section 3: Specific issue: overstocking and stock-outs

This section is oriented towards identifying the disadvantages of overstocking finished goods versus the disadvantages of having stock-outs. Again, the scope is on finished goods stocks (7-items) for insulin products.

Question	**Answer Type**	**Purpose of the question**
6. In your opinion, does *PharmaNordic* tend to overstock 7-items at the affiliates? With overstocking, we refer to as having *more* than the *necessary* number of finished goods at our affiliates.	- Yes - No, the amount of finished goods stock at the affiliates is the right amount (needed amount).	To determine whether overstocking is seen as an issue in the case study company.
7. In your opinion, is overstocking an issue?	- Yes - No, it is preferable than having stock-outs. - I do not have sufficient information to answer this question	To determine respondent's perception on whether overstocking is a problem within the company.
8. (If you answered *yes* in question 6), which of the following **brands** tend to be more overstocked?	Multiple Choice: - Product P1 - Product P2 - Product P3 - Product P4 - Product P5 - … - Product P12 - I do not have sufficient information to answer this question	The products listed present different degrees of complexity. The hypothesis that wants to be tested is whether product complexity has an inherent impact on stock levels. The answers in this question will be benchmarked with quantitative data from the case study company.
9. (If you answered *yes* in question 6), which of the following **delivery systems** tend to be more overstocked?	Multiple Choice: - D1 - D2 - … - D6 - I do not have sufficient information to answer this question	The products listed present different degrees of complexity. The hypothesis that wants to be tested is whether product complexity has an inherent impact on stock levels. The answers in this question will be benchmarked with quantitative data from the case study company.
10. Of the following countries presented, which ones them tend to have more stock on hand relative to the amount they would really need?	Multiple Choice: - List of countries (MRP)	The answers in this question will be benchmarked with quantitative data from the case study company.
11. In your opinion, do you think the number of 7-items stored at the affiliates could be reduced, through better inventory management and control policies?	- Yes - No	
11-a. (If you answered yes in Question 11). Could you please elaborate your answer?	Text Type	

Section 4: Identifying inventory drivers

This part of the survey will be used to document in more detail what are the perceived factors that impact inventory levels at affiliates the most.

An extensive literature review on inventory management practices and policies has identified more than 35 factors impacting inventory levels in different degrees and intensities.

This section wants to determine industry experts' views on the impact of each of the drivers on inventory (i.e. which factors have more impact on inventory levels) at the affiliates.

The combination of both quantitative data from [*internal system name*] and your answers will help in identifying the *pain* points; where we can improve our processes and pay special attention in order to reduce inventory levels.

* When rating the driver's impact, the factors across each of the sub-groups should be compared:

- Read the list of *Production/Internal Operations* Capabilities factors first, thinking which of them are more likely to have a higher impact on inventory levels.
- Rate each of the factors: cross the level of impact in the correspondent cell.
  - Two factors in the same sub-group can have the same level of impact.
  - However, try to split the grades across the different factors.
- Move on to the next sub-group: *Product Characteristics*, and repeat the process.

Type of question: Multiple choice grid (numbers are to be assigned for each of the factors).

Please indicate the kind of importance that each factors have on inventory levels. The possible responses are: (1) Not important (2) Low importance (3) Medium importance (4) High importance and (5) Extremely important.

Inventory Driver	**1.Very low impact**	**2. Low Impact**	**3. Medium Impact**	**4. High Impact**	**5.Very High Impact**
Internal Production Requirements					
12. Order Quantity/Order Size	1	2	3	4	5
13. Replenishment policy: MRP, Cycle, L4L, Manual	1	2	3	4	5
14. Production Capacity Utilzation	1	2	3	4	5
15. Production Flexibility	1	2	3	4	5
16. Production Lead Time	1	2	3	4	5
17. Lead Time Variance	1	2	3	4	5
18. Inventory Space	1	2	3	4	5
Product Characteristics					
19. Product Complexity	1	2	3	4	5
20. Degree of Product Customization to specific market	1	2	3	4	5
21. Shelf life/Product Durability	1	2	3	4	5
Market Factors					
22. Average Demand per product	1	2	3	4	5
23. Standard Deviation of Demand: σ_D	1	2	3	4	5
24. Forecast Accuracy	1	2	3	4	5
25. Forecast Horizon	1	2	3	4	5
26. Service Level	1	2	3	4	5
27. Sales Channel Type and contract	1	2	3	4	5
Financial Factors					
28. (Final) Product price/unit	1	2	3	4	5
29. Raw material costs	1	2	3	4	5

30. Order Cost	1	2	3	4	5
31. Holding Cost	1	2	3	4	5
32. Stock-out Penalty Cost	1	2	3	4	5
33. Scrap or Obsolescence Cost	1	2	3	4	5
34. Transportation Cost per product	1	2	3	4	5
Downstream SC characteristics					
35. Lead Time Delivery to Customers	1	2	3	4	5
36. De-coupling Point position	1	2	3	4	5
37. Degree of Customer.-Orientation	1	2	3	4	5
38. Type of Transportation	1	2	3	4	5
Managerial and other factors					
39. Outsourced Logistics	1	2	3	4	5
40. Lean Supply chain capabilities	1	2	3	4	5
41. Personal Bias	1	2	3	4	5
42. Management Attitude towards Inventory Control	1	2	3	4	5
43. Degree of employee training & empowerment	1	2	3	4	5
44. Degree of Information Sharing	1	2	3	4	5
45. Degree of Cooperation among SC players	1	2	3	4	5
46. Aggregation (Centralisation/De-centralisation)	1	2	3	4	5
47. Regulation Requirements (Governments and Drug Administrations)	1	2	3	4	5

Section 5: Final remarks

Question	Answer Type	Purpose
48. Do you have further suggestions for factors that should be considered when determining optimal stock levels?	Text Type	To identify potential new factors to be added to the framework
49. Do you have any further suggestions on how the factors presented have been grouped? If so, please specify how you would rather group them.	Text Type	To identify improvements for the framework and its structure.
50. Do you have any comments, critique or suggestions to this survey?	Text Type	
51. Would you like to contribute further, if it becomes relevant?	Multiple Choice: - Yes - No	
52. If you answered yes, please, enter your e-mail.	Text Type	
53. Would you like to receive the results of the survey and the final article?	Multiple Choice: - Results of the survey - Full thesis - Article only	

Final thank you notes

Thank you once again for your contribution to this research. If needed, you're welcome to contact me:
Clara Masvidal Andreu ; +45 50207299; clva@pharmanordic.com

2. Survey questionnaire analysis

2.1. Survey results

Table 2. Scores allocated to the inventory drivers in the Internal Production Capabilities category

	Internal Production Capabilities Factors						
Role within the company	**Order Quantity /Order Size**	**Order policy**	**Production Capacity Utilization**	**Production Flexibility**	**Production Lead Time**	**Lead Time Variance**	**Space Allocated for inventory**
Material Planner supervisor	5	3	1	5	1	1	1
Specialist in Supply Chain Planning	5	4	5	3	3	3	2
Planning Team Manager	4	3	2	3	4	3	2
Production planner	4	3	3	3	4	2	2
7-items vial and bulk, Planner	3	4	3	3	3	3	4
Production planner. Site Moc.	5	4	5	4	3	2	4
API Controller	5	5	4	4	4	4	4
Team leader in supply chain	4	5	4	3	4	4	2
SCI, previously S&OP Partner	3	4	5	3	3	3	3
Production planner	2	5	2	2	3	2	2
Production Planner	4	4	4	2	2	2	2
Supply Chain Consultant	2	3	2	2	3	3	3
Business Analytics Consultant	3	5	1	3	5	5	2
Supply Chain Analyst	4	3	3	4	2	4	2
Business Analyst SC	3	4	3	4	4	4	2
Supply Chain Business Analyst	4	4	2	2	5	5	1
Average	**3,75**	**3,9375**	**3,0625**	**3,125**	**3,3125**	**3,125**	**2,375**
Variation	1	0,7719	1,3402	0,885	1,078	1,147	0,957
Median	4	4	3	3	3	3	2
Category Weight							**3,1428**

Table 3. Scores allocated to the inventory drivers in the Product Characteristics category

	Product Characteristics		
Role within the company	**Product Complexity**	**Product Customization to Specific Market**	**Shelf Life/Product Durability**
Material Planner supervisor	1	1	1
Specialist in Supply Chain Planning and SAP ECC/APO ARSU	4	3	3
Planning Team Manager	3	2	4
Production planner	3	4	4
7-items vial and bulk, Planner	4	4	3
Production planner. Site Moc.	4	4	5
API Controller	4	4	4
Team leader for production planners	3	3	5
SCI, previously S&OP Partner	1	3	3
Production planner	1	1	4
Production Planner	2	2	4
Supply Chain Consultant	3	3	2
Business Analytics Consultant	4	4	3
Supply Chain Analyst	2	3	2
Business Analyst SC	2	3	3
Supply Chain Business Analyst	**1**	2	3
Average	**2,6**	**2,9**	**3,3**
Variation	1,2	1,0	1,1
Median	3,0	3,0	3,0
Category Weight			**3,0**

Table 4. Scores allocated to the inventory drivers in the Market Factors Characteristics category

	Market Factors					
Role within the company	**Average demand per product**	**Standard deviation of demand**	**Forecast Accuracy**	**Forecast Horizon/Forecasting frequency**	**Service level**	**Sales channel type and contract type**
Material Planner supervisor	5	5	5	5	5	5
Specialist in Supply Chain Planning and SAP ECC/APO ARSU	4	4	5	3	3	3
Planning Team Manager	4	4	4	3	2	2
Production planner	3	3	3	5	3	4
7-items vial and bulk, Planner	4	3	2	3	4	3
Production planner. Site Moc.	5	4	5	5	3	4
API Controller	4	4	5	5	4	5
Team leader for production planners	4	3	5	5	4	3
SCI, previously S&OP Partner	2	3	3	2	5	4
Production planner	4	2	5	5	3	2
Production Planner	4	5	5	2	4	4
Supply Chain Consultant	3	3	3	3	3	3
Business Analytics Consultant	5	3	4	3	5	2
Supply Chain Analyst	3	5	5	4	3	4
Business Analyst SC	1	5	5	5	4	3
Supply Chain Business Analyst	5	5	4	3	5	3
Average	**3,8**	**3,8**	**4,3**	**3,8**	**3,8**	**3,4**
Variation	1,1	1,0	1,0	1,2	0,9	1,0
Median	4,0	4,0	5,0	3,5	4,0	3,0
Category Weight						**3,9**

Table 5. Scores allocated to the inventory drivers in the Financial Factors category

	Financial Factors						
Role within the company	**Product price/unit**	**Raw material costs**	**Order costs**	**Holding costs**	**Stock-out penalty costs**	**Scrap or obsolescence costs**	**Transportation costs**
Material Planner supervisor	5	1	2	1	4	5	5
Specialist in Supply Chain Planning and SAP ECC/APO ARSU	2	1	1	1	4	4	4
Planning Team Manager	4	2	2	2	2	3	2
Production planner	2	2	2	2	4	2	3
7-items vial and bulk, Planner	2	2	2	2	4	2	3
Production planner. Site Moc.	2	2	3	3	5	3	4
API Controller	4	4	5	5	4	5	4
Team leader for production planners	3	3	3	3	5	5	4
SCI, previously S&OP Partner	1	1	1	2	3	1	2
Production planner	3	3	3	3	3	3	3
Production Planner	1	1	1	1	5	5	2
Supply Chain Consultant	3	3	3	3	3	3	3
Business Analytics Consultant	4	1	1	1	4	1	1
Supply Chain Analyst	4	4	3	4	3	2	2
Business Analyst SC	1	1	3	3	3	3	3
Supply Chain Business Analyst	5	2	4	4	5	1	4
Average	**2,9**	**2,1**	**2,4**	**2,5**	**3,8**	**3,0**	**3,1**
Variation	1,4	1,1	1,2	1,2	0,9	1,5	1,1
Median	3,0	2,0	2,5	2,5	4,0	3,0	3,0
Category Weight							**2,9**

Table 6. Scores allocated to the inventory drivers in the Downstream SC Characteristics category

	Downstream SC Characteristics		
Role within the company	**Lead Time Delivery To customers**	**De-coupling point position**	**Type of transportation**
Material Planner supervisor	1	3	1
Specialist in Supply Chain Planning and SAP ECC/APO ARSU	4	3	4
Planning Team Manager	1	1	5
Production planner	4	4	3
7-items vial and bulk, Planner	3	3	3
Production planner. Site Moc.	5	2	4
API Controller	5	4	5
Team leader for production planners	4	4	5
SCI, previously S&OP Partner	3	3	2
Production planner	4	2	4
Production Planner	4	3	2
Supply Chain Consultant	3	2	2
Business Analytics Consultant	5	5	5
Supply Chain Analyst	3	4	2
Business Analyst SC	4	3	3
Supply Chain Business Analyst	4	5	3
Average	**3,6**	**3,2**	**3,3**
Variation	1,2	1,1	1,3
Median	4,0	3,0	3,0
Category Weight			**3,3**

Table 7. Scores allocated to the inventory drivers in the Managerial and other cooperation factors category

	Managerial and other cooperation factors							
Role within the company	**Oustourced Lgistics**	**Lean SC Capabiulities**	**Personal Bias**	**Management attitude towards IC**	**Employees' training level and autonomy**	**Info sharing across SC players**	**Centralization/Decentralization**	**Regulations Requirements**
Material Planner supervisor	3	5	4	4	4	4	4	4
Specialist in Supply Chain Planning and SAP ECC/APO ARSU	1	2	3	2	2	3	2	2
Planning Team Manager	2	4	2	4	4	4	4	2
Production planner	2	4	2	2	2	2	2	2
7-items vial and bulk, Planner	2	2	3	4	4	3	3	4
Production planner. Site Moc.	3	5	5	4	4	5	5	4
API Controller	4	4	4	4	3	4	4	4
Team leader for production planners	3	3	3	3	3	4	3	4
SCI, previously S&OP Partner	2	3	4	5	2	4	4	3
Production planner	2	2	2	2	2	2	2	2
Production Planner	1	3	4	4	2	2	2	3
Supply Chain Consultant	2	2	2	2	2	1	1	1
Business Analytics Consultant	1	3	5	5	5	5	5	1
Supply Chain Analyst	2	4	3	4	4	5	5	4
Business Analyst SC	5	5	5	5	3	5	5	5
Supply Chain Business Analyst	5	3	4	2	2	4	4	5
Average	**2,5**	**3,4**	**3,4**	**3,5**	**3,0**	**3,6**	**3,4**	**3,1**
Variation	1,3	1,1	1,1	1,2	1,0	1,3	1,3	1,3
Median	2,0	3,0	3,5	4,0	3,0	4,0	4,0	3,5
Category Weight								**3,4**

Table 8. Scores allocated to the inventory drivers in the Upstream Supply Chain Characteristics category

	Upstream SC Characteristics			
Role within the company	**Delivery Performance**	**Delivery Frequency**	**Discounts Suppliers**	**LT delivery from suppliers**
Material Planner supervisor	2	2	1	2
Specialist in Supply Chain Planning	2	2	4	5
Planning Team Manager	4	4	2	4
Production planner	2	2	2	2
7-items vial and bulk, Planner	2	3	1	4
Production planner. Site Moc.	5	3	2	4
API Controller	4	4	1	2
Team leader for production planners	5	4	2	3
SCI, previously S&OP Partner	3	1	1	4
Production planner	5	2	2	3
Production Planner	3	5	3	4
Supply Chain Consultant	4	3	3	2
Business Analytics Consultant	3	2	1	5
Supply Chain Analyst	4	4	1	5
Business Analyst SC	3	3	4	4
Supply Chain Business Analyst	3	4	3	5
Average	**3,4**	**2,89**	**2,1**	**3,6**
Variation	1,1	1,1	1,0	1,14
Median	3,0	3,0	2,0	4,0
Category Weight				**3,3**

Table 9. Weight of the factor categories presented in the IDM framework according to survey respondents

		Production / Internal Operation Capabilities	**Product Characteristics**	**Market Factors**	**Financial Factors**	**Upstream & Downstream SC Characteristics**	**Cooperation and Managerial Factors**
Managers & Supply Chain Specialists	Average	3,22	2,86	3,69	2,88	3,48	3,45
	Percentage	16,47%	14,60%	18,86%	14,70%	17,76%	17,61%
Planners (S&OP, SNP and Production)	Average	3,25	3,00	3,87	2,78	3,26	3,08
	Percentage	16,91%	15,59%	20,11%	14,43%	16,94%	16,02%
Global (all)	Average	3,24	2,94	3,79	2,82	3,35	3,24
	Percentage	16,72%	15,15%	19,56%	14,55%	17,30%	16,72%

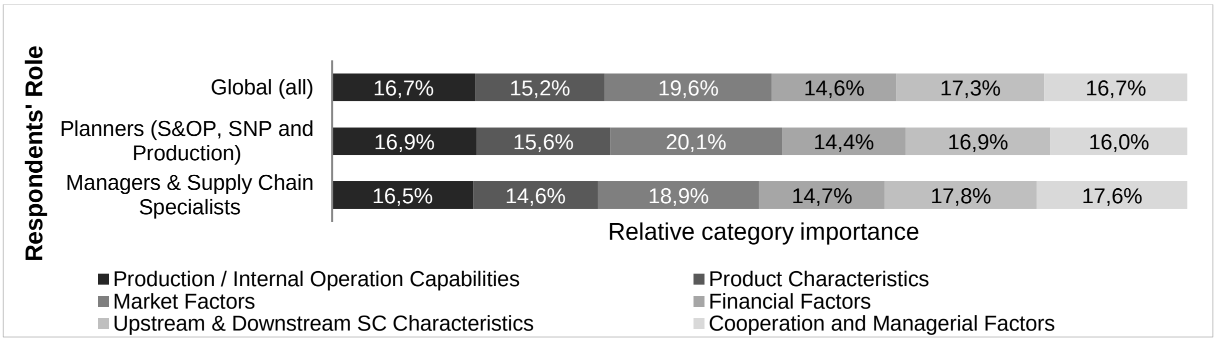
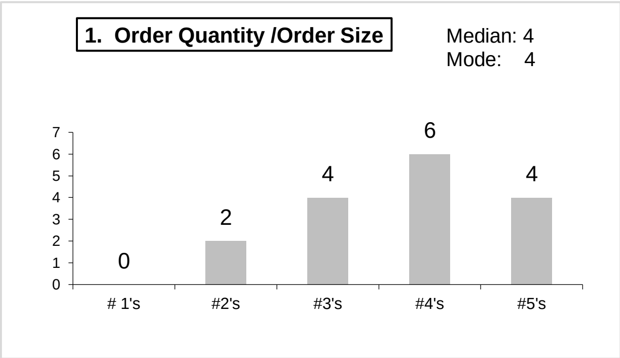


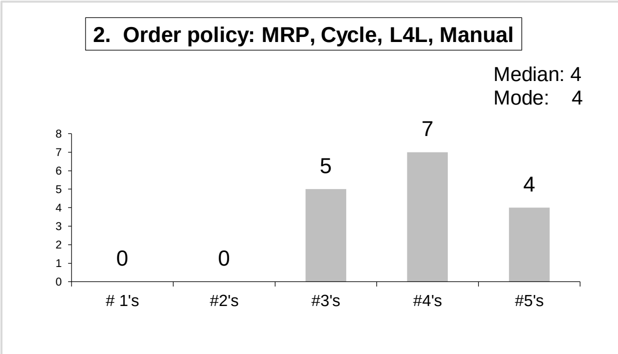
Figure 1. Weight of categories from the IDM framework according to respondents' role.

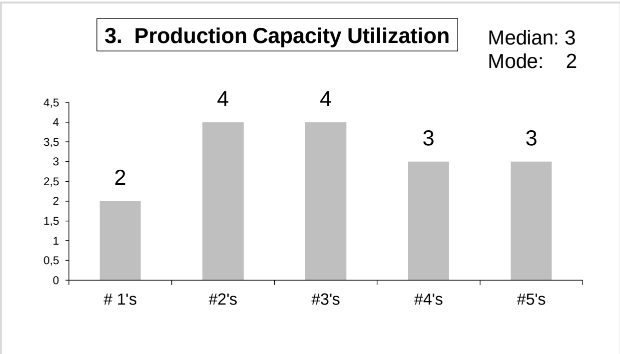
2.2. Frequency analysis

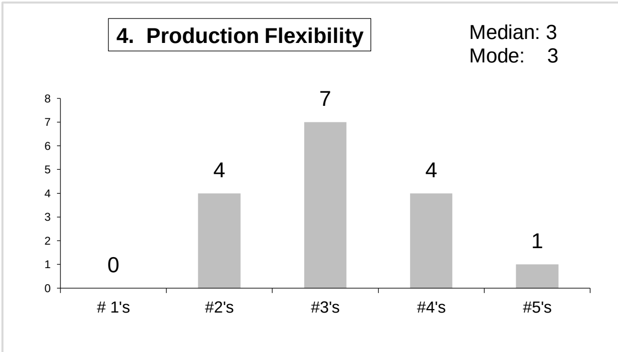
The frequency analysis is a count of the number of times a score has been assigned to a certain parameter for each particular factor of the IDM framework. Furthermore, the measures median and mode were added to the frequency analysis to provide a better overview of the survey answers.

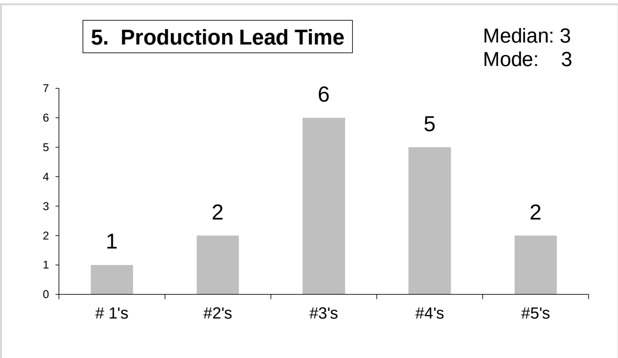
1. Internal Production Capabilities Factors

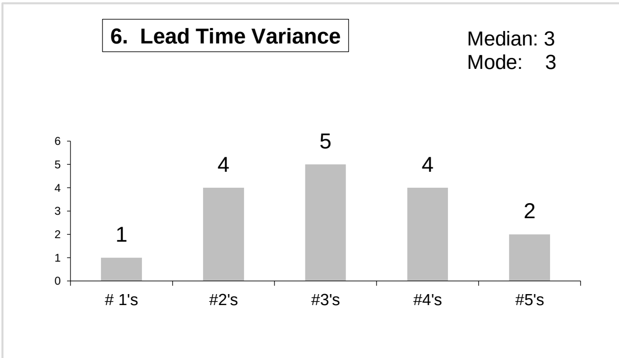


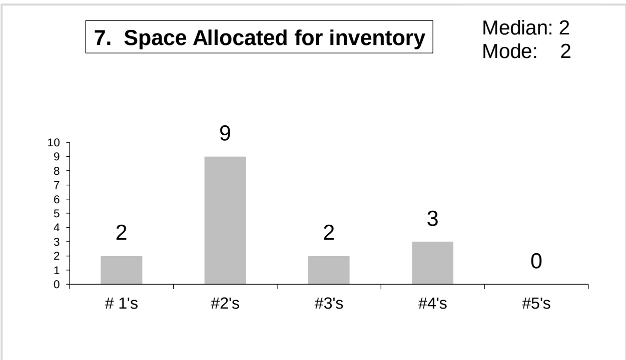


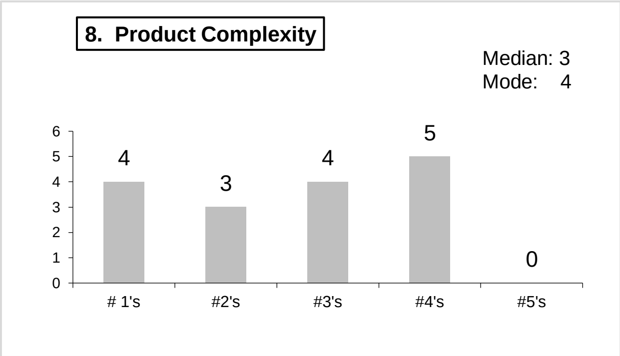


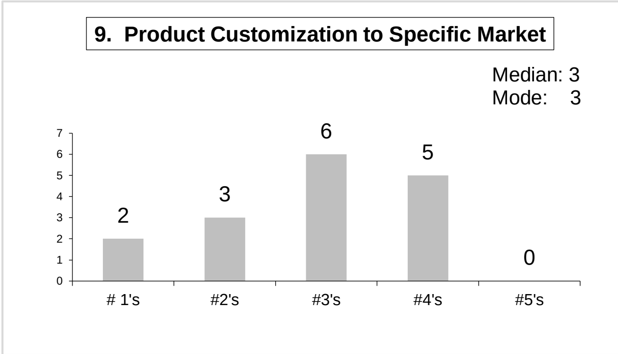


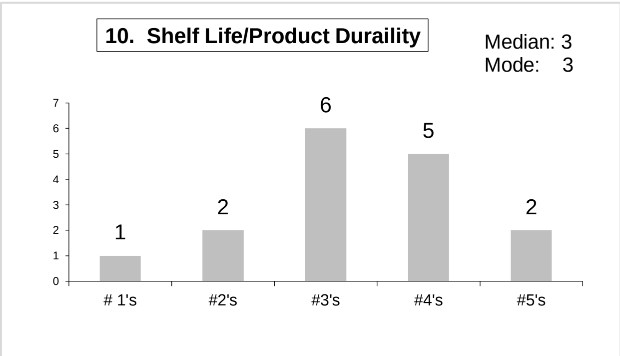




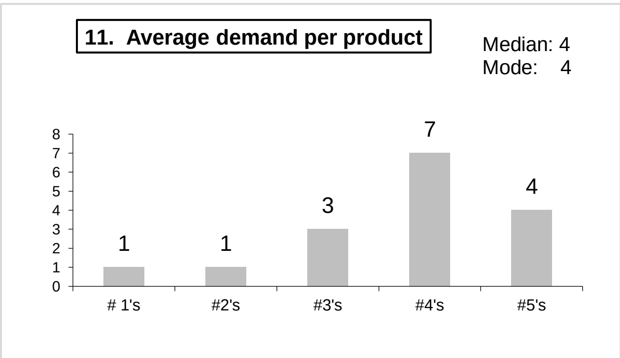


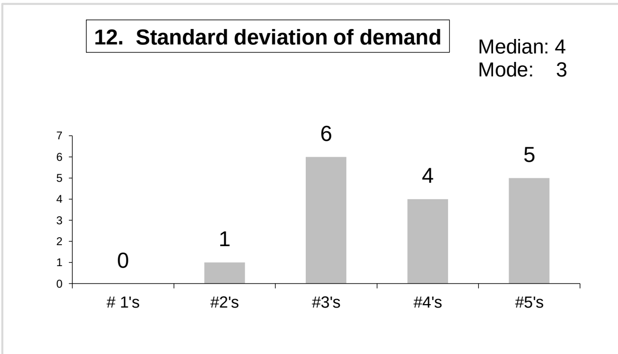


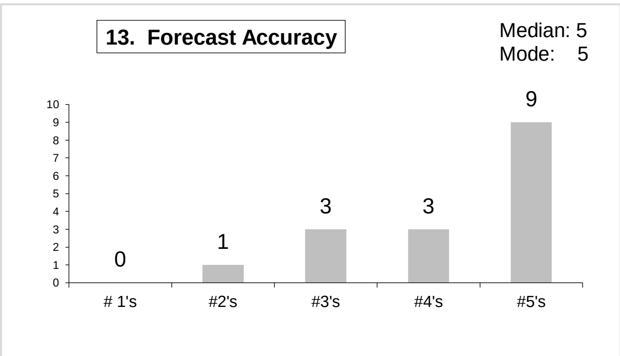


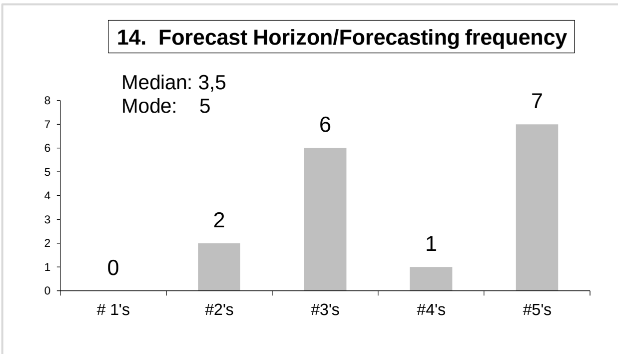


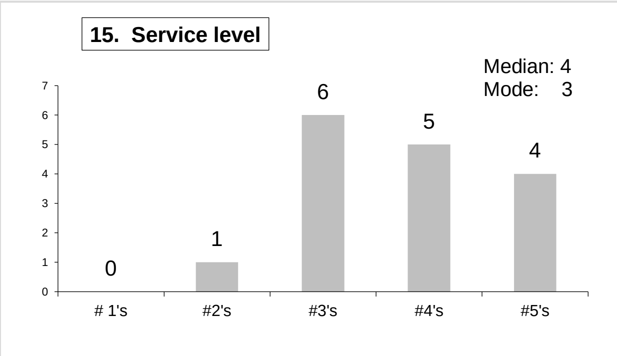
3. Market Factors

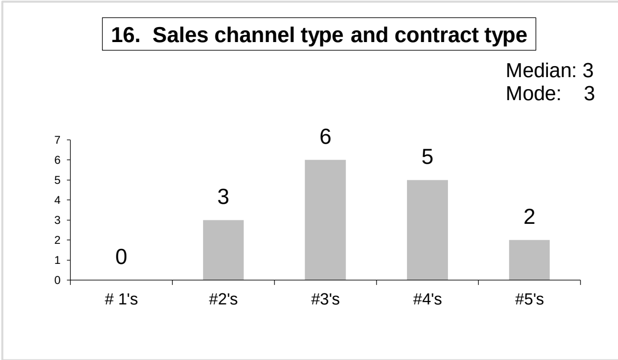




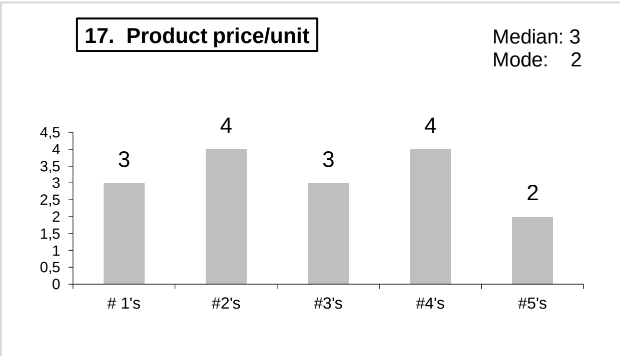


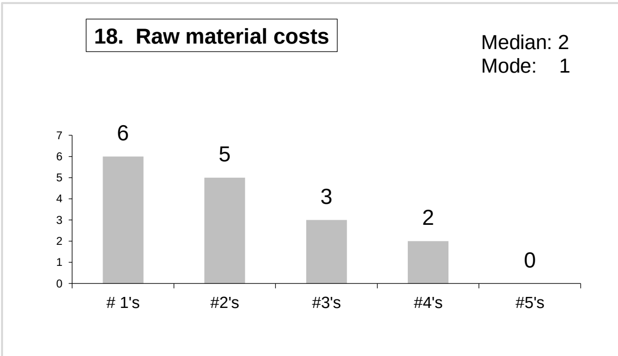


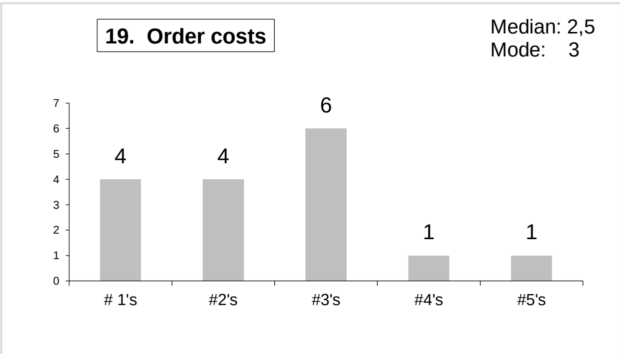


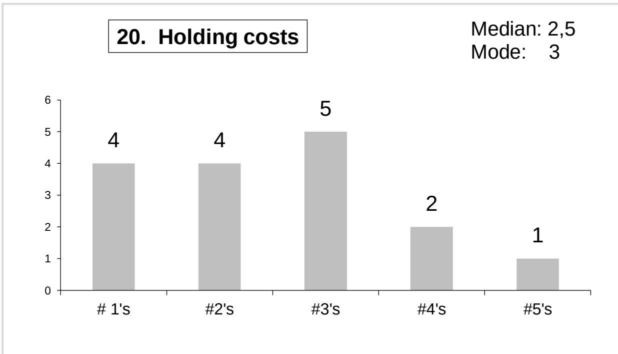


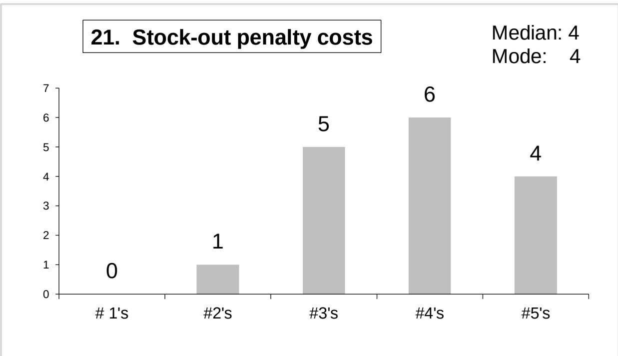
4. Financial Factors

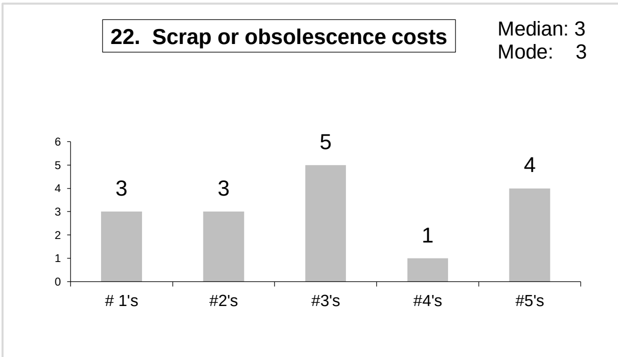


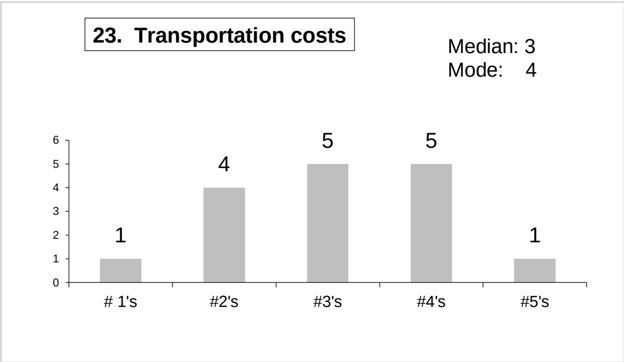




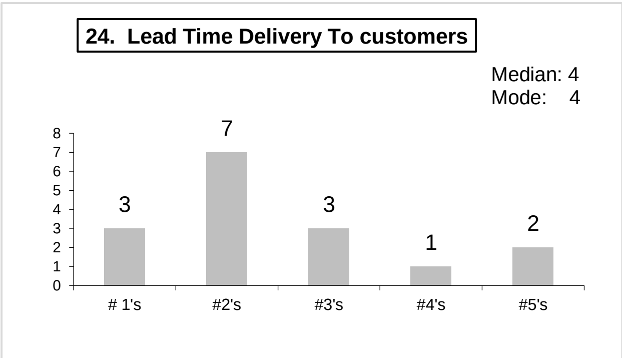


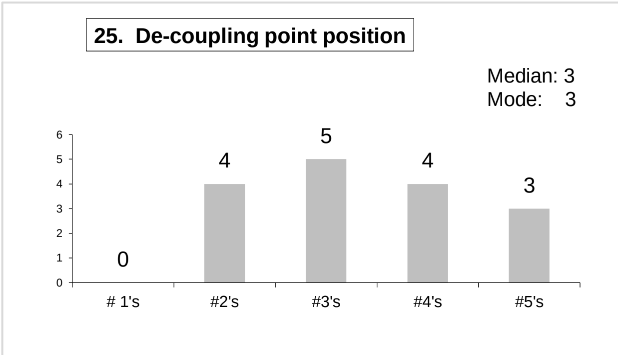


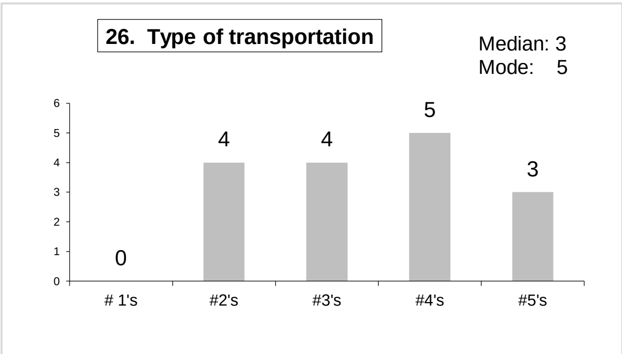




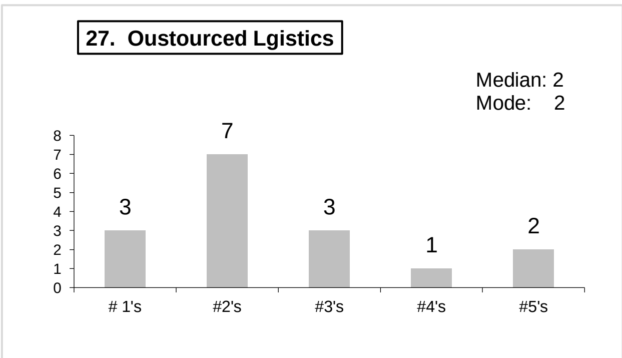
5. Downstream SC Capabilities

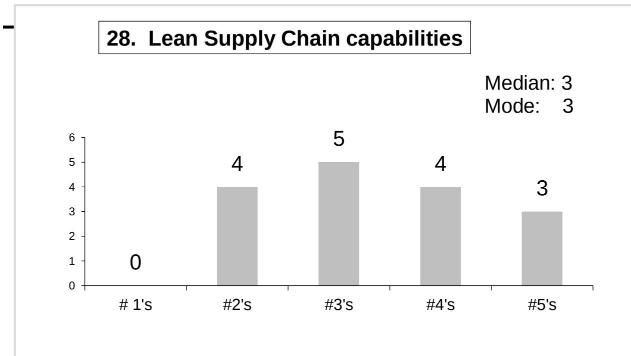


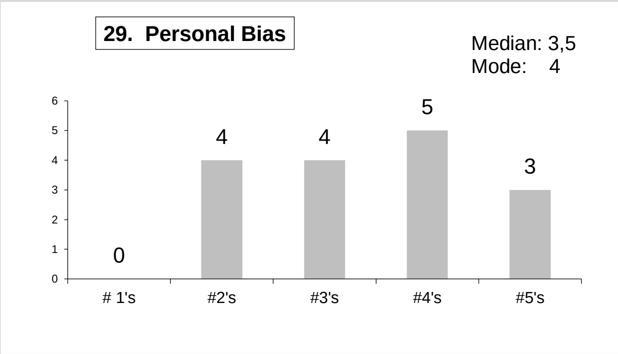


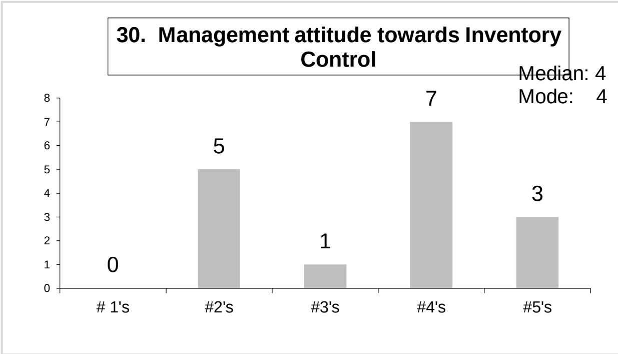


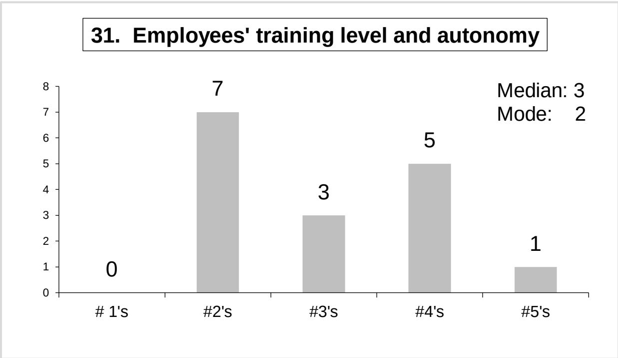
6. Cooperation and Managerial Factors

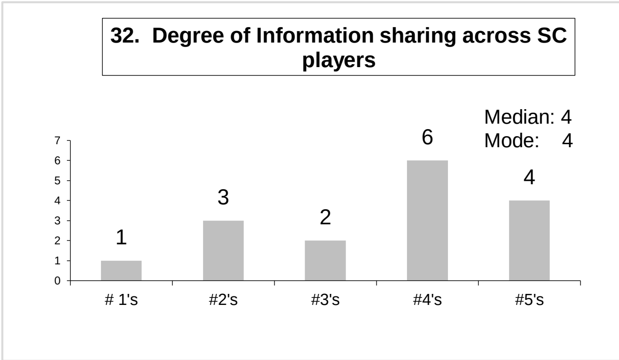


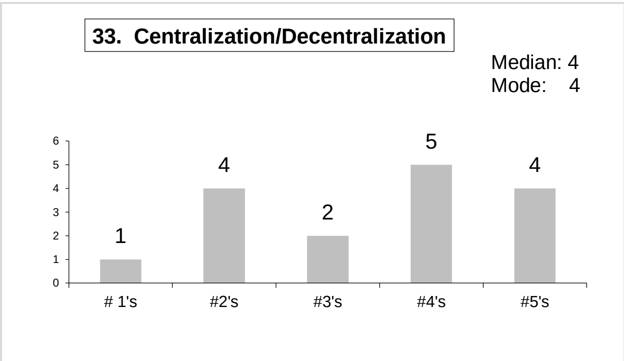


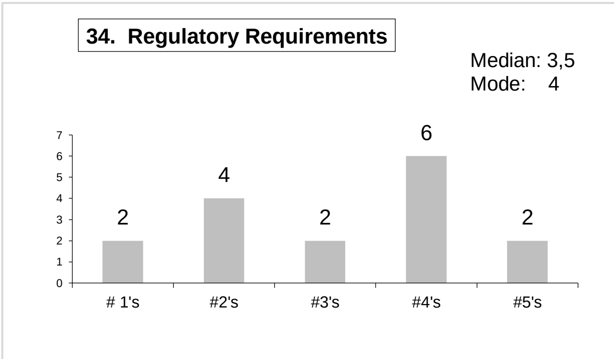

29. Personal Bias
Median: 3,5
Mode: 4
0
4
4
5
3
1's
#2's
#3's
#4's
#5's


30. Management attitude towards Inventory Control
Median: 4
Mode: 4
0
5
1
7
3
1's
#2's
#3's
#4's
#5's


31. Employees' training level and autonomy
Median: 3
Mode: 2
0
7
3
5
1
1's
#2's
#3's
#4's
#5's


32. Degree of Information sharing across SC players
Median: 4
Mode: 4
1
3
2
6
4
1's
#2's
#3's
#4's
#5's


33. Centralization/Decentralization
Median: 4
Mode: 4
1
4
2
5
4
1's
#2's
#3's
#4's
#5's


34. Regulatory Requirements
Median: 3,5
Mode: 4
2
4
2
6
2
1's
#2's
#3's
#4's
#5's

2.3. Kruskal-Wallis tests

2.3.1. Code generated to perform the Kruska-Wallis test (R code)

```
OQ<-c(5, 5, 4, 4, 3, 5, 5, 4, 3, 2, 4, 2, 3, 4, 3, 4)
OrderPolicy<-c(3,4,3,3,4, 4, 5, 5, 4, 5, 4, 3, 5, 3, 4, 4)
CapacityUtilizat<-c(1, 5, 2, 3, 3, 5, 4, 4, 5, 2, 4, 2, 1, 3, 3, 2)
ProductionFlexib<-c(5, 3, 3, 3, 3, 4, 4, 3, 3, 2, 2, 2, 3, 4, 4, 2)
ProdLT<-c(1, 3, 4, 4, 3, 3, 4, 4, 3, 3, 2, 3, 5, 2, 4, 5)
LTVar<-c(1, 3, 3, 2, 3, 2, 4, 4, 3, 2, 2, 3, 5, 4, 4, 5)
Space<-c(1, 2, 2, 2, 4, 4, 4, 2, 3, 2, 2, 3, 2, 2, 2, 1)
ProdComplexity<-c(1, 4, 3, 3, 4, 4, 4, 3, 1, 1, 2, 3, 4, 2, 2, 1)
ProdCustomization<-c(1, 3, 2, 4, 4, 4, 4, 3, 3, 1, 2, 3, 4, 3, 3, 2)
ShelfLife<-c(1, 3, 4, 4, 3, 5, 4, 5, 3, 4, 4, 2, 3, 2, 3, 3)
AvgDemand<-c(5, 4, 4, 3, 4, 5, 4, 4, 2, 4, 4, 3, 5, 3, 1, 5)
StdvDemand<-c(5, 4, 4, 3, 3, 4, 4, 3, 3, 2, 5, 3, 3, 5, 5, 5)
ForecastAccuracy<-c(5, 5, 4, 3, 2, 5, 5, 5, 3, 5, 5, 3, 4, 5, 5, 4)
ForecastHorizon<-c(5, 3, 3, 5, 3, 5, 5, 5, 2, 5, 2, 3, 3, 4, 5, 3)
Servicelevel<-c(5, 3, 2, 3, 4, 3, 4, 4, 5, 3, 4, 3, 5, 3, 4, 5)
SalesChannel<-c(5, 3, 2, 4, 3, 4, 5, 3, 4, 2, 4, 3, 2, 4, 3, 3)
Priceunit<-c(5, 2, 4, 2, 2, 2, 4, 3, 1, 3, 1, 3, 4, 4, 1, 5)
Rawmaterialcosts<-c(1, 1, 2, 2, 2, 2, 4, 3, 1, 3, 1, 3, 1, 4, 1, 2)
OrderCosts<-c(2, 1, 2, 2, 2, 3, 5, 3, 1, 3, 1, 3, 1, 3, 3, 4)
HoldingCosts<-c(1, 1, 2, 2, 2, 3, 5, 3, 2, 3, 1, 3, 1, 4, 3, 4)
StockoutCosts<-c(4, 4, 2, 4, 4, 5, 4, 5, 3, 3, 5, 3, 4, 3, 3, 5)
ScrapCosts<-c(5, 4, 3, 2, 2, 3, 5, 5, 1, 3, 5, 3, 1, 2, 3, 1)
TransportationCosts<-c(5, 4, 2, 3, 3, 4, 4, 4, 2, 3, 2, 3, 1, 2, 3, 4)
DelivSupplier<-c(2, 1, 2, 2, 2, 3, 5, 3, 1, 3, 1, 3, 1, 3, 3, 4)
DelivFreq<-c(4, 2, 4, 2, 4, 4, 3, 3, 2, 2, 2, 2, 5, 4, 3, 2)
DiscountSup<-c(1, 2, 2, 2, 4, 4, 4, 2, 3, 2, 2, 3, 2, 2, 2, 1)
LeadTimSup<-c(4, 3, 4, 2, 3, 5, 4, 4, 4, 2, 2, 1, 5, 5, 5, 4)
LTCustomers<-c(1, 4, 1, 4, 3, 5, 5, 4, 3, 4, 4, 3, 5, 3, 4, 4)
DeCoupling<-c(3, 3, 1, 4, 3, 2, 4, 4, 3, 2, 3, 2, 5, 4, 3, 5)
Transportation<-c(1, 4, 5, 3, 3, 4, 5, 5, 2, 4, 2, 2, 5, 2, 3, 3)
OustourcedLgistics<-c(3, 1, 2, 2, 2, 3, 4, 3, 2, 2, 1, 2, 1, 2, 5, 5)
Lean<-c(5, 2, 4, 4, 2, 5, 4, 3, 3, 2, 3, 2, 3, 4, 5, 3)
PersonalBias<-c( 4, 3, 2, 2, 3, 5, 4, 3, 4, 2, 4, 2, 5, 3, 5, 4)
ManagementAtt<-c(4, 2, 4, 2, 4, 4, 4, 3, 5, 2, 4, 2, 5, 4, 5, 2)
EmployeesTraining<-c(4, 2, 4, 2, 4, 4, 3, 3, 2, 2, 2, 2, 5, 4, 3, 2)
InfoSharing<-c(4, 3, 4, 2, 3, 5, 4, 4, 4, 2, 2, 1, 5, 5, 5, 4)
Centralization<-c( 4, 2, 4, 2, 3, 5, 4, 3, 4, 2, 2, 1, 5, 5, 5, 4)
Regulations<-c( 4, 2, 2, 2, 4, 4, 4, 4, 3, 2, 3, 1, 1, 4, 5, 5)

dati = list(g1=OQ, g2=OrderPolicy,
            g3=CapacityUtilizat, g4=ProductionFlexib,
            g5=ProdLT, g6=LTVar,
            g7=ProdComplexity, g8=ProdCustomization,
            g9=ShelfLife, g10=AvgDemand,
            g11=StdvDemand, g12=ForecastAccuracy,
            g13=ForecastHorizon, g14=Servicelevel,
            g15=SalesChannel, g16=Priceunit,
            g17=Rawmaterialcosts,   g18=OrderCosts,
            g19=HoldingCosts,g20=StockoutCosts, g21=ScrapCosts,
            g22=TransportationCosts,
            g23=LTCustomers, g34= DelivSupplier, g35= DelivFreq,
            g36=DiscountSup, g37= LeadTimeSup,
            g24=DeCoupling,  g25=Transportation,
            g26=OustourcedLgistics, g27=Lean,
            g28=PersonalBias,g29=ManagementAtt,
            g30=EmployeesTraining,  g31=InfoSharing,
            g32=Centralization, g33=Regulations)
kruskal.test(dati)
```

2.3.2. Output of the Kruskal-Wallis tests

- Output (Kruskal-Wallis Test #1)

```
        Kruskal-Wallis rank sum test
data:  dati
Kruskal-Wallis chi-squared = 9.3276, df = 5, p-value = 0.09669
```

- Output (Kruskal-Wallis Test #2)

```
Kruskal-Wallis rank sum test
data:  dati
Kruskal-Wallis chi-squared = 2.5145, df = 2, p-value = 0.2844
```

- Output (Kruskal-Wallis Test #3)

```
        Kruskal-Wallis rank sum test
data:  dati
Kruskal-Wallis chi-squared = 6.1792, df = 5, p-value = 0.2892
```

- Output (Kruskal-Wallis Test #4)

```
        Kruskal-Wallis rank sum test
data:  dati
Kruskal-Wallis chi-squared = 19.122, df = 6, p-value = 0.003962
```

- Output (Kruskal-Wallis Test #5)

```
        Kruskal-Wallis rank sum test
data:  dati
Kruskal-Wallis chi-squared = 19.122, df = 6, p-value = 0.00366742
```

- Output (Kruskal-Wallis Test #6)

```
        Kruskal-Wallis rank sum test
data:  dati
Kruskal-Wallis chi-squared = 6.8367, df = 3, p-value = 0.07729
```

- Output (Kruskal-Wallis Test #7)

```
        Kruskal-Wallis rank sum test
data:  dati
Kruskal-Wallis chi-squared = 3.1329, df = 6, p-value = 0.792
```

2.4. Comparison of medians: Boxplots

2.4.1. Code generated to perform the comparison of medians (R code)

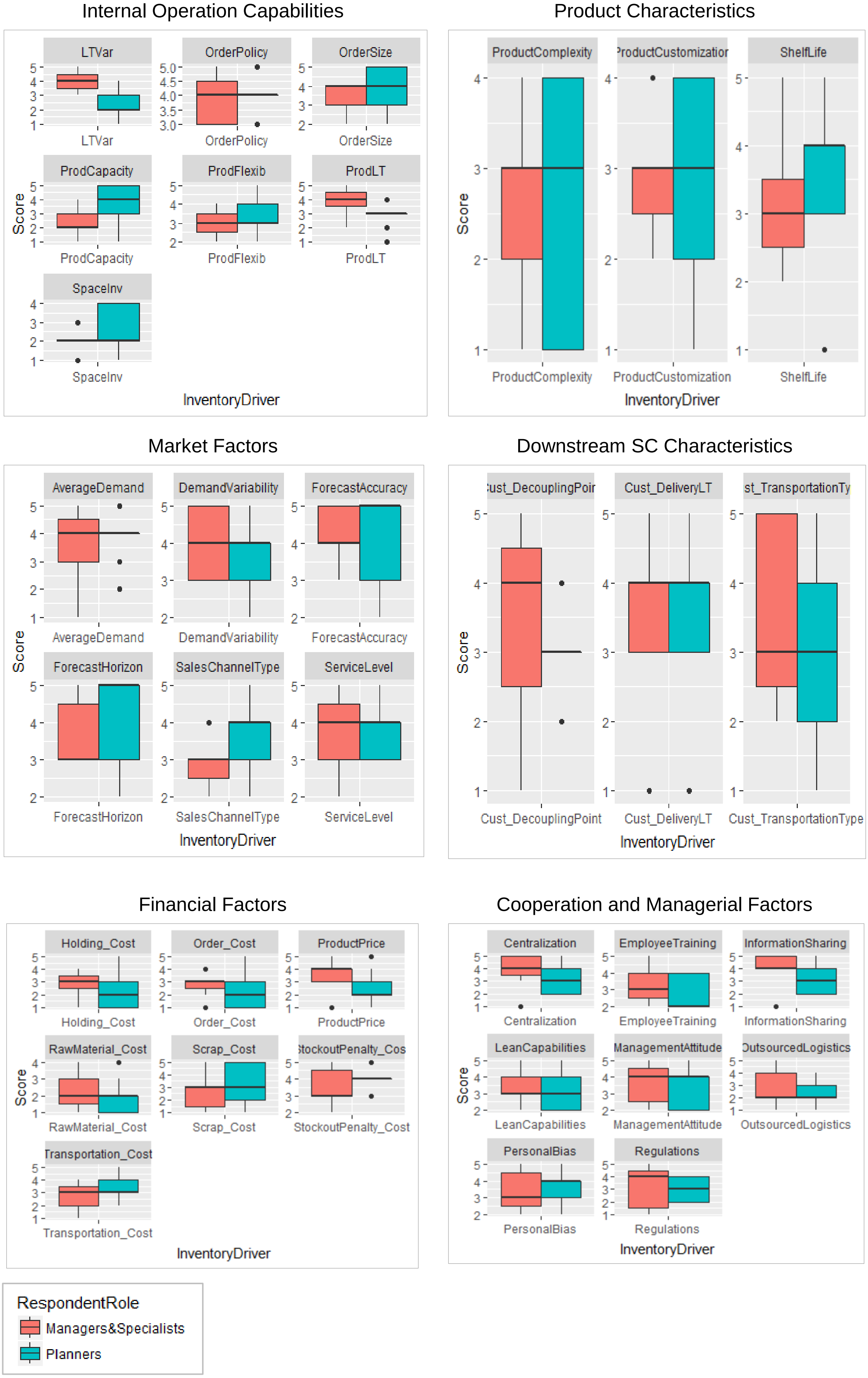
```
################################Internal Production Capabilities####################
require(reshape2)
df <- read.csv2("Boxplot_Production.csv", header=TRUE)
df
require(ggplot2)
ggplot(data = df, aes(InventoryDriver, Score)) + geom_boxplot(aes(fill=RespondentRole))

p <- ggplot(data = df, aes(x=InventoryDriver, y=Score)) +
  geom_boxplot(aes(fill=RespondentRole))
p + facet_wrap( ~ InventoryDriver, scales="free")
```

```
###############################Product Characteristics##############################
require(reshape2)
df <- read.csv2("Boxplot_ProductCharacteristics.csv", header=TRUE)
df
require(ggplot2)
ggplot(data = df, aes(InventoryDriver, Score)) + geom_boxplot(aes(fill=RespondentRole))
p <- ggplot(data = df, aes(x=InventoryDriver, y=Score)) +
  geom_boxplot(aes(fill=RespondentRole))
p + facet_wrap( ~ InventoryDriver, scales="free")
################ Market Factors ############################################
##Product Characteristics##
require(reshape2)
df <- read.csv2("Boxplot_MarketFactors.csv", header=TRUE)
df
require(ggplot2)
ggplot(data = df, aes(InventoryDriver, Score)) + geom_boxplot(aes(fill=RespondentRole))
p <- ggplot(data = df, aes(x=InventoryDriver, y=Score)) +
  geom_boxplot(aes(fill=RespondentRole))
p + facet_wrap( ~ InventoryDriver, scales="free")
################ Financial Factors ############################################
require(reshape2)
df <- read.csv2("Boxplot_FinancialFactors.csv", header=TRUE)
df
require(ggplot2)
ggplot(data = df, aes(InventoryDriver, Score)) + geom_boxplot(aes(fill=RespondentRole))
p <- ggplot(data = df, aes(x=InventoryDriver, y=Score)) +
  geom_boxplot(aes(fill=RespondentRole))
p + facet_wrap( ~ InventoryDriver, scales="free")
################ DownstreamSCCharacteristics ###########################################
require(reshape2)
df <- read.csv2("Boxplot_DownstreamSCCharacteristics.csv", header=TRUE)
df
require(ggplot2)
ggplot(data = df, aes(InventoryDriver, Score)) + geom_boxplot(aes(fill=RespondentRole))
p <- ggplot(data = df, aes(x=InventoryDriver, y=Score)) +
  geom_boxplot(aes(fill=RespondentRole))
p + facet_wrap( ~ InventoryDriver, scales="free")
################ Cooperation&ManagerialFactors ##################################
require(reshape2)
df <- read.csv2("Boxplot_Cooperation&ManagerialFactors.csv", header=TRUE)
df
require(ggplot2)
ggplot(data = df, aes(InventoryDriver, Score)) + geom_boxplot(aes(fill=RespondentRole))
p <- ggplot(data = df, aes(x=InventoryDriver, y=Score)) +
  geom_boxplot(aes(fill=RespondentRole))
p + facet_wrap( ~ InventoryDriver, scales="free")
require(ggplot2)
p <- ggplot(data = df.m, aes(x=variable, y=value))
p <- p + geom_boxplot(aes(fill = Label))
# color for points replace group with colour=Label
p <- p + geom_point(aes(y=value, group=Label), position = position_dodge(width=0.75))
p <- p + facet_wrap( ~ variable, scales="free")
p <- p + xlab("x-axis") + ylab("y-axis") + ggtitle("Title")
p <- p + guides(fill=guide_legend(title="Legend_Title"))
p
```

2.4.2. Output of the comparison of medians (Boxplots)

The output of the comparison of medians (boxplots) for each of the inventory drivers of the survey is shown in the next page.

Figure 2. Boxplots for the Inventory Drivers Matrix factors per group of respondents.



Appendix B- Interview guide and transcripts

1. Interview guide

1. Your role is ____________________. Could you explain what are your primary tasks (focus) and how does this relate to inventory control within *PharmaNordic*?
2. Of our current supply chain stages, your role mainly interacts with______________. (Let them point at which part of the supply chain they role interacts the most with).
3. What would you say is the purpose of having good inventory control systems in place?
   - Less tied-up capital on inventory
   - To protect us against demand (and supply) uncertainties
   - Satisfy the service level desired
4. You rated *PharmaNordic*'s ability to manage and control inventory levels at the affiliates as 4 [P1, P2] 2 [P3]. Were you thinking about the difference between MRP and non-MRP countries/affiliates?
5. Show them the results of the survey (Questions 4-9). And point at what they answered vs. the rest of the answers. Do you agree with the results shown?
6. Let's take each *underlying issue* to overstocking one by one. Do you have any comments on how these "issues" might affect the right inventory levels at the affiliates?

   6.1. We have the right ERP systems in place. Scores: 4[P1, P2], 3[P3].
   - Do you think the ERP systems should be applied to more non-MRP countries?
   - Do you think the formulas in SAP APO are well implemented?
   - How often do planners overrule these orders?

   6.2. We have the right visibility on what we have on stock at the affiliates. Scores: 4[P2], 3[P1, P3].
   - Did you distinguish between MRP and non-MRP countries?

   6.3. The sales forecast is accurate enough. Scores: 2[P1, P2], 3[P3].

   6.4. We expedite too often in order not to have stock-outs. Scores: 4[P2], 3[P1, P3].

   6.5. Lead Times are usually longer than what the LT policy establishes (Delivery Plant-Delivery System). Scores: 4[P2], 3[P1, P3].
7. Additional underlying causes for overstocking: Do you see any of these causes also affecting inventory levels (non-target)?

   7.1. Production mind-set (excess of capacity, push towards affiliates).

   7.2. KPI focused on production and not in reducing inventory levels.

   7.3. [How could late stage customization improve inventory levels?]

   7.4. [Trade-off between agility and resilience: Any inputs?]
8. [Showing the Inventory Drivers Matrix framework]. Now, if we focus on individual inventory drivers, these have been highlighted by all survey respondents as the ones impacting inventories the most.

   8.1. Do you agree with the list?

   8.2. Is there any of these factors that you would remove from the Top 10 list or any of the other factors that you would add? (Highlight which ones have they scored high).

2. Interview transcripts

2.1. Interview #1

Interview nr.	#1 (Follow-up interview)
Interviewee	P1 (Name not shown for confidentiality reasons)
Male/Female	Male
Position	OP Planner at Production site (Assembly and packaging site 25A)

Planning Horizon and steps:

Orders are processed in 42 days (normal procedures)

1) Lead time between the affiliate placing an order and until it is released from production is 42 days.
    a. Reason 1: The number of processes involved
    b. Reason 2: Avoid extra work/firefighting
    c. Main reason: Long LT from PPM suppliers (22 days)
2) Every day, planners extract reports from SAP: Order status 10. They look at the product and the size of the order.
3) They log into the planning book, and check if the production site has capacity available.
    a. If there's available capacity, the planner confirms the order.
4) If they confirm, the planners do not look into that order until three weeks before production, when they receive a confirmation from Søborg (central planning), which order the printed pack materials (8-item): Labels, cartons, inserts.
5) Suppliers are located in DK, Holland, etc. They have a LT of 22 days to deliver the PPM to HA.
6) Production planners don't look at the order until three weeks after the order is placed and confirmed. Then they order penfill batches from BA.
7) Penfill LT is around 2 days: Planners place the penfill order to BA or other prod. Sites and it takes approx. 48 h until they arrive at 24A in HI. Penfills are stored in cold storage.
8) Then Orders get into stage 14 (assembly).
9) Assembly starts around day 27 (after the order
10) Assembly takes around 24 hours
11) From the start of the assembly, they have around 1 week to release the batch.
12) The orders start packagin
13) Day 35: packaging starts (7 days before the agreed 42 days). Packaging starts 1 week before they have to be released. (So packaging material needs to be ready 9 days before orders are released).
14) After day 35, the steps that we saw in the board apply: PS, QA and …
15) Day 42: the order is released.

What is the fastest LT that an order can be processed?

(Assuming that there's PPM available in site), an order could be processes within 2-3 days:

- Order accepted within 2 hours.
- 24 hours to assemble.
- 24 hours to pack.
- 24 hours release.

From the planner's perspective, it is the PPM (8-item) what causes the LT of an order being processed (22 days until they receive it), out of the 42 days (total), half of the time.

Other points (miscellaneous):

- When planners accept orders, they assume there's filling available. So, they confirm the orders assuming that there are penfills available (given that there's a decoupling point in filling).

Experienced planners know which 5-item are usually low on stock and they first ask production if they have enough 5-items to fulfil the order, but unexperienced planners would probably accept the order coming from the affiliates without looking at 5-item availability. They need to assume that there are 5-item available.

  - FlexTouch is usually better at having filling available than FlexPen. FlexPen usually presents some variants. FlexPen is more challenging when it comes to filling available.

- If affiliates they want to increase or decrease an order and its already in the packaging stage
- Orders are postponed quite often when there's limited capacity in the production site. Planners need to respond to an order within 48hours. What they do when there's limited capacity is to write the affiliate and ask them if they can cope with a delay of 3 weeks, 4 weeks…
- If an order is cancelled, they do not usually scrap the PPM. They will probably cancel and place it later, so that it can be used after.
- Above the 6 weeks horizon, capacity is planned on the production agreement, which is a rough estimate.

Optimal OQ: Large orders (from an economical point of view). But then if the orders change, ten you have to scrap a large amount of PPM.
LE: Latest forecast for 2017. There are three scenarios are possible:

- **Sales demand increase**: They need to make sure they can deliver. This is especially critical for FlexTouch because they cannot make country transfers as they can do with Flexpen.
- **Sales demand is stable**: Ok.
- **Sales demand decrease**: If demand decreases, they can have the situation where they could be pulling orders to reach the target of the AB, unless it is revised.
  AB is the target used for receiving budget.
  If the forecast decreases, LE and RE also decrease, and then the plan is adjusted.
  When demand decreases, or if it is even lower than the adjusted RE and LE, production pulls the orders. They lack orders, so what they do is to pack X weeks in advance. And then they push everything to the shipping hub and ultimately the affiliates.

2.2. Interview #2

Interview nr.	#2 (Follow-up interview)
Interviewee	P2 (Name not shown for confidentiality reasons)
Male/Female	Female
Position	Currently role: Senior Business Analyst in Supply Chain Integration, previously S&OP partner

00.00 min.
Interviewer:

- Briefly explains the scope of the project and the reasons why he/she has been selected for the study (interview). Scope: Finished-goods inventory levels at MRP affiliates. Contextualize the projects.
- Introduce what the interviewer expects from her: The interviewer wants to know what kind of role does he/she has within the company, and how relevant the tasks he/she performs are in terms of inventory planning and control (what impact do these tasks have on inventory planning and control?).
- The interviewer also wants to hear his/her point of view with regards to the current inventory management policies and what are the main issues he/she identifies from her current role.

02.53 min.

- The interviewer currently holds a role in Supply Chain Integration, in which she does not have that much relation with Inventory/Stock levels. However, she replied at the survey applying the knowledge she had from her previous role in the S&OP team. She is somewhat involved with inventory management today but more on a theoretical level than at a practical level.

- Now she is looking at how the parameters used in the APO system affect the stock levels; that is how the measures used in the Inventory Management model affect the stock levels. For instance, if the Safety Stock calculations were performed in quantities instead of DOH, what effect would that trigger to safety stock levels (what would be the safety stock sensitivity to that change). They have discovered that the calculations done with the current model (IM model) are quite sensitive to all these measures).
- They are looking at how to make the calculations less sensitive by either setting a minimum and a maximum level target, for instance, instead of having just the minimum stock level target.
- This is due to the fact that, with the current setup, when inventory levels change abruptly, this can place or cancel an order.
- **They are looking at how our current setup is affecting volatility in the long term planning.**

06.44 min.

- Clarifying the role of Safety Stock and Strategic Stock in the case study company.
    - <u>Safety Stock</u> is calculated automatically by APO on a monthly basis during the S&OP process, using de demand predicted by the affiliates.
    - <u>Strategic Stock is</u> set up as a policy guideline, and is based, according to the interviewee, on god-feeling.

She has shared a presentation on Inventory Management principles, which is a new updated version than the one the interviewer had.

08.39 min.

- In the survey, when asked about how would she/he rate *PharmaNordic*'s ability to manage and control inventory levels, the interviewee answered with a low score. The next section of the interview is entirely a discussion on possible better practices for the company with regards to inventory management.
- The interviewee has been asked what she thinks are the main issues related to inventory management in the company.
- The intentions in the company are good. But there are so many other restrictions that are more important to other people than inventory management, especially in production sites and in the affiliates.

Issues at production sites:

- For the production sites, it is more important to have a low unit cost; therefore, they want to produce as much as possible in order to achieve economies of scale. They are interested in having big and large orders and volumes.
- In the S&OP process, they run the half-yearly budgets, where they set targets for specific processes and specific products, and one those are set, they calculate the budgets based on that, and that is what the production sites want to produce. Perhaps they will try to produce more, if they can, because then the unit cost will go down; but they will never produce less because then they need to return money back to the Corporate Functions. And that is a problem, for instance, if the production site director has already hired some people.
- The interviewer has asked if the production sites are measured on a unit cost KPI. The interviewee has corroborated the hypothesis: production sites are measured on unit costs. This unit cost KPI is much more important to them than the Supply Chain KPIs.
- What happens is that they ask the SNP planners to create orders by increasing the inventories using temporary safety stock and if the SNP doesn't do that, then they go to the OP planners and say "we don't have enough orders to keep the lines running for the next two weeks, please pull some orders forward, so that we can produce in the next two weeks". So, production sites ask to pull some orders, to advance them, in order to keep the lines running. And this happens to a <u>**very high**</u> degree.

Personal note from the interviewer: This last input is very relevant, and is in line with the impression I got when I interviewed the OP planner in the production site 25A. Review notes from the previous interview.

12.02 min.

Issues at affiliates:

- Affiliates are basically measured on their ability to sell products, and they care more about having enough products so that they can supply their local customers than the amount they have on stock.
- Affiliates are not measured on any specific maximum stock amount, they only ask planners to stop pushing stock to the affiliates when they reach their maximum space capacity in their warehouses.
- Sometimes the planner may decide to build up extra safety stock because they foresee that a specific production facility will close down for two weeks, so they pull orders in advance and ship the products to the affiliates.
- An S&OP planner made a presentation with graphs per production site-product stating the amount of stock and comparing the DAMS report to the total applied Safety Stock, for a specific day. For Clayton, the curve was ok, where the Safety Stock matched the amount/level they should have. The rest of the sites looked skewed, where they had way too much graphs.
- If we would compare that with what the IM tool would have said, we would see a larger difference between the theoretical stock that the affiliates should have and the real stock that they have.
- The SNP team overwrites the instructions from APO based on external factors (e.g. production site closedown) and then the OP planner (the ones in the production sites) overwrite more and make the orders bigger or larger; the result being that the amount of safety stock increases a lot. OP planners stock builds up on what the SNP planner is doing.

Personal note from the interviewer: This last note is very interesting and is in line with literature, where personal decisions (biases) can affect stock levels more than one could think of.

17:41 min.

- In the interviewee's perspective, the amount of stock at affiliates COULD be reduced by basically following the principles that we have set through the IM model. That would be a first step to start reducing the amount tied up in inventories.
- Interviewer asked whether she thinks it is a matter of being a very KPI-focused organization, where the performance measure is so important, that sometimes this can generate a distortion is other parts of the business.
- From her point of view, *PharmaNordic* is a very KPI-driven and Supply-driven organization. It is not a demand-driven organization or supply chain. This is because the supply chain (Product Supply) organization (incl. production sites) are very "punished" by these KPIs if they are not able to supply.

18.55 min.

- When looking in general, at the scores she gave when rating each of the inventory drivers in the survey, the results or scores are very much in line with what the rest of the planners said, but there are some interesting differences between her response and what the rest of the planners scored:
- Forecast accuracy and forecast horizon have been rated as "very high impact", but she gave a relatively low score to these drivers. When asked the reason why, she argued that of course forecast is important, but we are making it so much worse in Product Supply.
- Forecast accuracy is around 70% (depending a lot on the affiliates and specific products), but as a general rule of thumb, one could say forecast accuracy is 70% from the affiliates. So, forecast is around 30% wrong.
- When we forecast the production in Product Supply, which is based on the forecast made from the affiliates, the planners make a forecast which is up to 70 % wrong (30% production forecast accuracy). This is for all the affiliates. Forecast accuracy is important, of course, but we are making it so much worse based on all these individual decisions made, which collectively, add up to a high level of safety stock.
    - First, you have the S&OP planner making certain assumptions to set the targets, then you add a little bit extra because you want to be sure you can always deliver. Then in the next

step the SNP team adds stock because they want to make sure they fill the lines to the targets. Then in production maybe the lines run a bit faster than expected so they want to keep putting the orders on the line and filling them up. We are making them worse in each step.
    - The forecast could be better,
- There is a specific project in the track “Flow of Demand”, in which they are looking at all these steps and seeing which of the stakeholder groups is adding more noise to the safety stock or flow of demand.
    - All these decisions: demand corrections, the KPIs, the country transfers, they all create volatility, but we cannot see a clear outlier; they cannot see a specific item creating the majority of the volatility. They can see they are all contributing, in an exponential way.
    - They haven’t managed to conclude which group/processes add more distortion.
- This forecast error (70%) is for all affiliates. Of course MRP affiliates are a bit better, but not as much as she would expect. Manual orders (non-MRP affiliate demand) are more difficult to forecast from a production perspective, but the MRP affiliates are not as good as one would think.
- From the interviewee’s perspective, it is easy to point fingers at affiliates, because “we have all heard that the forecast accuracy for non-MRP countries is not very good”, but not many have seen how bad our internal accuracy (Product Supply) on forecasting what we want to produce is.

25.57 min.
- When asked if she could point at a special factor impacting inventory levels, the interviewee has answered: “*I have said all along that it is the KPI, the production agreement KPI, the unit cost KPI, that states that what we have said we should produce, that is what we need to produce, at, basically, whatever cost.”* This is one of the main drivers, according to the interviewee. But they haven’t been able to prove that yet with the project they are running, because there are also a lot of other decision makers adding up to that. Like the S&OP are making demand corrections, the SNP team are making TSS changes and also demand corrections the OP planners and then pulling orders.
- “Supply Chain management in this company is not on the top of the agenda in this company. We are very much a production-oriented organization; even though we have all these supply chain KPIs and tools, as long as the production agreement is not fulfilled, that one has top priority.”

28.46 min.
- The interviewer has asked about the stock-out costs: With regards to costs, are we penalized a lot if we are not able to supply products? Is the stock-out cost high?
    - For tender markets, the stock-out cost is high, yes.
    - But there are also MRP countries, for instance *Finland*, where there’s a governmental requirement on the minimum stock levels we should keep in inventory and therefore the stock-out costs for that country would be high. They actually check every end of the year in *PharmaNordic* holds the specific amount strategic stock is the amount we promised to have.
    - The S&OP team is the one that manages the strategic stock, which is based on the AB forecast.
    - Strategic Stock levels are checked once a year.

- With regards to supplier’s lead time for Printed Packaging materials, the interviewee has corroborated that these could also be a direct driver for inventory, given the fact that it is very high (around 22 days out of the 42 days for production). In MOC they have even longer lead times than in Denmark.

32.05 min.

Final thank you notes.

2.3. Interview #3

Interview nr.	#3 (Follow-up interview)
Interviewee	P3 (Name not shown for confidentiality reasons) **JHRV**
Male/Female	Female
Position	Senior API Controller, S&OP Process execution

00.00 min.

Interviewer:

- Briefly explains the scope of the project and the reasons why he/she has been selected for the study (interview). Scope: Finished-goods inventory levels at MRP affiliates. Contextualize the projects.
- Introduce what the interviewer expects from her: The interviewer wants to know what kind of role does he/she has within the company, and how relevant the tasks he/she performs are in terms of inventory planning and control (what impact do these tasks have on inventory planning and control?).
- The interviewer also wants to hear his/her point of view with regards to the current inventory management policies and what are the main issues he/she identifies from her current role.

00.00 min.

- The interviewee holds a role of API controller, sitting in the S&OP Process execution department. She is in charge of the API ("raw material" for pharma products, also produced within *PharmaNodic*) controlling and doing the variant planning for 5-item numbers (semi-finished goods), basically Penfill and Vial products.
- The current responsibilities of the interviewee lie on the operational tasks for the API; that is, when the whole S&OP process has been carried out, she chooses all the batches going to all affiliates sites. All the API orders are processed and assigned a batch number by the interviewee. She chooses a batch number depending on which country are they going to fill to, what have they been approved for, depending on the king of CR cases they have and other external requirements.
- Basically, all production sites would place an order on the SAP system when they receive the orders from the affiliates or central planning systems in DK. Then the API planner (interviewee) matches that order with a Penfill or Vial (API) available, which in turn, triggers an API order.
- She matches the orders from the production site (filling sites) with the specific API stored in inventory.
    - BA is a filling site only.
    - KLBG is a filling + assembly + packaging site.

02.54 min.

- Elaborating on variant numbers: On the 5-item numbers, we have a variant. All 5-item numbers are pointing to a 7-item number. Countries that are pointing to 7-item numbers (finished-goods) do have different approval of CR cases. Almost all CR cases are coming form 3-item numbers (API, raw materials). This 7-item number is pointing down to a 5-item number, and what they have approved, they will have this variant. So we have more variants than 5-item numbers (and consequently, more variants than 7-item numbers).
- In BA, we have 5-item numbers with 6 different variants. At the end of the month, she and another planner look at all the variants and check whether there is something that could be improved or not: if there is any CR case that could be moved to another variant that is better for us to move, and this kind of processes.
- The number of variants per product differs on the production sites. CL they have only one variant. 2H have plenty of variants. CH they have almost only one variant for each item, as they are a very simple filling site. *PharmaNordic* centralises the production of complex items in one single site (2H, DK) and them sometimes they move one country from 2H (DK) to CH. That would be in the case of large orders or if they need to free-up some capacity in these countries.
- European countries are very easy because approvals are quite fast, so they can almost take any variant. Whereas countries like China are more complicated.

- They have the variant system in order to ensure that they have enough API to cover the small countries which actually have a long lead time for approvals.

05.51 min.

With regards to the API de-coupling point, the interviewee has added the following comments:

- We have different stock levels on the API. For some of them we are trying to have 18 months of stock. This has something to do with a long lead time in DAPI in Kalundborg (KA). But for the moment, we have something like a year on stock in all our products, so we are in a really good shape. But this is really important because if something goes down in DAPI, then we need to be able to react and cover for customer demand.
- Furthermore, all filling sites (except for the Danish ones) have a policy of 3 months of safety stock of API. This safety stock is kept for security reasons (e.g. if there's a sudden disruption in the transportation routes, this stock would cover at least three month of filling). In China, this stock is even higher due to regulatory constraints in approving different variants.
- With regards to the shipping methods, API is shipped by airfreight. There is a project roll-out which will be operational at the end of this year in which API will start to be shipped by sea freight.
- Nowadays, we have one shipment per week to CL (either on Monday or Friday). The ones shipped on Monday are because they are going to be packed on a special freight box.

07.52 min.

- What we will try to do at the end of the year is to combine all this shipment in one container by sea. With sea freight, it will take 2-5 weeks to CL, 7 weeks to reach China and 7 weeks to MOC. Shipping the API by sea will be much cheaper.
- The API is very expensive; so the organization needs to make sure that when they send the API, it will be sent in the conditions so that it does not compromise its quality. There are special conditions in which it might be shipped (-18 degrees) and this also requires of special regulatiry approval.

09.18 min.

The interviewee has been asked if she thinks there is a relationship between the API stock and the final inventory stock levels (i.e. if finished-goods inventory levels depend on raw-material inventories).

- From the interviewee's point of view, it is very difficult to relate finished-goods inventory levels with raw material inventories, given that there is a huge de-coupling point for raw material inventories and long lead times.
- Affiliates would never think about having finished-goods inventories based on the API inventories. Affiliates must assume that orders will be received when they order them. Production sites (assembly and packaging) usually assume that there's filling available: Penfill and Vials. Filling sites (production planners), in turn, usually assume that there is API available.
- Planners would never compromise on API, this is the reason why there is a stock policy of around 1 year of API in the production sites.

Note: This is in line with the notes form the OP planner.

11.10 min.

The study focuses on inventory drivers and inventory levels at the affiliates, but the interviewer asks now for API (insulin raw material) inventory levels at a production plant level. The interviewee has been asked if she is able to relate some of the factors impacting inventory levels at the affiliates with the factors imoacting API inventory levels.

Are there any policies with regards to the API inventory levels?

- The Product Supply organization, and in particular, the S&OP group look at the annual forecast (AB forecast) and calculate how much do the production (filling) plants need in order to fill up three months (the time it can take to approve a new product).
- They need the flexibility to be able to switch to another API production site.
- The API stored in DK is around 1 year on stock. Besides, production sites (filling) keep 3 months of API stock.In China the API stocked is a bit more due to regulation requirements.
- There is no KPI in place measuring the levels of API in stock. The production sites are allowed to go under a certain level of API. They are working on a policy, but there is not any regulation

measure or KPI in place, but it will be around 3 months on stock for all FILLING sites, except for DK, which will be less due to the fact that the API production is in DK.

- When API is shipped to one production site, it cannot be brought back or used in another production site, due to regulations. If there is a problem, the API batch is put into quarantine, but it cannot be used for anything else, because PharmaNordic does not have the approval to ship it to another country. When we have a case like this, then the planners need to create an NC, and ask if there is any country that accepts the batch, and then they would create a variant for that.
- API is approved and shipped for a country specific.

13.57 min.

The API Production system could be seen as a push system (make-to-stok), in which production facilities have a yearly production agreement which they have to meet.

If demand changes throughout the year, there is not much they can do from an API production, given the fact that the Lead Time is very long (production LT is from 6 to 9 months). Therefore, it is difficult to adjust for demand changes if there is a drop.

- The production agreements are revised every half a year with the RE updates, and if it looks completely off, then they adjust the production agreements. But otherwise, there is not much they can do.
- They look at the AB and the RE. The AB and RE estimates are coordinated from the DFP (filling and assembly production sites) and the DAPI (API production sites).

16.25 min.

The results of the survey are presented and the interviewer compares the answers from the interviewee with the average total.

The responses are a bit skewed from the rest of the respondents: The interviewee has placed more importance on production factors than the rest of factors. This is interesting and shows that the role of the respondent could actually impact the analysis of the survey.

The interviewee has stated that this is actually true, the responses of the survey could be affected by the particular role of each respondent. She mentions: "*I am thinking API, I am thinking long Lead Times, therefore I will be a much more production-oriented mindset than probably the rest of the respondents*".

The Order Size is very important for production planners, also the forecast accuracy will have an impact on how the stock is planned.

The forecast horizon could also be revised more often (now it's monthly forecast horizon), but if we could have a better ongoing overview, this could actually help the planners plan in advance.

2.4. Interview #4

Interview nr.	#4 (Follow-up interview)
Interviewee	P4 (Name not shown for confidentiality reasons)
Male/Female	Female
Position	SNP Tactical Planner

00.00 min.

Interviewer:

- Briefly explains the scope of the project and the reasons why he/she has been selected for the study (interview). <u>Scope:</u> Finished-goods inventory levels at MRP affiliates. Contextualize the projects.
- Introduce what the interviewer expects from her: The interviewer wants to know what kind of role does he/she has within the company, and how relevant the tasks he/she performs are in terms of inventory planning and control (what impact do these tasks have on inventory planning and control?).
- The interviewer also wants to hear his/her point of view with regards to the current inventory management policies and what are the main issues he/she identifies from her current role.

03.29 min.

The interviewee role within the company is as an SNP Tactical Planner. Basically, there are two plans: Operational Plans (operated by the operational planners sitting in the production sites) and the SNP planners, which are sitting in the headquarters.

- Operational planners need to focus on what is going on now, on the short term. They are planning the production and tell the production lines what do they need to produce on a specified date (short term planning, from week to week). They keep an eye on what they need to produce according to the customer requirements. **The time horizon they look at is around three months**. It depends from product to product. This time period is called *frozen* horizon. For some products, this is the time it takes to produce, release and send to the affiliates, depending on the sites, product and the affiliate as well. These are the ones executing, based on the forecast, sales orders and so on.
- In the SNP planning, they focus after this horizon, which is not frozen anymore, up until two years from now. What is the plan, inventory levels, capacity in the lines and make sure they match. This is a monthly process, where they take a snapshot of the system SAP, and see if there is any imbalance between the capacities at the production sites and the demand, and if there is an imbalance, check what they can do to solve it.
- Ideally, the plan that the SNP makes, is the one the operational planners would execute upon, but this never happens, the SNP planners do not have any control on that.
- At the end, it is the affiliates who place the orders to the production sites, but ideally what the affiliates order is what the SNP planner have planned. However, the affiliates don't go through the SNP team to place the orders, they place the orders directly at the production sites. SNP does not have contact with the affiliates: they are in contact with the operational planners, which are in charge of maintaining the data for capacity of the lines and they are in contact with the market access team, which has information on the forecast of the affiliates.

07.57 min.

Moving to the next point of the interview questions, the interviewer has asked the planner her opinion on the way the company manages inventory levels at the affiliates.

The interviewee's point of view on how the company manages inventories at affiliates is the following:

- The IM model is very smart and gives a lot of good meaning.
- She has challenged the frequency in which the stock levels are updated. Is it efficient, to update safety stocks every month? Can that cause volatility? The project Flow of Demand is looking into factors that could cause volatility in the Supply Chain, and the frequency in which the plan (and therefore, safety stock) is updated is one of the main focus points. Perhaps updating safety stock with this frequency is causing too much volatility.
- Another focus point is the units in which safety stock is calculated. In the current setup, safety stock is calculated in DOH (days), which, when transferred to units, can cause an impact. The way we transform from days into quantities can have an impact on stocks and also on th eBOM, because we would then need to update all the materials necessary to build that stock.

10.05 min.

The interviewer shows in the system how the safety stock is updated in this monthly process (SNP process) and also the conversion from days on hand into product quantities.

The planning book shows the forecast in weekly buckets. It also shows the applied safety stock (planned) for these weeks, and when the replenishment orders should be placed: when should we produce something. The days on hand is translated into units based on the demand consumption based on the demand history of the past 26 weeks.

16.20 min.

Going back to the original question, (what are some of the key issues impacting stock)?

The safety stock calculation will never be perfect, because there is a way in which the system splits the forecast into week buckets (affiliates do update their forecasts monthly), and then the system splits this demand into week buckets. So there is a small difference between the monthly forecast and the weekly forecast, although this difference is small.

Another thing we should look at is the IM tool and the **temporary safety stock**.

- This is another thing that is like the safety stock but is harder to measure. We have normal safety stock, which is stable. If you want to deviate from your normal safety stock during a period of time, then you can apply the temporary safety stock. If the product only has safety stock but it has applied the temporary safety stock, this temporary safety stock overrules the safety stock in the APO system.
- If we apply a temporary safety stock, it overrules the original safety stock.

So we can say we in *PharmaNordic* have three types of stock:

- Real Safety Stock, the one present in the affiliates.
- The temporary Safety Stock: It can be chosen in the system the period during which we want t deviate. This could cause a lot of volatility. This is the only way the planners have to level demand, but this can cause a lot of volatility.
- Strategic Stock is the one that builds upon the safety stock: this is only for high value products. The strategic Stock policy is revised once or twice a year.

The interviewer has asked in which situations would safety stock be applied?. It could be a closedown in a factory, and then the planner would build safety stock in order to be able to meet the demand in advance. Or it could be that the forecast is higher than expected: then the planner would check the MRP items, check which ones have high volumes and apply safety stock to do this levelling

Safety stock is the way that SNP planners pull the orders in order to level demand and capacity in the production lines. They see the load or capacity in number of hours of work.

The impact of temporary safety stock on final stock is something that we should be looking at.

26.51 min.

Discussion around practices from the operational planners (OP Planners). The way of levelling demand for SNP planners is different to how OP planners level demand. In their case, what would they do is to advance orders in time in order to be able to fill all the “gaps” in the production plan, so that there is not any moment in which the lines are stopped.

The interviewer has asked if she thinks that could be one of the main inventory drivers for having overstock in some of the affiliates. The OP planners are very supply driven, they have to fill capacity in the lines, they have the affiliates asking for more orders and calling them all the time.

- Some OP planners (moreover the ones that have MRP items), if they do not have enough orders to fill the lines, they would just raise the amount of safety stock using temporary safety stock, and then the system would trigger more orders. This way, they would keep the lines running and the unit cost KPI would be met.
- Not all the planners do that, mostly the planners with MRP products.
- MOC or Clayton, or even CH would do that, the ones that have MRP customers.
- From affiliate point of view, and from a shelf life perspective, this is not that convenient.

30.11 min.

The interviewee has showed an analysis done which compares the actual days on hand in stock with the APO suggestions on Safety Stock, per production site and per specific product.

- Based on the DAMS report, the results show for all sites and all the products, (MRP only), the percentage of products with different percentages comparing current stock on hand with safety stock. If they are 50% below the safety stock, if they are between 50% and 100%, 100% to 150% or over 200% of the safety stock.
- And then it shows the percentage of days on hand vs. safety stock and the percentage of products that have an overstock of 50% over the safety stock. But the majority of the graphs show overstock. But ideally, the majority of the products should be around 100% of safety stock.

- There are some exclusions made in the graphs: For instance, if the lot size is too small compared to the safety stock, this has been excluded. If the minimum lot size is too big, it has been excluded. Also the safety stock is 0 for some products, because there is no forecast, these have been excluded as well. And still, it doesn't look as good as we would like.
- But this matches with what we hear from the affiliates.

The interviewee has shared a user guide of the DAMS report with the interviewer. The user guide is intended for the OP planners, but it can be used to gather.

They have to secure the manual customers, but they fill the rest of the plans with MRP countries.

If they have a lot of manual orders they prioritize these manual orders before the MRP, because they have visibility on what the affiliates have on stock in MRP countries.

There is another planner who has built upon this information and actually looked at the development of the safety stock vs. stock on hand for a specific period of time.

39.14 min.

When looking at specific factors, the interviewee has shared her opinion on which ones have the most impact on safety stock levels:

- Market factors inevitably have a great deal of impact on our safety stock levels. This is considered in the safety stock formula.
- Temporary safety stock is another factor.

41.31 min.

From an SNP perspective, all the products are updated every month in each affiliate? Not all the products, but a lot of them. This is because the affiliates update the forecast every month. In terms of countries, which ones are the ones having more stock?

The interviewee has talked about Germany, which has a lot of safety stock. Countries, or affiliates, should update their forecasts monthly. In theory, they do. The interviewee does not recall any special countries with special rules with regards to safety and strategic stock. Part of the SNP process starts with the forecast being updated.

Looking at the data in the report, Flexpen is produced in all the sites. FexTouch is only US and Hillerøod producing FlexTouch. FlexPen is under stock. A lot of FlexTouch is overstocked. Flexpen is more overloaded.

- Flexpen is more overloaded. A lot is MRP.
- FlexTouch a lot is manual.

A lot of what happens with inventories, so the behaviour part could be very interesting to look at (in production sites). Some production sites will be more KPI oriented than others. Which ones could be more KPI oriented? MOC definitely is very KPI-oriented.

52.21 min.

We have the indication that pulling orders could have an impact on what we have on stock, but it is more a combination of factors. We need to be sure also about that, to what extend they do it (pulling orders to keep the lines running). The production agreements are in place in order to meet demand, but also it should be noted that the planners will probably go to 100%, they do not produce much more, because they would be impacted in their scorecard.

Are our production agreements higher than they were before?

- Is there more capacity installed than demand?

Final thank you notes

3. Summary of findings

Table 10. Summary of findings stemmed from the interviews and internal documentation of the case study company

Concept	Measure	Value
Affiliate configuration	# MRP Countries	~60. Countries: Argentina, Australia, Austria, Belgium, Bulgaria,Canada, Chile, Colombia, Croatia, Czech Rep, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Latvia, Lithuania, Mexico, Netherlands, New Zealand, Norway, Pakistan, Philippines, Poland, Portugal, Romania, Russia, South Korea, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, UK, USA.
	# Non-MRP Countries	~110. The rest of the markets served (usually small markets): Algeria, Brazil, Hong Kong, India, Peru, Iran, Irak, etc.
	No. Sales Regions	6: North America, Region China, Region Europe, Region Japan& Korea, Region LATAM, Region AAMEO.
Product Characteristics	No. of commercialized brands (finished-goods insulin products)	12 (ProductName1, ProductName2, ProductName3, ProductName4, ProductName5, ProductName6, ProductName7, ProductName8, ProductName9, ProductName10, ProductName11, ProductName12)
	No. of insulin finished-goods delivery systems	6 (Vial, Penfill®, Innolet®, Flexpen®, FlexTouch®, VI®). Delivery systems are containers of the liquid insulin product (semi-finished product) and characterize the complexity of the product sold.
	Product shelf life (%)	Policy: 60% for most MRP countries; 75% and 80% requirements in exceptions
	Packaging size (pcs)	DS1: (1,4 pcs) | DS2®: (5, 10 pcs) | DS3®: (5 pcs) | DS4®: (1, 5, 10 pcs) | DS5®: (1, 3, 5 pcs) | DS6®: (1, 2, 3 pcs)
Internal Operation Capabilities	Order Quantity (Minimum Order Quantity) Depends on the packaging size	DS1: (400, 2000 MOQ) | DS2® (700 MOQ) | DS3®: (1005 MOQ) | DS4®: (6400, 1296, 648 MOQ) | DS5®: (6720, 2240, 1344 MOQ) | DS6®: (1280, 640, 427 MOQ). The packaging size and MOQ are determined by the type of delivery system.
	Lead Time ▪ Order Lead Time (OLT_{actual}): Average per Delivery Plant and Delivery System	Policy: Delivery Plant-Delivery System (insulin products only)

SITE	OLT (days)	Delivery System	OLT (days)
CH (France)	51	DS1	48,4
TJN (China)	42	DS2®	50,8
MOC (Brazil)	56	DS3®	44
CL (United States)	63	DS4®	44,2
DK Sites (Denmark)	42	DS5®	48,2

Concept	Measure	Value
	▪ From affiliate to end customer	Outbound transportation is under 3PLs' responsibility. No data available
	Lead time variance	No data available
	Replenishment Policy	MRP countries: IM model (based on a periodic review policy where Reorder Point and Safety Stock levels are determined). Non-MRP countries: Manual orders, continuous review.
	Production Capacity Utilization	Depends on production site. In general, there is more capacity installed than demand.
	Production Strategy	MRP countries: make-to-stock | Non-MRP countries: Make-to-order
	Inventory Space	No data available
Market Factors	Average Demand per product	Sales data is updated on a monthly basis. Demand from affiliate sites aggregated into the last 26 weeks. Specific per affiliate and product type in number of units.
	Demand variability	Depending on product type and country. No data available.
	Demand uncertainty	12,5% (standard deviation divided by mean of the actual demand)
	Forecast Accuracy	MRP countries: 70% on average (depends on product type and country). Non-MRP countries: lower sales forecast accuracy.
	Forecast horizon	MRP countries: Forecast is updated on a monthly basis. Non-MRP countries: Depends on the sales affiliate supply chain manager
	Service Level	The service level policy for the company is set at 99.5%. The stock-out risk is 0.5% of deliveries or 1 in 200 orders.
	Financial Factors	Data could not be accessed due to confidentiality reasons. Transportation costs: 57% of total supply chain costs. Storage: 19%. Others
	LT delivery from suppliers	Contracts for packaging material establish that suppliers have to deliver within 16 days to the production sites.
	Degree of Supplier Orientation, Delivery	*PharmaNordic* exerts great control over its raw materials suppliers. In the outbound part of the supply chain, the packaging material

	performance and Reliability of the suppliers	suppliers take especial importance. When planning an order, production planners assume that there is semi-finished (WIP) available. Deviations from the plan by the suppliers are rare.
	Discounts from suppliers	No data available
	Delivery frequency from suppliers	Based on order requests from the production sites (centralized and bundled from the central planning functions in the headquarters)
Downstream SC Characteristics	Degree of customer orientation	Depends on importance (sales volume and strategic importance) of the country and the product.
	Lead Time Delivery to customers	Depends on country and type of transportation, and approvals from each country.
	De-coupling point	There are various de-coupling points throughout the production and delivery chain: - API de-coupling point: Where raw material insulin product is stored (around 18 months on API stock for all the products stored in Denmark). Furthermore, each production (filling site) keeps three months of API stock. - Semi-finished goods de-coupling point at filling sites - Affiliates de-coupling point: Where finished products are stored before being shipped to wholesalers. API de-coupling point does not affect final stock. Disregard in the analysis.
	Type of Transportation	For API, air-freight due to the high value of the product and special conditions (currently developing a project to ship via sea-freight). Sea-freight, air-freight and road transportation for final products.
	Frequency of Shipments	MRP countries: Weekly/bi-weekly Non-MRP countries: Varies on urgent request / Monthly
	Centralization-Decentralization	Inventories follow a physically decentralized setup with a highly centralized technical and managerial-organizational config.
Stock Policies	Strategic Stock	Very High item sales: 25 DOH | High average item sales: 20 DOH |Medium average item sales: 15 DOH |Medium-low average item sales: 10 DOH | Products supporting new launches, high profit margin items and strategic products (important for market positioning): 10 DOH
	Safety Stock	For MRP countries, calculated automatically in the ERP systems ▪ Parameters for calculation : Average demand for the last 6 months, Replenishment Lead Time, σ_{Demand} (last 6 months), $\sigma_{LeadTime}$ (past 6 months) and Service Level (SL). For non-MRP countries, depends on the affiliate supply chain manager, no visibility from central HQ functions.
Inventory related KPIs	Finished Stock-outs alert (Stock below Minimum KPI)	The number of stocked-out items at an affiliate level on a weekly basis per Brand (Product Type). The reasons for the stock-outs are included: (i) Supply Chain/Quality issues, (ii) Stock scrapped or blocked in Production, (iii) Shipment received delayed, (iv) Lacking production capacity, (v) Sales deviation +/-50% from forecast within the last 6 weeks, (vi) Prioritization of Manual Orders over MRP orders, (vii) Other reasons. ▪ <u>Target:</u> For finished insulin products, maximum 4% weekly average of all MRP items across all affiliates (worldwide), or 28.8 stock-outs on average per week. ▪ <u>Realized 2016 and 2017 YTD:</u> 12.7 stock-outs per week (721 items): 1.8%, well below the 4% maximum.
	Stock Above Maximum KPI	The number of items over the Maximum Stock Level target at a production site level on a weekly basis per product type. ▪ <u>Target:</u> For finished insulin products, maximum 8% weekly average of all MRP items across all production sites (worldwide). ▪ <u>Realized 2016 and 2017 YTD:</u> 7.4% on average, close to the maximum target of 8%.
	Manual Orders on Time KPI at production sites	The number of orders delayed on a weekly basis from the production sites and the reasons of the delay: Supply Chain related causes, Production causes, External causes and Other. ▪ <u>Target for 2017:</u> 75% of Manual Orders (non-MRP) arrive on time. Target was reduced from 85% to 75% in order to exclude system errors (orders placed with wrong error dates, increase of order size on affiliate request, etc.) ▪ <u>Realised in 2016 and 2017 YTD:</u> 77% of orders on time: 2497 orders on time out of 3255.
	Shipping KPI (Sea freight Da½shboard)	The percentage of large-distance shipments made by ship and airfreight from the Shipping Hub in Greeve (DK), TJ (China) and MOC (Brazil) to the stock-holding affiliates. Measured in different units: Number of deliveries, number of items, by weight and by single units. ▪ <u>Target</u>: 76% of shipments (in number of deliveries) are to be made by ship. ▪ <u>Realised 2016 and 2017 YTD:</u> 80% Shipments made by sea freight and 20% by Air.

Appendix C- Quantitative analysis

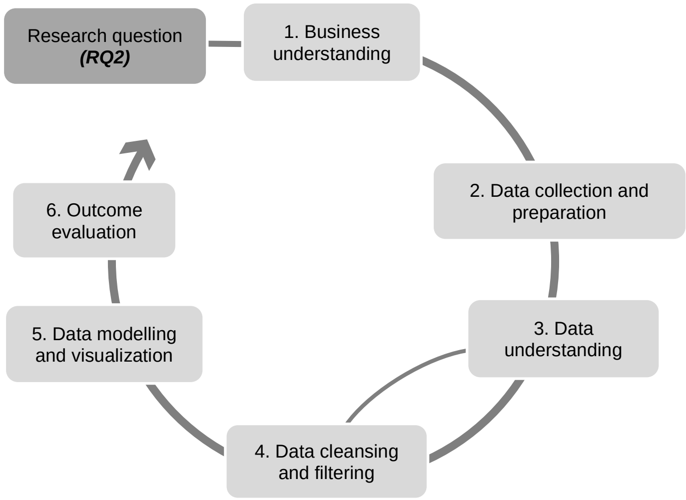


Figure 3. Iterative process to conduct the quantitative analysis

1. Data analysis

1.1. Data collection

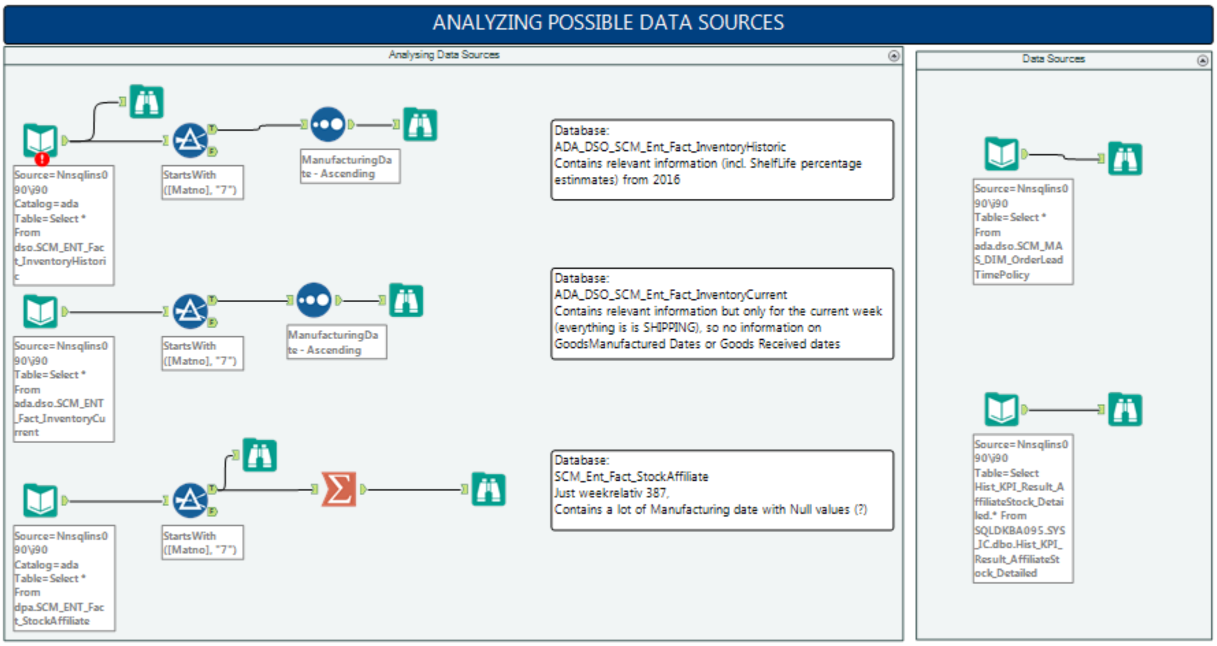


Figure 4. Modelling the analysis of possible data sources for the stock metrics. Entities from the SQL server of the case study company in Alteryx®

1.2. Data preparation: Merging data sources and mapping variables with SQL entities

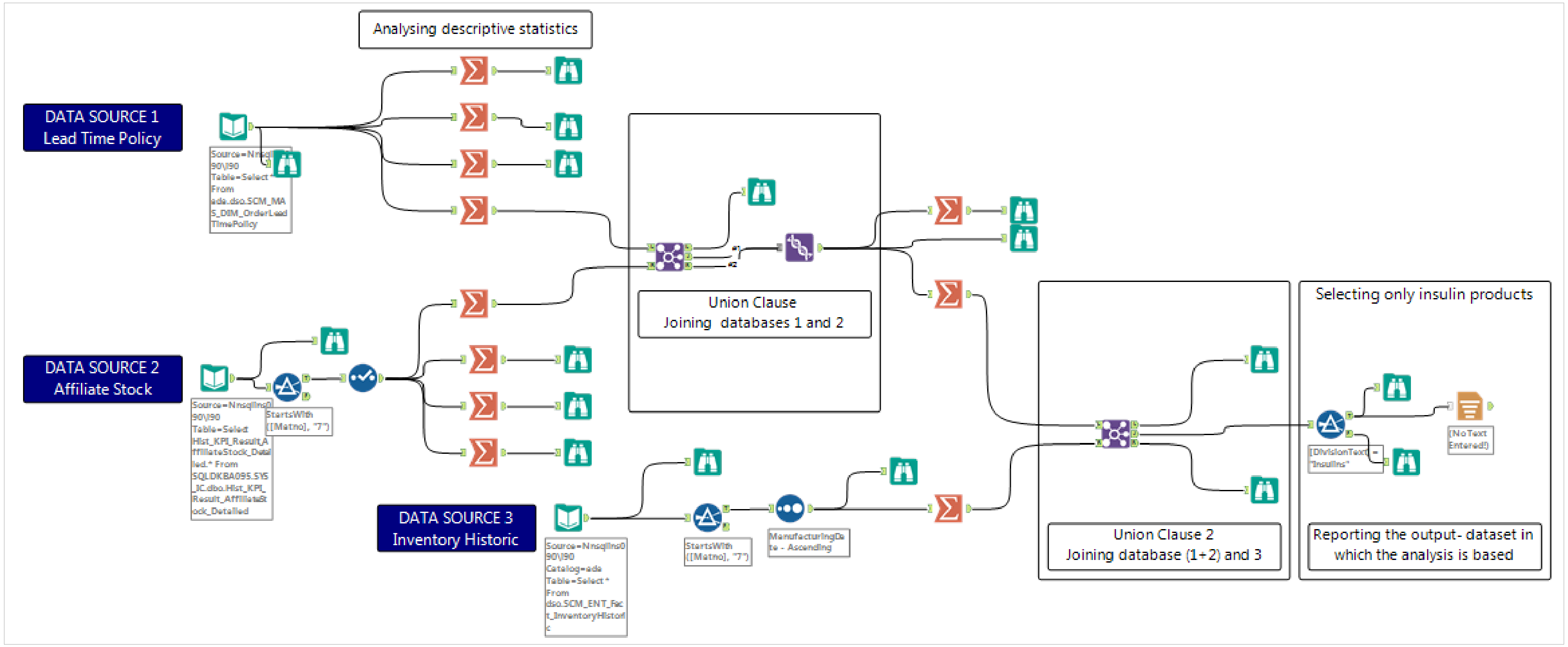


Figure 5. Merging three different data sources (SQL tables) in order to obtain the final data set in Alteryx®

1.3. Data understanding and data cleansing

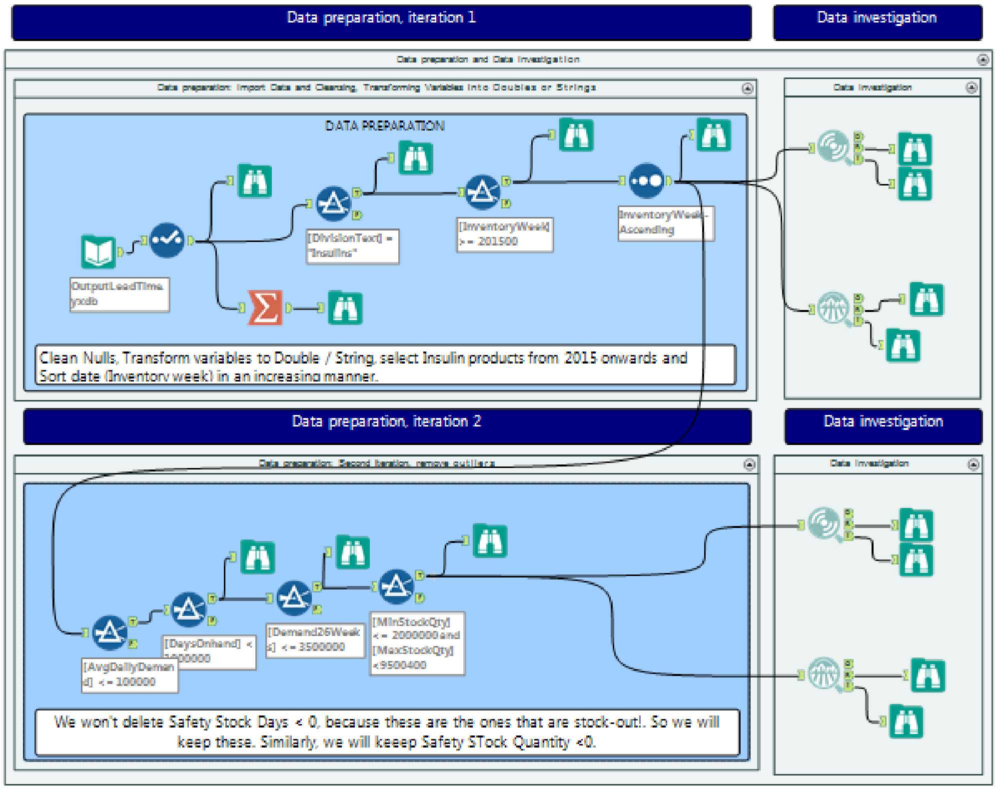


Figure 6. Two iterations performed: data preparation and data investigation, corresponding to the data understanding and data investigation steps in the iterative process in Alteryx®

Table 11. Code for the data cleansing and preparation

Step		Code in Alteryx Tool
	Retrieve data from database	`Table: SYS_IC_Insulins_AffiliateStock`
1st iteration Data Preparation		
#1	Converting variables from string to doubles	`StockOnhand, AvgDailyDemand`
#2	Selecting recors from 2015 onwards, since before 2015 there are some records missing	`[InventoryWeek]>201500`
#3	Deleting the records with Null values for the variables StockOnHand, SafetyStockQtity and StrategicStockQtity:	`!IsNull([StockOnHand]) and !IsNull([SafetyStockQty]) and !IsNull([StrategicStockQty]).`
#4	Covert Minimum and Maximum Stock Days into the adequate units	`[MinStockDays]/100000` `[MaxStockDays]/100000`
#5	Select variables in which we will base the analysis	`[MaxStockDays]/100000`
#6	Data investigation: Allows us to look at outliers, points out of sample, null values, and missing values among all records. - Field Summary - Frequency Table	
2nd Iteration Data Preparation		
#7	Delete records (filter) which present outliers in Demand	`[Demand26Weeks] <= 1800000`
#8	Delete records (filter) which present outliers in Safety Stock, Strategic Stock and TotalSafetyStock.	`[SafetyStockDays]>0 And[StrategicStockQty]<100000 and[TotalSafetyStockQty]<400000 and [MaxStockQty]<9500400`
#9	Re-group by BrandName (variable). Create a new variable (output field name) with less groups on BrandName. Reduction from 9 to 6 groups.	`IF [BrandNameText]="ProductName1" THEN "Group1" ELSEIF [BrandNameText]=" ProductName2" THEN " Group1" ELSEIF [BrandNameText]=" ProductName3"`

		THEN " Group2" ELSEIF [BrandNameText]=" ProductName4" THEN " Group3" ELSEIF [BrandNameText]=" ProductName5" THEN " Group1" ELSEIF [BrandNameText]=" ProductName6" THEN " Group4" ELSEIF [BrandNameText]=" ProductName7" THEN " Group5" ELSEIF [BrandNameText]=" ProductName8" THEN " Group6" ELSEIF [BrandNameText]=" ProductName9" THEN " Group4" ELSEIF [BrandNameText]=" ProductName10" THEN "Group4" ELSEIF [BrandNameText]=" ProductName11" THEN " Group5" ELSEIF [BrandNameText]=" ProductName12" THEN " Group5" ELSE "Others not ProductName12" ENDIF

1.4. Data modelling

1.4.1. Cluster Analysis: K-Centroids cluster diagnostics

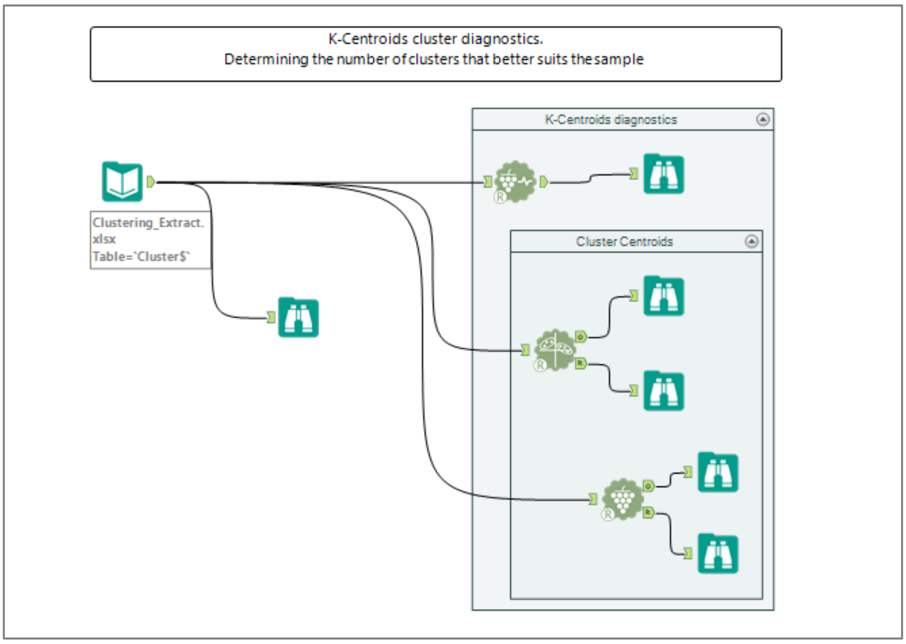


Figure 7. Cluster Analysis Algorithm. K-centroids diagnostics to determine the number of clusters present in the sample in Alteryx®.

1.4.2. *Cluster formation*

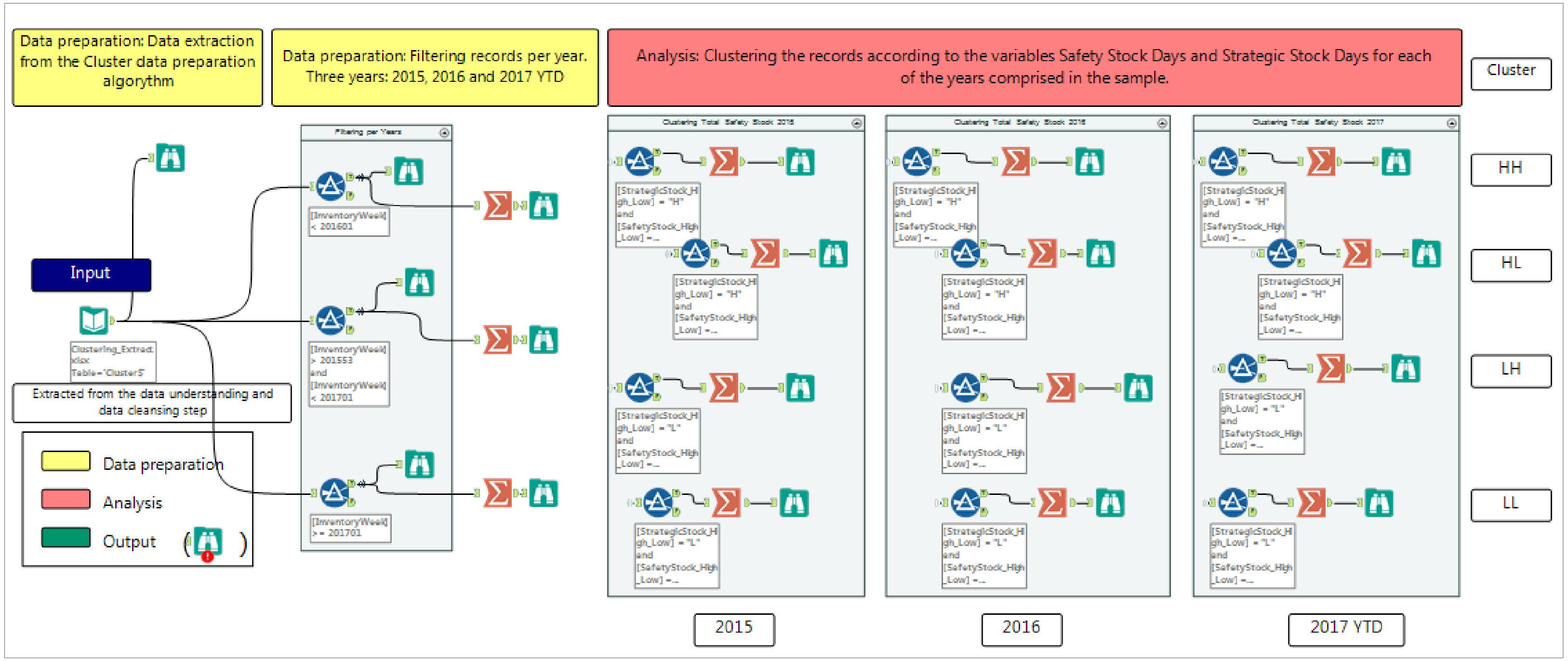


Figure 8. Determining the cluster's descriptive statistics in Alteryx®

Variable	**Sample Analysis**	**High/Low Assign code**	**Rationale**
Strategic Stock Days	Q1: 0; Median: 0; Q3: 0; Max: 360	IF [StrategicStockDays]<10 THEN [StrategicStock Days H/L]="L" ELSE "H" ENDIF	Only a few products carry Strategic Stock in the case company, and the minimum Strategic Stock associated to a product is 10 DOH.
Safety Stock Days	Q1: 30; Median: 36; Q3: 45; Max: 814	IF [SafetyStockDays]<36 THEN [SafetyStockDays H/L]="L" ELSE "H" ENDIF	Observations below the median are assigned "L" (low Safety Stock), and above the median, "H" (high).
Observations can belong to one of this 4 clusters	HH: High Strategic Stock and High Safety Stock HL: High Strategic Stock and Low Safety Stock LH: Low Strategic Stock and High Safety Stock LL: Low Strategic Stock and Low Safety Stock		

1.4.3. Predictive modelling: regression analysis and decision tree models

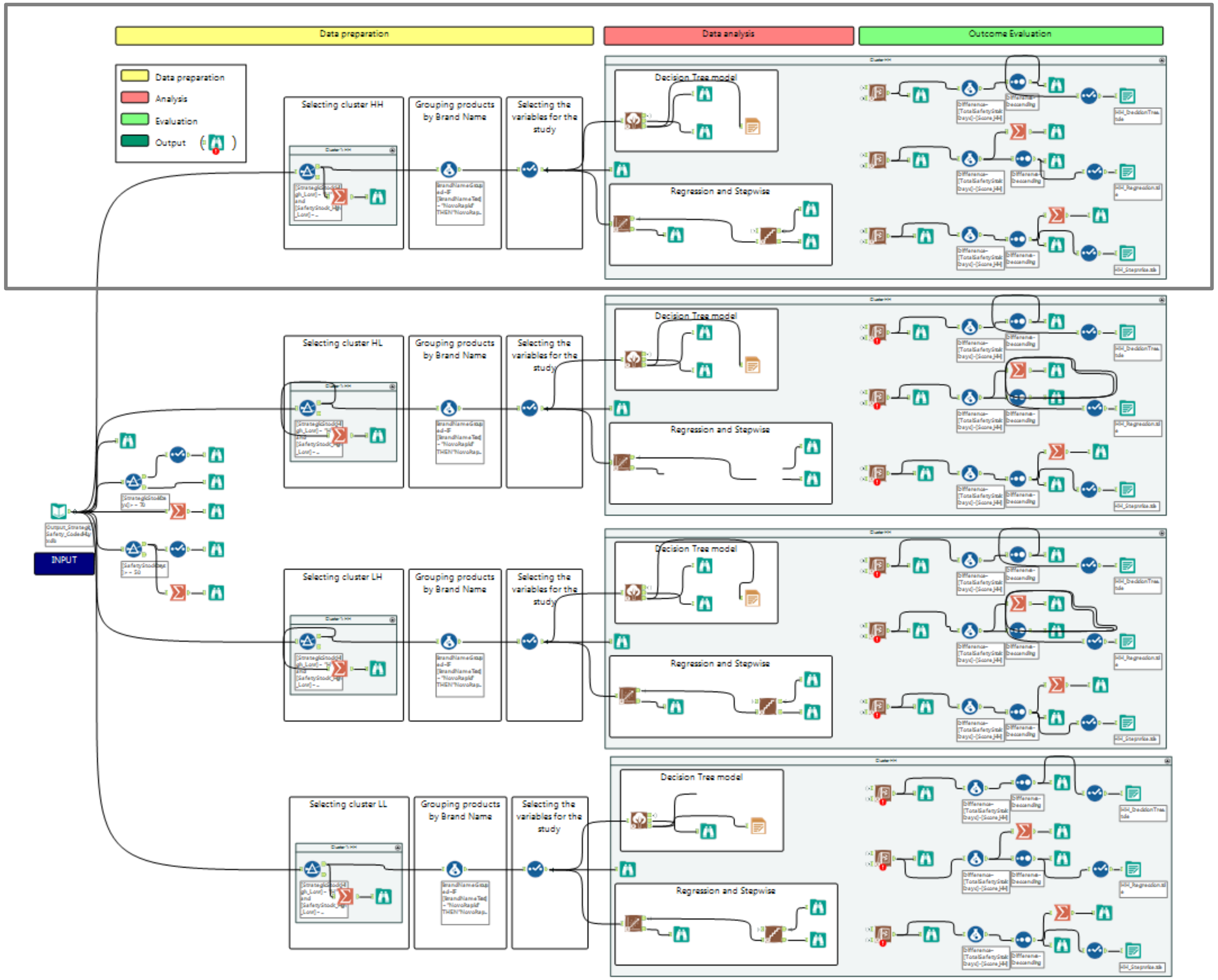


Figure 9. Regression analysis and decision tree models for each of the clusters in Alteryx®

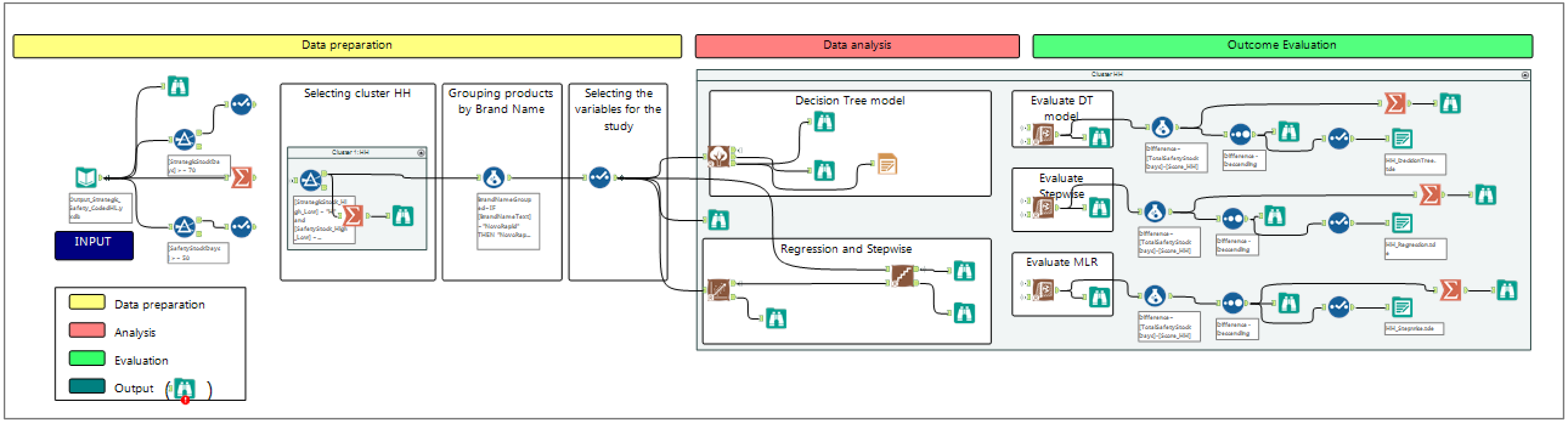


Figure 10. Detail of the regression analysis and decision tree models for cluster HH in Alteryx®

2. Results

2.1. Correlation Analysis

Table 12. Correlation Analysis results between variables selected

Correlation Matrix	U3U1 Factor	Strategic Stock Quantity	Order Size	Maximum Stock Quantity	Total Stock Quantity	Safety Stock Quantity	Demand 26 weeks	Stock on Hand
U3U1 Factor	1	-0.12	-0.27	-0.21	-0.18	-0.17	-0.16	-0.17
Strategic Stock Quantity	-0.12	1	0.52	0.42	0.43	0.25	0.24	0.26
Order Size	-0.27	0.52	1	0.58	0.56	0.49	0.49	0.51
Maximum Stock Quantity	-0.21	0.42	0.58	1	0.96	0.94	0.91	0.85
Total Stock Qty	-0.18	0.43	0.56	0.96	1	0.98	0.92	0.82
Safety Stock Quantity	-0.17	0.25	0.49	0.94	0.98	1	0.94	0.82
Demand 26 weeks	-0.16	0.24	0.49	0.91	0.92	0.94	1	0.88
Stock on Hand	-0.17	0.26	0.51	0.85	0.82	0.82	0.88	1

2.2. Cluster Analysis results

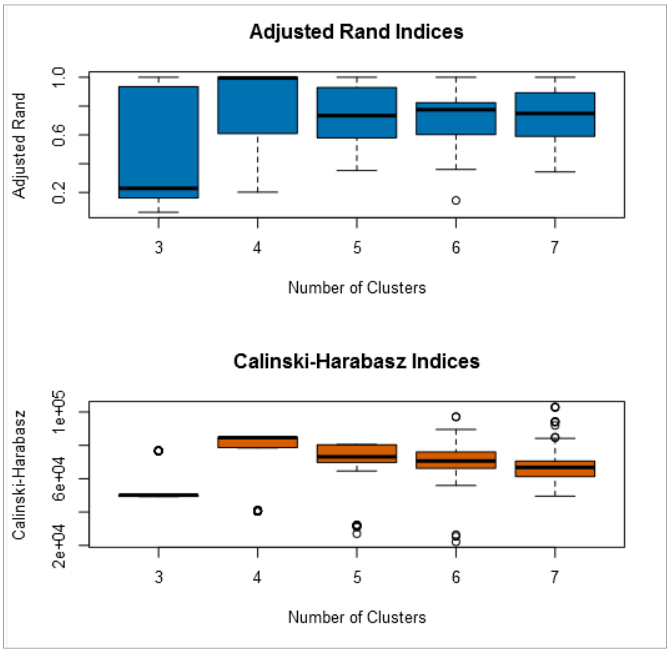


Figure 11. Output of the the cluster Analysis: Adjusted Rand and Calinski-Harabasz Indices for selecting the number of clusters in the sample.

Cluster	# obs.	Median DOH	Strategic Stock	Safety Stock	Total Safety Stock
HH	1933		15	41	55
HL	4492		15	30	43
LH	22239		0	45	45
LL	18880		0	30	30

Table 13. Number of observations distributed per cluster aggregated per years. Strategic, Safety and Total Safety Stock Days on Hand (Median).

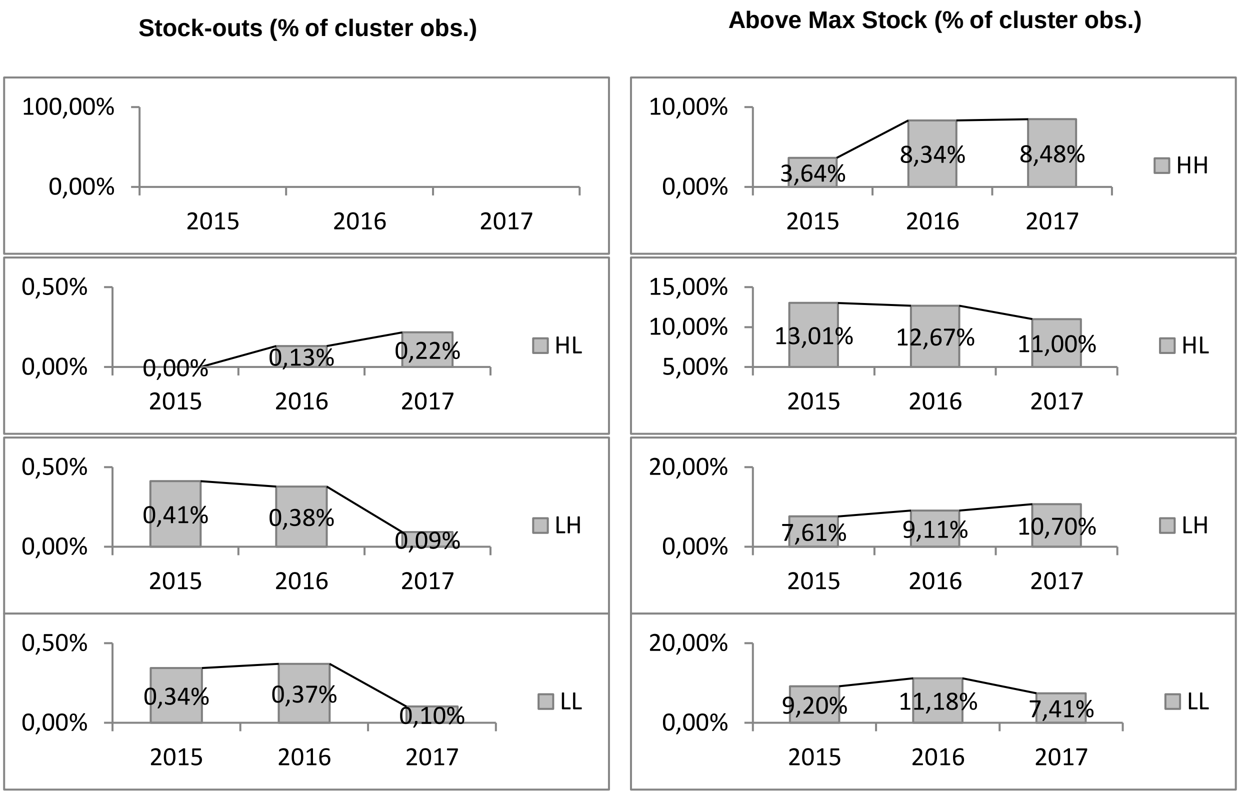


Figure 12. Stock-outs and observations above Max Stock as a percentage of the total observations

2.3. Country classification among clusters

Table 14. Raw data for the country classification among clusters (summary statistics in Alteryx®

Country	# observations	# obs. with High Strategic Stock	# obs. with High Safety Stock	% High Strategic Stock	% High Safety Stock	Region	Median Total Stock Days
Argentina	639	0	592	0,00%	92,64%	Region LATAM	45
Australia	1856	252	1358	13,58%	73,17%	Region AAMEO	42
Austria	2277	13	896	0,57%	39,35%	Region Europe	34
Belgium	2005	0	533	0,00%	26,58%	Region Europe	31
Bulgaria	746	0	420	0,00%	56,30%	Region Europe	42
Canada	1953	440	858	22,53%	43,93%	North America	42
Chile	1098	0	1029	0,00%	93,72%	Region LATAM	45
China	1453	455	13	31,31%	0,89%	Region China	30
Colombia	178	0	178	0,00%	100,00%	Region LATAM	45
Croatia	767	0	423	0,00%	55,15%	Region Europe	38
Czech Republic	1292	0	558	0,00%	43,19%	Region Europe	35
Democratic Republic of Congo	1	0	0	0,00%	0,00%	Region AAMEO	0
Denmark	4190	0	3301	0,00%	78,78%	Region Europe	45
Finland	1402	862	984	61,48%	70,19%	Region Europe	221
France	2152	333	296	15,47%	13,75%	Region Europe	29
Germany	5876	2681	1171	45,63%	19,93%	Region Europe	36
Greece	1463	0	1148	0,00%	78,47%	Region Europe	45
Hungary	643	0	326	0,00%	50,70%	Region Europe	39
India	81	11	2	13,58%	2,47%	Region AAMEO	30
Italy	1178	233	522	19,78%	44,31%	Region Europe	37
Japan	1784	0	0	0,00%	0,00%	Region Japan & Korea	24
Latvia	1468	104	544	7,08%	37,06%	Region Europe	33
Libya	3	0	0	0,00%	0,00%	Region AAMEO	0
Mexico	1088	0	1055	0,00%	96,97%	Region LATAM	56
Netherlands	1839	396	947	21,53%	51,50%	Region Europe	43
New Zealand	1328	0	801	0,00%	60,32%	Region AAMEO	37
Nigeria	4	0	0	0,00%	0,00%	Region AAMEO	0
Pakistan	232	0	177	0,00%	76,29%	Region AAMEO	45
Philippines	349	0	349	0,00%	100,00%	Region AAMEO	45
Poland	1055	252	144	23,89%	13,65%	Region Europe	31
Portugal	998	0	409	0,00%	40,98%	Region Europe	34
Romania	503	66	353	13,12%	70,18%	Region Europe	45
Russia	227	0	168	0,00%	74,01%	Region AAMEO	45
Saudi Arabia	4	0	0	0,00%	0,00%	Region AAMEO	0
Slovenia	1404	0	1105	0,00%	78,70%	Region Europe	45
South Africa	1508	66	1213	4,38%	80,44%	Region AAMEO	45
South Korea	194	0	194	0,00%	100,00%	Region Japan & Korea	45
Spain	1682	342	642	20,33%	38,17%	Region Europe	38
Sweden	1617	0	1278	0,00%	79,04%	Region Europe	58
Switzerland	2196	68	1495	3,10%	68,08%	Region Europe	45
Taiwan	151	0	144	0,00%	95,36%	Region China	45
Thailand	1282	0	759	0,00%	59,20%	Region AAMEO	43
Turkey	1247	320	517	25,66%	41,46%	Region AAMEO	41
Ukraine	6	0	0	0,00%	0,00%	Region AAMEO	0
UK	2086	704	863	33,75%	41,37%	Region Europe	44
United States	1470	1076	675	73,20%	45,92%	North America	49

Table 15. Country relative positioning in the Y and X axes (country classification among clusters)

Countries	**HH**	**HL**	**LH**	**LL**	**Relative positioning Y axis**	**Relative positioning X axis**
Argentina			592	47	0,00	0,93
Australia	141	111	1217	387	0,56	0,76
Austria	11	2	885	1379	0,85	**0,39**
Belgium			533	1472	0,00	0,27
Bulgaria			420	326	0,00	0,56
Canada	124	316	734	779	0,28	0,49
Chile			1029	69	0,00	0,94
China	0	455	13	985	0,00	0,01
Colombia			178	0	0,00	1,00
Croatia			423	344	0,00	0,55
Czech Republic			558	734	0,00	0,43
Democratic Republic of Congo			0	1	0,00	0,00
Denmark			3301	889	0,00	0,79
Finland	579	283	405	135	0,67	0,75
France	0	333	296	1523	0,00	0,16
Germany	637	2044	534	2661	0,24	0,17
Greece			1148	315	0,00	0,78
Hungary			326	317	0,00	0,51
India	2	9	0	70	0,18	0,00
Italy	109	124	413	532	0,47	0,44
Japan			0	1784	0,00	0,00
Latvia	33	71	511	853	0,32	0,37
Libya			0	3	0,00	0,00
Mexico			1055	33	0,00	0,97
Netherlands	136	260	811	632	0,34	0,56
New Zealand			801	527	0,00	0,60
Nigeria			0	4	0,00	0,00
Pakistan			177	55	0,00	0,76
Philippines			349	0	0,00	1,00
Poland	38	214	106	697	0,15	0,13
Portugal			409	589	0,00	0,41
Romania	57	9	296	141	0,86	0,68
Russia			168	59	0,00	0,74
Saudi Arabia			0	4	0,00	0,00
Slovenia			1105	299	0,00	0,79
South Africa	0	66	1213	229	0,00	0,84
South Korea			194	0	0,00	1,00
Spain	111	231	531	809	0,32	0,40
Sweden	0	68	1278	339	0,00	0,79
Switzerland			1495	633	0,00	0,70
Taiwan			144	7	0,00	0,95
Thailand			759	523	0,00	0,59
Turkey	14	306	503	424	0,04	0,54
Ukraine			0	6	0,00	0,00
United Kingdom	277	427	586	796	0,39	0,42
United States	294	782	381	13	0,27	0,97

2.4. Summary of the regression analysis and decision tree models output

Table 16. Results of the regression analysis and decision tree models. Output from Alteryx®

	Model	***Variable Importance***	***Fitted Measures and residuals***
Cluster HH	Decision Tree	Days On Hand (53.4%), Average Daily Demand (22.8%), Order Size (14.3%), BrandName Grouped (4%), Lead Time Policy (2.5%), DeliverySystem (1.9%), U3U1Factor (1.1%).	Number of nodes: 27 Prunning plot: X-val relative error= 0.19 Root node error: 19325984/2563 = 7540.4
	Regression Analysis	Strong relation (p-values<0.05): Lead Time Policy, Days On Hand, Delivery System (Flexpen), U3U1 Factor, Avg Daily Demand, Order Size, Brand Name Grouped (Insulatard), Brand Name Grouped (Mixtard). || Weak relation: Delivery System (Vial).	Residual standard error: 51.431 on 1867 degrees of freedom Multiple R-squared: 0.7159, Adjusted R-Squared: 0.7139 F-statistic: 361.8 on 13 and 1867 DF, p-value: < 2.2e-16 Plot of Residuals versus Fitted measures follows normality.
Cluster HL	Decision Tree	Days On Hand (36.6%), Average Daily Demand (27.5%), Order Size (21.7%), BrandName Grouped (4.7%), DeliverySystem (4.6%), U3U1Factor (3.9%), Lead Time Policy (1%).	Number of nodes: 27 Prunning plot: X-val relative error= 0.18 Root node error: 10720570/6111 = 1754.3 n= 6111
	Regression Analysis	Strong relation(p-values<0.05): Lead Time Policy, Days On Hand, Order Size, Name Grouped (Insulatard), Brand Name Grouped (Levemir), Brand Name Grouped (NovoRapid). Weak relation: Delivery System (Flexpen), Delivery System (Vial), Delivery System (Penfill), Avg Daily Demand, Brand, Brand Name Grouped (Mixtard), Brand, Brand Name Grouped (Others not Mixtard).	Residual standard error: 34.446 on 5769 degrees of freedom Multiple R-squared: 0.3582, Adjusted R-Squared: 0.358 F-statistic: 247.6 on 13 and 5769 DF, p-value: < 2.2e-16 Medium Adjuster R-Squared. Normal QQ plot follows normality. Residuals seem to be correct.
Cluster HL	Decision Tree	Average Daily Demand (36.6%), Days On Hand (19%), Order Size (14.5%), BrandName (13.1%), DeliverySystem (8.6%), U3U1Factor (6.3%), Lead Time Policy (1.9%).	Number of nodes: 166 Prunning plot: X-val relative error= 0.45 Root node error: 18728392/25877 = 723.75 n= 25877
	Regression Analysis	Strong relation (p-values<0.05): Lead Time Policy, Delivery System (Flexpen), U3U1Factor,), Avg Daily Demand, Order Size, Brand Name Grouped (Insulatard), Brand Name Grouped (Levemir), Brand Name Grouped (NovoRapid), Brand Name Grouped (Mixtard), Brand, Brand Name Grouped (Others not Mixtard). Weak relation: Delivery System Penfill), Delivery System (Vial),	Residual standard error: 20.768 on 19905 degrees of freedom Multiple R-squared: 0.03186, Adjusted R-Squared: 0.03113 F-statistic: 43.67 on 15 and 19905 DF, p-value: < 2.2e 16 Very low Adjuster R-Squared. Normal QQ plot follows normality, but residuals vs. Fitted measures does not have a flat shape.
ClusteLL	Decision Tree	Average Daily Demand (22.6%), Days On Hand (19.1%), Order Size (14.3%), Lead Time Policy (18.1%), BrandNameGrouped (12.8%), DeliverySystem (9%), U3U1Factor (4.1%).	Number of nodes: 122 Prunning plot: X-val relative error= 0.4 Root node error: 642648/22424 = 28.659 n= 22424
	Regression Analysis	Strong relation (p-values<0.05): Lead Time Policy, Delivery System (Flexpen), Delivery System (Innolet), Delivery System (Penfill), Delivery System (Vial), Avg Daily Demand, Order Size, Brand Name Grouped (Insulatard), Brand Name Grouped (Levemir), Brand Name Grouped (NovoRapid), Brand Name Grouped (Mixtard), Brand, Brand Name Grouped (Others not Mixtard). Weak relation: U3U1Factor.	Residual standard error: 4.1651 on 19008 degrees of freedom Multiple R-squared: 0.09499, Adjusted R-Squared: 0.09428 F-statistic: 133 on 15 and 19008 DF, p-value: < 2.2e-16 Low Adjuster R-Squared. Normal QQ plot follows normality, but residuals vs. Fitted measures do not have a flat shape.

2.5. Regression analysis and decision tree model output

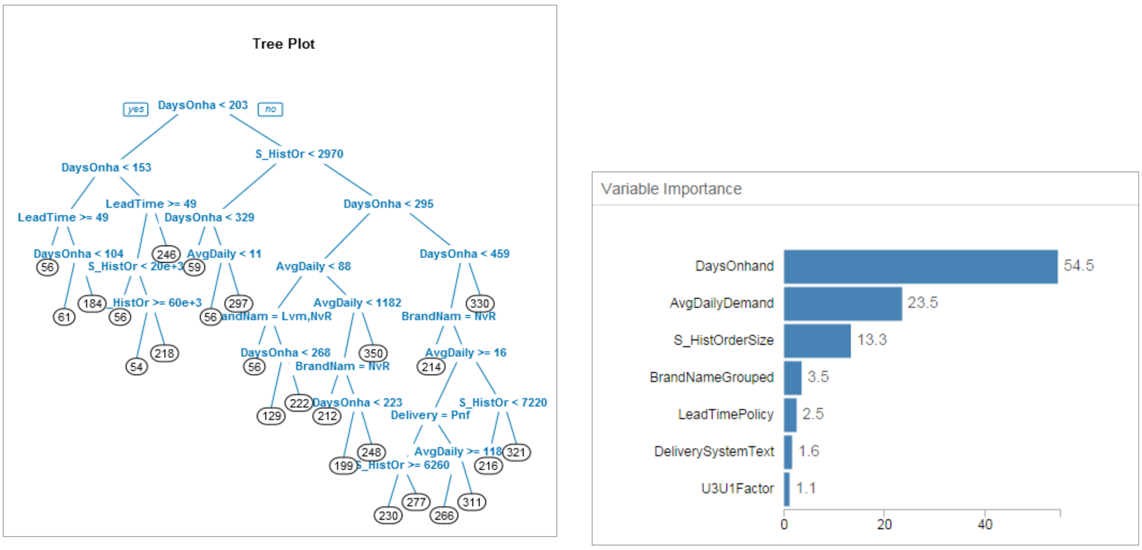


Figure 13. Cluster HH: Output form the Decision Tree model and variable importance

Report for Linear Model Regression_HH

Basic Summary

Call:

lm(formula = TotalSafetyStockDays ~ LeadTimePolicy + DaysOnhand + DeliverySystemText + U3U1Factor + AvgDailyDemand + S_HistOrderSize + BrandNameGrouped, data = the.data)

Residuals:

Min	1Q	Median	3Q	Max
-305.80	-22.97	-2.87	19.29	239.40

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.552e+02	2.052e+01	7.5643	6.08e-14 ***
LeadTimePolicy	-3.663e+00	3.490e-01	-10.4967	< 2.2e-16 ***
DaysOnhand	6.350e-01	1.185e-02	53.5895	< 2.2e-16 ***
DeliverySystemTextFlexpen	2.992e+01	8.306e+00	3.6023	0.00032 ***
DeliverySystemTextPenfill	1.757e+01	8.625e+00	2.0375	0.04174 *
DeliverySystemTextVial	4.233e+01	9.807e+00	4.3167	2e-05 ***
U3U1Factor	5.848e+00	1.139e+00	5.1365	3.09e-07 ***
AvgDailyDemand	-6.064e-03	1.855e-03	-3.2688	0.0011 **
S_HistOrderSize	3.939e-04	5.910e-05	6.6655	3.46e-11 ***
BrandNameGroupedInsulatard	-2.166e+01	4.790e+00	-4.5207	1e-05 ***
BrandNameGroupedLevemir	-1.233e+01	4.872e+00	-2.5306	0.01147 *
BrandNameGroupedMixtard 30	-2.288e+01	8.537e+00	-2.6803	0.00742 **
BrandNameGroupedNovoRapid	1.681e+00	5.128e+00	0.3279	0.74303
BrandNameGroupedOthers not Mixtard	-7.987e+00	6.808e+00	-1.1732	0.24086

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Figure 14. Cluster HH: Output from the Linear Regression Model

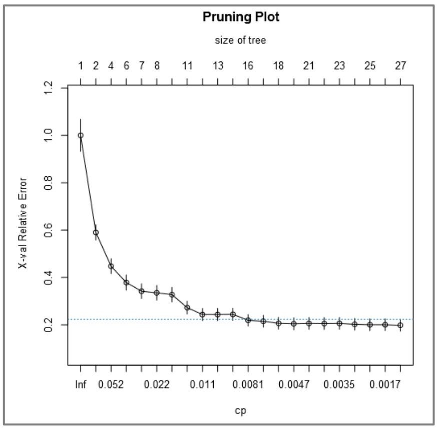
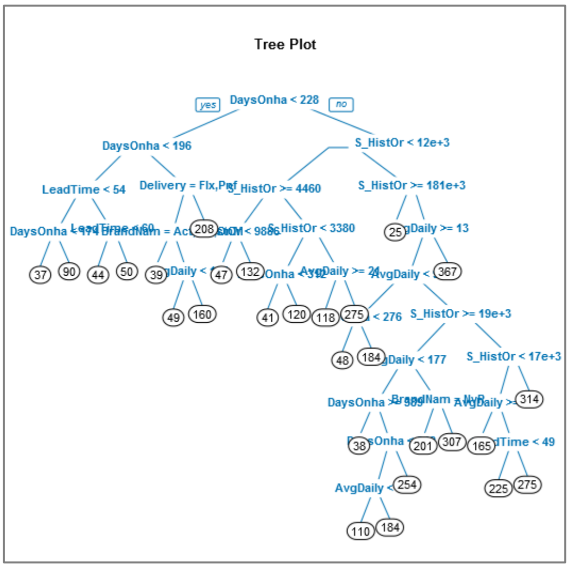


Figure 15. Cluster HH: Pruning plot of the decision tree model



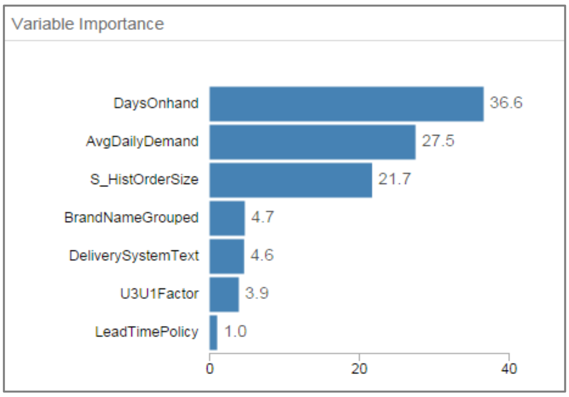


Figure 16. Cluster HL: Output form the Decision Tree model and variable importance

Report for Linear Model Regression_HL

Basic Summary

Call:

lm(formula = TotalSafetyStockDays ~ LeadTimePolicy + DaysOnhand + DeliverySystemText + U3U1Factor + AvgDailyDemand + S_HistOrderSize + BrandNameGrouped, data = the.data)

Residuals:

Min	1Q	Median	3Q	Max
-826.40	-10.87	-2.90	5.39	302.80

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	6.356e+01	9.841e+00	6.4587	1.14e-10 ***
LeadTimePolicy	-5.620e-01	8.534e-02	-6.5853	4.94e-11 ***
DaysOnhand	2.758e-01	5.659e-03	48.7359	< 2.2e-16 ***
DeliverySystemTextFlexpen	-1.850e+01	7.853e+00	-2.3553	0.01854 *
DeliverySystemTextPenfill	-1.978e+01	7.855e+00	-2.5183	0.01182 *
DeliverySystemTextVial	1.708e+01	7.963e+00	2.1444	0.03204 *
U3U1Factor	7.993e-02	2.838e-01	0.2817	0.77822
AvgDailyDemand	-4.095e-04	1.845e-04	-2.2201	0.02645 *
S_HistOrderSize	-6.511e-05	8.787e-06	-7.4092	1.45e-13 ***
BrandNameGroupedInsulatard	1.446e+01	1.804e+00	8.0170	1.30e-15 ***
BrandNameGroupedLevemir	1.007e+01	1.688e+00	5.9637	2.61e-09 ***
BrandNameGroupedMixtard 30	7.868e+00	2.734e+00	2.8783	0.00401 **
BrandNameGroupedNovoRapid	2.089e+01	1.661e+00	12.5723	< 2.2e-16 ***
BrandNameGroupedOthers not Mixtard	9.736e+00	1.839e+00	5.2951	1.23e-07 ***

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Figure 17. Cluster HL: Output from the Linear Regression Model

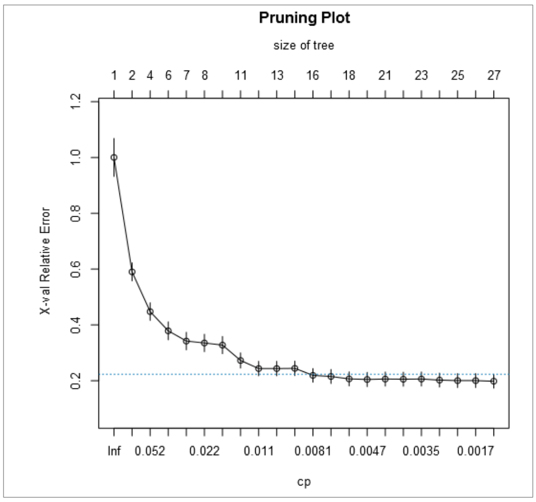


Figure 18. Cluster HL: Pruning plot of the decision tree model

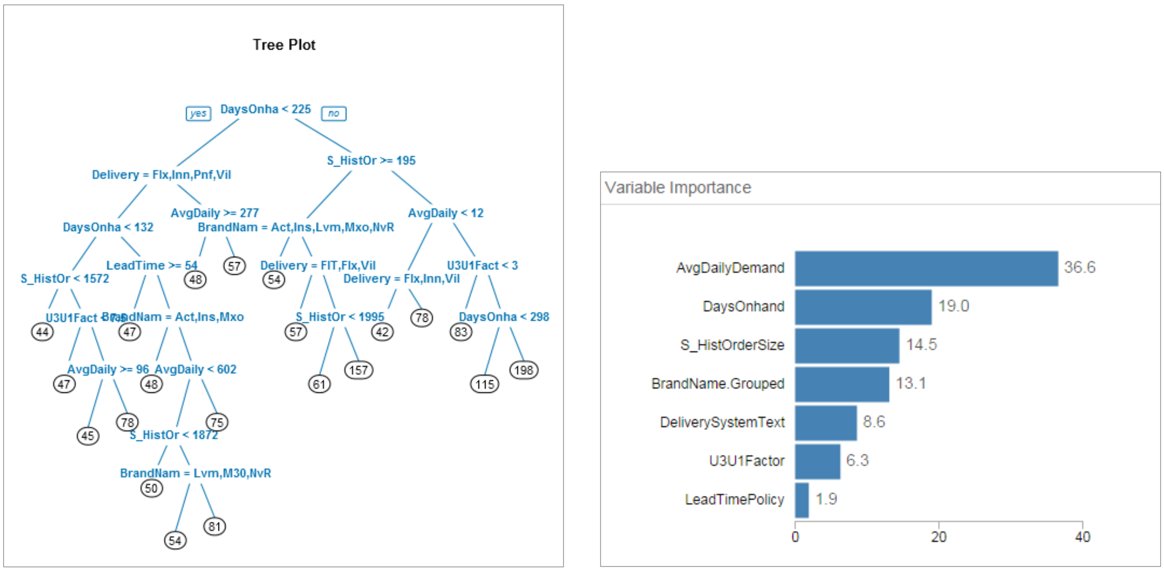


Figure 19. Cluster LH: Output form the Decision Tree model and variable importance

Report for Linear Model Regression_LH

Basic Summary

Call:

lm(formula = TotalSafetyStockDays ~ LeadTimePolicy + DaysOnhand + DeliverySystemText + U3U1Factor + AvgDailyDemand + S_HistOrderSize + BrandName.Grouped, data = the.data)

Residuals:

Min	1Q	Median	3Q	Max
-20.63	-7.99	-3.38	3.95	759.20

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.906e+01	1.596e+00	37.009	< 2.2e-16 ***
LeadTimePolicy	-3.059e-01	3.104e-02	-9.855	< 2.2e-16 ***
DaysOnhand	-7.131e-06	1.396e-05	-0.511	0.60938
DeliverySystemTextFlexpen	-3.470e+00	5.388e-01	-6.440	1.21e-10 ***
DeliverySystemTextInnolet	-1.755e+00	9.592e-01	-1.830	0.0673 .
DeliverySystemTextPenfill	6.404e-01	5.625e-01	1.139	0.25488
DeliverySystemTextVial	1.848e+00	7.415e-01	2.493	0.01269 *
U3U1Factor	5.017e-01	1.499e-01	3.346	0.00082 ***
AvgDailyDemand	-1.847e-03	3.338e-04	-5.534	3.16e-08 ***
S_HistOrderSize	2.472e-05	8.289e-06	2.982	0.00287 **
BrandName.GroupedInsulatard	3.218e+00	5.778e-01	5.569	2.58e-08 ***
BrandName.GroupedLevemir	4.923e+00	6.568e-01	7.495	6.89e-14 ***
BrandName.GroupedMixtard 30	5.500e+00	7.164e-01	7.677	1.70e-14 ***
BrandName.GroupedMixtard others	-8.037e+00	1.418e+00	-5.666	1.48e-08
BrandName.GroupedNovoRapid	3.147e+00	5.862e-01	5.369	7.99e-08
BrandName.GroupedOthers not Mixtard	7.225e+00	6.215e-01	11.624	< 2.2e-16

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Figure 20. Cluster LH: Output from the Linear Regression Model

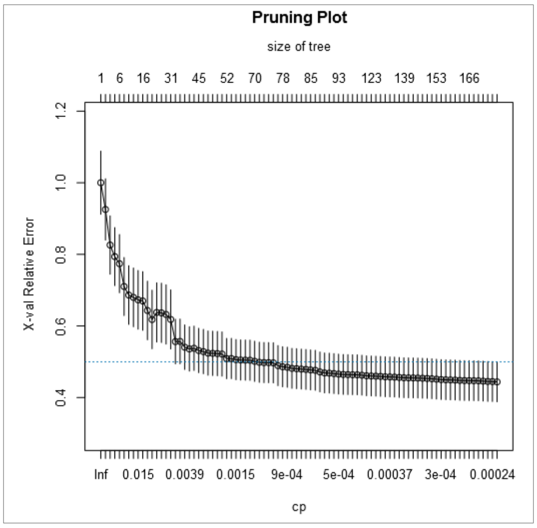


Figure 21. Cluster LH: Pruning plot of the decision tree model

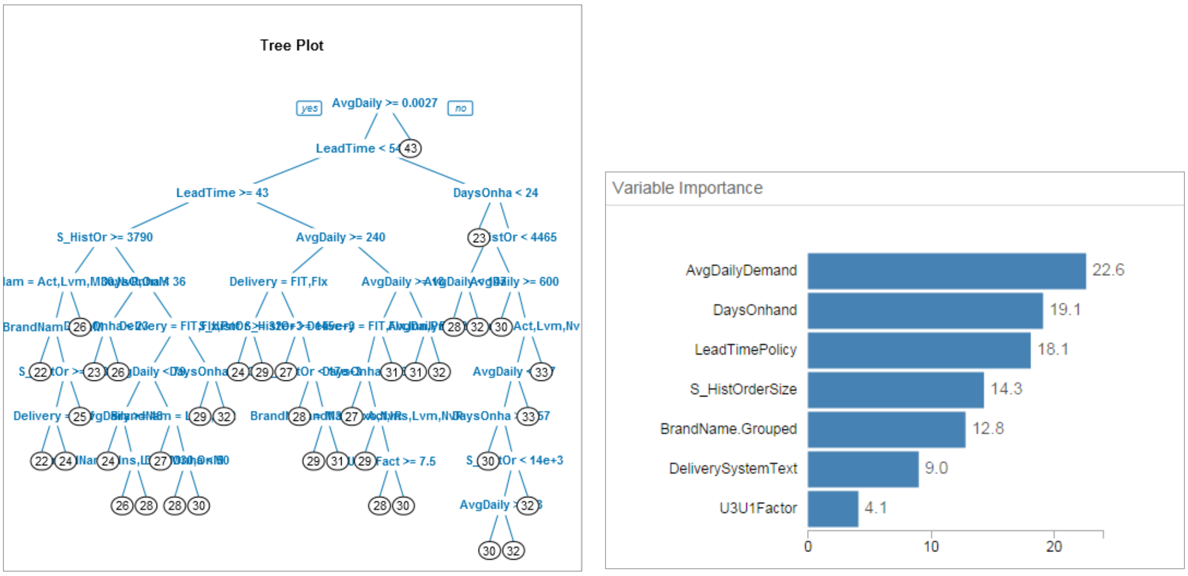


Figure 22. Cluster LL: Output form the Decision Tree model and variable importance

Report for Linear Model Regression_LL

Basic Summary

Call:

lm(formula = TotalSafetyStockDays ~ LeadTimePolicy + DaysOnhand + DeliverySystemText + U3U1Factor + AvgDailyDemand + S_HistOrderSize + BrandName.Grouped, data = the.data)

Residuals:

Min	1Q	Median	3Q	Max
-32.180	-1.757	0.569	2.728	14.030

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.671e+01	4.738e-01	35.257	< 2.2e-16 ***
LeadTimePolicy	7.967e-02	6.649e-03	11.982	< 2.2e-16 ***
DaysOnhand	-4.651e-06	4.130e-06	-1.126	0.26005
DeliverySystemTextFlexpen	6.525e+00	3.308e-01	19.726	< 2.2e-16 ***
DeliverySystemTextInnolet	7.690e+00	3.549e-01	21.668	< 2.2e-16 ***
DeliverySystemTextPenfill	8.143e+00	3.353e-01	24.282	< 2.2e-16 ***
DeliverySystemTextVial	9.555e+00	3.391e-01	28.177	< 2.2e-16 ***
U3U1Factor	4.646e-02	2.238e-02	2.076	0.03793 *
AvgDailyDemand	-1.131e-04	4.343e-05	-2.604	0.00922 **
S_HistOrderSize	-4.293e-06	9.545e-07	-4.498	1e-05 ***
BrandName.GroupedInsulatard	1.238e+00	1.175e-01	10.537	< 2.2e-16 ***
BrandName.GroupedLevemir	9.536e-01	1.319e-01	7.229	5.04e-13 ***
BrandName.GroupedMixtard 30	5.603e-01	1.239e-01	4.522	1e-05 ***
BrandName.GroupedMixtard others	1.121e+00	1.685e-01	6.654	2.92e-11 ***
BrandName.GroupedNovoRapid	2.138e-01	1.097e-01	1.948	0.05137 .
BrandName.GroupedOthers not Mixtard	1.320e+00	1.213e-01	10.880	< 2.2e-16 ***

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Figure 23. Cluster LL: Output from the Linear Regression Model

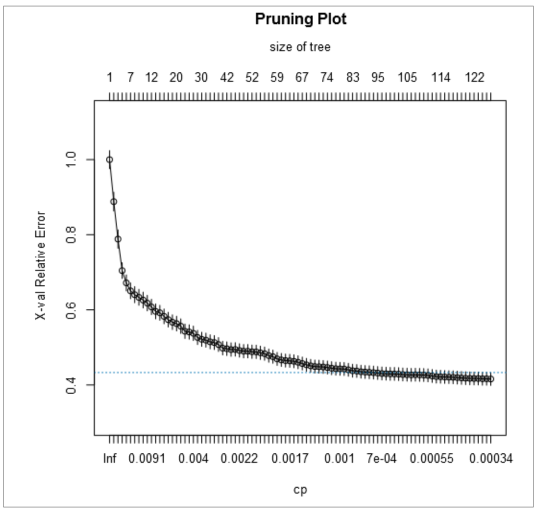


Figure 24. Cluster LL: Pruning plot of the decision tree model